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ABSTRACT

This seven-volume student text is designed for use by Air Force personnel enrolled in a self-study extension course for metal fabricating specialists. Covered in the individual volumes are general subjects (career progression, management of activities and resources, shop mathematics, and characteristics of metals); sheet metal tools and equipment (cutting tools and equipment; drilling, punching, and fastening; folding, forming, and seaming equipment and spot welding, lead soldering, and sealing); installed equipment and doors (fixed utility equipment, awnings and canopies, metal roof parts, and doors and gates); layout and duct systems (drawings and layout, seams and joint connections, characteristics and control of airflow, duct systems, and stacks and ventilators); oxyacetylene welding (equipment, welding and brazing castings, oxyacetylene cutting, forging, and carbon steel and heat- and corrosion-resistant ferrous alloys); electric welding and metallic arc equipment (preparation; metallic arc welding and applications; and gas-shielded, tungsten-inert-gas, and pipe welding); and general contingency responsibilities (first aid, field hygiene and sanitation, work party security, and convoy techniques). Each volume in the set contains a series of lessons, exercises at the end of each lesson, a bibliography, and answers to the exercises. Volume review exercises and a change supplement for the package are also included. (MN)

METAL FABRICATING SPECIALIST

(AFSC 55252)

Extension Course Institute
Air University

ECI COURSE MATERIALS SHIPPING LIST

COURSE NUMBER	COURSE TITLE	EFFECTIVE DATE
55252	METAL FABRICATING SPECIALIST (AFSC 55252)	16 Jul 86

INSTRUCTIONS: ***The following materials are needed to complete this course.*** *Check this list immediately upon receiving your course package, and if any materials are missing or incorrect (numbers don't match), notify ECI immediately. Use the ECI Form 17 for this purpose, and be sure to include your identification number, address, course and volume number, and VRE form designation (if a VRE is involved). Send all correspondence separately from your answer sheet.*[1]

ITEM	TYPE	DESIGNATION OR TITLE	INVENTORY CONTROL NUMBER	VRE ANSWER SHEET IDENTIFICATION
3	VOL	VOL 1, General Subjects	55252 01 8302	
4	VRE	VOLUME REVIEW EXERCISE (VOL 1)	55252 01 22	55252 01 22
5	VOL	VOL 2, Sheet Metal Tools and Equipment	55252 02 8302	
6	VRE	VOLUME REVIEW EXERCISE (VOL 2)	55252 02 22	55252 02 22
7	VOL	VOL 3, Layout and Duct Systems	55252 03 8301	
8	VRE	VOLUME REVIEW EXERCISE (VOL 3)	55252 03 22	55252 03 22
9	VOL	VOL 4, Installed Equipment and Doors	55252 04 8301	
10	VRE	VOLUME REVIEW EXERCISE (VOL 4)	55252 04 22	55252 04 22
11	VOL	VOL 5, Oxyacetylene Welding	55252 05 8301	
12	VRE	VOLUME REVIEW EXERCISE (VOL 5)	55252 05 22	55252 05 22
13	VOL	VOL 6, Electric Welding, Metallic Arc Equipment	55252 06 8301	
14	VRE	VOLUME REVIEW EXERCISE (VOL 6)	55252 06 22	55252 06 22
15	VOL	VOL 7, General Contingency Responsibilities	55252 07 8211	
16	VRE	VOLUME REVIEW EXERCISE (VOL 7)	55252 07 22	55252 07 22
17	SUPP	CHANGE SUPPLEMENT (VOLs 1,2,4,5 & 6)	55252 00 S01 8408	
		NOTES: DIRECT ANY QUESTIONS OR COMMENTS RELATING TO ACCURACY OR CURRENCY OF TEXTUAL MATERIALS TO AUTOVON 736-2072.		

[1]*SEE REVERSE SIDE FOR ADDITIONAL INSTRUCTIONS.*

ECI FORM JUN 84 25 PREVIOUS EDITION WILL BE USED.

3

LIST OF CHANGES

COURSE NUMBER	
55252	CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO, ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.
EFFECTIVE DATE OF SHIPPING LIST 16 Jul 86	

NOTE: PLEASE MAKE THE CORRECTIONS INDICATED BELOW. THESE CORRECTIONS MAY OMIT SOME ERRORS, SUCH AS TYPOS, THAT DO NOT AFFECT THE MEANING OF THE MATERIAL.

1. CHANGES FOR THE SUPPLEMENT: 55252 00 S01 8408

a. Supplement page 12, replacement page 80, answer 032-c: Change "5 2/3" to "5 2/13."

b. Supplement page 13, replacement page 81, answer 034-3.b: Change "9584.24" to "1583.37." Answer 034-5.a: Change "3531.4" to "4484.9." Answer 034-5.b: Change "130.79" to "166.11." Answ[illegible]-4: Change "137,455" to "530.145."

2. CHANGES FOR THE TEXT: VOLUME 2

a. Page 11, col 2, line 20: After "Porta-Band" add "R" and after "1-13" add "(Fig 1-13 has been reproduced courtesy of the Porter-Cable Power Tools, Jackson, Tennessee 38301)." Line 28: After "Porta-Band" add "R".

b. Page 12, col 2, line 5: After "1-14" add "(Fig 1-14 has been reproduced courtesy of Kyser Machine Tools Division, Stongville, Ohio 44136)."

c. Page 41, col 2, line 6: After "2-35" add "(Figs 2-35 thru 2-38 have been reproduced courtesy of Ramset Fastening Systems, East Alton, IL 62024)." Add "R" after "Ramset" each time it appears in the remainder of this exercise.

d. Page 59, col 2, line 15: After "4-4" add "(Fig 4-4 has been reproduced courtesy of Goodheart-Wilcox Co., Inc., S. Holland IL, 60473)."

3. CHANGE FOR THE TEXT: VOLUME 5

Page 51, col 1, line 11: After "thoroughly" add "steam." Line 12: Change "as soon . . . as possible" to "within 30 minutes after steam cleaning."

4. CHANGES FOR THE TEXT: VOLUME 6

a. Page 36, col 1, line 15: Change "titanium bearing rods in" to "rods containing titanium for." Line 27: Change "ordinary" to "carbon." Line 29: Change "common" to "carbon."

b. Page 54, col 1, lines 19-last: Delete "6-3. Titanium and . . . speed and pressure."

c. Pages 55-59: Delete pages in their entirety.

d. Page 75, answers A29-1 through A31-5: Delete.

5. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 1

Question 19 is no longer scored and need not be answered.

6. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 2

The following questions are no longer scored and need not be answered: 15, 19, 29, 31, 39, 63, 73 and 74.

LIST OF CHANGES

COURSE NUMBER	
55252	CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO, ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.
EFFECTIVE DATE OF SHIPPING LIST 16 Jul 86	

7. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 3

The following questions are no longer scored and need not be answered: 5, 38, 48, 58 and 69.

8. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 4

Question 38 is no longer scored and need not be answered.

9. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 5

The following questions are no longer scored and need not be answered: 1, 2, 35, 47, 48, 94, 95 and 96.

10. CHANGES FOR THE VOLUME REVIEW EXERCISE: VOLUME 6

a. Page 6, question 50: Change "(A26)" to "(A27)."

b. The following questions are no longer scored and need not be answered: 25, and 53 thru 58 inclusive.

11. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 7

The following questions are no longer scored and need not be answered: 46, 57 and 76.

55252 00 S01 8408

CHANGE SUPPLEMENT

CDC 55252

METAL FABRICATING SPECIALIST

(AFSC 55252)

IMPORTANT: Make the corrections in this supplement before beginning study of Volumes 1, 2, 4, 5, and 6. This supplement contains both "pen-and-ink" changes and replacement pages. It is perforated and three-hole-punched so that you can tear out the replacement pages and insert them into your volumes.

Extension Course Institute
Air University

CHANGES FOR THE TEXT: VOLUME 1

Pen-and-Ink Changes:

Page-Col	*Subject*	*Line(s)*	*Correction*
38R		13 fr bot	After "1" add "11/18."
		11 fr bot	After "1" and "35" add "11/18."
		7 fr bot	After "1" add "5/8."
		5 fr bot	After "1" and "196" add "5/8."
39L		5	Change "22 2/4" to "22 3/4."
		2	After "1" add "3/32."
		3	After "1" add "1/8."
		4	after "6" add "7/16."
		6	After "3" add "5/8."
		15	Change "d" to exercise "8."
55R		3 fr bot	Change "=C" to "XC."
57R		2 fr bot	Change "furnace" to "air."
59		Figs. 4-4 and 4-5	Reverse the legends.

Page Changes:

Remove Pages	*Insert Pages*
iii–iv	*iii–iv*
17–18	17–18
	78a–78 b
79–82	79–82

Preface

THIS VOLUME of CDC 55252, Metal Fabricating Specialist, contains information about the following subjects: base civil engineering organization, career progression, publications, activities management, resources management, shop mathematics, and characteristics of metals. The other volumes in the course include: Volume 2, *Sheet Metal Tools and Equipment;* Volume 3, *Layout and Duct Systems;* Volume 4, *Installed Equipment, Doors, and Hoists;* Volume 5, *Oxyacetylene Welding;* Volume 6, *Electric Welding;* and Volume 7, *General Contingency Responsibilities.*

When you successfully complete the seven volumes of this course, you will have the knowledge you need to perform your duties as a metal fabricating specialist. By performing the exercises before you look at the answers, you learn to master the contents of the course. Then when you combine the knowledge gained with the practical experience you get on the job, you earn success, prestige, and promotions that are awaiting you.

Code numbers appearing on figures are for use by preparing agency only.

The inclusion of names of any specific commercial product, commodity, or service in this publication is for information purposes only and does not imply indorsement by the Air Force.

Call the author between 0800 and 1600 CT, Monday through Friday, to get an immediate response to subject matter questions which come up while you are studying this course. Or you may write the author 3770 TCHTG/TTGIC, ATTN: MSgt Thomas P. Kelley, Jr., Sheppard AFB TX, 76311. Sending subject matter questions to ECI only slows the response time. You should also tell the author about subject matter and technical errors (except minor printing errors) that you find in the text, the volume review exercises, or the course examination. This will help the author to keep up with changes that must be made when the course is revised.

Consult your education officer, training officer, or NCO if you have questions on course enrollment or administration, Your Key to a Successful Course, and irregularities (possible scoring errors, printing errors, etc.) on the volume review exercises and course examination. Send questions these people can't answer to ECI, Gunter AFS AL 36118, on ECI Form 17, Student Request for Assistance. *NOT[illegible]: Do n[illegible] se[illegible] [illegible] Sugge[illegible] Progr[illegible] o submit corrections for print[illegible] [illegible]*

[illegible]lume is valued at 24 hours (8 points).

[illegible]ial in this volume is technically accurate, adequate, and current as of January 1984.

Contents

Management of Activities and Resources

THE MANAGEMENT philosophy of the Air Force includes getting maximum efficiency for each dollar spent while reaching planned objectives. This means that human resources, material resources, and financial resources must be used in the most effective way to meet the goals of the organization. As you supervise people working on your base, you should ask and answer these two questions. "Are the jobs being done well? and "Is there a better way to do them?"

The key to improving jobs is not necessarily an attempt to speed up work by prodding people. Substandard work may be brought up to standard by planning projects better, improving material support, eliminating delays, and coordinating with other people. Plan your projects well—that is, with activities and resources management in mind.

2-1. Activities Management

As we stated in Chapter 1, the Air Force owns a tremendous amount of property which must be operated, maintained, and managed properly. To manage these activities effectively and efficiently, the Air Force uses a program concept which has been planned by "planners" in advance. The program includes allocating labor hours and materials for work and services performed by CE troops. Various Air Force forms are initiated by CE personnel and processed through a computer. Data printouts from the computer include data which assist CE managers to make good management decisions.

015. Very briefly state how the civil engineering management system works.

CE Management System. As a worker in Civil Engineering, you may ask the question, "Who originates all the work that CE personnel have to do?" The greatest majority of the work in Civil Engineering has been identified and planned ahead of its actual start date. The planning and controlling of this work could not be done without a sound management plan. The plan we are talking about is called the In-Service Work Plan. Like all other plans, it is only as good as the information used to develop it and the effort put forth to adhere to its principles and objectives.

Planning. Do you recall an office called Resources and Requirements? Under this office is a unit known as Planning. Each year the planners visit each facility on base and thoroughly inspect it for any work that needs to be done. The inspection is called a Facility Survey.

After compiling the information from these surveys, the planner determines the labor hours needed to do the identified work. He uses one of the 85-series manuals to do this. These manuals contain Engineered Performance Standards for the various jobs in civil engineering. These standards have been compiled over a number of years by engineers who have studied the results of numerous time and motion studies. These studies break down each job into different tasks and assign a specific time to it. This time is how long it should take a skilled craftsman to complete that task. The planner then totals the time of these tasks to get the total labor hours for the job. When this survey is completed it is one of the inputs provided to Civil Engineering to develop its work plan.

In addition to the facility survey, shop foremen are responsible for two inputs to the work plan. One of them is for recurring labor-hours, and the other is for equipment maintenance labor-hours. The recurring labor-hours are for work done on a periodic basis within a particular year. An example of this work is to inspect and repair drainage facilities. Another example is the hours required for removing snow and ice from paved surfaces. There are other inputs used to formulate the civil engineer's work plan which do not concern you. They are also used to preidentify work requirements.

After all the work inputs are sent to Resources and Requirements, they are gathered together and then assigned labor-hours on a document called the In-Service Work Plan. Each month, work items from this plan are sent to the production control section for assignment to CE units. These work items are on forms known as work authorization documents. As the words indicate, these documents are the authority from Civil Engineering to perform the work stated on the forms.

Performance evaluation. Civil Engineering also has a management plan. In this plan there are provisions for evaluating the performance of CE units. By knowing types of work which have been done in the past with a certain amount of labor-hours, the industrial engineering secti through the use of a computer, can predict what work can be done in the future with various amounts of labor-hours. Units who fall behind the labor-hours expected by using more hours than predicted must answer for the deviations.

Base Engineer Automated Management System. In Civil Engineering an enormous amount of records are required to be kept. These records include the amount and cost of roads on base; amount and cost of runways; amount of sewage disposed; labor-hours required to operate plants; and the size, shape, condition, and cost of each facility. Many other records are required by law to be kept. Even your name and employee number are part of the records. When information of this sort is needed, Civil Engineering merely asks the computer in symbols it understands to

furnish this information. In a matter of seconds, the computer replies with up-to-date answers.

The name of the automated data processing system is BEAMS. This acronym stands for Base Engineer Automated Management System. The computer used is the Burroughs 3500. BEAMS is a way to automate a large number of civil engineering records and files. CE files can be maintained with ease and accuracy. It is valuable because it provides a variety of computer products to managers on demand. These products are used by managers to make many important decisions. Actions of most craftsmen within Civil Engineering affect the information within the computer and records and, ultimately, influence the content of the management products. It is of utmost importance that all civil engineering personnel know that their actions directly or indirectly influence the accuracy of the information contained in the automated system and, consequently, the management products that the system produces. The reliability of their contributions builds their own faith in BEAMS and the decisions of those who use it.

Exercises (015):

1. What is the management plan used in Civil Engineering to plan ahead called?

2. What are inspections by planners called?

3. What two inputs do shop foremen make to the CE work plan?

4. What are Engineered Performance Standards used for?

5. Work items come from the production control section on what documents?

6. How can the industrial engineering section determine the amount of labor-hours required to do certain work in the future?

7. What is the name of the automated computer system used to process Civil Engineering records?

016. State how to request work using AF Form 332, BCE Work Request.

Work Requests. The number of requests and the myriad types of work on an Air Force base far exceed the Civil Engineering resources available. Resources for essential construction, operation, maintenance, repair, and services must be given first priority. If for example, you request that 150 feet of concrete sidewalk be constructed near a facility in which you work, you would request this work on an AF Form 332, BCE Work Request. Because of the large number of work requests, you must explain why the work is needed. You must also include an impact statement, that is, a justification concerning your organization and its mission if the work is not done. It is this justification that is used by the Facilities Board in deciding which requests should be approved. Since the mission comes first, it is obvious that those requests that have the greatest impact on the mission have the best chances of being approved.

There are a number of ways that people make their desires for work or service known to Civil Engineering. One of these ways is to use AF Form 332. This dual-purpose form is both a request for work and a work approval or disapproval document. The 332 is used to request:

- New work.
- Self-help work.
- Repair of damages to real property caused through neglect or abuse.
- In-service minor construction costing less than $1,000 for base work or over $100 for military family housing (MFH).
- Projects that are done on contract.

You should have no trouble in preparing the work request, since instructions are provided on the back of the form. Figure 2-1 is a completed copy of the front of the form. The description of the work requested (item 9) should be supported where possible by sketches, plans, diagrams, specifications, photographs, drawings, or any other description of the work you request.

Notice item 23 of figure 2-1. It is the BCE recommendation. The Facilities Board will use this recommendation and other data on the form to decide its approval or disapproval. If, for instance, the base civil engineer has recommended disapproval because required resources were not available, it is highly probable that the board would disapprove the work request.

Exercises (016):

1. What information is required in the following blocks on AF Form 332?
   a. Block 3?

   b. Block 6?

   c. Block 9?

   d. Block 12?

   e. Block 26?

055. Match the agencies with their areas of responsibility to the Hazardous Waste Program.

Hazardous Waste Awareness. Every year, billions of tons of solid waste are discarded in the United States. These wastes range in nature from common household trash to complex materials in industrial waste, sewage sludge, agricultural residue, mining refuse, and pathological wastes from institutions such as hospitals and laboratories.

Included with these solid wastes are millions of tons of hazardous waste. Most of this waste is being managed in a manner that has the potential of degrading the environment and causing health hazards. This mismanagement has caused streams, lakes, rivers and groundwaters to be polluted—killing aquatic life., destroying wildlife and killing large areas of vegetation. In some cases human life has been affected by exposure to hazardous wastes that are not properly handled.

Subtitle C of the Solid Waste Act was amended by the Resource Conservation and Recovery Act (RCRA) of 1976. This act directed the Environmental Protection Agency (EPA) to put into effect regulations to protect human health and the environment from the improper management of hazardous waste. The EPA published the Hazardous Waste Management System rules in May of 1980, and their effective date was November 1980.

The Department of Defense and the United States Air Force are committed to properly manage the hazardous waste that has been generated on its military installations. The primary objective is to provide a management plan that gives the hazardous waste program managers the essential tools for effective management.

The use of the Hazardous Waste Management Program, which was made mandatory by the RCRA, requires the maximum cooperation of all activities on an installation. The installation commander is responsible to ensure compliance with all RCRA requirements on his or her installation.

The individual facility operational managers are accountable for conducting their activities in accordance with RCRA. These facility managers, including all tenant activities and Defense Property Disposal (DPDO) activities, will provide the necessary documentation to the installation commander for permit application, will provide to the stallation commander reports required by the EPA or the state, and will ensure compliance with RCRA regulations and permit requirements at that facility. All reports will be signed by both the facility operator and the installation commander.

Hazardous materials entering an Air Force Base are recorded in the Base Hazardous Waste Management Plan, and disposition instructions are provided to the user. Products most familiar include oil, petroleum products, paint, and products used in painting. All recoverable petroleum products are sold and recycled. Many paints and products used in painting are considered hazardous materials. However, once paint is applied and dries, it is no longer considered to be hazardous.

Means of disposal for each hazardous material is determined by directives. Disposition may include such means as:

(1) Used in process;
(2) Neutralized-sanitary sewer and;
(3) To be disposed of in containers.

All wastes being neutralized through the addition of other chemicals and then flushed through the sanitary sewer are closely monitored through the National Pollutant Discharge Elimination System (NDPDES).

Reducing the amount of hazardous waste is an ongoing process and is the responsibility of everyone. Substitute products are sought and used where possible.

An accumulation point is that area in or near the workplace where hazardous waste is accumulated prior to turn-in to DPDO for disposal. Storage in this area is temporary and must not exceed 90 days from the time the waste begins to accumulate in the container. This activity does not require a permit under RCRA but is subject to certain procedural requirements.

a. Assurance that wastes are placed in proper containers and that the date accumulation begins is posted on the container.

b. Assurance that hazard warnings are posted and containers are kept closed.

c. Inspection of containers regularly and remedial action initiated for leaks, spills, or improper storage.

d. Documentation of inspections.

e. Notification of proper installation authority in event of spills.

Waste Packaging Procedures

a. All wastes are packaged and stored in accordance with AFR 71-9, *US Air Force Packaging*. All wastes listed by EPA are accumulated in Department of Transportation-approved drums or holding tanks.

b. All drums of waste will be handled by trained personnel using gloves and protective clothing if necessary.

c. Accumulation point managers assure proper labeling of drums. Hazardous waste labels are obtained from the Base Civil Engineers. These plastic labels must be completed using a pen with indelible ink. The outside of the drum must be clean so the labels will stick.

One of the prime objectives of the RCRA is to promote the reuse and recycling of valuable resources before disposal. hazardous waste program managers must evaluate all wastes being generated to determine their potential reuse either on base or at other authorized locations.

The hazardous waste manager must coordinate with technical personnel to determine if the accumulated hazardous waste can be neutralized or safely chemically altered to a non-hazardous waste. This can save money in disposal charges and lessen the total amount of waste to manage. Disposal of non-hazardous waste is less costly and easier to manage.

If disposal in drums is required, waste must be stored in approved containers and certain inspection and storage procedures adhered to. The containerized waste must be stored in containers (110 gallons or less) which meet Department of Transportation Standards, or in storage tanks that meet EPA criteria. The date on which accumulation of waste begins must be clearly labeled on each container.

The Accumulation Point Manager must inspect his or her facility for malfunctions and deterioration, operator errors, and discharges which may be causing—or may lead to—

(1) Release of hazardous waste constituents to the environment or

(2) A threat to human health.

He or she must conduct these inspections often enough to identify problems in time to correct them before they become harmful to the environment or human health. The frequency of inspection may vary for the items on the schedule. The frequency of inspection should be based on the rate of possible deterioration of the containers. Once leakage is detected, the containers will be placed in another container over-pack.

Once the container is full and/or the 90-day storage period is up, the waste must be removed from the accumulation point. At this time, the DPDO agency should be notified to arrange for movement to an off-site Treatment, Storage, Disposal Facility (TSDF). This will be handled through a civilian contracting firm which is licensed to properly dispose of hazardous waste.

Exercises (055):

1. Match the agencies listed in column B with their areas of responsibilities listed in column A by placing the correct letter from column B in each space provided in column A.

Column A	*Column B*
____ (1) Civilian firm which is licensed to properly dispose of hazardous wastes.	a. Defense Property Disposal (DPDO).
____ (2) Arranges for the movement of waste to an off-site facility.	b. Accumulation Point Manager.
____ (3) Monitors the facility for malfunctions and operator errors.	c. Installation commander.
____ (4) Responsible for establishing rules to protect human health and the environment.	d. Treatment, Storage, Disposal Facility.
____ (5) Held responsible for implementation of the hazardous waste program at base level.	e. Environmental Protection Agency.

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

001 – 1. No.
001 – 2. Yes.
001 – 3. Yes.
001 – 4. No.
001 – 5. Yes.
001 – 6. Yes.
001 – 7. No.
001 – 8. Yes.
001 – 9. Yes.
001 – 10. No.
001 – 11. Yes.
001 – 12. Yes.

002 – 1. Mechanical.
002 – 2. Sanitation.
002 – 3. Resources and Requirements.
002 – 4. Operations.
002 – 5. Pavements and Grounds.
002 – 6. Civil Engineer.
002 – 7. Civil Engineer.
002 – 8. Civil Engineer.
002 – 9. Structures.
002 – 10. Structures.
002 – 11. Pavements and Grounds.
002 – 12. Pavements and Grounds.

003 – 1. (1) a.
(2) b.
(3) c.
(4) c.
(5) d.
(6) e.
(7) g.
(8) b.
(9) f.
(10) c.

004 – 1. C.
004 – 2. C.
004 – 3. I.
004 – 4. C.
004 – 5. C.
004 – 6. I.

005 – 1. Base Engineer Emergency Force.
005 – 2. You should have written BEEF in a, c, d, e, g, and h.

006 – 1. 55212.
006 – 2. a. Basic Pavements and Soils Course.
b. Basic Const. Equip. Course.
006 – 3. a. 55230.
b. 55231.
c. 55232.
006 – 4. a. 55255.
b. 55350.
006 – 5. a. Pavements Maintenance Technician, 55170.
b. Construction Equipment Technician, 55171.
006 – 6. Pavements Superintendent, 55191.

007 – 1. (1) i.
(2) f.
(3) b.
(4) d.
(5) c.
(6) d.
(7) e.
(8) c.
(9) j.
(10) h.
(11) a.
(12) g.

008 – 1. (1) T.
(2) S.
(3) S.
(4) T.
(5) T.
(6) S.
(7) T.
(8) T.
(9) S.
(10) S.
008 – 2. Intelligence indicators.
008 – 3. Only those people with a "need to know."
008 – 4. Aircraft loadings, takeoffs and landings; information about materials and specific military operations.

009 – 1. To determine the effectiveness of formal schools and career development courses.
009 – 2. (1) When the graduate can't meet the proficiency requirements of the STS, (2) when the STS lists tasks not performed in that AFS, and (3) when the STS code levels are too high.
009 – 3. 6 months.

010 – 1. (1) b.
(2) d.
(3) c.
(4) a.
(5) a.

011 – 1. AFM–85–3.
011 – 2. Resources and Work Force Management.

012 – 1. 34C2, I–2.
012 – 2. 34C2–3, I–4.
012 – 3. 34W8, I–73.
012 – 4. 34Y1–1, I–73.

013 – 1. (1) Spark plugs.
(2) Ignition wiring and battery connection.
(3) Engine distributor timing.
(4) Wear or pitting of distributer breaker points.
(5) Engine generator belt.
014 – 1. No.
014 – 2. Yes.
014 – 3. No.
014 – 4. Yes.
014 – 5. Yes.

CHAPTER 2

015 – 1. Inservice work plan.
015 – 2. Facility surveys.

015 – 3. Recurring labor-hours and equipment maintenance labor-hours.
015 – 4. To determine how long it should take a skilled craftsman to complete a task.
015 – 5. Work authorization documents.
015 – 6. By post work and the use of a computer.
015 – 7. BEAMS.

016 – 1. a. Requester's name and phone number.
b. Building or facility number.
c. Work requested.
d. Date signed.
e. Signature of base civil engineer.
016 – 2. On the back of the form.
016 – 3. a. New work.
b. Self-help work.
c. Repair of damages to real property caused through neglect or abuse.
d. Inservice minor construction costing less than $1000.00 for base work or over 100.00 for military family housing.
e. Projects that are accomplished by contract.

017 – 1. AF Form 1135.
017 – 2. AF Form 332.
017 – 3. AF Form 332.
017 – 4. AF Form 1135.
017 – 5. AF Form 1135.

018 – 1. F. Initiate AF Form 1135.
018 – 2. T.
018 – 3. F. Emergency situations.
018 – 4. T.
018 – 5. T.
018 – 6. T.

019 – 1. Self-help.
019 – 2. Hopper.
019 – 3. Service call.
019 – 4. SMART.
019 – 5. Service call.
019 – 6. IWP.

020 – 1. Recommend that a larger storage area be constructed.
020 – 2. BCE Work Order (AF Form 327).

021 – 1. To compute man-hour requirements.
021 – 2. To compute allowed time for a job.
021 – 3. The planner.
021 – 4. The front side.

022 – 1. T.
022 – 2. F.
022 – 3. F.
022 – 4. T.

023 – 1. (1) To provide a uniform reporting system.
(2) To identify direct labor cost against work orders.
023 – 2. ATA and ETA.
023 – 3. AF Form 1734.
023 – 4. Handprinted on AF Form 1734 below the first group of names.

024 – 1. (1) c.
(2) f.
(3) d.
(4) e.
(5) a.
(6) f.
(7) e.
(8) e.
(9) d.
(10) b.
(11) c.
(12) e.

025 – 1. You should have placed an x by (1), (3), (4), (5), (6), and (7).

026 – 1. AFR 67-23.
026 – 2. a. Requisition equipment initially.
b. Request replacement.
c. Increase authorization.
d. Reduce authorization.
e. Turn in equipment.
f. Receipt for equipment.

026 – 3. Nomenclature, unit of issue, and quantity.
026 – 4. It is used to order materials.

027 – 1. Materiel Control.
027 – 2. Stock number.
027 – 3. Turkey.

028 – 1. To make a visual check to see if property listed on paper is actually there.
028 – 2. Obeying a set of rules necessary to conserve and protect Air Force equipment and supplies.
028 – 3. (1) AF equipment must be operational; (2) adequate supplies in good condition must be on hand; (3) use equipment and supplies only for their intended purposes; (4) safeguard equipment and supplies; and (5) keep accurate records.

029 – 1. Yellow.
029 – 2. Unserviceable but reparable.
029 – 3. Condemned—do not use.

030 – 1. Expendable items.
030 – 2. Place I (initial), R (recurring), or N (nonrecurring) in the Issue block.
030 – 3. No.
030 – 4. A justification for the issue.
030 – 5. Unit of issue, quantity, unit price, and total cost.
030 – 6. Receipt for AF materials issued on a temporary basis.
030 – 7. 24 hours.
030 – 8. Custody receipt and hand receipt.

CHAPTER 3

031 – 1. a. Improper fraction.
b. Mixed number.
c. Proper fraction.
031 – 2. a. 2.
b. 32.
c. 2.
d. 7.
031 – 3. a. $6\frac{3}{4}$.
b. $16\frac{6}{8}$
c. $1\frac{1}{64}$
d. Cannot be converted.

032 – 1. a. 7/2.
b. 201/32.
c. 47/8.
d. 5/4.
e. 73/16.
032 – 2. a. 77/96.
b. 161/9.
c. 5/12.
032 – 3. a. 5.
b. 16/27.
c. $5\frac{2}{3}$.
d. $4\frac{25}{26}$

032 – 4. Items b, c, e, and f contain improper fractions.
032 – 5. a. $21\frac{16}{24}$
$7\frac{15}{24}$
$18\frac{18}{24}$
$11\frac{6}{24}$
$15\frac{21}{24}$
$4\frac{20}{24}$
b. $1\frac{3}{32}$
$1\frac{4}{32}$
$6\frac{14}{32}$
$14\frac{8}{32}$
$3\frac{20}{32}$

032 – 6. a. 80.
b. $26\frac{17}{32}$

032 – 7.

a. $21\ ^{30}/_{66} = 20\ ^{96}/_{66}$

$-14\ ^{55}/_{66} \quad -14\ ^{55}/_{66}$

b $14\ ^{3}/_{16} = 13\ ^{19}/_{16}$

$-5\ ^{10}/_{16} \quad -5\ ^{10}/_{16}$

032 – 8. a. $6\ ^{41}/_{66}$
b. $8\ ^{9}/_{16}$

033 – 1. 46.4858.
033 – 2. a. 83.824
b.
c. 9.66

034 – 1. 53 inches = 1346.2 mm
034 – 2.

a.	6″	=	152.4 mm
	9″	=	228.6 mm
	21″	=	533.4 mm
	54″	=	1371.6 mm
	68″	=	1727.2 mm
b.	12″	=	304.8 mm
	14″	=	355.6 mm
	23″	=	584.2 mm
	28″	=	711.2 mm
	39″	=	990.6 mm
	89″	=	2260.6 mm

034 – 3.

a.	6 7/8″	=	174.6245 mm
	29 47/64″	=	755.237 mm
	86 11/32″	=	2193.08 mm
	1 3/4	=	44.4491 mm
	36 13/16″	=	935.019 mm
b.	98 miles	=	157.72 km
	61 miles	=	98.17 km
	984 miles	=	9584.24 km

034 – 4. a. 4 feet 4½ inches = 1333.50 mm
b. 3 pounds = 1.36 kg
c. 5½ gallons = 20.82 l
034 – 5. a. 3531.4 cubic feet.
b. 130.79 cubic yards.

035 – 1. An equation.
035 – 2. π, 3.1416
035 – 3. Transposition.
035 – 4. Add 4.
035 – 5. An equal (=) sign.

036 – 1. The branch of geometry that deals with the measurement of lines, angles, surfaces, and solids.
036 – 2. Triangle.
036 – 3. Right, obtuse, acute.

037 – 1. Quadrilateral.
037 – 2. (1)
(2) d.
(3) a.
(4) b.
037 – 3. a. 24.6272 square inches.
b. 262.1426 square inches.

038 – 1. $A = \pi r^2$ or $A = \frac{d^2}{4}$

038 – 2. Arc, chord, tangent, sector, and segment.

039 – 1. $V = 1/3\,(9) \times A_b = 4$ cubic yards.
039 – 2. 226.2 square inches.
039 – 3. 6,720 cubic inches.
039 – 4. 137.445 cubic inches.

CHAPTER 4

040 – 1. Two. All steel goes through the blast furnace; then it must go through either the open-hearth furnace, Bessemer converter, electric furnace, or induction furnace.
040 – 2. Cast iron.
040 – 3. By electric current.
040 – 4. The inglots are placed in an underground furnace called a soaking pit and heated uniformly all the way through at approximately 2200° F.

041 – 1. Permanent mold, sand mold, and die.
041 – 2. Drawing.
041 – 3. Die casting.
041 – 4. Casting or wrought.
041 – 5. Any metal that has been shaped by force while it is in the solid form.
041 – 6. Forging, extruding, rolling, piercing, and drawing.

042 – 1. (1) e.
(2) h.
(3) a.
(4) i.
(5) b.
(6) g.
(7) d.
(8) f.
(9) c.

042 – 2. A change in one property will usually cause a change in one or more additional properties.
042 – 3. Tensile strength.
042 – 4. Elasticity.
042 – 5. A brittle metal *will not* bend without breaking, and a ductile metal *will* bend without breaking.
042 – 6. Hardness.

043 – 1. A ferrous metal is any metal that has iron as its main element.
043 – 2. A nonferrous metal is any metal that contains no iron.
043 – 3. a. Nonferrous.
b. Nonferrous.
c. Ferrous.
d. Ferrous.
e. Ferrous.
f. Nonferrous.
g. Nonferrous.
043 – 4. Alloy steel refers to steel that contains one or more elements other than the iron and carbon which comprises steel.

044 – 1. The percent of carbon content.
044 – 2. Painted or coated with zinc or tin.
044 – 3. Chromium 17–20 percent.
044 – 4. Black iron dipped in hot zinc.
044 – 5. Heating is not required.
044 – 6. It must be painted.
044 – 7. Yes.
044 – 8. Makes them harder without using alloys.
044 – 9. Can be worked cold on the machines and may be bent up to 180°.
044 – 10. Less resistance to corrosion.
044 – 11. Hard metal, and resists scratches and corrosion.

045 – 1. The combination of the chemical composition and grain structure.
045 – 2. Ferrite, pearlite, cementite, austenite, and martensite.
045 – 3. Determines the properties of the metal, the properties that can be changed, and the amount of change that is possible.
045 – 4. Mechanical mixture, solid solution, and a combination of mechanical mixture and solid solution.
045 – 5. Heat increases the size of the grain.
045 – 6. Metal with No. 8 grain size.

046 – 1. By cold-working.
046 – 2. 2 to 4 times the thickness or 1/2 to 1 inch.
046 – 3. The difficulty of making reliable soldering joints.
046 – 4. Heat treatable and nonheat treatable.
046 – 5. It is much lighter.
046 – 6. Magnesium.
046 – 7. Manganese.
046 – 8. Amount of cold-work.

047 – 1. The 75 in 1075 means that there is 0.75-percent carbon in that steel.
047 – 2. SAE–1040 is equivalent to AISI–C2040.
047 – 3. To give complete procurement specifications for materials used in the manufacturing of aircraft, aircraft engines, propellers, and other aircraft accessories.
047 – 4. AMS–5095C.
047 – 5. SAE–9235 indicates:
9—Type of steel (silicon managanese).
2—Percent of alloy (2 percent).
35—Carbon content (0.35 percent carbon).
047 – 6. MIL (military specifications) and JAN (Joint Army and Navy specifications).
047 – 7. Military Handbook H1B, Cross-Index of Chemically Equivalent Specifications and Identification Codes (Ferrous and Nonferrous) Alloys.

048 – 1. Flame test, heat and quench test, spark test, and chemical test.
048 – 2. Flame test.
048 – 3. Use the caustic soda test. Weldable aluminum will become bright and shiny, while nonweldable aluminum will turn black.
048 – 4. Heat and quench test.
048 – 5. The nitric acid test will distinguish between stainless steel and hardened carbon or alloy steels. Nitric acid will attack the hardened carbon or alloy steel very rapidly but attacks stainless steel slowly.
048 – 6. Known samples of steel to use for comparison.

049 – 1. Across the diameter.
049 – 2. Stenciling.
049 – 3. a. Maroon, black, green, orange.
b. AA–1100.
c. White, blue, black, red, orange.
d. Red, olive drab, black, black.
e. AA–2024–Q.
f. SAE–71650–N.

050 – 1. Copper and zinc.
050 – 2. Solder, X-ray shield, and sewer vents or acid tanks.
050 – 3. Zinc.
050 – 4. To increase corrosion resistance.

051 – 1. Temperature.
051 – 2. Place a hot piece of metal in water, salt water, or oil and circulate for even cooling.
051 – 3. Heat it to red hot and let it cool slowly.
051 – 4. By heating it to a specific temperature and allowing it to cool slowly.
051 – 5. To observe the color change of the metal as it is heated.

CHAPTER 4

052 – 1. To prevent continued corrosion after refinishing.
052 – 2. When the chemicals may become entrapped and cannot be completely removed, thus allowing corrosion to continue.
052 – 3. Use an acid resistant container and mix in a ratio of 1:1 with water. Add the acid to the water and apply to ferrous metals only.
052 – 4. Pasa-Jell No. 101 because it is compatible with liquid oxygen.
052 – 5. Wear protective clothing, avoid breathing fumes, and *DO NOT* apply with aluminun or steel wool.
052 – 6. Use on ferrous metals, never on aluminum. Its action can be accelerated by increasing the temperature of the solution.
053 – 1. Breathing air containing solvent vapors, toxicity; absorbing solvents throught the skin; ingestion by swallowing; and dermatitis.
053 – 2. By irritating the nose, throat, or eyes, or by acting as anesthetics.
053 – 3. Absorption through the skin.
053 – 4. Swallowing.
053 – 5. A skin sensitizer.
053 – 6. By direct action where it touches if it is permitted to act long enough in sufficient intensity and quantity.

054 – 1. Selection of chemicals selection of equipment, ventilation,
054 – 1. Selection of chemicals, selection of equipment, ventilation, and protective clothing.
054 – 2. Use the least toxic chemical that will satisfactorily do the job.
054 – 3. Exhaust ventilation.
054 – 4. Air-supplied and air-purifying.
054 – 5. Rubber and plastic gloves, aprons, boots, hoods, and face shields.
054 – 6. Personal cleanliness.

CHANGES FOR THE TEXT: VOLUME 2

Pen-and-Ink Change:

Page-Col	*Subject*	*Line(s)*	*Correction*
iv	Ac-knowledg-ment	3–5	Delete "Rockwell Mfg. Co. . . . Pa. 15230" and replace with "PORTER-CABLE POWER TOOLS, Jackson, Tennessee 38301."
		10–11	Change "P. O. Box 1840, Dept B., New Haven, Connecticut 06504" to "East Alton, Illinois 62024."
			At bottom of page add "In accordance with the copyright agreement, distribution of this volume is limited to DOD personnel."
3R		16 fr bot	After "metal" add a period and change "cutting" to "Cutting."
47L		17, 18	Delete "d. Lock adjustment . . . screws BB."

CHANGES FOR THE TEXT: VOLUME 4

Pen-and-Ink Changes:

Page-Col	*Subject*	*Line(s)*	*Correction*
35L		11	Change "me" to "metal."
70L		20	Change "tension" to "line."
		21	Delete "is to draw a horizontal line on the spring."

Page Changes:

Remove Pages	*Insert Pages*
iii–iv	*iii–iv*
73–74	73–78

Preface

YOU HAVE NOW progressed to Volume 4 of CDC 55252. We would like to give you a "pat on the back" for satisfactory progress up to this point. We want to encourage you to continue with your fine effort. After this volume, you have only three more to complete. Then, you will be in a position to try for upgrading to the 5 skill level.

In this volume, we present information on installing, fabricating, and repairing such items as fixed utility equipment, awnings, canopies, metal roofs, doors (overhead and sliding), and hoists. With this volume, you will have received most of the technical knowledge needed to perform sheet metal work.

Code numbers appearing on figures are for preparing agency identification only.

The inclusion of names of any specific commercial prod ıct, commodity, or service in this publication is for information purpospes only and does not imply indorsement by the Air Force.

This volume is valued at 21 hours (7 points).

Materiel in this volume is technically accurate, adequate, and current as of January 1984.

Acknowledgement

THE ITEMS listed have been reproduced by permission of the following:

Figure 5–1	Eaton Corporation
Figure 5–2	Hoisting Equipment Division
Figure 5–2	P.O. Box 1000
	Forrest City, AR 72335

Contents

the axle welded to a collar that can be adjusted to different heights on the post (fig. 4-29). The gate may be operated or powered manually. The latch mechanism may be operated manually or have an electromagnet-operated latch within a secure box of some type.

Maintenance and repair. The most common problem with these gates involves the rollers. If they are not lubricated and adjusted regularly, the bushing and/or bearings will wear out rapidly. Usually there is a grease fitting (zerk) in the axle shaft or on the roller hub which facilitates lubricating the roller. The position of the rollers supports the gate and prevents its being removed. Only one set of rollers (top or bottom) supports the gate, while the other set guides and secures the gate in position. Another variation would be to have the upper and lower gate rails both on the inside of the rollers. Then only the lower set would support the gate while the upper set would guide and secure it. The rollers are adjusted on the gateposts by loosening the bolt in the collar, sliding the assembly into the required position, and retightening the bolt. The rollers should not be adjusted tight enough to cause drag or stress nor loose enough to allow the gate to come off the rollers. You also must be careful to align the latch properly when the gate is closed.

Power units. The power unit on a mechanical gate is similar to that of the overhead door. The principle is the same. A power unit (operator) turns a shaft and sprocket, which moves a roller chain. The gate is attached to the roller chain and moves on tracks. As with the overhead door operator, dust and dirt collect on the roller chain and cause many problems. This dust and dirt must be removed during regular maintenance.

Exercises (638):

1. Why are the upper and lower rollers installed either on the inside or the outside of the rails?

2. What items should be checked during inspection of a gate system?

Hoists

INSPECTION AND MAINTENANCE of hoists and cranes is a portion of our job that supports other units on base. If we as Metal Fabricating Specialists fail to support them, their ability to do their job and support the mission is severely hampered. Some of the other units on base that have and use hoists in their day-to-day operation are the aircraft jet engine shop, the ammunition storage area and Base Supply. There is probably even a small hoist in your shop.

5-1. Preventive Maintenance

A preventive maintenance program should be established based on the hoist manufacturer's recommendations. All data collected during any phase of inspection and maintenance should be put into detailed records for each hoist. These records should be readily available for future reference. Any time a part has to be replaced, the part should be obtained from the manufacturer. The preventive maintenance program will identify any part that has weakened to the point that it could cause a hoist to fail and result in a mishap.

When performing maintenance and inspection of a hoist, it is a good idea to remove the hoist and take it back to the shop or to a designated repair area. By removing the hoist to the shop area, you'll have all the necessary tools and equipment to check the hoist. You'll also have access to the records on the hoist and the technical expertise of your supervisor and other craftsmen assigned to your shop.

When you are inspecting hoists, the most important item to have on hand is the owner's manual for that particular hoist. If the owner's manual is not available, we have to use T.O. 36—1—58, titled *General Requirements for Repair, Maintenance, and Testing of Lifting Devices*. These publications outline exactly what we have to check and how it is to be accomplished. The types of inspections that are performed can be broken into two separate types, the Frequent Inspection and the Periodic Inspection.

639. State the procedures to follow when accomplishing a frequent inspection.

Frequent Inspection. We may schedule the frequent inspection as often as daily or before each use. The items that we have to inspect include, but are not limited to, the hook, load chains, and braking mechanisms.

Hooks. In an inspection of the hook, the first sign of a damaged hook would be a sprung safety latch. A sprung or released latch indicates that the hook has been overloaded. Most of the hooks on hoists are made of cast steel. Instead of breaking, the hook will stretch and release the latch. The factor that tells us when we have to change the hook is if the hook has an opening of more than 15 percent larger than the original opening (fig. 5-1) or a twist of more than 10 percent from the plane of the unbent hook (fig. 5-2). We can find the exact measurements of the hook in the owner's manual for that particular hoist. We also have to check the hook for chemical damage or internal cracks. The easiest and best method to use in checking the hook for cracks is known as the nondestructive inspection. Civil engineers do not have the capability to perform this type of test. The nondestructive inspection (NDI) section of the local aircraft maintenance squadron has the equipment and knowledge to do these inspections. They will use X-rays, a magnetic particle, or dye penetrant test to detect cracks that are invisible to the naked eye or internal cracks.

Load chains. We have all heard the old saying that a chain is only as strong as its weakest link. This is equally important on a chain hoist. We need to check the load chain for wear, twists, broken, cracked, or otherwise damaged links. This should be done daily or before each use. We also have to check the chain to make sure there are no deposits of foreign material that could be carried into the hoisting mechanism and cause damage.

Brake mechanism. The braking mechanism is the heart and strength of a hoist. No matter how strong the hook and chain are, a hoist can fail due to a faulty braking mechanism. To check the brake mechanism during a frequent inspection, all you have to do is operate the hoist in the unloaded state. The lower block and hook will provide enough weight to cause the brakemechanism to engage. This check should be done daily or prior to each use.

Exercises (639):

1. A frequent inspection should be performed daily or ______ ______ ______ .

2. A sprung or released hook latch indicates that a hook has been __________ .

3. A hook having an opening of _________ _________ larger than the original opening should be replaced.

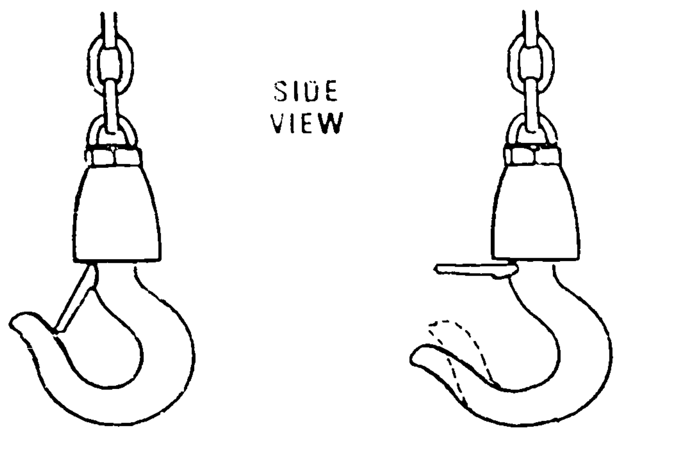

Figure 5-1. Sprung hook.

4. A dye penetrant test will identify _____________ _____________.

640. State the procedures to follow when accomplishing a periodic inspection.

Periodic Inspection. The periodic inspection is a more thorough and complex inspection than a frequent inspection. The periodic inspection should be accomplished at an interval that takes into consideration many variables. The factor that is the driving force to determine how often you inspect a hoist is the frequency of its use. The climate and severity of use also have to be taken into consideration when developing an inspection program. You should schedule your periodic inspection at least annually, but you can schedule it as often as monthly, quarterly, or semi-annually. During the periodic inspection every component of the hoist is checked.

The first step of the inspection should be to check with the people who use the hoist in the day to day accomplishment of their jobs. They can tell you if any unusual sounds have been coming out of the gearbox of the hoist. They can also tell you whether or not the hoist has had any other problems. After talking with the operators of the hoist, the next step of the inspection is to operate the hoist (without a load) making sure all parts of the hoist are operating properly. This portion of the periodic inspection could be called a preinspection. From this point on you are going to check each piece of the hoist.

Chain. When inspecting the chain, you are looking for signs of excessive wear and stretch. To check the chain for wear, separate the links and look at the load bearing surfaces of the link. Excessive wear will be indicated by a highly polished area and a wearing away of the material where the links come in contact with one another. To check the chain for stretchage select an unworn, unstretched length of chain (e.g., the slack end). Suspend the chain vertically under tension and use a caliper-type gauge that is approximately 12 to 14 inches long to measure the outside length of the chain. Next measure the same number of links in the used section of chain. If the used chain length exceeds the manufacturer's recommended length or, if you do not have the specific manual for that hoist, the used portion of chain is 2½ percent longer than the unused chain, the chain should be replaced.

The existence of gouges, nicks, corrosion, weld splatter, or distorted links is sufficient reason to question the quality (safety) of the chain. Safety in this respect depends largely upon the use of good judgement by the person evaluating the degree of deficiency. If it is determined that the chain should be changed, the replacement chain should be the same size, grade, and construction as the original chain supplied by the hoist manufacturer. The load chain should be installed with the welds away from the center of the sprocket. Also, the chain will not be installed with any twists between the hoist and the anchored end on either the loaded side or the slack side.

When the chain is being replaced, disassemble and inspect the mating parts (chain sprockets, guides, and stripper) for signs of excessive wear and replace if necessary.

Hooks. Hooks should be removed at least once a year. The hooks should be inspected for cracks by using a dye penetrant or magnetic particle test. Another method that can be used to check the hook for cracks is to have the hook X-rayed. The X-ray picture will identify internal cracks or cracks that are too small to be seen with the naked eye. Hook retaining nuts, or collar and pins, and the welds or rivets used to secure the retaining member should be checked for cracked welds or split rivets and pins.

The brake mechanism should be taken apart and inspected. Check for worn, glazed, or oil-contaminated

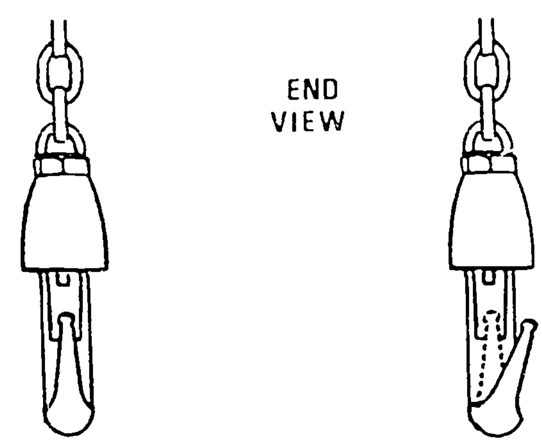

Figure 5-2. Twisted hook.

friction disc. Next inspect the pawls, making sure they are not cracked or bent. Figure 5-3 shows the internal components of the brake mechanism. Inspect the cam or ratchet for signs of wear. Replace these items if the wear appears to be excessive. Check the pawl springs for corrosion and also for collapsed or broken springs. Remove the corrosion if possible and replace any broken or collapsed pawl springs.

Next check for any worn, cracked, or distorted parts such as hood blocks, suspension housing, outriggers, hand chain wheels, chain attachments, clevis, yokes, suspension bolts, shafts, gears, and bearings. When any of these components are found to be damaged or worn out, take the hoist out of service until replacement parts can be installed. Tighten all nuts, bolts or rivets that are found to be loose. The supporting structure (e.g., I-beams, ceiling joists, or A-frames) and trolley, if the hoist is equipped with these, should be inspected to ensure that they still have the ability to support the loads that they will be subjected to.

Exercises (640):

1. A periodic inspection should be accomplished at least once a __________.

2. The __________ __________ __________ determines how often a periodic inspection will be performed.

3. Excessive wear on a load chain would be indicated by a __________ __________ load-bearing surface.

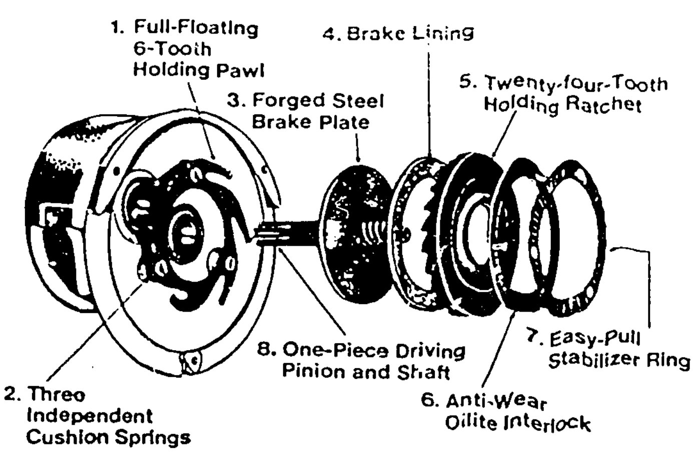

Figure 5-3. Brake mechanism (exploded).

4. A __________ __________ would installed with the welds away from the center of the sprocket.

5. The __________ __________ should be taken apart and inspected prior to installing a new load chain.

641. Determine when a weight test will be performed on a hoist.

Testing. The next portion of maintaining a hoist is to perform a weight test. Weight tests can be broken into two types: an operational test and a load test.

Operational test. An operational test is performed on any hoist that has been altered, repaired, or has not been used in the preceding 12 months. All functions of the hoist including hoisting and lowering should be checked with the hoist suspended in the unloaded state. After testing in the unload-supportinged state, a load of 50 pounds times the number of load parts of chain should be applied to the hoist to check for proper load control.

Load test. All hoists that have had load-sustaining parts altered,, repaired or replaced should be tested by or under the direction of an appointed person. A written report of the weight test should be prepared and kept on record. The test weight should be 125 percent of the rated load. Therefore, if a hoist is rated at 6000 pounds, the test bet should weigh 7500 lbs. On a hoist that has an overload device incorporated into the lifting mechanism that prevents the lifting of 125 percent of a rated load, the test weight should be 100 percent of the rated load, after which the load limiting device should be checked.

Exercises (641):

1. An __________ __________ is performed on a hoist that has not been used in the preceding 12 months.

2. An operational test is performed with the hoist suspended in the __________ state.

3. The weight to perform a load test should be ______ percent of the rated load capacity.

4. A hoist with an overload prevention device should be tested to ________ percent of its capacity.

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

600 – 1. 6 inches on side and 12 inches in front.
600 – 2. 20-gage stainless steel.
600 – 3. Monel rivets.

601 – 1. Plan view.
601 – 2. Triangulation method.
601 – 3. The true length chart.
601 – 4. The 1-inch 90° bend portion.
601 – 5. Dividers or trammel points.
601 – 6. Slant notche[illegible] ach end.

602 – 1. Squaring shears and straight snips, so you won't clip the 2-inch collar.
602 – 2. Straighten about 2 inches of each seam end, so the cornice brake won't damage the metal when you clamp it.
602 – 3. Cornice brake and box and pan brake.

603 – 1. One 2 inches from each end of standing seam and one in the center.
603 – 2. Measure distances between diagonally opposite corner to make sure they are equal.
603 – 3. 50/50 solder for the corner lap joint, but silver solder for the outlet; silver solder is stronger.
603 – 4. Use turnbuckles to lower the drain outlet so that grease will drain out properly.

604 – 1. 14-gage stainless steel.
604 – 2. 1-inch stainless steel tubing.
604 – 3. 16 gage and 1 [illegible] inches in diameter.

605 – 1. 20 gage.
605 – 2. Stainless steel is stronger, requiring more force to bend, and it has more springback.
605 – 3. Use shears and forming equipment with a larger capacity than you would use for the same gage of mild steel.

606 – 1. Make straight (butt) cuts, insert a piece of brass round stock about 6 inches long, drill and tap hole in the bottom side, and attach the pieces with roundhead screws.
606 – 2. Use new brackets, because welding removes the chromium plate.
606 – 3. With a 3/8-inch corrosion-resistant bolt.

607 – 1. Do the rough cut with a medium coarse grit, do the second cut with a medium fine grit, and stop grinding before the bead is flush.
607 – 2. Use a wheel that hasn't been used on other metals; apply adhesive paper to protect the surface; avoid overheating the surface. (Any two of these is a good answer.)
607 – 3. Use 120 grit aluminum oxide applied with a soft wheel, using a lubricant.

CHAPTER 2

608 – 1. Before.
608 – 2. Material of the same type and thickness as the original material.
608 – 3. A masonry drill and expandable sleeves (anchors).
608 – 4. Shaping (flattening and bending) the ends and drill holes in them.

609 – 1. It has seam allowance for two standing seam flanges because the side trim has the pocket portion of the standing seam.
609 – 2. Punch press, straight snips, and cornice brake.
609 – 3. The corner lap seams on the ends of the side pieces.

610 – 1. The top panel installed last is the one with two flanges and no standing seam pocket.
610 – 2. First attach the hanger, position the canopy on the wall angle and level it, then drill holes and bolt to wall angle.
610 – 3. Rivets or bolts and caulking compound.

CHAPTER 3

611 – 1. Galvanic action.
611 – 2. Copper, aluminum, and galvanized iron. Don't use steel nails with copper.
611 – 3. A coating of oxide (patina) that forms when copper is exposed to the air and weather.
611 – 4. Lower cost and strength.

612 – 1. Less than a 3-inch slope to the foot.
612 – 2. The roofing standing seam is a double seam.
612 – 3. Grooved (flat) seamed roofs are held in place with cleats and the seams are soldered.
612 – 4. Corrugated, rib, or 5 V-crimp.
612 – 5. Because, for a batten seam you nail the cleats to the batten strip.

613 – 1. Double seamers are used to make double seams out of standing seams.
613 – 2. Mallet.
613 – 3. Clamping tongs hold seams in place while you work; squeezing tongs are used to tighten seams.
613 – 4. Grooved or flat.

614 – 1. The first sheet installed is the lower sheet in the direction of the prevailing wind.
614 – 2. After the first row has progressed far enough that it will not overlap any of the second row.
614 – 3. So that a good solder joint can be made easily.
614 – 4. A metal strip the full length of the gable is nailed to the roof deck and extends 3/4 inch past the bottom edge of the gable.
614 – 5. The cap is flattened over the end of the batten.
614 – 6. a. Under the ridge flashing.
b. Lay the roof, place the closure strip, place the ridge cap, fasten with screws through the cap-closure strip and into the roof.

615 – 1. Solder the hole or break
615 – 2. By replacing the sheet with the break.
615 – 3. Clean with wire brush or emery cloth and apply flux.
615 – 4. Make a patch from like material; use roofing cement and blind rivets to fasten the patch in place.
615 – 5. Solder, usually 50/50.

616 – 1. Fascia and gravel guard flashing.
616 – 2. Ridge flashing.
616 – 3. a. With bolts, screws, rivets, nails, or cleats.
b. Always use the same kind of material as the flashing.

616 – 4. Fascia and gravel guard flashing, and it should be wide enough to extend under the roofing material 4 inches and cover the entire fascia.
616 – 5. Gable flashing.
616 – 6. On the ridge of a roof; it should be lapped at least 4 inches.

617 – 1. Tar stop.
617 – 2. Piece A of an expansion joint.
617 – 3. (a) Clean the area, (b) apply flux, and (c) apply 50 50 solder.

618 – 1. Half-round double-bead gutter.
618 – 2. Nonhardening type.
618 – 3. Ferrules and spikes.
618 – 4. Strainer.
618 – 5. On the front, the ogee gutter has a slow S-shape.
618 – 6. End cap, held in place by friction, solder, or plastic cement

619 – 1. Route water from the gutter to the drainage system.
619 – 2. Cold areas; freezes.
619 – 3. They will match the gutters.
619 – 4. Avoiding sharp turns.
619 – 5. Prevent washing the soil away.
619 – 6. An anchor bolt and strap hanger.

620 – 1. Opposite the downspout and as close to the eave overhang as possible.
620 – 2. Mastic (plastic cement).
620 – 3. Secure the downspout in place by placing sheet metal screws through the hanger into the downspout.
620 – 4. Not over 30 inches apart.
620 – 5. Slip joints are installed with mastic.
620 – 6. Measure the distance between the pockets of the slip joints.
620 – 7. 6 inches.

621 – 1. Remove all of the old mastic and reseal with new mastic.
621 – 2. Replace it with a like hanger.
621 – 3. Clean the area around the hole and solder.

622 – 1. Sketch the gutter, including dimensions and shape, and determine what material to use.
622 – 2. Prick-punch the bend lines.
622 – 3. Cornice brake with a former.
622 – 4. Make the first four bends on the second gutter; then you can make all the curve bends when you put the former in.

623 – 1. The 3/8-inch flanges on three sides of the drop outlet are bent out 90° with a stake and mallet.
623 – 2. Three.
623 – 3. Inside.
623 – 4. Left and right ends.
623 – 5. In the back.
623 – 6. The one at the back remains straight to fit the back of the gutter.
623 – 7. With rivets or spot weld.
623 – 8. 1/2 inch, on only one piece.
623 – 9. Inside.
623 – 10. A 6-foot section of 2" x 2" x 1/4" angle iron.
623 – 11. An item placed at the bottom of a leader to turn water out away from the building. It is made by making two 45° miters.

624 – 1. Test the new gutter with water to insure that the water will flow out. Make the test before you install any other components.
624 – 2. Three.

CHAPTER 4

625 – 1. (1) c.
(2) b.
(3) a.
(4) a.
(5) e.

626 – 1. b, d, e.

627 – 1. (1) e.
(2) d.
(3) g.
(4) f.
(5) b.
(6) a.
(7) d.

628 – 1. a, d, e.

629 – 1. (1) b.
(2) a.
(3) c.

630 – 1. a, d, e, f, g, i, j.

631 – 1. b, f, g, i.

632 – 1. c, d, b, a, e.

633 – 1. Left hand.
633 – 2. It has the hinges on the right and swings out (toward you) as you face it from the outside.
633 – 3. On the outside.

634 – 1. Determine the cause of the damage.
634 – 2. By drilling through the casing and plug welding the hinge plate in place.
634 – 3. Difficult to close and springs open.
634 – 4. Taper, because of the long tapered section at the starting end which helps center and guide the tap into the hole.
634 – 5. In a blind hole because threads will not be cut the full depth of the hole.
634 – 6. F.

635 – 1. Rollup.
635 – 2. The shaft has cables and cable drums. The cables attach to the bottom panel and wind around the cable drum as the door is raised.

636 – 1. Place a straight edge across the face of the sprockets. The straight edge must contact the full face of both gears for proper alignment.
636 – 2. Parafin wax or silicone, because these lubricants do not attract dirt as other lubricants do.
636 – 3. Adjust the cable drums to level the door.
636 – 4. To obtain an accurate count of the number of revolutions the spring has been wound.
636 – 5. It should fall through the midrange of its travel and barely tend to lift off the floor. When opened it should snap into the head assembly.

637 – 1. By adjusting the wheels you can raise or lower each end of the door independently.
637 – 2. Limit switch operation.
637 – 3. Because they attract dust, dirt and sand.

638 – 1. To support the gate and prevent its being removed easily.
638 – 2. Proper lubrication, roller positioning, and broken or worn components.

CHAPTER 5

639 – 1. Before each use.
639 – 2. Overloaded.
639 – 3. 15 per cent.
639 – 4. Internal cracks.

640 – 1. Year.
640 – 2. The amount of use.
640 – 3. Highly polished.
640 – 4. Load chain.
640 – 5. Brake mechanism.

641 – 1. Operational test.
641 – 2. Unloaded.
641 – 3. 125.
641 – 4. 100.

CHANGES FOR THE TEXT: VOLUME 5

Pen-and-Ink Changes:

Page-Col	*Subject*	*Line(s)*	*Correction*
6R		6 fr bot	Change "less" to "more."
26R		30	Change ".08" to ".03."
42L		7	After "fluxing" add a comma.
57L/R–58L/R	840		Delete objective segment 840, including exercises and figure 6-9.
63R			Delete all 840 answers.

CHANGES FOR THE TEXT: VOLUME 6

Pen-and-Ink Changes:

Page-Col	*Subject*	*Line(s)*	*Correction*
2L		7	After "series" add "of plug receptacles."
		17	Change "*positive*" to "*negative*."
		18	Change "*negative*" to "*positive*."
49R		15	Change "olate" to "plate."
52L		9	Change "purpose" to "purple."
60R		23	Change "side" to "size."

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CDC 55252

METAL FABRICATING SPECIALIST
(AFSC 55252)

Volume 1

General Subjects

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THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

THIS VOLUME of CDC 55252, *Metal Fabricating Specialist*, contains information about the following subjects: base civil engineering organization, career progression, publications, activities management, resources management, shop mathematics, and characteristics of metals. The other volumes in the course include: Volume 2, *Sheet Metal Tools and Equipment;* Volume 3, *Layout and Duct Systems;* Volume 4, *Installed Equipment and Doors;* Volume 5, *Oxyacetylene Welding;* Volume 6, *Electric Welding;* and Volume 7, *General Contingency Responsibilities*.

When you successfully complete the six volumes of this course, you will have the knowledge you need to perform your duties as a metal fabricating specialist. By performing the exercises before you look at the answers, you learn to master the contents of the course. Then when you combine the knowledge gained with the practical experience you get on the job, you earn success, prestige, and promotions that are awaiting you

Code numbers appearing on figures are for use by preparing agency only.

Direct your questions or comments relating to the accuracy or currency of this volume to the course author: 3770 TCHTG/TTGIC, ATTN: Msgt Arnold D. Ringstad, Sheppard AFB, TX 76311. If you need an immediate response, call the author, AUTOVON 736–2879, between 0800 and 1600 (CST), Monday through Friday. *(NOTE: Do not use the suggestion program to submit changes or corrections for this course.)*

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This volume is valued at 24 hours (8 points).

Material in this volume is technically accurate, adequate, and current as of August 1982.

Contents

NOTE: In this volume, the subject matter is developed by a series of student-centered objectives. Each of these carries a three-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see whether your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

BCE Organization, Career Progression, and Publications

THOSE OF US who are engaged in constructing, repairing, and maintaining Air Force property recognize it as a very important Air Force job. Just as buildings will deteriorate if not kept in a reasonable state of repair, so will other Air Force facilities run down and eventually become unserviceable. The upkeep of Air Force buildings is of primary concern to the Air Force and to the metal fabricating specialist.

The Air Force owns a tremendous number of facilities. If you were to compare the real estate property of the entire U.S. Air Force with the physical plants of civilian industrial businesses, you would have to add up the value of some 10 to 15 of the more significant, each considered a giant, to total the value of Air Force real property. Such businesses could include all physical assets of General Motors, Ford, Chrysler, Standard Oil, Texaco, American Telephone and Telegraph, Goodyear, International Harvester, American Tobacco Company, and the Carrier Corporation, among others.

The cost of servicing, operating, and maintaining this Air Force property is tremendous. Yet Air Force funds, like your personal funds, are limited. Have you bought metal roofing lately? The cost of lumber, tools, and other building materials has skyrocketed in the past few years. Your job is not only that of construction and maintenance but also using Air Force resources wisely. Don't waste materials or your time. To waste either is to waste Air Force money. Learn your job well so that you can operate more efficiently. Learn also how to cooperate with other workers in the civil engineering organization. When we all work together toward common goals, we stretch the Air Force dollar and make it go further, thereby giving the American people more value for their investment.

In this chapter, you will cover the base civil engineering organizational structure, mission of the 55 career field, duties and responsibilities of the metal fabricating specialist, publications, and security.

1-1. Base Civil Engineering Organization

The base civil engineering organization is commanded by an Air Force officer who is called the base civil engineer (BCE). He or she is responsible for all the work done by Civil Engineering (CE). The job includes getting maximum efficiency for each dollar spent while attaining planned objectives. This means that human resources, material resources, and financial resources must be consumed in the most effective way possible to meet the goals of the organization.

CE is a large, complex organization with many jobs going on at the same time. The BCE uses many assistants to help manage the organization. One of these managers is the structural superintendent. This person manages the structures activities, which include (among others) metal working.

You and the people in your shop will fabricate, repair, weld, and install sheet metal and metal components. You will be working with the carpenters, plumbers, painters, and masons in constructing and repairing base facilities. Before getting an in-depth look at your job tasks, let's take a look at the overall mission of a civil engineering organization.

001. From a list of activities, select those that pertain to the overall mission of a civil engineering organization.

Base Civil Engineering Mission. The primary mission of civil engineering is to acquire, construct, maintain, and operate real property facilities and other support work and services. Examples of overall mission are:

- Acquire land to contruct military family housing.
- Construct air-conditioning ducts.
- Modify and repair buildings.
- Operate and maintain heating plants.
- Provide water and electricity to base facilities.

Although CE provides utilities to base facilities and performs maintenance on them, CE does not operate most facilities on base. These functions belong to other Air Force units. For example, CE does not operate aircraft, missiles, clubs, or dining halls.

Exercises (001):

Write yes beside each activity that directly pertains to the BCE overall mission. Write no beside the others.

_____ 1. Fuel aircraft.
_____ 2. Acquire land.
_____ 3. Paint aircraft hangar.
_____ 4. Maintain missiles.
_____ 5. Provide natural gas.
_____ 6. Engineer air conditioning for facility.
_____ 7. Operate dining hall.
_____ 8. Manage Air Force real property.
_____ 9. Repair concrete floor in aircraft hangar.
_____ 10. Operate NCO club.
_____ 11. Construct concrete walk.
_____ 12. Maintain asphalt parking lot.

002. State the command level of various units on a CE organizational chart.

Civil Engineer Organization Chart. Figure 1-1, Base Civil Engineer Organization Chart, shows the structure of CE. Study the chart in order to learn the level of command throughout the organization. At the very top of the chart is the base civil engineer. The BCE ultimately is responsible for CE mission accomplishment.

As President Truman said, "The [illegible] stops here." Passing the buck in CE will eventually [illegible] at the BCE. You well know that Air Force personnel should go through the chain of command. If you skip a link in the chain, things start to go wrong. As the saying goes, a chain is no stronger than its weakest link. The lines on the chart represent the chain in the CE structure. Each block represents an office, shop, or unit in which a manager or supervisor is in control. Find the metal working block on the chart. The chain of command line for all units in this block goes through the structural superintendent. From operations, the command line goes up the chain to the civil engineer. As you can see from figure 1-1, the BCE holds the chief of operations responsible for all the CE shops. Resources and Requirements is not in a direct command line to the structural shop. It works in a staff function to help the operations chief. From the example above, you should be able to trace the command line through the various units. Let's see if you can.

Exercises (002):

Refer to figure 1-1 and name the command block immediately above each of these CE units.

1. Heat Systems.

2. Custodial Services.

3. Planning.

4. Mechanical.

5. Equipment Operations.

6. Fire Protection.

7. Industrial Engineering.

8. SQD SEC.

9. Masonry.

10. Structural.

11. Grounds.

12. Quarry.

003. Identify CE functions and responsibilities with the CE unit to which they apply.

Base Civil Engineer Responsibilities. The base civil engineer requires a number of CE units to help him perform his mission and responsibilities. His job entails even more than the mayor or city manager of a large city. Although the mayor is responsible for providing the city with fire prevention equipment and police protection, garbage and refuse collection and disposal, and furnishing utility services, the BCE in addition to the above responsibilities must:

- Maintain real property facilities in condition for normal use.
- Conserve natural resources and control environmental pollution.
- Construct and alter facilities to support mission changes.
- Provide management and professional engineering services to insure effective and economical operation of all activities.

These activities are broad in scope. Now let's take a look at the CE units that help the BCE perform this mission, let's

Base Civil Engineer Organization Chart

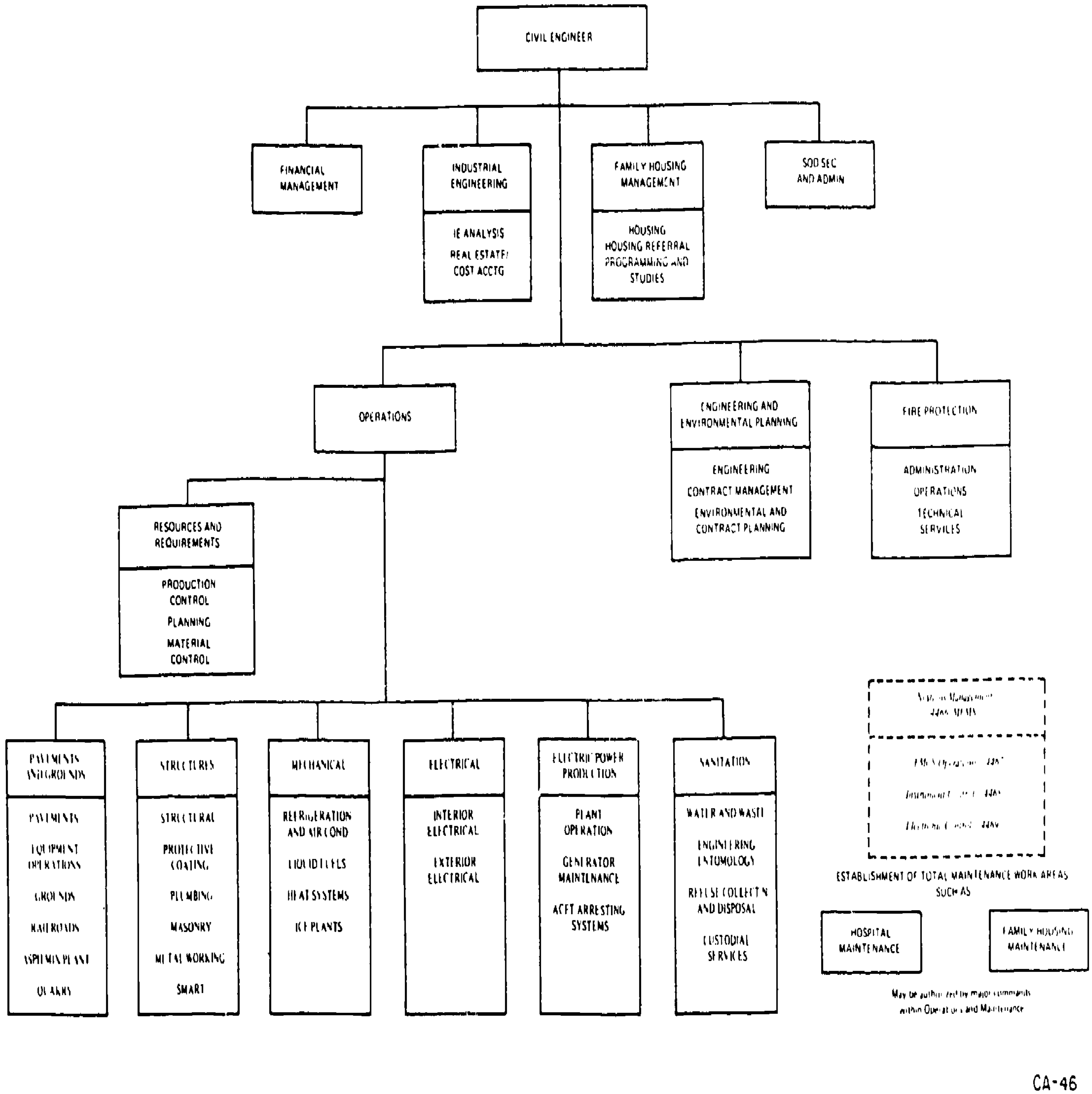

Figure 1-1. Civil engineer organization.

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break down these broad areas into narrower areas of activities.

Functions and Responsibilities of CE Units. As we look into these individual sections, refer to figure 1-1 as frequently as necessary to understand their mutual relationships.

Squadron and administration. This unit handles the administrative and personnel work of the CE organization. The administrative section receives, distributes, and dispatches all communications for CE; prepares reports and correspondence; maintains correspondence files; maintains the CE library; conducts special programs, such as fund drives and awards; and supervises the records. The squadron section takes personnel actions delegated by the squadron commander. Some of these duties include counseling, maintaining duty rosters, conducting general military training and commander's call, and enforcing discipline.

Industrial engineering analysis (IE). This unit serves as a general evaluation and advisory group. The unit evaluates work performed by all CE personnel. IE personnel inspect facilities, equipment, programs, and procedures. They identify deficiencies and recommend corrective action. If the size of the base warrants an automated system, the industrial engineering section implements it, monitors and interprets the results, and uses the information to advise the BCE.

The quality control section of industrial engineering inspects in-house and self-help work while it is in progress to determine work quality, work force efficiency, supervisor adequacy, and directive compliance. This section also checks the adequacy and quality of the supplies used in performing the work.

Operations. This unit directs, coordinates, and controls all work approved and authorized to be done by the CE work force. Personnel of this section serve as consultants during the design of new (or alteration of old) facilities. The resources and requirements section serves as a staff activity to operations. This section assigns priorities and schedules work to appropriate shops. This section also operates the service call system and controls the use of vehicles assigned to CE.

The main work areas under operations are: pavements and grounds, structures, mechanical, electrical, electric power production, and sanitation. Each of these areas may contain several shops; for instance, the pavements and grounds area contains the pavements shop and the equipment operations shop. Sometimes there are needs for other shops, such as grounds, railroads, asphalt mix plant, and quarry. These shops are added to a base when the needs are justified.

Fire protection. This unit takes care of fire prevention activities on base. It performs fire control services, inspects and tests fire protection and fire alarm systems, and it services ground-type portable fire extinguishers.

Financial management. CE financial matters are managed by this section. They are responsible for financial plans, budgets, and annual and long-range work plans. This unit also approves work requests and obtains materials for the approved work.

Engineering and environmental planning. The architectural and professional engineering services for CE are handled through this section. Problems that are beyond the capability of operations people are referred to the professional engineers of this unit. This unit also reviews and develops technical provisions of contracts for real property facilities. This section prepares architectural and engineering drawings and maps to support the base master plan. In addition, section personnel monitor all real property facilities and systems to develop improvements and to update systems or equipment. They also make technical inspections of all maintenance, repair, construction, and service work done by contract to assure quality work and contract compliance.

Family housing management. This unit manages activities in the following functional areas:

- Use of military family housing including inquiries, interviews, assignments, terminations, and related administrative work.
- Planning, programming, and budgeting for maintenance, repair, alternation, and new construction applicable to military family housing.
- Change-of-occupancy inspection.
- Housing referral services.

Exercises (003):

1. Match each BCE unit in column B with its function in column A.

Column A	*Column B*
______(1) Dispatches letters to base organizations.	a. Squadron and Administration.
______(2) Checks the quality of lumber.	b. Industrial Engineering.
______(3) Operates service calls.	c. Operations.
______(4) Repairs bituminous pavements.	d. Fire Protection.
______(5) Fills empty extinguishers.	e. Financial Management.
______(6) Approves work requests.	f. Engineering and Environmental Planning.
______(7) Inspects military family housing.	g. Family Housing Management.
______(8) Inspects in-house work.	
______(9) Inspects construction work performed by contract.	
______(10) Removes wall from section of headquarters building.	

004. Identify the functions of project RED HORSE.

Functions of RED HORSE. Air Force squadrons with the title of RED HORSE have the ability to repair major damage that is inflicted upon a base. Like BEEF, RED HORSE is an acronym: RED means "rapid engineer deployable," and HORSE means "heavy operations repair squadron, engineer." When you put it all together, RED HORSE means "rapid engineer deployable heavy operations repair squadron, engineer." Try telling your friend the title of that unit. It's a mouthful isn't it? "RED HORSE" is so much easier for you to say. The full title, however, pretty well explains the function of the unit.

RED HORSE squadrons provide heavy equipment repair and construction of base facilities when and where the requirements exceed the base CE's capabilities and when Army or Navy support is not readily available. These squadrons are formed with trained personnel from all major commands. Personnel are given training to make them proficient in all areas of their skills. The training is necessary to meet the high standards required of RED HORSE squadrons. RED HORSE squadrons are capable of rapid deployment and are responsive to the following:

- Worldwide requirements as directed by Headquarters USAF.
- Establishing new base facilities or expanding and upgrading existing base facilities.
- Repairing or replacing damaged or destroyed facilities in combat zones.
- Meeting recovery requirements for Air Force facilities in case of natural disasters.
- Training exercises, maneuvers, and special projects.

RED HORSE also makes major construction alterations and additions to an existing base, as would be the case when a runway is lengthened, a hangar is built, or aircraft parking ramps and taxiways are constructed. The RED HORSE squadron can move on to an abandoned air base and restore it to the extent necessary for flying operations. Likewise, the squadron can move into an area where there has never been a base and build one.

Exercises (004):

Mark the following statements on the function of RED HORSE with a "C" if they are correct; "I" if incorrect.

_____ 1. Squadrons are formed from trained personnel from all major commands.
_____ 2. Provide heavy repair and construction when Army or Navy support is not readily available.
_____ 3. Provide depot level maintenance for real property installed equipment.
_____ 4. Have the ability to repair major damage that may be inflicted upon a base.
_____ 5. Perform major construction alterations and additions itions to an existing base.
_____ 6. Have the capability, but are not required to build a new base.

005. Give the meaning of BEEF, and identify six objectives of the Prime BEEF program.

Project Prime BEEF. "When the whistle blows, are we ready to go?" This was the question the Deputy Director in CE Operations, HQ USAF, asked in December 1963. The answer was "no." However, under Project Prime BEEF the answer is "yes." Project Prime BEEF creates within Air Force civil engineering the ability to respond to emergencies. The emergencies may result from acts of aggression or disasters.

The role of civil engineering has changed considerably since World War II. Civil engineering now has a direct combat support role. If you are selected to be a member of the base engineer emergency forces team, you must train to become more involved in contingency operations. In normal BCE operation, you will be a member of a BEEF team and be trained and prepared to deploy with that team on relatively short notice. This training will not only give you the knowledge and ability to perform various required tasks of contingency operation but will give you the knowledge and ability to protect these facilities from enemy acts.

BEEF means "base engineer emergency forces." This type of force is made up of selected airmen and officers at bases throughout the United States. The personnel are members of units within the force, called Prime BEEF teams. In the event of an enemy attack, a natural disaster, or an emergency workload (at either a stateside or an oversea base) a BEEF team can be made available to supplement the work force at the affected base. There are a number of Prime BEEF teams, with six major objectives stated in AFR 93-3, flAir Force Civil Engineering Prime (BEEF) Program-Base Engineering Emergency Force.

(1) Align the civil engineering military force to perform direct combat support tasks in support of the Air Force mission worldwide.

(2) Develop and maintain a highly skilled mobile military engineering force capable of rapid response for direct combat support of worldwide contingency operations.

(3) Insure effective use of the civilian engineering force in meeting requirements generated as a result of natural disasters and in response to indirect combat support need.

(4) Provide supplementary training as necessary to insure that military personnel are capable of performing tasks peculiar to direct combat support operations.

(5) A balanced military-civilian mix providing equitable career development opportunities for both military and civilian personnel.

(6) Provide an adequate military manning base to support Air Force rotation requirements.

Exercises (005):

1. What do the letters BEEF stand for in the Prime BEEF program?

2. Write BEEF in the blank before each objective of the Prime BEEF program.

_____ a. Balanced military-civilian mix.
_____ b. Unskilled personnel tabbed for training in an emergency.
_____ c. Military manning to support rotation requirements.
_____ d. Supplemental training to perform direct combat support tasks.
_____ e. Mobile rapid response capability.
_____ f. Trained military personnel for permanent overseas duty.
_____ g. CE military force to perform direct combat support roles.
_____ h. Effective use of civilian personnel to satisfy indirect combat support needs.

1-2. Career Progression

How would you like to be the superintendent of structures before you have 20 years in the Air Force? You might say "I would have to be extremely lucky." Or, as most airmen who don't make E-8 or E-9 by the time they have been in 20 years, "I didn't know the right people." The fact is, you can progress to a high rank if you are willing to follow four simple rules. These rules work. They rarely fail. Ask E-8s or E-9s. They will verify these four rules for success in any field:

(1) Work hard.

(2) Study effectively.

(3) Cooperate with other workers.

(4) Listen to and respond positively to the desires of your immediate supervisor.

006. Use an Airman Structural/Pavements Career Field Chart to state requirements for progression in the 55 career field.

Progression in the 55 Career Field. The chart in figure 1-2 is the Airman Civil Engineering Structural/ Pavements Career Field Chart. The 55 career field is a family of closely related Air Force specialties. Your specialty, as you well know, is metal fabricating. By observing the chart, you can see how you fit into the picture. Notice that your present position is an Apprentice Metal Fabricator, AFSC 55232. It is shown just below the position you are now working for, a Metal Fabricating Specialist, AFSC 55252. The grade for an apprentice in the 55 career field is E-3; for the specialist it varies from E-3 upwards through E-4 to E-5.

To trace the progression in the career field, start at the bottom of the chart. In our example, we will progress through the plumber portion of the career ladder. In your exercises, you will trace progress through other specialties. By following the black line, you can see that a basic airman (AFSC 99000) enters the career field as a plumbing helper (AFSC 55215). From the 55215, the airman goes through the basic plumbing course. Upon graduation, he or she becomes an apprentice plumber (AFSC 55235). With on-the-job training, he or she advances to the plumbing specialist (AFSC 55255). The next advancement is to the plumbing technician (AFSC 55275), and the top of the ladder is structural superintendent (AFSC 55299). This person's top rank as a superintendent is E-8.

Exercises (006):

Refer to figure 1-2.

1. From basic airman, what is the first AFSC in your ladder?

2. What course is desirable for the first step up the ladder for:

   a. Pavements?

   b. Construction equipment?

3. As an apprentice, what is the AFSC for:

   a. Carpenter?

   b. Mason?

   c. Metal fabricator?

4. What is the AFSC for the specialist:

   a. Plumber?

   b. Engineering Assistant?

5. What is the title and AFSC of progression to the technician from the three level in:

   a. Pavements?

   b. Construction equipment?

6. What is the title and AFSC of the highest grade that can be attained by progressing up the pavements ladder?

007. Identify given tasks with the appropriate specialty in the 55 career field.

Functions of the 55 Career Field. The Airman Civil Engineering Structural/Pavements Career Field includes

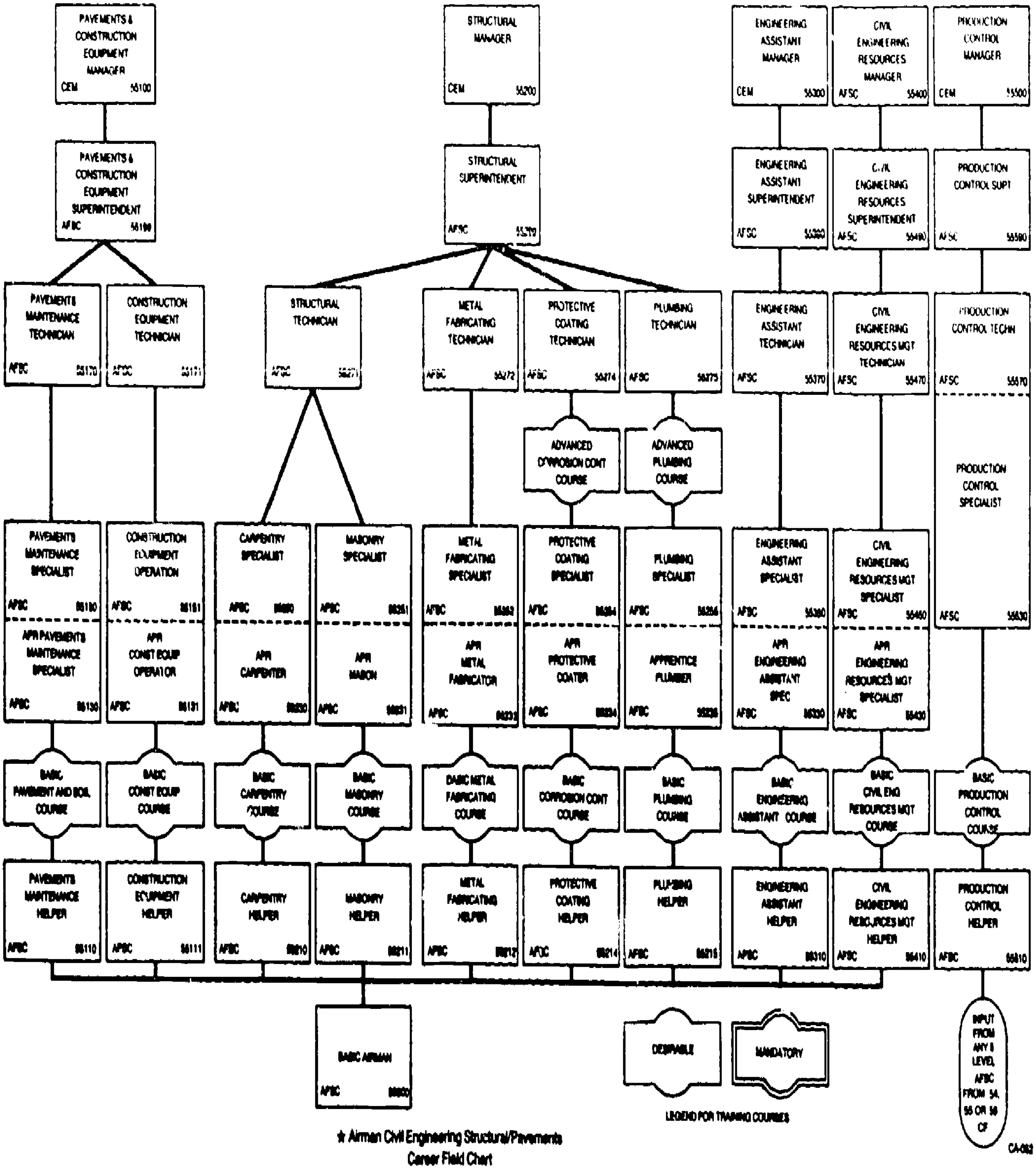

Figure 1-2. CE structure/pavements career field chart.

construction and maintenance of structural facilities and pavement areas. It includes maintaining pavements, railroads, and soil bases; performing erosion control; and operating heavy equipment. The structural area includes carpentry, masonry, metal fabrication, protective coating, and plumbing construction and maintenance. The 55 career field also includes engineering assistant, real estate-cost-management analysis, and programs and work control functions.

Pavement Maintenance Specialist (55150). This specialist constructs, maintains, and repairs airfield pavements, streets, walks, parking areas, and associated drainage.

Construction Equipment Operator (55151). The equipment operators operate and maintain equipment such as: dozers, front-end loaders, sweepers, graders, and cranes. They use this equipment to level, grade, and fill surface. They lift and move heavy objects such as sand gravel. The specialty calls for excavating ditches, stablizing and compacting soil, and removing snow and ice from surface areas.

Carpentry Specialist (55250). This job includes laying out work and preparing materials for use. Carpentry specialists construct, modify, and repair buildings. Specialists assemble and erect prefabricated or portable structures. In addition, they fabricate and repair interior facilities; construct packing and shipping containers; maintain woodworking tools; install and repair building hardware; and supervise carpentry personnel.

Metal Fabricating Specialist (55252). In our field, the specialist fabricates, repairs, installs, and maintains metal articles, parts, and assemblies (such as heating and ventilating ducts, metal roofing, gutters, and downspouts; shower stalls, sink tops, steamtables, and metal buildings).

Masonry Specialist (55253). Notice in figure 1-2 that as the carpentry specialist and the masonry specialist climb the career ladder, they both become structural technicians at the 7 level. The masonry specialist advises the carpentry specialist in placing and building forms. They construct concrete footings, foundations, and floor slabs and lay brick, building blocks, stone, and tile. In addition, they plaster the interior and exterior of buildings.

Protective Coating Specialist (55254). This specialist applies coatings (such as paint) to structural surfaces. Before applying the coating, he or she must prepare the surface by eliminating or neutralizing surface films. This specialist makes surface repairs to cracks or holes in wood, metal, masonry, or concrete surfaces with fillers or sealants; also, applies markings to runways, roads, and parking lots.

Plumbing Specialist (AFSC 55255). Personnel holding this position read and interpret blueprints, and maintain plumbing fixtures such as heating devices, sinks, toilets, showers, water heaters, radiators, sterilizers, and laundry machinery.

Engineering Assistant Specialist (55350). These individuals perform construction materials tests, prepare engineering drawings; perform surveys, assist professional engineers on project designs; and perform other general engineering tasks.

Civil Engineering Resources Management Specialist (55450). Personnel who work in this position maintain records and accounts for real estate-cost-management analysis activities; prepare summaries of statistical, cost accounting, and management data reflecting actual versus planned performance with objectives; and ascertain variances from work plans.

Production Control Technician (55570). In this area of CE, there is no 5 skill level. The 55530 may be semiskilled or apprentice. Note from figure 1-2 that input to this career ladder is from any 5 level in the 54, 55, or 56 career field. The programs and work control technician identifies, plans, monitors, and supervises work requirements for maintenance, repair, and minor construction work performed by civil engineering work forces and/or contract. He or she also supervises programs and work control activities.

When you become a metal fabricating specialist, your contact with other members of the 55 career field assumes a cooperative attitude. This will help CE to get the jobs done faster and more efficiently, which is a prime objective of the CE work forces.

Exercises (007):

1. Match the tasks in column A with the appropriate specialties in column B.

Column A	Column B
_____(1) Plans work for minor construction.	a. Pavements maintenance.
_____(2) Surveys a location to construct a building.	b. Equipment operator.
_____(3) Levels the construction site.	c. Carpentry.
_____(4) Constructs the concrete floor slab.	d. Masonry.
_____(5) Erects the frame of the building.	e. Plumbing.
_____(6) Bricks the building exterior.	f. Engineering assistant.
_____(7) Places hot and cold pipes inside building.	g. Metal fabricating specialist.
_____(8) Installs gypsum boards for inside walls.	h. Civil engineer resource management.
_____(9) Paints interior walls and ceilings.	i. Production control.
_____(10) Keeps records of cost of building.	j. Protective coating.
_____(11) Constructs parking area and walks for building.	
_____(12) Repairs metal roofing.	

008. Differentiate between duties of the metal fabricating specialist and the technician, and cite security vulnerabilities.

Duties and Responsibilities. AFR 39-1, *Airman Classification Regulation,* is the official document that governs your duties and responsibilities. Each specialty is listed so that everyone knows what is expected. The specialty description for Apprentice Metal Fabricator (55232) and the Fabricating Specialist (55252) are the

same. This means that your duties and responsibilities are the same, although you are only semiskilled in these tasks. Let's look at a few of these duties for both the specialist and the technician.

The metal fabrication specialist draws working sketches and makes templates; cuts and trims metal; drills and punches holes; folds, forms, and seams sheet metals; assembles and fastens metal parts; fabricates, installs, and repairs duct sections; repairs small holes or open seams; installs sections of metal roofing; sets up job by tack welding; welds butt, lap, tee, and corner joints in all positions; hard surfaces metals; and forges metals to required shape.

Since you will probably be working for a technician (55272), and you will work towards being one, you should have some idea of the duties involved. Since the metal fabricating technician has passed through the 5-level specialist step, he or she should be able to perform these tasks. Some of the other duties and responsibilities of the technician are: perform trial metal fabrication operations; advise and assist subordinates on the proper use and safe operating procedures of tools and machines; solve problems by studying schematic diagrams or engineering drawings; develop procedures for doing work; adapt directives of higher authority to shop routine; inspect and evaluate metal activities; plan and schedule work assignments; supervise metal cutting, drilling, punching, forming and welding; conduct and supervise on-the-job training; and orient newly assigned personnel.

Security Vulnerabilities. In your job as a metal fabricating specialist, you probably don't feel that you will have any information or be exposed to situations that would be vulnerable to operational security (OPSEC) violations. Granted your job is not one which will continually expose you to classified information or equipment, but you see and hear much that can be called intelligence indicators.

When you perform maintenance on a hangar, you see aircraft loadings, takeoffs, and landings which are of intelligence value. There will be occasions when you are required to enter areas that have classified equipment and materials. You may overhear conversations about this material. Whatever you see or hear, whether it is classified or not, could be of intelligence value to an enemy. If you work with RED HORSE, you may build prefabricated airfield surface mats, membrane surfaces for aircraft landings, aircraft protective revetments, and pavements in forward areas of possible combat. These and many more types of jobs that you perform are subject to enemy intelligence. You should never tell a person without a need to know what you hear, see, or do on your job.

Exercises (008):

1. Write S (for specialist) or T (for technician) before each duty.
   ____ (1) Orients newly assigned personnel.
   ____ (2) Draws working sketches and makes templates.
   ____ (3) Drills and punches holes.
   ____ (4) Supervises metal cutting and welding.
   ____ (5) Inspects and evaluates metal activities.
   ____ (6) Installs sections of metal roofing.
   ____ (7) Develops procedure for doing work.
   ____ (8) Performs trial metal fabrication operations.
   ____ (9) Hard surfaces metal.
   ____ (10) Forges metals to required shape.

2. What can bits of unclassified information be called?

3. Who can be told about what you see or hear on the job which may have intelligence value?

4. What type of information will you be exposed to that has possible intelligence value?

009. State the purpose of the graduate evaluation program and the reasons to complete AF Form 1284.

Field Evaluation of Formal School Graduates. To determine the effectiveness of formal schools and career development courses (CDC), an evaluation is made of recent graduates. The training activity needs to know how well the students are doing on the job. This information is used to make adjustments in training and (possibly) the specialty training standard (STS). These evaluations are used to determine the:

a. Ability of recent graduates to perform their assigned tasks to the level of proficiency as indicated in the STS.

b. Extent to which acquired skills are used.

c. Extent to which knowledge attained is retained.

d. Need to revise the STS, formal courses, or CDCs in order to improve training effectiveness and responsiveness to the requirements of the using commands.

e. Need for further evaluation of training problem areas by this evaluation of graduates.

We get this information from field evaluation visits, direct correspondence questionnaires, and job performance evaluation reports.

In field evaluations, personnel from training activities visit the using agencies to evaluate graduates who have been assigned within 6 months. Evaluation data comes from discussions with the graduate, immediate supervisors, or others who know about the graduate's performance. Using an STS as a reference, the graduate is evaluated on the frequency of use and ability to perform the tasks for which trained.

Direct correspondence questionnaires are sent to recent graduates and their supervisor. These questionnaires pertain to the graduate's qualification in terms of the skill and proficiency levels reflected in the approved STS.

Job performance evaluations are made by the immediate supervisor. The supervisor will fill out an AF Form 1284, Training Quality Report, when:

a. A student does not meet the proficiency level specified for a task or knowledge listed in an approved STS. To be objective, the supervisor considers the elapsed time between graduation and operational performance as well as the difference between training equipment and operational equipment.

b. The graduate is not required to perform tasks listed in the STS while working in the assigned AFS.

c. The STS code levels or tasks exceed the requirements of the graduate's AFSC.

Two copies of the AF Form 1284 are prepared. The original is sent to the major command headquarters.

The CDC is evaluated by means of a short questionaire (11 questions) contained in the VRE for the last volume of the course. Information from these questions will be used, along with other data, to revise and change the course as needed.

Exercises (009):

1. What is the purpose of the graduate evaluation program?

2. List two requirements for the supervisor to complete AF Form 1284.

3. Personnel from training activities visit using agencies within how many months after the graduates are assigned?

1-3. Publications

Have you ever bought a packaged bicycle or stereo "knocked down" so that you had to assemble it? If you have, did you follow the instructions and sketches in the package, or did you start out haphazardly to assemble the unit by trial and error? If you did not follow the manufacturer's instructions, the chances are that you had a tough time getting the pieces together correctly or that it did not operate according to your expectations.

Instructions from the manufacturer on assembly, operation, and maintenance are called by such various names as assembly instruction, operator's manual, maintenance checklist. The Air Force has a system of publications that furnish you the information you need to maintain metal working equipment and to do your job. The two main types of publications available to Air Force personnel are standard publications and Air Force technical orders.

010. Identify Air Force standard publications with the specific type of information they contain.

Standard Publications. Standard publications are used to announce policies, assign responsibilities, prescribe procedures, issue instructions, and give information. Some are in the form of regulations, manuals, supplements, and operating instructions, which are directive. Pamphlets, visual aids, bulletins, and staff digests are standard publications that are nondirective and intended for information or instructional purposes. In this text, we will only cover those standard publications you deal with most frequently: regulations, manuals, supplements, and pamphlets.

Regulations. Air Force regulations (AFRs) are the primary administrative directives used for governing the Air Force. Regulations also announce policies, assign responsibilities, direct actions, and when necessary, prescribe brief procedural details. The policies outlined in regulations are usually permanent in nature. This means that the purpose or intent of the regulation will remain in effect until there is a major change in mission or objective.

Manuals. Air Force manuals (AFMs) contain permanent and detailed instructions, procedures, and techniques telling people how to perform their duties. A manual may be general and deal with principles or doctrine. It may be a combination of material related to an entire function. It may also be a step-by-step directive telling how to accomplish a specific task or operation. Manuals may include policies or assign responsibilities when they do not repeat material in another Air Force publication. Manuals are often identical with regulations. The Air Force is in the process of phasing out manuals and republishing them as regulations, but this may take many years.

Supplements. The dictionary defines a supplement as something that completes or makes an addition; a part added to a publication. For example, a higher headquarters issues a publication for all units under its command. A lower headquarters can issue an auxiliary publication that deals with the same subject, but in more detail. For instance, an Air Force publication dealing with storage of water makes general policy statements on the subject. A command in Florida and one in Alaska may supplement the regulation. Obviously the protection required against freezing will be different. With the use of supplements, a commander insures efficient local application of directives issued by higher headquarters.

Pamphlets. Air Force pamphlets (AFPs) usually contain information rather than directive material. They are normally issued as a booklet or brochure and may be written in an informal style. For instance, if you are being assigned overseas, you may receive a pamphlet concerning the customs, religions, and history of the country in which you will be stationed.

Exercises (010):

1. Match the type of publication in column B with type of information in column A.

Column A *Types of Information*	*Column B* *Types of Publications*
______ (1) Permanent and detailed procedures for performing duties.	a. Regulations.
______ (2) Customs of a country.	b. Manuals.
______ (3) Command X adds information to a directive.	c. Supplements.
______ (4) Sets standards of management.	d. Pamphlets.
______ (5) Announces policies and assigns responsibilities.	

011. Using an extract from a numerical and subject matter index, locate the standard publication number and title.

Standard Publication Indexes. Suppose you were interested in buying a tent and had a Sears catalog. Would you page through the book until you happened to find tents, or would you go to the index and then turn directly to the indicated pages? From the standpoint of efficiency and time saved, the answer is obvious.

The situation is similar with Air Force standard publications. It would be time consuming and inefficient to search through all the existing publications to find a particular subject you need.

You are aware by now that the Air Force has a tremendous number of publications of various types with many and diverse uses. Naturally, there must be a system for cataloging those directives. To identify them, the Air Force has adopted the following system.

Numerical and subject matter index. Air Force Regulation 0–2 is entitled *Numerical Index of Standard and Recurring Air Force Publications*. This index is a combination of both a numerical and subject matter index. The index is a booklet of about 80 pages. The actual publications it references would fill many library-type cabinets. Your base has a publications reference library, and there is probably a library of Air Force publications in the administrative section of CE. The library is there for your use—so learn how to use it. The index lists about 100 subjects, which are identified by series numbers.

Standard publications numbering system. The first number before the dash (-) such as 0–35 is the series number of the subject of the publication. The subject series 0 is *Indexes;* 5 is *Publications Management;* 35 is *Military Personnel;* 127 is *Ground Safety;* and 205 is *Security*. Each of the subjects is further identified by adding a dash number to the basic series number. For example, R 35–3 is *Services Dates* (of military personnel); R 35–18 is *Financial Responsibility* (of military personnel); and R 35–44, *Military Personnel Records System*. The major series of publications that concern your work in CE range from the 85 to 93 series:

85—CIVIL ENGINEERING GENERAL.
86—CIVIL ENGINEERING PROGRAMMING.
87—REAL PROPERTY MANAGEMENT.
88—FACILITY DESIGN AND PLANNING.
89—FACILITY CONSTRUCTION.
90—HOUSING.
91—REAL PROPERTY OPERATION AND MAINTENANCE.
92—CIVIL ENGINEERING-FIRE PROTECTION.
93—SPECIAL CIVIL ENGINEERING.

The key to using a library is learning to find the publication you need. AFR 0–2 is that key. Figure 1-3 shows a page from an out-of-date AFR 0–2. The series of standard publications in this figure is 85. Notice on the left side of the figure the entries R, M, and P. R means that the publications is an Air Force regulation; M, Air Force manual; and P, Air Force pamphlet. Look at the entry for AFM 85–8. Its publication date is 25 August 1958, and the title is *Maintenance of Pavement*. The black square indicates reprinted. The current AFR 0–2 does not list AFM 85–8, but does list AFR 85–8 as Maintenance and Repair of Surface Areas, with a publication date of 31 March 1977. The publication has been changed from a manual to a regulation and the title has changed, but the numbering enables you to locate it again. ALWAYS USE A CURRENT INDEX.

The following publications listed in AFR 0–2 may be of interest to you:

AFM 88–3, Chapter 8, Metal Roofing and Siding.
AFR 93–3, The Prime BEEF Program.
AFR 127–101, Ground Accident Prevention Handbook.

Exercises (011):

Refer to figure 1-3.

1. What is the standard publication number for paints and protective coatings?

2. What is the title of AFR 85–1?

012. Use a TO index to find the numbers of TOs with information on specified equipment.

Technical Orders (TOs). When your commander gives you an order to do something, you are required by your oath of enlistment to follow that order and do it. Technical orders are official orders of the United States Government. AF Regulation 8–2, *Air Force Technical Order (TO) System*, under the heading of Air Force Policy, states that "all Air Force systems/equipment will be operated and maintained in accordance with procedures described in TOs." If you operate a bandsaw, for example, contrary to the procedures described in the TO for that saw, you are breaking a lawful order of your Government and you are subject to the penalties prescribed by law for your unlawful action. The reason for these orders is twofold. First, the

85 — CIVIL ENGINEERING GENERAL

	R 85-1	19Apr74	Resources and Work Force Management	PREMA	F
	Changes		• 1 • 2		
	P 85-1	14Nov67	Electrical Facilities Safe Practices Handbook (Reprint, 28May74, includes Changes 1 and 2)	PREEU	F
	Changes		3		
	EMC		75-1		
	R 85-2	26Nov68	Family Housing for Essential Employees at Research and Development Installations (PA)	PRENB	F
	M 85-3	15Jan69	Paints and Protective Coatings	PREES	F
	Changes		1		
	R 85-4	30Oct63	Implementing Guarantees of Equipment Installed in AF Construction	PRE	F
	M 85-5	1Nov65	Maintenance and Operation of Cathodic Protection Systems	PREMM	F
	Changes		1		
	M 85-6	30Aug63	Land Management and Grounds Maintenance	PREVP	F
	Changes		A		
	R 85-7	20Apr76	MAJCOM Engineering and Services Organizations and Functions	PREM	F
■	M 85-8	25Aug58	Maintenance of Pavement	PREMM	F
	R 85-9	1Mar76	Inactive Installations-Inactivation and Maintenance	PREM	F
	R 85-10	24Oct75	Operation and Maintenance of Real Property	PREM	F
	Changes		• 1		
	M 85-12		Operation and Maintenance of Central Heating Plants and Distribution Systems	PRE	F
	■ Vol 1	1Jun64			
	Changes		A B C D		
	Vol 2	15Jun64	Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization		
	M 85-13	5Feb59	Maintenance and Operation of Water Plants and Systems (Reprint, 15Jun68, includes Changes A thru D)	PREE	F
	M 85-14	5Jan59	Maintenance and Operation of Sewage and Industrial Waste Plants and Systems (Reprint, 1Sep67, includes Change A)	PREEH	F
■	M 85-15	1Jun56	Coal Handling (Reprint, 1Feb68, includes Changes A and B)	PREMM	F
	Changes		C		
	M 85-16	12May65	Maintenance of Permanently Installed Storage and Dispensing Systems for Petroleum and Unconventional Fuels (See also M 91-13, Vol II)	PREE	F
	Changes		A B C D E F G H		
	M 85-17	3Nov58	Maintenance and Operation of Electric Plants and Systems	PRE	F
■	M 85-18	1Oct57	Maintenance and Operation of Refrigeration, Air Conditioning Evaporative Cooling and Mechanical Ventilating Systems	PREE	F
	R 85-19	26Aug74	Maintenance and Operation of Electric Power Generating Plants	PREEU	F
	Changes		1 2		
	M 85-20	11Aug58	Plumbing	PREM	F
	R 85-23	30Jan73	Well Drilling Operations	PREE	F
■	M 85-25	1Jul66	Index--Guide Specifications for Military Family Housing	PRE	F
	Changes		■ 1 ■ 2 3 4 5		
	M 85-30	18Feb66	Operation and Maintenance of Air Compressor	PREEU	F
	Changes		1		
	M 85-31	25Mar68	Industrial Water Treatment	PREE	F
	Changes		1		
	M 85-33	15Dec67	Maintenance and Repair of Expeditionary and Theater of Operation Airfield Facilities	PRE	F
	M 85-38	12Jul71	Civil Engineering Management Review	PREMA	F
	Changes		1		
	•IMC		76-1 76-2		
	M 85-200	1Feb75	BEAMS, The Base Engineer Automated Management System	*PRE	F

88-083

Figure 1-3. Typical page from AFR 0-2.

Government is vitally concerned in protecting you and other personnel who work with you and around you. Second, the Government is concerned for its equipment and its property. Some of the buddies you work with may not understand the concern that the Government has for you. They may encourage you to remove a guard or to operate equipment dangerously. Don't do it. The technical order may be a manufacturer's manual on which the Air Force has placed a TO number, or the order may be an operator's manual approved by your unit.

Using TO indexes. Like the index for standard publications, the TO index lists series of subjects. In the TO system, these subjects are referred to as categories. TO 1–1–01 is the key to the technical order system. Its official title is *Numerical Index, Alphabetical Index,* and *Cross Reference Table Technical Orders*. The Air Force has such a large number of technical orders that it maintains an index for each category of equipment. TO 0–1–01 can be thought of as an index of the 50 indexes, master index. It is the first one filed in book number one in the TO file cabinet. Keep in mind that the standard publications filing system and the TO filing system are two different types of publications systems. They are kept separately, although they both may be in the same room.

Suppose that you are doing research on Type MC–7, Model GR 125, Air Compressor. Go to the first TO book in the library, TO 0–1–01. There are only about 10 pages in this TO and you are only concerned with half of those. By skimming through five pages you see TO 0–1–34, *Shop Machinery and Associated Equipment Technical Orders*.

All ndex numbers begin with 0–1. To complete the numb for the numerical index to any of the 50 TO categories, you simply add the category number as the third part of the index number. In our example, the numerical index to category 34 is TO 0–1–34. Our next step in locating the technical publication we need is to look in the file for TO 0–1–34. You should find it at about book number five.

Figure 1-4 shows a part of the cover page of the TO and the table of contents. By going down the table of contents of this index, you can find air compressors. On what page of this TO would you find compressors? The correct page is 1-73. Going to page 1-73 in this index, you find the TO number and description of several air compressors. There is one listed as TO 34Y1–134–1, Type MC–7, Model GR 125. This TO is for operation and service instruction. Your last step in the process of finding the publication is to locate the book containing TO 34Y1–134-1, and it will give you the information you need.

Exercises (012):

Refer to figure 1-4. Give the TO number and page number for the following equipment:

1. Metal cutting machines.

2. Drill presses.

3. Regulators.

4. Air compressors, general.

013. Solve a hypothetical maintenance problem by using an extract from a technical publication.

Using TOs. Once you have the TO you need, the instructions are usually quite detailed and specific about what you must and must not do. Look at figure 1-5. Note that the inspection and servicing requirements are spelled out in months and hours. Other parts of the TO give you the same sort of precise technical information on assembly, installation, operation, overhaul, and parts identification.

Many commercial publications have been intergrated into the TO system. The actual manufacturer's publication has been stamped with a TO number and is treated as an official Air Force technical order. Other publications deal with safe operation of equipment in a general way. If you have any doubts about which publications to use, check with your supervisor and the CE personnel that operate the library. They will be happy to help you find the publications that apply to the situation at hand.

Exercises (013):

1. You are a metal fabricating specialist in charge of seeing that the MC–7 air compressor receives its periodic inspection, maintenance, and lubrication as called for by the TO. The engine is not running as smoothly as it has in the past. The engine and compressor oil filters were replaced at 200 hours. The unit has operated 248 hours. The base motor pool performs the necessary maintenance when requested by operating personnel. On what five items should you request maintenance?(Use fig. 1-5).

014. Select from a list of TO deficiencies those that are reportable and those that are not.

A TO improvement report is recommended correction of an error in a TO, the omission of a technical nature, a correction of terminology, or an improvement in procedures for performing a task.

Reportable TO Deficiencies. Do not report minor inaccuracies of a nontechnical nature unless they change the meaning of instructive information and procedures.

TO 0-1-34

NUMERICAL INDEX AND REQUIREMENT TABLE

SHOP MACHINERY AND ASSOCIATED EQUIPMENT TECHNICAL ORDERS

TABLE OF CONTENTS

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Figure 1-4. Cover page and table of contents for TO 0-1-34.

TO 34Y1-134-1 MC7, Model GR125 Air Compressor	
Components or Parts Requiring Inspection or Servicing	Operational Time Period
*Engine oil filter - clean and replace cartridge if operating unit under normal conditions.	Twice a month or 100 hours.
Compressor oil filter - clean sump if operating unit under normal conditions.	Twice a month or 100 hours.
Fuel tank - drain accumulated condensate. (Refer to figure 5-6.)	100 hours.
Safety valve - operate by hand to assure it is operable. (Refer to figure 5-4.)	Once a month or 250 hours.
*Spark plugs - clean and re-gap or replace.	250 hours.
All ignition wiring and battery connections - inspect for loose connections and for corrosion. (Refer to figure 5-11.)	250 hours.
*Engine generator belt - check for wear and correct tension; replace if worn and adjust for correct tension.	250 hours.
*Engine distributor - adjust timing.	250 hours.
*Engine distributor breaker points - check for wear or pitting.	250 hours.
Unit - inspect for loose or missing studs, screws, nuts and washers	500 hours.
Running gear spring bracket bolt - use grease gun.	Three months or 500 hours.
Running gear spring slip end - apply grease with brush.	Three months or 500 hours.
Compressor lubricating oil - change oil completely	Three months or 500 hours.
Fuel pump - inspect mounting and gaskets.	Six months or 1250 hours.
All tubings and fittings - inspect for leaking conditions.	Six months or 1250 hours.
*Engine distributor breaker points - replace.	1250 hours.
*Engine valve tappets - adjust for clearance - intake and exhaust 0.014 inch.	1250 hours.
*Engine generator - inspect for worn parts.	1250 hours.
Running gear wheel bearings - inspect for worn parts, clean and repack, not over half-full. Refer to paragraph 5-10.	Six months or 1250 hours.
*Engine distributor - inspect for worn or broken parts.	1250 hours.
*Engine starter - inspect for worn or broken parts.	1250 hours.
Radiator - drain and clean engine cooling system.	Six months or 1250 hours.
*For applicable instructions on the lubrication, replacement and general maintenance of all engine parts, refer to applicable engine Technical Order listed in the 0-0-39 Series Technical Order Index.	

BEG-212

Figure 1-5. Air compressor servicing requirements.

Technical Order 00-5-1, *AF Technical Order System*, explains how you should report TO improvements on AFTO Form 22, Technical Order System Publication Improvement Report and Reply.

The person who discovers a condition that requires a change submits an improvement report to the supervisor, who must then ascertain the validity of the report. If it is a valid report, the supervisor signs the report and forwards it to CE quality control for processing. Emergency reports must be initiated and submitted immediately after discovery of the condition, urgent reports on an expedited basis, and routine reports as soon as practicable.

Exercises (014):

Which of the following publication deficiencies should be reported? (Write yes or no in the blank).

_____ 1. Change the word value to valve.
_____ 2. A tolerance should read .030 instead of .300.
_____ 3. The word blade is misspelled as bade.
_____ 4. A critical adjustment should read 1/4 turn instead of 4 turns.
_____ 5. A welding procedure could cause an accident.

Management of Activities and Resources

THE MANAGEMENT philosophy of the Air Force includes getting maximum efficiency for each dollar spent while reaching planned objectives. This means that human resources, material resources, and financial resources must be used in the most effective way to meet the goals of the organization. As you supervise people working on your base, you should ask and answer these two questions. "Are the jobs being done well?" and "Is there a better way to do them?"

The key to improving jobs is not necessarily an attempt to speed up work by prodding people. Substandard work may be brought up to standard by planning projects better, improving material support, eliminating delays, and coordinating with other people. Plan your projects well—that is, with activities and resources management in mind.

2-1. Activities Management

As we stated in Chapter 1, the Air Force owns a tremendous amount of property which must be operated, maintained, and managed properly. To manage these activities effectively and efficiently, the Air Force uses a program concept which has been planned by "planners" in advance. The program includes allocating labor hours and materials for work and services performed by CE troops. Various Air Force forms are initiated by CE personnel and processed through a computer. Data printouts from the computer include data which assist CE managers to make good management decisions.

015. Briefly state how the civil engineering management system works.

CE Management System. As a worker in Civil Engineering, you may ask the question, "Who originates all the work that CE personnel have to do?" Most of the work in Civil Engineering has been identified and planned ahead of its actual start date. The planning and controlling of this work could not be done without a sound management plan. The plan we are talking about is called the Inservice Work Plan. Like all other plans, it is only as good as the information used to develop it and the effort put forth to adhere to its principles and objectives.

Planning. Do you recall an office called resources and requirements? Under this office is a unit known as planning. Each year the planners visit each facility on base and thoroughly inspect it for any work that needs to be done. The inspection is called a facility survey. This survey is one of the inputs required by Civil Engineering to develop its work plan.

In addition to the facility survey, shop foremen are responsible for two inputs to the work plan. One of them is for recurring labor-hours. The recurring labor-hours are for work done on a periodic basis within a particular year. An example of this work is to inspect and repair drainage facilities. Another example is the hours required for removing snow and ice from paved surfaces. There are other inputs used to formulate the civil engineer's work plan which do not concern you. They are also used to preidentify work requirements.

After all the work inputs are sent to Resources and Requirements, they are gathered together and then they place the labor-hours on a document called the In-Service Work Plan. Each month work items from this plan are sent to the production control section for assignment to CE units. These work items are on forms known as work authorization documents. As the words indicate, these documents are the authority from Civil Engineering to perform the work stated on the forms.

Performance evaluation. Civil Engineering also has a management plan. In this plan there are provisions for evaluating the performance of CE units. By knowing types of work which have been done in the past with a certain amount of labor-hours, the industrial engineering section, through the use of a computer, can predict what work can be done in the future with various amounts of labor-hours. Units that fall behind the labor-hours expected by using more hours than predicted must answer for the deviations.

Base engineer automated management system. In Civil Engineering an enormous number of records are required to be kept. These records include the amount and cost of roads on base; amount and cost or runways; amount of sewage disposed; labor-hours required to operate plants; and the size, shape, condition, and cost of each facility. Many other records are required by law to be kept. Even your name and employee number are part of the records. When information of this sort is needed, Civil Engineering merely asks the computer in symbols it understands to furnish this information. In a matter of seconds, the computer replies with up-to-date answers.

The name of the automated data processing system is BEAMS. This abbreviation stands for base engineer automated management system. The computer used is the Burroughs 3500. BEAMS is a way to automate a large number of Civil Engineering records and files. CE files can be maintained with ease and with accuracy. It is even better because they make a variety of computer products available to managers on demand. These products are used by managers to make many important decisions. Actions of most craftsmen within Civil Engineering affect the

information within the computer and records and, ultimately, influence the content of the management products. It is of utmost importance that all civil engineering personnel know that their actions directly or indirectly influence the accuracy of the infomation contained in the automated system and, consequently, the management products that the system produces. The reliability of their contribution builds their own faith in BEAMS and the decisions of those who use it.

Exercises (015):

1. What is the management plan used in Civil Engineering to plan ahead called?

2. What are inspections by planners called?

3. What two inputs do shop foremen make to the CE work plan?

4. Work items come from the production control section on what documents?

5. How can the industrial engineering section know the amount of labor-hours required to do certain work in the future?

6. What is the name of the automated computer system used to process Civil Engineering records?

016. State how to request work using AF Form 332, BCE Work Request.

Work Requests. The number of requests for myriad types of work to be done on an Air Force base far exceed the Civil Engineering resources available. Resources for essential construction, operation, maintenance, repair, and services must be given first priority. If, for example, you request that 150 feet of concrete sidewalk be constructed near a facility in which you work, you would request this work on an AF Form 332. Because of the large number of work requests, you must explain why the work is needed. You must also include an impact statement, that is, a justification concerning your organization and its mission if the work is not done. It is this justification that is used by the facilities board in deciding which requests should be approved. Since the mission comes first, it is obvious that those requests that have the greatest impact on the mission have the best chances of being approved.

There are a number of ways that people may make their desires for work or services known to Civil Engineering. One of these ways is to use AF Form 332. This dual-purpose form is both a request for work and a work approval or disapproval document. The 332 is used to request:

- New work.
- Self-help work.
- Repair of damages to real property caused through neglect or abuse.
- Inservice minor construction costing less than $1,000 for base work or over $100 for military family housing (MFH).
- Projects that are done on contract.

You should have no trouble in preparing the work request since instructions are provided on the back of the form. Figure 2-1 is a completed copy of the front of the form. The description of the work requested (item 9) should be supported where possible by sketches, plans, diagrams, specifications, photographs, drawings, or any other description of the work you request.

Notice item 23 of figure 2-1. It is BCE's recommendation. The facilities board will use this recommendation and other data on the form to decide its approval or disapproval. If, for instance, the base civil engineer has recommended disapproval because required resources were not available, it is highly probable that the board would disapprove the work request.

Exercises (016):

1. What information is required in the following blocks on AF Form 332?

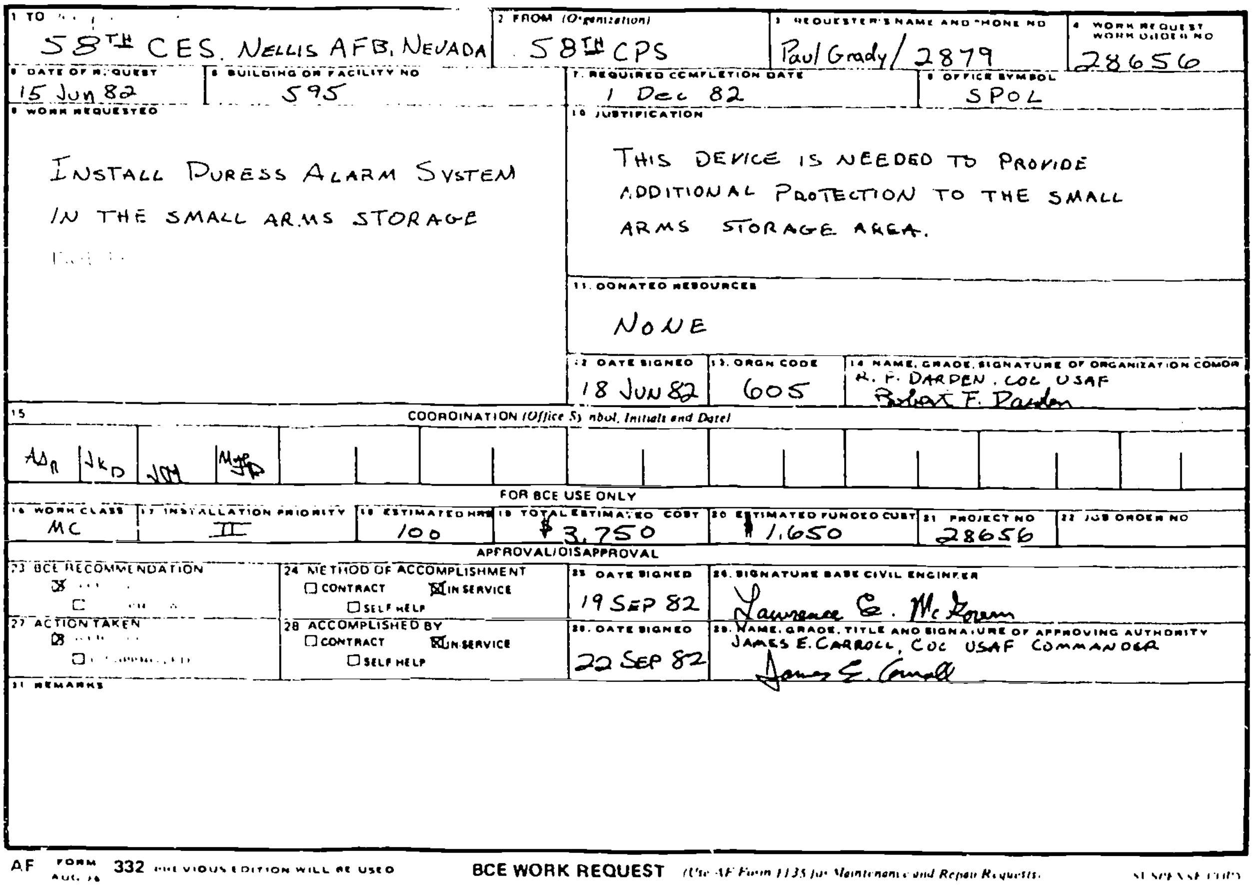
   a. Block 3?

   b. Block 6?

   c. Block 9?

   d. Block 12?

   e. Block 26?



1 TO: 58TH CES, NELLIS AFB, NEVADA
2 FROM (Organization): 58TH CPS
3 REQUESTER'S NAME AND PHONE NO: Paul Grady / 2879
4 WORK REQUEST / WORK ORDER NO: 28656
5 DATE OF REQUEST: 15 Jun 82
6 BUILDING OR FACILITY NO: 595
7 REQUIRED COMPLETION DATE: 1 Dec 82
8 OFFICE SYMBOL: SPOL
9 WORK REQUESTED: INSTALL DURESS ALARM SYSTEM IN THE SMALL ARMS STORAGE
10 JUSTIFICATION: THIS DEVICE IS NEEDED TO PROVIDE ADDITIONAL PROTECTION TO THE SMALL ARMS STORAGE AREA.
11 DONATED RESOURCES: NONE
12 DATE SIGNED: 18 JUN 82
13 ORGN CODE: 605
14 NAME, GRADE, SIGNATURE OF ORGANIZATION COMDR: R. F. DARDEN, COL USAF
15 COORDINATION (Office Symbol, Initials and Date)

FOR BCE USE ONLY

16 WORK CLASS: MC
17 INSTALLATION PRIORITY: II
18 ESTIMATED HRS: 100
19 TOTAL ESTIMATED COST: $3,750
20 ESTIMATED FUNDED COST: $1,650
21 PROJECT NO: 28656
22 JOB ORDER NO

APPROVAL/DISAPPROVAL

23 BCE RECOMMENDATION
24 METHOD OF ACCOMPLISHMENT: ☐ CONTRACT ☒ IN SERVICE ☐ SELF HELP
25 DATE SIGNED: 19 SEP 82
26 SIGNATURE BASE CIVIL ENGINEER
27 ACTION TAKEN
28 ACCOMPLISHED BY: ☐ CONTRACT ☒ IN SERVICE ☐ SELF HELP
29 DATE SIGNED: 22 SEP 82
30 NAME, GRADE, TITLE AND SIGNATURE OF APPROVING AUTHORITY: JAMES E. CARROLL, COL USAF COMMANDER
31 REMARKS

AF FORM 332 — PREVIOUS EDITION WILL BE USED — BCE WORK REQUEST

Figure 2–1. Sample of AF Form 332.

2. Where are the instructions for preparing AF Form 332?

3. Name three types of work that are requested on AF Form 332.

017. Differentiate between work requests that are submitted on AF Form 332, BCE Work Request, and those on AF Form 1135, BCE Real Property Maintenance Request.

BCE Real Property Maintenance Request (AF Form 1135). The AF Form 1135, shown in figure 2-2, is used by building custodians and military family housing (MFH) occupants to identify to Civil Engineering routine maintenance and repair needs for the facility. Typical examples are:

- Repair screen door on MFH.
- Replace three cracked floor tiles in plant office.
- Repair leaky cold water faucet in latrine.
- Patch crack in driveway pavement.

Notice in the upper right-hand side of figure 2-2 that BCE requires an original and one copy of the form. The copy showing the planned action is returned to the requester.

Exercises (017):

Refer to objectives 016 and 017. State which request form to use in each request:

1. Request BCE to repair floor tile in MFH quarters.

2. Request BCE to erect a new partition in an existing building.

3. Request approval of BCE for you to alter interior offices. You will do the work; BCE will furnish the materials.

BCE REAL PROPERTY MAINTENANCE REQUEST

Use to identify routine maintenance or repair requirements that do not meet the emergency criteria for a service call, or are not urgent in nature. Prepare and forward original and one copy to BCE for each facility on which work is requested.

TO: Base Civil Engineering
21ST CES

FROM: *(Name, Grade and Organization)*
ARNOLD RINGSTEAD MSgt, 25PS

RETURN TO: *(Office Symbol)*
SPOL

1. FACILITY NO. OR MFH STREET ADDRESS
5050

2. PHONE NUMBER(S)
2814

3. DESCRIPTION OF WORK REQUIREMENTS *(A thorough description of maintenance requirement(s) will minimize the need for CE personnel to visit the job site to determine what work is requested and what tools, equipment, and materials are needed, thereby completing the work on the first attempt. Answer these questions: What? Where? How many? Type/size? Color? Rate? Urgency? Time restrictions?)*

FOR CE USE ONLY

9. DATE RECEIVED
11 Sept 79

10. ACTION

3. Description of work requirements	10. Action
Replace 24 SF of Light Blue 12"x12" Floor Tile	Joborder # A5659
IN ROOM 222	21 Sept 79
Repair Wall (sheetrock) has been damaged by Water	WORKORDER NO
IN ROOM 241 APPROX 150 SF	15436
Relamp 12 EA Outside FLOODLIGHTS	Joborder # A5660 21 Sept 79
LOCK BINDING ON DOOR to Room 201	Job ORDER # A5659 21 Sept 79
Door Will Not secure properly, WEST END	JOBORDER # 5658 12 Sept 79
ENTRANCE	(URGENT) DIN

4. DATE OF REQUEST
12 Sept 79

SIGNATURE OF REQUESTOR
Arnold Ringstead

5. REVIEW/ACTION BY CUSTOMER SERVICE
DATE
11 Sept 79
SIGNATURE
P. Grady

6. REVIEW/ACTION BY CHIEF PRODUCTION CONTROL
DATE
11 Sept 79
SIGNATURE
Fred Wakeman

7. ASSIGNED FOR ACTION
A. FUNCTION/INDIVIDUAL
CSU-GRADY
B. ACTION REQUIRED
Cut Work order and have planning check # 2

8. CUSTOMER NOTIFIED
DATE
12 Sept 79
SIGNATURE
P. Grady

AF FORM MAY 78 1135 PREVIOUS EDITION IS OBSOLETE. CUSTOMER'S COPY

Figure 2–2. Sample of AF Form 1135.

4. Request BCE to repair door hardware on an exterior metal door.

5. Request BCE to adjust excess water flow at drinking fountain.

018. State whether given hypothetical problems justify a service call.

Service Calls. The service call method of requesting work is used strictly for emergency situations. Examples of emergency situations follow:

- Loss of steam in steam-heated building.
- Water flooding floor in kitchen.
- Water pressure failure in military family housing.
- Electrical power failure in a facility.
- Clogged plumbing in latrine.
- Leak in natural gas line.
- Window knocked out in subzero weather.

When such situations occur, the service call would be used to correct them. Under the BCE service call concept, BCE uses two ways to satisfy these emergency situations. First is the do-it-now (DIN) service call. The second method is the routine service call.

Do-it-now (DIN) service calls. If you must call the service call specialist in CE in regard to an emergency situation (such as a stuck latrine valve), he or she will dispatch a DIN plumber by two-way radio to your location. The DIN plumber has a DIN vehicle, stocked with parts, tools, and equipment for service call work.

The goal of service call management is to get the job done right the first time and every time. You should expect the DIN plumber to unstick the latrine valve and perform maintenance on it so that it will not stick again. CE expects DIN craftsmen to complete the job on the first trip to the jobsite. To do this it is necessary to clearly describe the job to the craftsman. The service call specialist must be courteous but must find out if a danger exists, what the problem consists of; when, where, how many, and how it happened; make, type, size, or color; urgency of need; and any time restrictions. See figure 2-3 for a record of a completed service call. Although there is not a time established for DIN calls, it is essential that the DIN capability be kept as mobile as possible.

Routine service calls. A service call can be referred to a shop only with coordination through the chief of Production Control. A service call which would be referred to a shop for completion must meet at least one of the following conditions:

- If the work appears to be beyond the DIN capability.
- If the DIN craftsman is unable to complete the work.
- If the work would require more than a reasonable time to be completed by the DIN craftsman (not limited to 1 hour, but should not be tied up for several hours).

FACILITY NO. 253 | ACTIVITY OR STREET ADDRESS 3rd TPS Operations | DATE 791029 | TIME 0805 | JOB ORDER NO. D1441

NAME AND GRADE OF REQUESTOR: J CARUSO CMS | PHONE NO./ALTERNATE: 3558/2662 | COLLECTION WORK ORDER NO. 00058

SERVICE REQUIRED: Repair siding APPROX 4 Pieces Need to be Replaced

ZONE NO. 8

TYPE OF SERVICE: EMERGENCY | URGENT | ✓ ROUTINE | SMART | MFH | MC

ESTIMATED COMPLETION DATE: 791106

INDICATE WHEN WORK IS TO BE ACCOMPLISHED

CREW SIZE: 1 | EST TOTAL TIME

AREA/FACILITY WHERE JOB IS LOCATED: Northeast side of Bldg

REMARKS (Tools, equip, materials, special craftsman multi-shop notes, etc.)

DANGEROUS CONDITIONS EXISTING (if any)

RESTRICTIONS (time, entry, security)

MAKE OF EQUIPMENT	TYPE/SIZE OF ITEM	COLOR OF ITEM
EXTERIOR Siding		Autum Green

ASSIGNED TO	DATE	TIME	COMPLETED BY	DATE	TIME	INITIALS	LUC 12	LUC
451	6 Nov	1000	DEEM	6 Nov	1100	JED		16
REFERRED TO	DATE	TIME	COMPLETED BY	DATE	TIME	INITIALS	LUC 12	LUC
DEFERRED TO	DATE	TIME	DISPOSITION		AUTHORIZED [illegible]			

AF FORM MAY 78 1879 PREVIOUS EDITION IS OBSOLETE. SHOP COPY BCE JOB ORDER RECORD

Figure 2–3. Sample of AF Form 1879.

For any emergency service call referred to the shop, the service call specialist prepares an AF Form 1879, BCE Job Order Record. See figure 2-3.

Exercises (018):

Place a T in the blanks provided for a correct statement and an F for a false statement. Correct the false statement.

_____ 1. Replacing two damaged roof shingles on a MFH should be requested through a service call.

_____ 2. Call service call if the front door of an office will not lock at quitting time.

_____ 3. Service calls are used for emergency and simple routine situations.

_____ 4. If your house (MFH) is without water, call "service call."

_____ 5. Two-way radio is used to contact the do-it-now carpenter specialist.

6. If a DIN craftsman is unable to complete an emergency job, it will be referred to a shop.

019. State how the work is processed in given work request situations.

Work Request Processing. As we stated before, all CE work must be authorized on official work documents. AF Forms 332 and 1135 are not work authorizing documents in the strict sense of the word. They are work request documents. Even when these request documents are approved, they do not constitute the appropriate paperwork needed to spend Air Force resources.

You will deal with two Air Force documents that authorize the expenditure of funds (labor-hours and materials are resource funds), the job order and the work order. These are official military orders authorizing the expenditure of CE resources. AF Form 327, Base Civil Engineer Work Order, is used for big jobs. AF Form 1879, BCE Job Order Record (fig. 2-3) is used for small jobs. The AF Form 1879 authorizes service calls, self-help jobs, hopper jobs, SMART (structural maintenance and repair team) jobs, and IWP (Inservice work plan) jobs.

The self-help job order is used to authorize simple self-help work which does not change a facility. For example, you desire to paint a room. CE issues a self-help job order giving you authority to paint the room.

The hopper job orders are orders for minor maintenance or repair. Hopper refers to a box with many compartments. Work requests for simple work that is not urgent are placed in a section of the hopper representing a zone of the base. When a shop has labor available to do the work or they are working in the same zone indicated in the hopper, a hopper job order is issued for the work. This work should be completed within 30 days after it is assigned to the shop.

The SMART team is composed of craftsmen of various skills performing routine minor maintenance and repair work on high-use facilities. These facilities include dormitories, dining halls, service clubs, and so forth. This team normally uses AF Form 1219, BCE Multi-Craft Job Order. If however, a SMART crew is working in a particular facility and already has an approved AF Form 1219, additional task requirements in that facility can be identified on AF Form 1879, BCE Job Order Record.

The IWP job order covers routine work of a simple nature generated within civil engineering, some work requests taken from AF Forms 332 and 1135, and work received through the service call system, but not considered an emergency.

Exercises (019):

State whether the work should be processed by IWP, SMART, hopper, self-help, or service call.

_____ 1. An aircraft unit requested that they perform the work of laying floor tile in a recreational area.

_____ 2. Carpenters are working in zone 15. A job in this zone of repairing a ceiling joist has come to CE. It is not an urgent job but should be completed within 30 days.

_____ 3. A water faucet is leaking badly. Although the situation is not an emergency, it is urgent and should be completed within 5 days.

_____ 4. A crew working on a dining hall is given an AF Form 1879 directing them to replace a door lock on a pantry door. This job is in addition to the minor maintenance work they are performing.

_____ 5. An emergency call at 1900 hours to restore an electrical power outage.

_____ 6. Job order for work which was requested on AF Form 332, BCE Work Request.

020. Given a problem related to storage facilities, analyze the problem, recommend a solution, and state the process required for the work.

Base civil Engineer Work Order (AF Form 327). This document authorizes the performance of work (fig. 2-4). It is usually used for large or complex jobs that require detailed planning and control. The 327 is also used with other records to keep track of the cost of labor and materials needed to complete the job. The form is used if a change is made in a real property facility. This includes an increase or

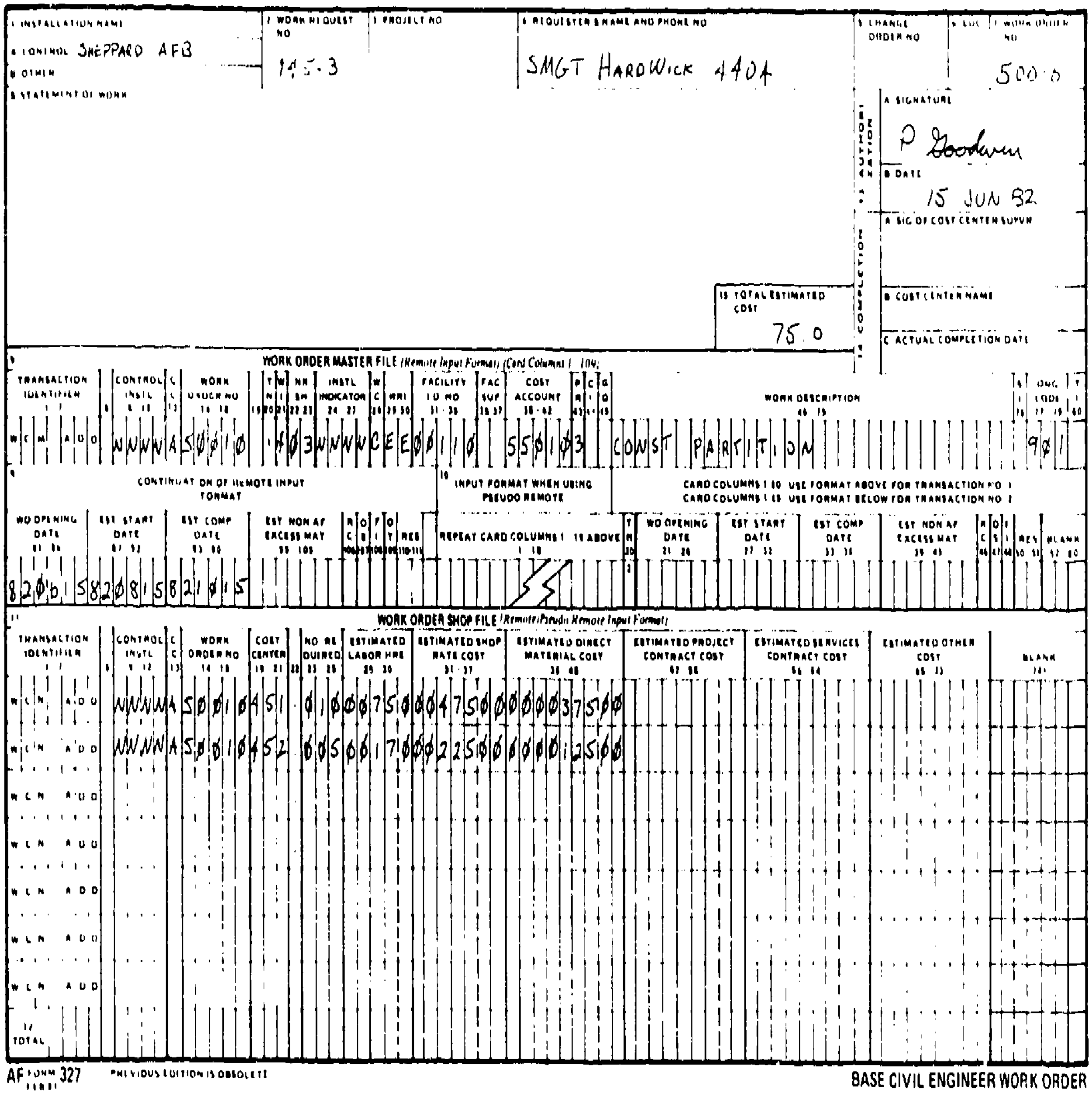


Figure 2-4. Sample of AF Form 327.

BEST COPY AVAILABLE

decrease in the value of the property. It also includes physical changes, such as making an opening in a wall, wires, plumbing, ducts; adding, removing, or installing chain-link security fences; and so forth.

Exercises (020):

A change in the mission at your base has not only created a problem of finding a working area to house the additional personnel you'll be receiving but for space to store additional equipment, etc., as well. The present area is too small already and cannot be expanded. Your boss will take the necessary steps to acquire sufficient housing, but asked you to find a suitable location for storage and to get this project started. You have found a nearby area that is ideal. Since this area has been used as a temporary parking area, only minor maintenance needs to be done. The area is not secured, however, so a chain-link fence must be installed.

1. What solution do you recommend?

2. What work process is required?

021. State the use of the DD Form 2167.

DD Form 2167, Job Phase Calculation Sheet. This form, as shown in figure 2-5, is used to compute the man-hour requirements for work orders and job orders when detailed planning and/or job phasing is required. The DD Form 2167 will show:

a. The work to be accomplished by cost center.

b. The phase or phases in which the work should be accomplished.

c. The total phase time, using a nomograph.

One side of the form is a nomograph chart with graduated lines representing variable data, such as time and man-hours. With this the planner can quickly and accurately transform the total "craft time" to the "allowed time" by utilizing the predetermined graphical relationship of its lines.

The other side of the form is most important to you, the craftsman, and the supervisors. It lists the tasks to be performed under the task description block in the order they are normally expected to occur. All the important items are listed, and with this information you are able to accomplish the job more effectively.

Exercises (021):

1. What is the DD Form 2167 used for?

JOB PHASE CALCULATION SHEET

BLDG 516

1 | 3 | A S1208 | 17 MAY 81

754 / WELDING — E T Smith

REPLACE COOLING TOWER - BLDG - 716
CUT & WELD PIPE & SUPPORT BRACKETS - ASSIST
REFRIGERATION SHOP (SEE ATTACHED - 2)

1445's

NONE REFRIG HAS MATLS. TRAVEL EQUIP 2 CREW SIZE

EAT-44	CUT BAR STOCK TO LENGTH &	6	2	12	
44-C	PUNCH HOLES (4 EA 36" LONG & 4 EA				
	12" LONG)				
QT-232	CUT PIPE SECTIONS TO LENGTH	60	1	60	
44-H					
EAT-2	CUT "H" BEAM TO LENGTH (2 EA 9'-6")	.3	2	6	
39-B					
EAT-53	MAKE-UP & WELD PIPE ASSEMBLY -	6.0	2	12.0	
45-H	REDUCERS & FLANGES				
EAT-41	WELD PIPE JOINTS	60	1	6.0	
46-H					
EAT-30	WELD TOWER SUPPORT PLATES	.13	4	.6	
42-A	& "H" BEAM				
PWA-5	MATERIAL HANDLING	.11	18	2.0	
EOT	ALLOWED - WORK W/REFRIG SHOP				12
		TOTALS		264	12
		TOTAL			44
		TOTAL JOB PHASE TIME			56

DD FORM 2167 SHEET 1 OF 1

Figure 2–5. Sample of DD Form 2167.

2. Why is the nomograph put on the back side of the DD Form 2167?

3. Who uses the nomograph side of the form?

4. What side of the form are the craftsman and supervisors mainly concerned with?

022. State the use of AF Form 561.

AF Form 561, Base Civil Engineer Weekly Work Schedule. This form (fig. 2-6) is used to identify how a cost center's manpower resources are to be expended over a 1-week time period. Each weekly schedule consists of two parts. The first part, or the front side, is used to identify all of the indirect labor and manhours to be reserved for continuous assignments, such as service calls, recurring maintenance, and direct operation work. The second part of the schedule is used to reflect a listing of individual work

BASE CIVIL ENGINEER WEEKLY WORK SCHEDULE (PART I)	WEEK ENDING 8 DEC 78	COST CENTER 451	APPROVED J. Riley

LINE NO.	DESCRIPTION A	LABOR UTIL. CODE (LUC) B	MAN HRS. C	MON SCHED	MON ACT	TUES SCHED	TUES ACT	WED SCHED	WED ACT	THU SCHED	THU ACT	FRI SCHED	FRI ACT	SAT SCHED	SAT ACT	SUN SCHED	SUN ACT
			MANHOUR ALLOCATIONS														
1	ASSIGNED		400	80		80		80		80		80					
2	BORROWED																
3	OVERTIME	38	16											16			
4	TOTAL AVAILABLE (total of items 1, 2, and 3)		416	80		80		80		80		80		16			
5	SUPERVISION	31	40	8		8		8		8		8					
6	TRAINING	32	16							8		8					
7	LEAVE	33	24	8		8		8									
8	ALL OTHER	34															
9	LOANED LABOR	39															
10	TOTAL INDIRECT (total of items 5 through 9)		80	16		16		16		16		16					
11	AVAILABLE FOR WORK (items 4 minus item 10)		336	64		64		64		64		64		16			
	PART II (RESERVED MAN-HOURS)																
12	EMERGENCY JOB ORDERS	12	24														
13	DIRECT SCHEDULED WORK	16	130														

THE ITEMS BELOW COMPETE FOR AVAILABLE MAN/HRS. (SCHEDULED WORK)

WORK ORDER JOB ORDER NUMBER	DESCRIPTION A	(LUC) B	MAN/HRS REQ. C	MON SCHED	MON ACT	TUES SCHED	TUES ACT	WED SCHED	WED ACT	THU SCHED	THU ACT	FRI SCHED	FRI ACT	SAT SCHED	SAT ACT	SUN SCHED	SUN ACT
	RECURRING MAINTENANCE	11															
	OPERATIONS AND SERVICES	19															
14456	CONST. CONTROL CENTER BLDG 505	15	94	16		16		16		16		16					
10769	REPR. WALLS & FLOORS BLDG 53	18	173	16		16		16		16		16					
10883	REPR. WALLS BLDG 1200	18	57							4		8					
A4341	ASSIST MASON SHOP CONST. FORMS BLDG 1851	16	16											16			
A4603	REPR. DOOR BLDG 51	16	7					7									
	SHOP LOADERS JOB ORDERS																
	A-1586 A-4495																
	A-1604 A-4611																
	A-1743																
	A-3842																
	A-3949																
	A-4021																
	A-4032																
	A-4076																
	A-4099																
	A-4487																
	A-4491																

AF FORM 561 MAY 78 PREVIOUS EDITION IS OBSOLETE.

SCHEDULER'S COPY

Figure 2–6. Sample of AF Form 561.

orders, IWP job orders, and those job orders that the chief of Work Control has reviewed and consolidated into hoppers for accomplishment at a later date. Each IWP work order and job order is listed separately on Part II of the AF Form 561. For each work requirement the work order number, the job description, the appropriate labor utilization code (LUC), and the man-hours required for the job must be entered on the form.

Part 1 of AF Form 561 is normally prepared at the beginning of the week prior to its use, and the scheduler notifies the chief of Work Control when Part I is completed. The chief of Work Control directs the preparation of Part II around midweek, and the scheduler meets with each foreman and superintendent on an individual basis to prepare this part of the schedule. The chief of Materiel Control should also be available to advise and assist the scheduler and the foreman so that a worthy product is developed.

Before each scheduling meeting, the foreman reviews the work orders and job orders to be scheduled and indicates whether there are any material or man-hour support problems. If bench stock materials are needed, Materiel Control should be made aware of the shortage and should request a replenishment from Base Supply.

The foreman decides if a job will require the skills of a particular craftsman, and should write the craftsman's name across the face of the work order or job order in a bold manner. This is done to alert the controller to assign that individual to the job when listing the jobs on the daily work schedule. In addition, for multishop jobs, an onsite job coordinator is designated. This individual is normally from the lead shop and will act as a point of contact for actions concerning the job as it is in progress.

Exercises (022):

Indicate in the blank space provided those statements that are true or false.

_____ 1. The BCE weekly work schedule consists of two parts.

_____ 2. All work orders and job orders are listed on Part I of AF Form 561.

_____ 3. When the weekly schedule is being developed, the scheduler is the only person who has an input.

_____ 4. An onsite job coordinator is assigned to multishop jobs.

023. State the purposes of man-hour accounting, the two methods of time accounting, and the correct procedure to record man-hours expended.

Man-hour Accounting. A man-hour accounting system is designed to provide a uniform method of maximum accuracy with minimum effort and cost. Man-hour accounting provides CE management and base accounting and finance with direct labor costs against work order numbers. It also helps CE management to direct and control manpower resources. There are two methods of time accounting, the actual time accounting (ATA) system and the exception time accounting (ETA) method. Each BCE uses one method or the other to report labor.

Actual time accounting (ATA). Cost centers of BCE using ATA report the total number of direct hours expended against each work order number by labor utilization code (LUC) and the total number of indirect hours charged to another LUC. An AF Form 1734, BCE Daily Work Schedule, is used by ATA cost centers to record man-hours daily. An AF Form 1734 is shown in figure 2-7.

The back of the form is used to record the indirect hours, such as leaves, etc., and to compute the total direct and indirect hours for the day. The back of the form is not shown in the figure.

This form will allow a maximum of 44 individuals' names to be printed on each page. It is desirable to have no more than 44 individuals assigned to any cost center or subcost center. The cost center foreman (CCF) coordinates with the appropriate controller who enters the following information on AF Form 1734.

a. The date that labor is to be performed is entered at the top of the form in the space provided.

b. Names of individuals being borrowed from another cost center and those assigned to that cost center but not listed on the AF Form 1734 are handprinted on the form. They should be shown below the first group of names (military personnel) if they are military and below the second group (civilian personnel) if they are civilians.

c. If an individual is being loaned to another cost center, the control center code and cost center code of the gaining cost center are entered on the form.

d. Note that if an individual is borrowed from another cost center, the leading control center code and cost center code are not entered on the form. The individual will be reported as loaned by the CCF.

e. Personnel being loaned and/or borrowed between subcost centers within the same cost center are not reported as loaned or borrowed. Their names will be charged to the work order number against which it was expended.

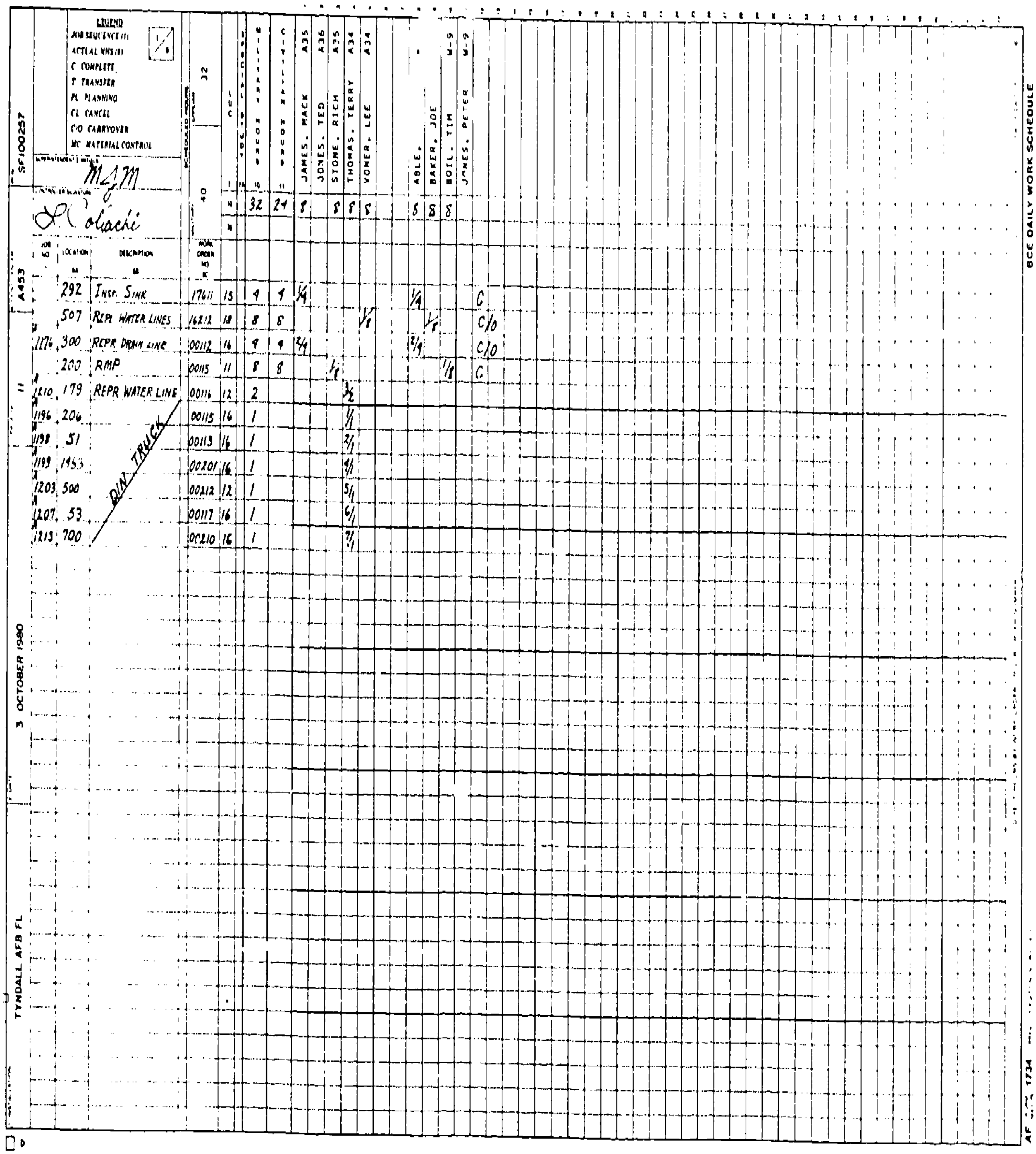
f. Borrowed and loaned labor will always be reported when a change of cost center is involved.

g. If an individual is assigned to the cost center of subcost center, but does not appear on the appropriate AF Form 1734, the administration section is contacted to make corrections of the situation.

Exception time accounting (ETA). Exception time accounting cost centers use an optional form to report exceptions from their anticipated work schedule. Those personnel assigned to cost centers whose duty is related to only a single BCE cost account code report their time on an exception basis only. Hence, normal duty will not be reported. All labor is assumed to be direct, under the LUC column, until reported otherwise.

Exercises (023):

1. What are the two purposes of man-hour accounting?



BCE DAILY WORK SCHEDULE

SF100257 · A453 · 11 · 3 OCTOBER 1980 · TYNDALL AFB FL

LEGEND
JOB SEQUENCE (I)
ACTUAL HRS (II)
C COMPLETE
T TRANSFER
PL PLANNING
CL CANCEL
C/O CARRYOVER
MC MATERIAL CONTROL

MJM

L. Colacchi

SCHEDULED HOURS: 32 / 40

JOB NO	LOCATION	DESCRIPTION	WORK ORDER NO		SCHED	ACTUAL	JAMES, MACK A35	JONES, TED A36	STONE, RICH A35	THOMAS, TERRY A34	YONER, LEE A34	ABLE	BAKER, JOE	BOIL, TIM M-9	JAMES, PETER M-9	
					32	24	8		8	8	8	8	8	8		
	292	INSP. SINK	17611	15	9	9	1/4					1/4				C
	507	REPR WATER LINES	16212	18	8	8					1/8		1/8			C/O
1176	300	REPR DRAIN LINE	00112	16	9	9	2/9					2/9				C/O
	200	RMP	00115	11	8	8			1/8					1/8		C
1210	179	REPR WATER LINE	00116	12	2					1/2						
1196	206	DIN TRUCK	00115	16	1					1/1						
1198	51		00113	16	1					2/1						
1199	1453		00201	16	1					4/1						
1203	500		00212	12	1					5/1						
1207	53		00117	16	1					6/1						
1213	700		00210	16	1					7/1						

AF 1734

Figure 2-7. Sample of AF 1734.

2. What are the two methods of time accounting?

3. What form is used to record man-hours daily?

4. How would the entry be made and where for Sgt Joe A. Foyt who is borrowed from another organization?

2-2. Resources Management

In order to get the job done, resources such as tools, materials, and equipment must be used. If proper management is not exercised, government property may become lost, stolen, or abused. Since you work for the Air Force, it is just as important that you keep a protective eye on Air Force property as you do on your own. If you own a new sports car with a tape player and CB, you certainly know how to protect it. You should protect a government vehicle or a test meter with the same diligence.

It is important that you understand your responsibility for government property, because there may come a time when the Air Force will ask you to pay for a piece of equipment that is damaged or lost. Your knowledge of the rules may make you conscious of your responsibility for its damage or loss.

024. Relate liability forms and concepts to the form numbers or to specific instances of property accountability and responsibility.

Property Accountability and Responsibility. The organizational commander is responsible and accountable for all property issued to his or her organization, whether he or she signs for it or not. But because the duties of the commander make it impracticable to exercise personal supervision of the supply functions, a commander designates a person to act as supply officer. The commander or the supply officer may then designate other representatives to receive and sign for property. However, delegation of duty does not make the commander exempt from financial liability for loss, damage, or destruction of property. Property responsibility is the obligation of each individual for the proper care of property belonging to the Air Force, whether or not such property has been issued to the person or his or her unit. Such responsibility includes pecuniary liability.

When you buy an article from a store, the moment the sales clerk completes the transaction, the store drops its accountability. It then becomes your property, and you are ountable and responsible for whatever use you make of Similarly, when a stock clerk issues an AF item to you, ntability is dropped insofar as the issuing authority is ned. However, you do not become the owner of the instead, the Air Force retains ownership, and you assume responsibility for the care and protection of the item.

Supervisory responsibility. Supervisory responsibility applies to any person who exercises supervision over property received, in use, in transit, in storage, or undergoing modification or repair. The supervisor is responsible for selecting qualified personnel to perform the duties under his or her control and for properly directing or training them. The supervisor instructs them in supply procedures in order to insure compliance with Air Force regulations governing property. The supervisor is also responsible for indoctrinating his or her people in the principles of supply discipline.

Custodial responsibility. Any individual who has possession of Government property has custodial responsibility for it. He or she is personally responsible for such property if it is for his or her official or personal use, whether or not this person has signed a receipt for it. The individual is also personally responsible for any property under his or her direct control for storage, use, custody, or safeguarding.

"Finders, keepers" may apply in some circumstances but not to Government property. If you find Government property that has apparently been lost, stolen, or abandoned, you must assume custodial responsibility for it and must protect or care for it until it can be returned to the proper authorities. Personnel may be relieved of responsibility for a particular piece of property in a number of ways, depending upon the circumstances. For example, property may be turned back to Base Supply as being excess to the unit's needs. Other items may be transferred from the responsibility of one person or organization to that of another. If you have custody of items that are damaged or lost through your carelessness, you may be held liable and may have to pay for them by deductions from your paycheck.

Pecuniary liability. The word "pecuniary" means money. Personnel having property responsibility also have pecuniary liability to make good property lost, destroyed, or damaged due to their negligence. Pecuniary liability may be shared by persons having command, supervisory, or custodial responsibility. If a person pays for an item of Government property, the property remains the possession of the Government. This keeps the supply system from becoming a source of supply for individual personnel.

Cash Collection Voucher. When pecuniary liability is admitted, the least troublesome way to settle a monetary obligation is to pay in cash. DD Form 1131, Cash Collection Voucher, is used for this purpose.

Statement of Charges. If airmen or civilian employees admit liability but do not have the money to pay cash for property damaged or lost, DD Form 362, Statement of Charges for Government Property Lost, Damaged, or Destroyed, is used. When either the Cash Collection Voucher or the Statement of Charges is used, the amounts involved must be less than $250. If $250 or more, then the Report of Survey is used.

Report of Survey. When an individual will not admit pecuniary liability or when the amount involved is $250 or more, a DD Form 200, Report of Survey, must be prepared. Two officers are directly concerned in preparing a Report of

Survey: the appointing authority and the investigating officer. The appointing authority is the commander or other officer with jurisdiction over the individual responsible for the property. The appointing authority appoints a survey officer (the investigating officer) whose duty it is to make a detailed and impartial investigation (survey) of the circumstances connected with the loss, damage, or destruction of the property. A survey officer is not necessary in every instance. In some cases, the appointing authority may make recommendations and forward the Report of Survey to the base commander for review and approval.

As a result of the findings, the person responsible for the property may or may not be required to pay for it. If the authorities decide from the evidence that the responsible individual is negligent in caring for the property involved, then he or she has to reimburse the Government by paying in cash (the Cash Collection Voucher) or authorizing a pay deduction (Statement of charges).

Exercises (024):

1. Match the items in column A with the applicable responsibility or liability form in column B.

Column A	*Column B*
______(1) Make good the loss of property.	a. Supervisory responsibility.
______(2) Loss of property in excess of $250.	b. Custodial responsibility.
______(3) DD Form 1131.	c. Cash Collection Voucher.
______(4) Admit liability and pay for property lost.	d. Statement of Charges.
______(5) Indoctrination in supply procedures.	e. Report of Survey.
______(6) Detailed investigation concerning loss of property.	
______(7) Admit liability but do not have the money to pay for the loss.	
______(8) Less than $250 involved in the loss.	
______(9) Least troublesome way to settle for loss.	
______(10) Take care of property you find.	
______(11) Meas "money."	
______(12) DD Form 362.	

025. State how the equipment authorization system operates.

Before you start to work on a job, you must have the proper tools and equipment. The equipment authorized your work center is based on two interrelated factors(emthe unit mission and the number of people. If the mission requires authorization for certain vehicles or similar major items, operator personnel must be authorized; as more personnel are authorized, quantities of other types of equipment are affected.

Equipment Authorization. Bases obtain supplies and equipment and issue them to units according to an authorization system. Although there are a variety of authorization documents, the most common one is the Table of Allowance (TA). Such tables are published to prescribe the exact items and quantities that each base or unit may draw (procure). The TA lists equipment on the basis of the needs of average Air Force units, since the exact composition and mission, number of facilities belonging to the unit, its geographic location, and many other factors vary from one unit to another. Naturally, these factors affect the types and amounts of items a unit requires.

The Master Equipment Management Index (MEMI) is used in connection with the TAs. The MEMI (TA-001) is a consolidated listing of equipment items in accordance with the latest USAF Federal Supply Catalog. The items are cross-referenced to TA numbers for the particular equipment items.

Suppose you need to find out how many desks a newly organized AF unit is authorized. First look up the item by name (desk) in the latest USAF Federal Supply Catalog. This will give you the class number, 7110, in the descriptive portion, which will let you choose the desk suitable for your organization. At this point, you will find the complete stock number and the correct nomenclature (description) for the desk you want. Now look up the stock number in the MEMI, which lists stock numbers in numerical order. This will refer you to the correct TA number. This TA will tell you how many desks your unit is authorized. The Table of Allowance takes into consideration not only the kind of unit to be equipped but also the total manpower employed.

Exercises (025):

1. Identify the following situations that are correct by placing an "X" in the blank provided.
   ______(1) The unit mission and the number of people assigned are equipment authorization criteria.
   ______(2) The equipment authorization document is the AF Form 1297.
   ______(3) The nomenclature of an authorized piece of equipment is found in the MEMI.
   ______(4) The TA is based on average AF units.
   ______(5) TA-001 is the MEMI.
   ______(6) The MEMI and TA are cross-referenced.
   ______(7) The TA lists the equipment authorized for a base.
   ______(8) TA-001 indicates the number of items of equipment a unit can procure for mission accomplishment.

026. State five pruposes of AF Form 601b and the use of AF Form 1445.

Equipment Requisitioning. As a supervisor, you will probably need to initiate a requisition for equipment on AF Form 601b, Custodian Request/Receipt (fig. 2-8). Notice (in block 24) that the form is used for an initial issue or as a replacement issue and (in block 23) to increase or reduce

1. NAME OF CUSTODIAN PHONE NUMBER ORGANIZATION/CUSTODIAN CODE: MSgt Harry Jones/4123/483DQ

2. CUSTODIAN REQUEST NO.: 224DQ7041-0007

3. BEMO/EMO CONTROL NO.:

4. AF FORM 601A CONTROL NO.:

5. STOCK OR PART NO.	6. IN-USE DETAIL DOC. NO.	7. ALLOWANCE IDENT.	8. PRESENT QNTY AUTH.	9. QNTY IN USE INCLUDE SUBS	10. QNTY. REQ'D NEW AUTH.	11. QNTY. REQUESTED	12. UNIT OF ISSUE	13. UNIT COST	14. UND	15. FAD	16. USE CODE
3740 00 434 6555	0084	008A	0	0	1	1	EA	$559.00	C	III	

ACTION REQUESTED

23. AUTHORIZATION: ☐ INCREASE ☒ ADD ☐ REDUCE ☐ DELETE

17. BUDGET CODE: 9

18. EPRC: NF2

19. ITEM DESCRIPTION: Sprayer, Insect AERO

26. I certify that I have evaluated this request and the action requested herein is required.

SIGNATURE OF ORGN. COMDR.: Calvin J. Mills, Major, USAF

24. ISSUE/DUE OUT: ☐ ADVICE ☒ INITIAL ISSUE ☐ REPLACEMENT ISSUE

20. CUSTODIAN SIGNATURE: Harry Jones

21. TRANSACTION SERIAL NO.:

22. JUSTIFICATION OR EXPLANATION OF REQUEST:

This equipment is required by the Entomology Section to insure their insect eradication responsibilities. At present, the base has no means to control pests. Previously, this work was done by contract. Since the contract expired and the only contractor with this capability has moved to another city, this responsibility is now assigned function of the Entomology Section. If pest control is not accomplished, this base will be in violation of Air Force and Environmental Protection Agency regulations.

25. TURN-IN ☐

CONDITION: ☐ SERVICEABLE ☐ REPARABLE ☐ CONDEMNED ☐ UNKNOWN

STATUS: ☐ COMPLETE ☐ INCOMPLETE[1]

CALIBRATION REQUIRED YES ☐ NO ☐

CLEAN/PAINT REQUIRED YES ☐ NO ☐

DISASSEMBLY REQUIRED YES ☐ NO ☐

27. ACTION TAKEN BY EMO/BEMO

APPROVED AS REQUESTED ☐

APPROVED AS INDICATED ☐

DISAPPROVED (See block 22) ☐

ADDITIONAL INFORMATION REQUIRED (See block 22) ☐

SIGNATURE/BEMO/EMO/EAA

RECEIPT OF PROPERTY ACKNOWLEDGE (Signature-Receiving Custodian)

DATE AVAILABLE FOR PICK-UP

[1] Enter Missing Components in Block 22

28. BEMO/EMO COMMENTS AND/OR OTHER REVIEWING ACTIVITY COMMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47

48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

AF FORM 601b APR 70 — PREVIOUS EDITION OF THIS FORM WILL BE USED.

CUSTODIAN REQUEST/RECEIPT

SE-601-8

Figure 2-8. Sample of AF Form 601b.

BEST COPY AVAILABLE

the authorization. An increase in authorization must be justified in block 22. Block 25 lets you use this same form to turn in equipment. When the equipment is received, the receiving custodian must sign for the property on the form. Before you complete an AF Form 601b, refer to AFR 67–23, *Standard Base Supply Customer's Guide*. It explains in detail how to requisition and turn in equipment.

Materials Requisitioning. Materials are requisitioned by the planning section of BCE for all work orders requiring materials. Materiel Control prepares the requisition when materials are required by service calls and job orders.

Figure 2-9 shows a completed Air Force Form 1445, Materials and Equipment List, which is used to order materials. There may be times that you will be told by your shop foreman to pick up work order or job order materials from the BCE holding area. When you go, you should take the AF Form 1445 with you and compare the materials you are picking up against the items listed on the form. Check the nomenclature to insure that the item you are to pick up is the same as the one described on the form. Also, check the unit of issue to insure that they agree; most important, you should insure that the quantity you are to pick up agrees with that shown on the AF Form 1445. If these items do not agree, do not sign or accept any of the items. You should immediately notify your shop foreman so that he or she can take appropriate action.

Exercises (026):

1. Which AFR explains how to complete AF Form 601b?

2. Briefly state five purposes of AF Form 601b.

3. What information on the AF Form 1445 should be checked against the actual materials?

4. What is the purpose of AF Form 1445?

027. State how to order supplies through BCE supply.

BCE Supply. Materiel Control is the focal point in Civil Engineering for all items of supply. This section is operated by CE supply personnel. They are the authority on obtaining supplies. Materiel Control is also responsible, jointly with Base Supply, for establishing and restocking all bench stocks, shop supplies, and rolling stock. Items on bench stock are limited to those used frequently and those that must be available in the immediate work area. Each shop and service truck should have a separate bench stock.

Before Materiel Control can order the materials you need for a job, it must know exactly what you want. The best way to communicate with supply personnel is to give them a stock number. Sometimes it's very easy to get the stock number; other times require a joint effort between you and Materiel Control.

If you have ever tried to buy a part for a car, motorcycle, gun, or camera, you probably remember the clerk asking you the make or manufacturer of the item for which the part was needed. Unless he or she was very familiar with the part in question, the clerk had to consult the manufacturer's catalog to find the part number.

National stock numbers. The Air Force uses 13 digits (numbers) to identify any item of supply in the Government's inventory. These national stock numbers are keyed to national or geographical areas. For example, 7110–00–273–8971 is furniture, office, chair, rotary, typist, steel, without arms. The 00 in the fifth and sixth positions represents the United States (as does 01). Other nations' double-digit numbers, for example, are 12, Germany; 14, France; 15, Italy; 21, Canada; 23 Greece; 27, Turkey, etc. The other parts of the stock number are codes to identify items. Some numbers identify what an item is; others indicate its weight, size, shape, color, and even where or how it is to be used. Just as cost accounting personnel can interpret the holes punched in specified positions on a punchcard, supply people can decode national stock numbers. The Government stocks millions of items of supply and equipment. Supply people can tell exactly what each item is from the stock number. You may see references to the old, 11-digit Federal stock numbers. Do not let this concern you, since they will be updated when the publications are revised.

Supply manuals and catalogs. Supply manuals and catalogs are useful in finding information on Government equipment and supplies. As it is with a city phone book or a mail order catalog, instructions are given in the information section. The supply publication that you will use more than any other is the General Services Administration (GSA) Supply Catalog. The GSA catalog contains items that are common to most organizations (furniture, cleaning supplies, handtools, laboratory equipment, office machines, paint, and sports equipment, etc.).

Exercises (027):

1. What unit in Civil Engineering is the contact point for ordering supplies?

2. What is the most important information you can furnish supply people if you want a sieve set?

AF Form 1445, SEP. 69.

TRANSACTION IDENTIFICATION CODE ①	DELIVERY DESTINATION ②	MATERIALS AND EQUIPMENT LIST

STOCK NUMBER ③	NOMENCLATURE	UNIT OF ISSUE ④	QUANTITY ⑤	UNIT COST	TOTAL COST	TRANSACTION SERIAL NUMBER ⑩	DEMAND CODE ⑪	IN STOCK YES	IN STOCK NO	DATE EXPECTED	REC. BY BCE	EXCESS MATERIALS QUANTITY	EXCESS MATERIALS DISPOSITION
5305 00 854 6689	Screw MS2461733	HD	00006	.76	4.56	ØØ45	R	✓					
5305 00 639 1089	Nut plain sq FFNB	GR	00006	.98	5.88	ØØ46	R		✓				
9515 00 640 4220	Sheet Metal galv 24ga 3'x10'	SH	00009	4.04	36.36	ØØ47	R	✓					

ACTIVITY CODE ⑥ R | ORGANIZATION CODE ⑦ 911 | SHOP CODE ⑧ SM | DATE MATERIAL REQUISITIONED ⑨ 6011 1 | WORK ORDER NO. ⑫ A00034 | TRANSACTION EXCEPTION CODE ⑬ | MATERIAL CONDITION ⑭ A | FORCE ACTIVITY DESIGNATOR ⑮ | SYSTEM DESIGNATOR ⑯ A1 | PROJ. CODE ⑰

DELIVERY PRIORITY ⑱ A6 | REQUIRED DELIVERY DATE ⑲ 241 | URGENCY JUSTIFICATION CODE ⑳ BW | FACILITY NO. ㉑ 00P-3 | INST. CODE ㉒ DJDB | JOB ORDER NO. SM ㉓ 0924 | PLANNER HARUEL | PAGE 1 OF 1 PAGES | HOLDING AREA BIN LOCATION

SHOP TITLE METAL | RECEIVED BY | MCNTH | FOLLOW-UP DATA FOR BACK ORDERED MATERIAL 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 | WORK ORDER NO.

Figure 2-9. Sample of AF Form 1445.

3. What does the number 27 mean in national stock number 7210–27–221–0352?

028. State the purpose of an inventory and list five rules that apply to supply discipline.

Inventory of Air Force Property. Inventory of supplies and equipment is an important task in managing resources. An inventory is an actual on-the-spot check with your own eyes to see whether or not specific signed for items of property are actually there. It also includes a check of expendable items (such as steel plate) to verify an amount on hand sufficient to perform the mission for a given period of time. Sgt Brown was given the job of inventorying equipment. Without actually seeing all the property, he signed papers stating that the equipment shown on the records was on hand. Five days later when a C–141 cargo plane landed to pick up equipment for delivery to a hostile area, the portable water purification unit was missing. This equipment was urgently needed to provide drinking water for our frontline troops. A court-martial investigation proved that Sgt Brown could not possibly have seen the unit, because it had been mistakenly shipped by an airman to another base. No need to stress that Sgt Brown was in trouble. The point to stress is that you are asking for trouble is you make such an inventory or falsify official papers. Certainly you wouldn't deliberately intend to hurt anyone, but a false inventory can cause serious difficulties and usually the one you hurt most is yourself.

During an inventory, if you detect errors in description of property, in amount, capacity, measurement, or condition, make a note of it and take steps to correct the records. Most deficiencies are the result of minor human errors. They can be solved easily by coordinating with other people and by using commonsense. Can you imagine the embarrassment to your supervisor if the Inspector General reports that your unit is charged with 12 cases of dynamite but that only 2 are on the premises?

Many deficiencies in inventory records are caused by simple errors of addition or posting. An example of such error of addition can be seen in this hypothetical situation. Suppose that it takes 1,200 pounds of epoxy cement each month to operate a runway and that it takes 2 weeks minimum to get epoxy when it is ordered. A specialist adding an inventory list added the following numbers, 359.5 + 436.2 + 204.3 = 10,000 pounds. Actually only 1,000 pounds of epoxy is on hand. If this error is not discovered, a very serious situation will develop, because in 25 days there will be no epoxy for the runway. This situation could even cause embarrassment when the base commander requests emergency funds and emergency deliveries from higher headquarters.

Supply Discipline. Supply discipline simply means obeying a set of rules necessary to conserve and protect Air Force equipment and supplies. To state it in another way, "Play the game according to Air Force rules, not according to personal desires." To protect our country from our enemies, the Air Force must be ready to act at a moment's notice. The following rules will assure this state of readiness:

Rule 1. Air Force equipment must be operational. If it is broken down, you can't use it. Proper maintenance must be provided to keep equipment in a like-new state.

Rule 2. Adequate supplies must be on hand and in good condition. Do not hoard or requisition more supplies than you actually need. This practice results in shortages in some areas and overages in others. Overstocking and hoarding to meet unforeseeable needs places a wasteful demand on procurement funds by generating false requirements.

Inadequate stocking of supplies and equipment can be equally damaging. This condition may result from failure to maintain adequate records and from failure to correlate past experiences with present needs.

Rule 3. Use equipment and supplies for their intended purposes. Do not take them for personal use.

Rule 4. Safeguard equipment and supplies. Millions of dollars of Air Force supplies and equipment have been lost, stolen, or damaged in the past. This condition benefits the enemy, not the Air Force.

Rule 5. Keep accurate, current records of resources required, received, consumed, and on hand. Accurate accounting and records result in an even flow of resources to meet Air Force needs.

Exercises (028):

1. Briefly state the purpose for an inventory of Air Force property.

2. Define supply discipline.

3. Briefly list five rules which apply to supply discipline.

029. State the meanings of equipment and supply condition tags.

Condition Tags. These forms, which are actually colored, cardboard tags, are attached to pieces of equipment and material denoting the condition of each item. The tags are extremely important, and each shows the following statement:

WARNING: Unauthorized persons removing, defacing, or destroying this tag may be subject to a fine of not more than $1,000 or imprisonment for not more than 1 year or both (18 USC 2461).

Never remove a tag unless you know you are authorized to remove it. The penalty is stiff, and the results can be disastrous. Suppose, for example, a service person has drained the oil from a motor and placed an unserviceable (reparable) green tag on the starter switch. If you operate

that engine, you will ruin it. If you remove the tag and operate the engine, you may be in grave trouble. There are three tags:

(1) Serviceable Tag. This yellow tag, placed on serviceable material, is DD Form 1574.

(2) Unserviceable (Condemned) Tag. This red tag, placed on material that probably will not be placed back in service, is DD Form 1577. Do not try to use equipment that has a red tag attached.

(3) Unserviceable (Reparable) Tag. This green tag is placed on material that the inspector declares unserviceable at the present time but is probably reparable. The tag is a DD Form 1577-2.

To be valid, condition tags must have the inspector's name or stamp in the appropriate block. The date must also be included.

Exercises (029):

1. Which color condition tag would you find on a serviceable item?

2. A piece of equipment has a green tag on it. What is its condition?

3. What does a red tag represent?

030. State how to use supply issue and turn-in slips.

Request Issue or Turn-In. There are a number of supply forms for requisitioning an item, but the most important to you is AF Form 1801, Request for Issue or Turn-In. It is used for expendable-type items. Figure 2-10 shows a partially completed AF Form 1801 requesting issue for 6 center bits and 6 countersinks. Note the Issue block at the top of the page is filled in with an "I." Now look at the bottom of the form and notice under Issue that "I" means it is an initial issue. Also, note that this same form can be used for turn-ins. Always place a justification for the items after listing the last item.

Temporary Issue Receipt. Figure 2-11 shows a completed AF Form 1297, Temporary Issue Receipt, for items issued on a temporary basis (normally, 24 hours). Once accomplished, however, this receipt can remain in force until surrendered by the unit supply officer. The form is sometimes called a custody receipt or, simply, a hand receipt.

Exercises (030):

1. For what kind of items do you use AF Form 1801?

2. How do you indicate whether you are issuing items or turning them in?

3. Must all items on one form be the same?

4. What must follow the last item on the form?

5. What information do you need (other than stock number, description, and coding) on each entry?

6. For what purpose is the AF Form 1297 used?

7. Normally, how long is the AF Form 1297 used for items on a temporary basis?

8. Give two other names for the Temporary Issue Receipt.

REQUEST FOR ISSUE OR TURN-IN

FROM	TTGIC, Step 43, Ringstad/2072
TO	TTGIE, Step 27, Neth/2879
DATE MATERIAL REQUIRED	18 JUN 82
DOCUMENT NUMBER	7082-009
PRIORITY	ROUTINE
ACCOUNTING AND FUNDING DATA	208 MF

ITEM NO.	STOCK NUMBER, DESCRIPTION AND CODING OF MATERIAL AND/OR SERVICES	UNIT OF ISSUE	QUANTITY	SUPPLY ACTION	UNIT PRICE	TOTAL COST
1.	5113-865-4221, Bit Center ½" dia.	EA	6		.55	$3.30
2.	5133-393-2297, Countersink ½" dia.	EA	6		.45	$2.70

//////////////// LAST ITEM ////////////

Justification: These tools will be used to replace like items that have been worn out due to fair wear and tear.

Jimmy Marsh, MSGT
FOREMAN METAL FABRICATION

FIA CODE | BUDGET CODE | SHEET TOTAL | GRAND TOTAL

ISSUE: I Initial R Recurring N Non Recurring — TURN IN: U Unserviceable S Serviceable

AF FORM 1801

Figure 2-10. Sample of AF Form 1801.

BEST COPY AVAILABLE

JAMES, W.W. SSGT 375OCE TYPED OR PRINTED NAME, GRADE AND ORGANIZATION	LT. HADLEY TO (Responsible Officer)	026 ORG ACCT NO	12 AUG 76 DATE ITEM(S) TO BE RETURNED

STOCK NO.	DESCRIPTION	UNIT	QUANTITY ISSUED	COST
5133-529-5691	DRILL SET (SET OF 26)	SE	1	$17.40
	LAST ITEM			

I ACKNOWLEDGE RECEIPT AND RESPONSIBILITY FOR ITEM(S) SHOWN IN "QUANTITY ISSUED" COLUMN, WHICH WILL BE RETURNED ON DATE SPECIFIED ABOVE.

DATE	SIGNATURE	DUTY PHONE	ISSUED BY
11 AUG 76	W. W. JAMES	2879	H. Jones

AF FORM SEP 70 1297 PREVIOUS EDITIONS WILL BE USED TEMPORARY ISSUE RECEIPT ☆GPO: 1971 – 427-611

BE – 1297

Figure 2–11. Sample of AF Form 1297.

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Shop Mathematics

ALMOST EVERY fabrication job that you work on as a metal fabricating specialist will require a working knowledge of mathematics. Because this knowledge is basic to everything you do it is very important that you understand, and can apply, the principles which we will cover now.

The shop mathematics discussed in this chapter includes the use of fractional and decimal numbers, solving equations and formulas, and measurement of plane and solid geometric figures related to sheet metalwork. You will frequently use shop mathematics in such jobs as developing layouts and patterns for sheet metal repair, fabrications, and installations.

If you have a background in arithmetic, geometry, or use of the metric system, this chapter will improve your ability to perform most of the mathematical problems related to sheet metalwork. If you have a good background in these functions of mathematics, this text and review exercises will serve to refresh your memory.

3-1. Fractions

Most of the measuring tools that you use are divided into fractions of an inch. To use these tools successfully you must be able to quickly add, subtract, multiply, divide, and convert these fractions to other units of measurement. First, let's define what a fraction is.

031. Specify fraction types and common divisors; reduce, and change fractions.

Types of Fractions. A fraction is part of something—part of an inch, foot, pie, apple, or just about anything. A fraction has two parts: a top and a bottom. The top is called the numerator, the bottom is the denominator.

Numerator	1	3
Denominator	4	8

Those two fractions are examples of what we call proper fractions. In a proper fraction, the numerator is smaller than the denominator. Improper fractions are those with a numerator larger than the denominator, such as 9/8. The fraction 9/8 may be considered to be the sum of 8/8 plus 1/8. It is customary to change improper fractions to mixed numbers by dividing the numerator by the denominator. The quotient (or result) is expressed as a whole number, followed by a fraction in which the remainder is the numerator, and the denominator is the same as before. For example 9/8 = 1 1/8, since 8 is contained in 9 one time with a remainder of 1.

Sometimes, as in multiplication, it is desirable to convert a mixed number to an improper fraction. This can be done by reversing the above process. To do this conversion, multiply the whole number by the denominator of the fraction and then add the numerator to your product; use this number as the new numerator for the original denominator. Thus, to change 2 3/4 to an improper fraction, multiply 2 X 4 and get 8; and 8 + 3 = 11. Putting this 11 over the original denominator 4, you now have 11/4.

When both the numerator and denominator of a fraction contain a common factor, the fraction should be reduced by this factor. That is, the numerator and the denominator are divided by the common factor. For example, the fraction 6/8 can be reduced by dividing both the 6 and 8 by 2 (6/8 = 6 divided by 2 = 3, and 8 divided by 2 = 4, which = 3/4.) The answer is 3/4, which has the same value as the original 6/8. This process is called reducing a fraction to its lowest terms. If both the numerator and denominator of a fraction are either multiplied or divided by the same number, the value of the fraction is not changed.

Exercises (031):

1. Identify the type of fraction of the following listed fractions:

   a. 9/8.

   b. 2 7/4.

   c. 57/64.

2. Identify the largest common divisor used to reduce each of the following fractions:

   a. 6/8.

   b. 32/64.

c. 14/32.

d. 49/42.

3. Convert the following to mixed numbers:

   a. 27/4.

   b. 134/8.

   c. 65/64.

   d. 2/16.

032. Convert mixed numbers to improper fractions and solve addition, subtraction, multiplication, and division problems, using fractions.

Multiplying Fractions. Perhaps the simplest operation with fractions is multiplication such as 1/4 X 3/4 = 3/16, and 2 X 3/4 = 6/4 = $1\frac{2}{4}$ = $1\frac{1}{2}$. When mixed numbers are to be multiplied, first change each to an improper fraction and proceed.

$1\frac{2}{3}$ X $3\frac{1}{2}$ = 5/3 X 7/2 = 35/6 = $5\frac{5}{6}$.
$1\frac{1}{4}$ X $2\frac{1}{2}$ = 5/4 X 5/2 = 25/8 = $3\frac{1}{8}$.

Frequently, you can simplify the multiplication of fractions by performing certain divisions of the numerators and the denominator before proceeding with the indicated multiplication. For instance, you can multiply 3/10 by 4/9 in the following way:

Example:

$$\frac{\overset{1}{3}}{\underset{5}{10}} \times \frac{\overset{2}{4}}{\underset{3}{9}} = \frac{2}{15}$$

Here, you divided (commonly called canceling) before performing the indicated multiplication. The numerator 3 and the denominator 9 were divided by the common factor 3. The numerator 4 and the denominator 10 were divided by the common factor 2. Then, with the numerators 1 and 2 and the denominator 5 and 3, you easily arrived at the answer 2/15.

Division of Fractions. Division is also simple, just like multiplication, except for one change. That is to invert the divisor. With the divisor inverted, multiply the dividend by the inverted divisor as in:

3/4 ÷ 1/4 = 3/4 X 4/1 = 12/4 = 3
or
3/4 ÷ 1/4 = 3/4 X 4/1 = 3/1 = 3

In division, after inverting the divisor, follow the principles of multiplication.

If the upper fraction is called the smaller of the two, first borrow one whole unit from the top whole number and convert it into the fractional equivalent of a whole number. Add this and the fraction you already have; then proceed with the subtraction.

Example:

$29\frac{1}{4}$	=	$28\frac{5}{4}$		
$-15\frac{3}{4}$	=	$-15\frac{3}{4}$		
		$13\frac{2}{4}$	=	$13\frac{1}{2}$

Adding Fractions. To add mixed numbers, you must first find the common denominator. The common denominator is a denominator that is devisable by all of the denominators involved.

To change fractions to common denominator fractions, you find the smallest number that all denominators will go into evenly. Let's look at an example.

To Add	*Change to*
$13\frac{1}{6}$	$13\frac{3}{18}$
$16\frac{2}{3}$	$16\frac{12}{18}$
$5\frac{7}{9}$	$5\frac{14}{18}$

Why did we use 18 as a common denominator? Because 6, 3, and 9 will go into 18 evenly. Now, let's look at the numerators 1, 2, and 7. What happens to them? Let's look. In the case of 1/6, 6 goes into 18, 3 times and 3 times 1 = 3, so all this equals 3/18. Now look at 2/3; 3 goes into 18, 6 times and 6 times 2 equals 12, so we get 12/18 and so forth. Now add them together. Remember, when adding common denominator fractions, you add the numerators only.

In the example we have 3, 12, and 14 that add up to 29 or 29/18, which equals 1 . Now, add the whole numbers in the example. 13, 16, and 5, that's easy; 34 is the correct answer. No! You forgot the fractions, 34 + 1 = 35

$120\frac{3}{4}$	=	$120\frac{6}{8}$		
$52\frac{3}{8}$	=	$52\frac{3}{8}$		
$23\frac{1}{2}$	=	$23\frac{4}{8}$		
195		(13/8	=	1)

So,
195 + 1 = 196

Subtracting Mixed Numbers. When the fraction in the top number (minuend) is greater than the fraction in the lower number (subtrahend), subtract the whole part from the whole part and the fraction from the fraction.

Examples:

$$\begin{array}{r} 22\ \tfrac{4}{5} \\ -12\ \tfrac{3}{5} \\ \hline 10\ \tfrac{1}{5} \end{array}$$

$$\begin{array}{rcr} 22\tfrac{3}{4} & = & 22\tfrac{3}{4} \\ -12\tfrac{1}{2} & = & 12\ \tfrac{2}{4} \\ \hline & & 10\tfrac{1}{4} \end{array}$$

Exercises (032):

1. Convert the following mixed numbers to improper fractions and reduce to lowest terms.
   a. $3\tfrac{1}{2}$.
   b. $6\ \tfrac{18}{64}$
   c. $5\ \tfrac{7}{8}$.
   d. $1\tfrac{1}{4}$.
   e. $4\ \tfrac{9}{16}$.

2. Solve the following problems:
   a. 11/12 X 7/8.
   b. $4\ \tfrac{2}{3}$ X $3\tfrac{5}{6}$.
   c. 3/4 X 5/9.

3. Solve the following problems:
   a. $\tfrac{5}{6} \div \tfrac{1}{6}$.
   b. $\tfrac{4}{9} \div \tfrac{3}{4}$.
   c. $16\tfrac{3}{4} \div 3\tfrac{1}{4}$.
   d. $25\ \tfrac{4}{5} \div 5\tfrac{1}{5}$.

4. Identify the mixed numbers below that contain improper fractions.
   a. $3\tfrac{15}{16}$.
   b. $7\tfrac{9}{4}$.
   c. $1\tfrac{3}{2}$.
   d. $6\tfrac{5}{6}$.
   e. $4\tfrac{6}{5}$.
   f. $2\tfrac{19}{8}$.

5. Prepare the following figures for addition:
   a.

$$\begin{array}{r} 21\ \tfrac{2}{3} \\ 7\ \tfrac{5}{8} \\ 18\ \tfrac{3}{4} \\ 11\ \tfrac{1}{4} \\ 15\ \tfrac{7}{8} \\ 4\ \tfrac{5}{6} \\ \hline \end{array}$$

b.

$$\begin{array}{r} 1 \\ 1 \\ 6 \\ 14\tfrac{1}{4} \\ \underline{3} \end{array}$$

6. Find the correct answers to a and b of exercise 5.

7. Prepare the following for subtraction:

a.

$$\begin{array}{r} 21\tfrac{5}{11} \\ \underline{-14\tfrac{5}{6}} \end{array}$$

b.

$$\begin{array}{r} 14\tfrac{3}{16} \\ \underline{5\tfrac{5}{8}} \end{array}$$

d. Find the correct answer to a and b of objective 032, exercise 7.

3-2. The Decimal System

When solving mathematical problems, it is often easier to convert a fractional number to a decimal before solving the problem. Also, many times measurements will be expressed in decimal form on a blueprint or drawing. Therefore, it is essential that you are able to perform math functions with decimal numbers.

033. Solve multiplication and addition problems with decimals and fractions.

Decimals. The decimal fractions express tenths of a unit—and that can be about anything—weight, length, size, hour, etc.

The decimal fraction is written so that it has only a numerator which contains a decimal point. The decimal point is written at the left of the number expressing the numerator. For example, 0.5 is a decimal and is read point 5, or five tenths. Its value is the same as the fraction 5/10.

Read a decimal precisely as if it were a whole number, and then give it the name of the lowest decimal place. Point 1 (0.1) is read one tenth, point 01 (0.01) is read one hundredth, point 001 (0.001) is read as one thousandth, etc.

An example of decimals you will be using is a No. 39-twist drill, which is 0.099 inch in diameter; the decimal 0.099 is read ninety-nine thousandths. Another example is 24-gage sheet metal, which is 0.025-inch thick; the decimal 0.025 is read twenty-five thousandths.

A mixed number with decimals such as 1.25 is read one and twenty-five hundredths, or simply one point twenty-five.

Changing Fractions to Decimals. To change a common fraction to a decimal fraction, divide the numerator by the denominator.

Example:

$$\begin{array}{r} 0.875 \\ 8\overline{)7.000} \\ \underline{64} \\ 60 \\ \underline{56} \\ 40 \\ \underline{40} \end{array}$$

Therefore:

7/8 = 0.875

Changing Decimals to Fractions. To change a decimal fraction to a common fraction, omit the decimal point, write the understood denominator, and reduce to lowest terms.

Example:

$$.875 = \frac{875}{1000} = \frac{35}{40} = \frac{7}{8}$$

Using Decimal Equivalent Charts. Figure 3-1 is a decimal equivalent chart which you can use to convert fractions to decimals and decimals to fractions without using the preceding mathematical procedures. The chart contains the decimal equivalents of all fractional values from 1/64 to 64/64. In shop work, you will save time by using the decimal equivalent charts; however, sometimes you will encounter fractions that are not on the chart and must be figured arithmetically.

Example: Use figure 3-1 and determine the decimal equivalent of 1/64, 5/32, 6/16, and 7/8.

1/64 = 0.015625
5/32 = 0.15625
6/16 = 0.375
7/8 = 0.875

Adding Decimals. To add numbers containing decimals, the decimal points must be aligned in a vertical column.

Example: Find the sum of 23.01 0.037, and 1.3.

$$\begin{array}{r} 13.01 \\ 0.037 \\ \underline{1.3} \\ 14.347 \end{array}$$

Decimal Equivalents

FRACTION	16TH.	32ND.	64TH.	DECIMAL	FRACTION	16TH.	32ND.	64TH.	DECIMAL
			1	013625				33	515625
		1	2	03125			17	34	53125
			3	.046875				35	546875
	1	2	4	0625		9	18	36	5625
			5	.078125				37	578125
		3	6	.09375			19	38	59375
			7	.109375				39	609375
1/8	2	4	8	.125	5/8	10	20	40	625
			9	.140625				41	640625
		5	10	15625			21	42	65625
			11	171875				43	671875
	3	6	12	.1875		11	22	44	6875
			13	203125				45	.703125
		7	14	21875			23	46	.71875
			15	.234375				47	734375
1/4	4	8	16	250	3/4	12	24	48	750
			17	265625				49	765625
		9	18	28125			25	50	78125
			19	296875				51	796875
	5	10	20	.3125		13	26	52	8125
			21	.328125				53	828125
		11	22	.34375			27	54	84375
			23	359375				55	859375
3/8	6	12	24	375	7/8	14	28	56	.875
			25	.390625				57	890625
		13	26	.40625			29	58	90625
			27	421875				59	.921875
	7	14	28	4375		15	30	60	.9375
			29	453125				61	.953125
		15	30	.46875			31	62	.96875
			31	484375				63	.984375
1/2	8	16	32	500	1	16	32	64	1.000

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Figure 3-1. Decimal equivalent chart.

Subtracting Decimals. To subtract decimal fractions, align the decimal points as in addition and determine the difference.

Example: Subtract 2.84 from 15.1.

```
 15.10
 -2.84
 -----
 12.26
```

Multiplying Decimals. To multiply decimal numbers, place the multiplier under the multiplicand, disregarding the position of the decimal points. Multiply as with whole numbers, and in the product, point off as many decimal places as there are decimal places in both multiplier and multiplicand, beginning at the right, adding zeros as necessary.

Examples:

```
   a.       b.       c.

  .25     11.25     .05
  2.5       .75      .5
  ----    ------    ----
  125      5625     .025
  50      7875
  ----    ------
  .625    8.4375
```

Exercises (033):

1. Add the following mixed numbers and fractions: 36.734, 2.4, .008, 13/16, and 6 17/32 .

2. Multiply the following:

   a. 2.08
      40.3

   b. .03
      .38

   c. 3.45
      2.8

3-3. Metrics

In this section, we discuss only part of the metric system. It was first established in France following the French Revolution. In the near future, the United States will officially start to use the metric system of measurement. Though the United States Government legalized the metric system back in 1866, the population has clung to the English system of measurement.

This metric system has three principal units, the meter, as the unit of length; the liter, as the unit of capacity; and the gram, as the unit of weight. 034. Convert inches and fractions of inches into parts of meters as used in the metric system and solve problems, using conversion charts.

The unit you will use most often is the meter. Did you know that the meter is the only legalized unit of measure of length in the United States? Well, it is. Terms used in the metric system are all in units of 10. Multiples of these are obtained by prefixing the Greek words: deca (10), hecto (100), and kilo (1000). Divisions are obtained by prefixing the Latin words: deci (1/10 or 0.1), centi (1/100 or 0.01), and milli (1/1000 or 0.001).

Notice in figure 3-2 that the meter is located in the center of the lists of names. At the left is a column of metric units and what they represent. Note that the difference is the location of the decimal point.

Millimeter (mm) is the smallest metric unit of length that we will talk about.

Now that we can identify the little marks of a meter, let's see what we get when we multiply meters. Ten meters is a decameter (dkm), ten decameters is a hectometer (hm), and ten hectometers is a kilometer (km). These different units are listed in figure 3-3.

Figure 3-4 shows a conversion table. Here is a quick reference to convert from given inches to millimeters.

1 Kilo 1000.
1 Hecto 100.
1 Deca 10.
1 * 1.
1 Deci .1
1 Centi .01
1 Milli .001

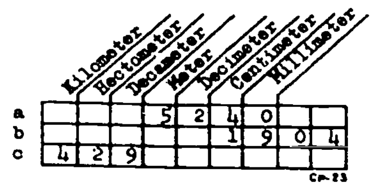

Figure 3–2. Units of measure.

In order to read blueprints and make accurate plans, when converting to/from metrics, check figure 3-5 for a quick conversion chart. Notice that in this figure measurements are converted both ways, inches to metrics, and metrics to inches, and includes several types of measurement units.

If 50 meters equals 54.68 yards, let's see what 64 meters equal: 65.62 + 4.37 = 69.99 yards.

Now you can convert whole numbers (inches) to meters. What do you do with fractions? You can take 25.3995 (metric equivalent of 1 inch) and divide and multiply and round off the answer to the fourth decimal point, or you can check figure 3-6 for a list of fractions of an inch with decimal and millimeter equivalents. These figures are useful in many ways—one of which is finding twist drill sizes.

From time to time, you will have a real need to work with dry volume. So that you can be prepared and ahead of the average, study figure 3-7. Let's say you have a job to construct a form, box, or whatever out of 16-gage galvanized metal that will hold 9 cubic meters of sand. Your container is to be 34 inches high and 94 inches wide. Now how long must it be? To find out let's start with what we know, 34" X 94" = 3196 sq in and 144 sq in = 1 sq ft. So by dividing 144 into 3196, we find that we have a container with 22.19 sq ft area on one end. Now all we need is the length. To find the length, divide the area of the end (in this case 22.19) into the total volume— (in this case, 9 cu meters = 317.8 cu ft) and we come up with 14.32 ft or 14'4". So now we know that your container must be 14'4" long.

When you are faced with a problem with liquid volumes in metrics, remember that the liter is the foundation of liquid measure. Refer to figure 3-8 and the back of a circumference ruler. Between these two you should be able to accurately solve any problem you may encounter.

To work with units of weight in the metric system, the kilogram (kg) is the foundation of measure. Figure 3-9 is a conversion of U.S. weights and metric weights. Study it so that when you work with blueprints (especially overseas) made under the metric system you won't make costly errors.

10 millimeters (mm)	=	1 centimeter (cm)
10 centimeters	=	1 decimeter (dm)
10 decimeters	=	1 meter (m)
10 meters	=	1 decameter (dkm)
10 decameters	=	1 hectometer (hm)
10 hectometers	=	1 kilometer (km)

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Figure 3–3. Measures of length.

Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters
1	25.4	26	660.4	51	1295.4	76	1930.4
2	50.8	27	685.8	52	1320.8	77	1955.8
3	76.2	28	711.2	53	1346.2	78	1981.2
4	101.6	29	736.6	54	1371.6	79	2006.6
5	127.0	30	762.0	55	1397.0	80	2032.0
6	152.4	31	787.4	56	1422.4	81	2057.4
7	177.8	32	812.8	57	1447.8	82	2082.8
8	203.2	33	838.2	58	1473.2	83	2108.2
9	228.6	34	863.6	59	1498.6	84	2133.6
10	254.0	35	889.0	60	1524.0	85	2159.0
11	279.4	36	914.4	61	1549.4	86	2184.4
12	304.8	37	939.8	62	1574.8	87	2209.8
13	330.2	38	965.2	63	1600.2	88	2235.2
14	355.6	39	990.6	64	1625.6	89	2260.6
15	381.0	40	1016.0	65	1651.0	90	2286.0
16	406.4	41	1041.4	66	1676.4	91	2311.4
17	431.8	42	1066.8	67	1701.8	92	2336.8
18	457.2	43	1092.2	68	1727.2	93	2362.2
19	482.6	44	1117.6	69	1752.6	94	2387.6
20	508.0	45	1143.0	70	1778.0	95	2413.0
21	533.4	46	1168.4	71	1803.4	96	2438.4
22	558.8	47	1193.8	72	1828.8	97	2463.8
23	584.2	48	1219.2	73	1854.2	98	2489.2
24	609.6	49	1244.6	74	1879.6	99	2514.6
25	635.0	50	1270.0	75	1905.0	100	2540.0

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Figure 3–4. Inches to millimeters.

Exercises (034):

1. Using figure 3-4, convert 53 inches to millimeters.

2. Using figures 3-4 and 3-5, find the answers to the following:
   a. Find the millimeter equivalent of 6, 9, 21, 54, and 68 inches.

   b. Find the millimeter equivalent of 12, 14, 23, 28, 39, and 89 inches.

3. Using figures 3-2, 3-4, 3-5, and 3-6, find the correct answer.
   a. Find the total millimeter equivalent of 6 7/8, 29 47/64, 86 11/32, 1¾, and 36 13/16 inches.

   b. Find the total kilometer equivalent of 98, 61, and 984 miles.

	km → miles	miles → kilometers	meters → yards	yards → meters	meters → feet	feet → meters	cm → inches	inches → centimeters
1	0.62	1.61	1.09	0.91	3.28	0.30	0.39	2.54
2	1.21	3.22	2.19	1.83	6.56	0.61	0.79	5.08
3	1.86	4.83	3.28	2.74	9.81	0.91	1.18	7.62
4	2.49	6.44	4.37	3.66	13.12	1.22	1.57	10.16
5	3.11	8.05	5.47	4.57	16.40	1.52	1.97	12.70
6	3.73	9.66	6.56	5.49	19.68	1.83	2.36	15.24
7	4.35	11.27	7.66	6.40	22.97	2.13	2.76	17.78
8	4.97	12.87	8.75	7.32	26.25	2.44	3.15	20.32
9	5.59	14.48	9.84	8.23	29.53	2.74	3.54	22.86
10	6.21	16.09	10.94	9.14	32.81	3.05	3.93	25.40
12	7.46	19.31	13.12	10.97	39.37	3.66	4.72	30.48
20	12.43	32.19	21.87	18.29	65.62	6.10	7.87	50.80
24	14.91	38.62	26.25	21.95	78.74	7.32	9.45	60.96
30	18.64	48.28	32.81	27.43	98.42	9.14	11.81	76.20
36	22.37	57.94	39.37	32.92	118.11	10.97	14.17	91.44
40	24.85	64.37	43.74	36.58	131.23	12.19	15.75	101.60
48	29.83	77.25	52.49	43.89	157.48	14.63	18.90	121.92
50	31.07	80.47	54.68	45.72	164.04	15.24	19.68	127.00
60	37.28	96.56	65.62	54.86	196.85	18.29	23.62	152.40
70	43.50	112.65	76.55	64.00	229.66	21.34	27.56	177.80
72	44.74	115.87	78.74	65.84	236.22	21.95	28.35	182.88
80	49.71	128.75	87.49	73.15	262.47	24.38	31.50	203.20
84	52.20	135.18	91.86	76.81	275.59	25.60	33.07	213.36
90	55.92	144.84	98.42	82.30	295.28	27.43	35.43	228.60
96	59.65	154.50	104.99	87.78	314.96	29.26	37.80	243.84
100	62.14	160.91	109.36	91.44	328.08	30.48	39.37	254.00

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Figure 3–5. Conversion chart.

CONVERSION OF FRACTIONS AND DECIMALS OF AN INCH TO MILLIMETERS

Fraction of Inch	Decimal of Inch	Millimeters	Fraction of Inch	Decimal of Inch	Millimeters
1/64	0.015625	0.3968	33/64	0.515625	13.0966
1/32	0.03125	0.7937	17/32	0.53125	13.4934
3/64	0.046875	1.1906	35/64	0.546875	13.8903
1/16	0.0625	1.5875	9/16	0.5625	14.2872
5/64	0.078125	1.9843	37/64	0.578125	14.6841
3/32	0.09375	2.3812	19/32	0.59375	15.0809
7/64	0.109375	2.7780	39/64	0.609375	15.4778
1/8	0.125	3.1749	5/8	0.625	15.8747
9/64	0.140625	3.5718	41/64	0.640625	10 2715
5/32	0.15625	3.9686	21/32	0.65625	16.6684
11/64	0.171875	4.3655	43/64	0.671875	17.0653
3/16	0.1875	4.7624	11/16	0.6875	17.4621
13/64	0.203125	5.1592	45/64	0.703125	17.8590
7/32	0.21875	5.5561	23/32	0.71875	18.2559
15/64	0.234375	5.9530	47/64	0.734375	18.6527
1/4	0.25	6.3498	3/4	0.75	19.0496
17/64	0.265625	6.7467	49/64	0.765625	19.4465
9/32	0.28125	7.1436	25/32	0.78125	19.8433
19/64	0.296875	7.5404	51/64	0.796875	20.2402
5/16	0.3125	7.9373	13/16	0.8125	20.6371
21/64	0.328125	8.3342	53/64	0.828125	21.0339
11/32	0.34375	8.7310	27/32	0.843750	21.4308
23/64	0.359375	9.1279	55/64	0.859375	21.8277
3/8	0.375	9.5248	7/8	0.875	22.2245
25/64	0.390625	9.9216	57/64	0.890625	22.6214
13/32	0.40625	10.3185	29/32	0.90625	23.0183
27/64	0.421875	10.7154	59/64	0.921875	23.4151
7/16	0.4375	11.1122	15/16	0.9375	23.8120
29/64	0.453125	11.5091	61/64	0.953125	24.2089
15/32	0.46875	11.9060	31/32	0.96875	24.6057
31/64	0.484375	12.3029	63/64	0.984375	25.0026
1/2	0.5	12.6997	1	1.0	25.3995

CP-18

Figure 3–6. Fractions to millimeters.

4. Using figures 3-4, 3-5, and 3-8, convert the following to metric.

   a. 4 feet 4½ inches.

   b. 3 pounds.

   c. 5½ gallons (NS).

5. Using figure 3-7, convert 127 cubic meters to:

   a. cubic feet.

   b. cubic yards.

cu.meters → cu.ft → cu.yd

cu.yd → cu.meters

cu.ft → cu.meters

cu.in	cu.cm	cu.meters	cu.meters	cu.ft	cu.yd
1	16.39	0.028	0.76	35.3	1.31
2	32.77	0.057	1.53	70.6	2.62
3	49.16	0.085	2.29	105.9	3.92
4	65.55	0.113	3.06	141.3	5.23
5	81.94	0.112	3.82	176.6	6.54
6	98.32	0.170	4.59	211.9	7.85
7	114.71	0.198	5.35	247.2	9.16
8	131.10	0.227	6.12	282.5	10.46
9	147.48	0.255	6.88	317.8	11.77
10	163.87	0.283	7.65	353.1	13.07
20	327.74	0.566	15.29	706.3	26.16
30	491.61	0.850	29.94	1059.4	39.24
40	655.48	1.133	30.58	1412.6	52.32
50	819.35	1.416	38.23	1765.7	65.40
60	983.22	1.700	45.87	2118.9	78.48
70	1174.09	1.982	53.52	2472.0	91.56
80	1310.96	2.265	61.16	2825.2	104.63
90	1474.84	2.548	68.81	3178.3	117.71
100	1638.71	2.832	76.46	3531.4	130.79

Example: 3 cu.yd = 2.29 cu. m

Volume: The cubic meter is the only common dimension used for measuring the volume of solids in the metric system

CP-18

Figure 3–7. Cubic conversion chart.

gal	lit	gal	lit	gal	lit
.1	.38	1	3.79	10	37.85
.2	.76	2	7.57	20	57.71
.3	1.14	3	11.36	30	113.56
.4	1.51	4	15.14	40	151.42
.5	1.89	5	18.93	50	189.27
.6	2.27	5	22.71	60	227.12
.7	2.65	7	26.50	70	264.98
.8	3.03	8	30.28	80	302.83
.9	3.41	9	34.07	90	340.69
				100	378.54

1 US GAL = 3.785412 Liters CP-17

Figure 3–8. Gallon to liter.

3-4. Equations and Formulas.

Many jobs will be difficult or impossible to accomplish unless you know a few basic formulas relevant to linear measurement or geometric functions.

In this section, you are entering into another branch of mathematics that is important to metal fabrication specialists. An understanding of this phase and the successful use of formulas will help you save time while solving problems. These formulas are not difficult, because they deal primarily with fundamentals of arithmetic and simple algebra.

035. List the parts of formulas and specify the rules concerning equations.

Equations. An equation is a mathematical statement which expresses the equality of two or more quantities. For example, the statement $5 + 4 = 9$ is an equation. It expresses, in an abbreviated form, the fact that the sum of 5 + 4 is equal to 9. Furthermore, if three quantities such as, a, b, and c are given, the whole equals the sum of the parts, the equation $a + b + c = x$ can be formed that will identify x as the unknown side of the equation. Example: a represents a length of 1 inch; b, 2 inches; and c, 3 inches. Now, you can solve the equation by substituting the numerical values and adding $1 + 2 + 3$, which is 6. Thus, $a + b + c = 6$, because x is equal to the sum of the parts $(a + b + c)$.

An equation is always divided into two parts by the equal sign (=). The two parts of an equation are called members of the equation or the two sides of the equation. It is necessary for an equation to be balanced at all times. If two unequal weights are placed in the pans of a common scale, the scale will not balance. Similarly, if you say $2 + 2 = 2 + 3$, the equation does not balance. It should read $2 + 2 = 1 + 3$, or other equal values. In an equation, changes may be made provided the equality is maintained. This means that you may add or subtract the same quantity from both sides of an equation or multiply or divide both sides of an equation by the same quantity without changing the value of the equation.

Formulas. A formula is a special type of equation that expresses a certain fact, law, or relation by means of symbols or letters. There are several reasons why a formula is used in solving many shop problems. First of all, a formula is more compact, making it easier for the eye to distinguish the whole meaning of the law or rule at a glance. Secondly, it is easier for an individual to memorize a few symbols rather than a paragraph of explanations. For example, the law for determining the area of a rectangle is usually stated as follows: The area of a rectangle is equal to the length of one side, multiplied by the length of the other side. This law, however, can be stated in simpler forms by the formula $A = bh$, where b represents the base and h represents the height or altitude. In this formula, you easily see how to attain the area of a rectangle. Notice that this formula eliminates using long terms that are difficult to interpret. In short, a formula is a simplified expression of the same law or rule.

Abbreviations Used in Formulas. Since formulas are equations that involve a sort of mathematical shorthand, you must understand the meaning of the various symbols used. From your experiences in school arithmetic, you should recall the meaning of the plus sign (+), minus sign (-), multiplication sign (X), division sign (÷), and equal sign (=). You should also recall that the exponent (^{2}) means to square a number. For example, 2^2 means 2 X 2, and 2^3 means 2 X 2 X 2, or 2 cubed. Now in formulas such as $A = bh$, we mean that the area equals the base times height. In the formula A =

$$\frac{bh}{2},$$

we mean that area (A) is equal to the base (b) times the height (h) divided by 2. An abbreviation often used when figuring the dimensions of circles is the Greek letter (π), pronounced pi, which is used in mathematics to represent the numerical value 3.1416. The number 3.1416 is the ratio of the distance around the circumference to the diameter of a circle. In the formula

$$a = P r^2,$$

we mean that the area of a circle is equal to 3.1416 times the radius squared.

Transposition in Formulas. The common method of working a formula is to place the known values on one side of the equal sign and the unknown values on the opposite side. For example, in the formula $A = bh$, the area of any rectangle (A) may be found if the base (b) is multiplied by the height (h). However, if the area and base are known, we could solve for the height by transposing the formula to read: $h = \frac{A}{b}$

Here, you have the same law but with a different arrangement for the purpose of finding the height when the area and base are known. To determine the values represented by different letters of the formula, it is necessary to know how a formula can be changed or transposed. Changing a formula in this way is known as transposition. The four general rules that apply to transposition are as follows:

metric ton → short ton		short ton → metric ton	kg → pounds	pounds → kilograms	grams → ounces	ounces → grams
1	1.10	0.91	2.20	0.45	0.04	28.1
2	2.20	1.81	4.41	0.91	0.07	56.7
3	3.31	2.72	6.61	1.36	0.11	85.0
4	4.41	3.63	8.82	1.81	0.14	113.4
5	5.51	4.54	11.02	2.67	0.18	141.8
6	6.61	5.44	13.23	2.72	0.21	170.1
7	7.72	6.35	15.43	3.18	0.25	198.4
8	8.82	7.26	17.64	3.63	0.28	226.8
9	9.92	8.16	19.81	4.08	0.32	255.2
10	11.02	9.07	22.05	4.54	0.35	283.5
16	17.63	14.51	35.27	7.25	0.56	453.6
20	22.05	18.14	44.09	9.07	0.71	567.0
30	33.07	27.22	66.14	13.61	1.06	850.5
40	44.09	36.29	88.14	18.14	1.41	1134.0
50	55.12	45.36	110.23	22.68	1.76	1417.5
60	66.14	54.43	132.28	27.22	2.12	1701.0
70	77.16	63.50	154.32	31.75	2.17	1981.5
80	88.18	72.57	176.37	36.29	2.82	2268.0
90	99.21	81.65	198.42	40.82	3.17	2551.5
100	110.20	90.72	220.46	45.36	3.53	2835.0

Example: Convert 28 pounds to kg
28 pounds = 20 pounds + 8 pounds
From the tables: 20 pounds = 9.07 kg and 8 pounds = 3.63 kg
Therefore: 28 pounds = 9.07 kg + 3.63 kg = 12.70 kg

a. 1 pound = 0.4535924 kg
b. The short ton (US) is 2000 pounds
c. The metric ton is 1000 kg

CP-16

Figure 3–9. Weight conversion chart.

81

A single term preceded by a plus sign can be transferred to the other side of the equal sign if the plus sign is changed to a minus sign. For example, the equation $x + 2 = 8$ can be changed to read $x = 8 - 2 = 6$.

Rule: You may subtract the same quantity from both sides of an equation without changing the value of the equation.

A single term preceded by a minus sign can be transferred to the other side of the equal sign if the minus sign is changed to a plus sign. For example, suppose in the equation $x - 2 = 6$, you want to find the value of x. To do this, transpose or change the -2 to the other side of the equation and change its $-$ sign to $+$. Therefore, $x - 2 = +6$ can be changed to $x = 6 + 2 = 8$. Here, all you have done is to add 2 to both sides of the equation which does not change the value of the equation.

Rule: You may add the same quantity to both sides of an equation without changing the value of the equation.

Any member of an equation that multiplies all the other members on one side of the equal sign can be transposed to the other side of the equal side if it is made to divide all the members on that side. For example, again consider the formula: $A = bh$, and suppose we are to solve for h. According to this rule, we can divide both sides by b, then cancel out the side with b in both numerator and denominator like this:

$$A = bh$$

$$\frac{A}{b} = \frac{bh}{b}$$

$$\frac{A}{b} = h$$

Rule: Both sides of an equation may be divided by the same quantity without changing the value of the equation.

Any member that divides all the other members on one side of the equal sign can be transposed or changed to the other side of the equal sign if it is made to multiply all the members on both sides of the equal sign. As an example of this rule, consider the formula for finding the area of a triangle: $A =$

$$\frac{bh}{2}.$$

If you need to transpose the formula in order to solve for h, proceed as follows. To transpose the denominator 2, multiply both sides of the equation by the whole number 2 like this:

$$A = \frac{bh}{2}$$

So

$$A \times 2 = \frac{bh}{2} \times 2$$

So

$$2A = \frac{2bh}{2}$$

Now cancel

$$2A = \frac{2hb}{2}$$

or

$$2A = bh$$

Now transpose the b to the other side of the equation, divide both sides by b, and cancel bs like this:

$$\frac{2A}{b} = \frac{bh}{b}$$

or

$$\frac{2A}{b} = h$$

Rule: Both sides of an equation can be multiplied by the same quantity without changing the value of the equation.

Exercises (035):

1. What is a mathematical statement which expresses the equality of two or more quantities?

2. Write the Greek letter that indicates the ratio of the circumference of a circle to its diameter, and give its numerical value.

3. Performing any of the four arithmetic functions (add, subtract, multiply, or divide) to both sides of an equation is an example of what general rule?

4. If you add 4 to one side of an equation, what must you do to the other side?

5. What sign divides an equation into two parts?

036. Define mensuration, state the formula for finding the area of a triangle, and name different kinds of triangles.

Mensuration. The branch of mathematics that deals with lines, angles, surfaces, and solids is known as geometry. The particular branch of geometry that deals with measurement of lines, angles, surfaces, and solids is known as mensuration. In laying out sheet metalwork, you will frequently make use of lines and angles in constructing various patterns for plane and solid figures. A plane figure is any part of a plane surface bounded by any number of straight or curved lines, or a combination of the two such as squares, rectangles, triangles, and circles. Plane figures have two dimensions—length and width. Solids such as

cubes, prisms, cylinders, pyramids, spheres, and cones are bodies that have three dimensions— length, width and thickness.

Lines. A straight line is the shortest line that can be drawn between two points. When the term "line" is used, it is understood to mean a straight line. A curved line is a line no part of which is straight. A broken line is made up of a series of straight lines or dashes. Parallel lines are lines in the same plane that will never meet, regardless of how far they are extended. All lines are measured in linear units and have only one dimension— length.

Angles. An angle is the amount of opening between two intersecting lines. The point of intersection of the two sides (lines), such as point B' (pronounced B prime) in figure 3-10, is known as the vertex. Angles are measured in degrees (°), which can be further subdivided into minutes and seconds. Point B' in figure 3-10 is the vertex of two 90° (right) angles. The sum of these two 90° angles in the straight line AC, equal to 180°.

A line is perpendicular to another line if it forms an angle 90° with the other line. In figure 3-10, BB' is perpendicular to line AC.

Plane figures. A plane figure is any part of a plane surface bounded by any number of straight or curved lines or combination of the two. When a plane figure is bounded by straight lines only, it is called a polygon. **Polygons** include figures with three, four, or more sides; however, it is customary to divide them into three classes. Those with three sides are triangles, those with four sides are quadrilaterals, and those with more than four sides are polygons. Plane figures bounded by a curved line include circles and ellipses.

Triangles. A triangle is a three-sided plane figure, such as that shown in figure 3-11. The sides of a triangle are the lines which bound or inclose it, and the sum of the included angles is always 180°. The base of a triangle is the side upon which it is supposed to stand; therefore, any side may be the base. The angle opposite the base is called the vertex angle, which is the point opposite to and farthest from the base. The altitude or height of a triangle is the perpendicular distance from the vertex to the base. In figure 3-11, A is the vertex angle, line DC is the base, lines AD and AC are the sides, and line AB is the altitude. The triangle illustrated in figure 3-11 is an isosceles triangle, in which two sides are equal, as shown by DAC. Side DA is equal to side AC. The unequal side (DC) of an isoceles triangle is usually called the base.

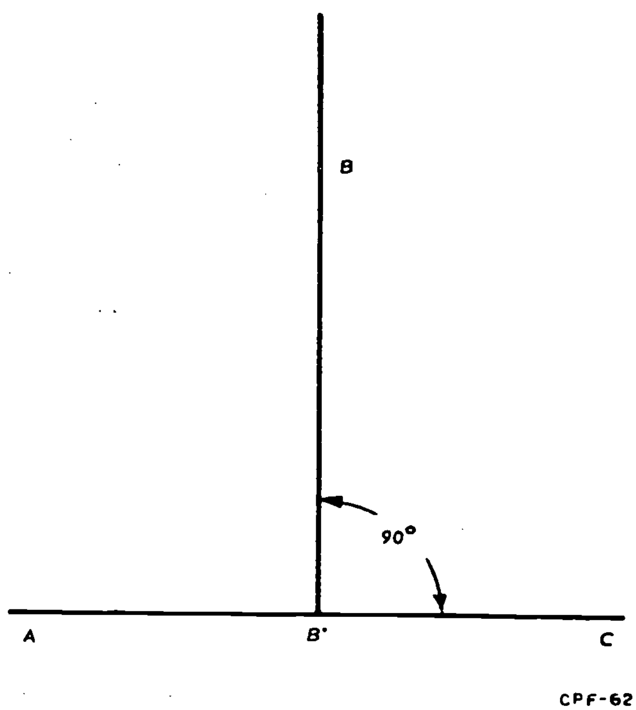

Figure 3–10. Perpendicular lines.

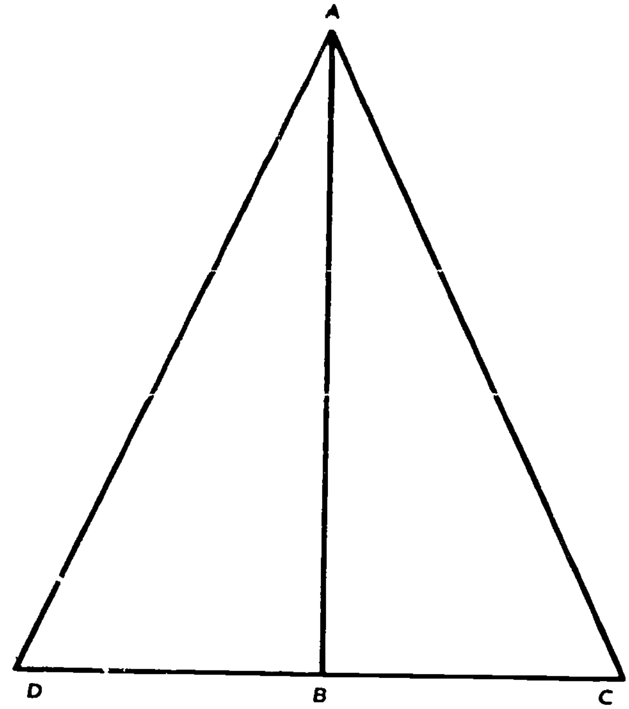

Figure 3–11. Isosceles triangle.

A right triangle, as shown in figure 3-12, is a triangle in which one of the angles is 90°. The side opposite 90° angle is known as the hypotenuse, and the other two sides are called legs.

An acute triangle, as shown in figure 3-12, is one in which each angle of the triangle is less than 90°. An obtuse triangle, as shown in figure 3-12, is a triangle in which one of the angles is more than 90°.

To find the area of any triangle, multiply the base times the height and divide by 2.

Example: Find the area of a triangle which has a base of 24 inches and an altitude or height of 12 inches.

$$A = \frac{bh}{2}$$

$$A = \frac{24 \times 12}{2}$$

$$A = \frac{288}{2}$$

A = 144 square inches

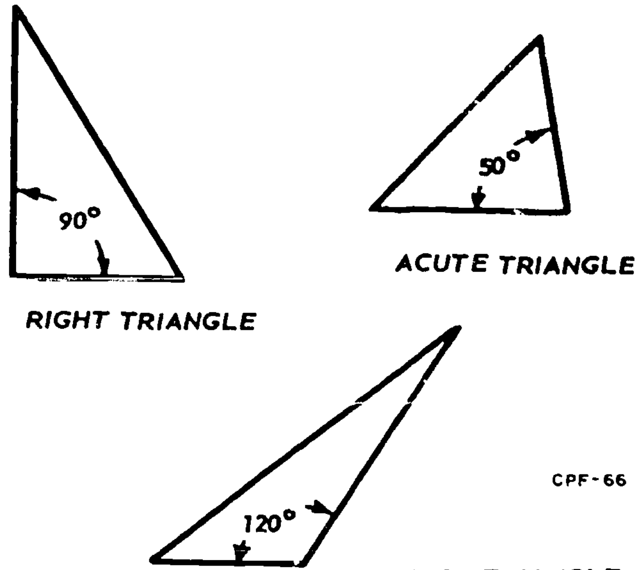

Figure 3–12. Triangles.

Exercises (036):

1. What is mensuration?

2. The formula

$$\frac{bh}{2} = A$$

is for what type of geometric figure?

3. Name three kinds of triangles.

037. Identify quadrilaterals and polygons and determine the areas of each.

Quadrilaterals. We have already said that a quadrilateral is a plane figure with four sides. Now, we introduce you to several types of quadrilaterals called parallelograms that have parallel and equal oppos te sides. In figure 3-13, notice that the square, rectangle, rhomboid, and rhombus have parallel and equal opposite sides. The altitude or height of a parallelogram is the perpendicular distance between two parallel sides. Notice that in the rhomboid and the rhombus, the altitude or height is indicated with a broken line. The trapezoid and the trapezium are also quadrilaterals but are not parallelograms.

The square, illustrated in figure 3-13, is a parallelogram with parallel sides that are equal and at right angles to each other. The broken diagonal line divides the square into two equal right triangles. The altitude or height of a square is the same as the sides. To determine the area of a square, multiply the length of one side by itself.

Example: If one side of a square is 15 inches, what is the area of the square?

$A = s^2$
$A = 15 \times 15$
$A = 225$ square inches

The rectangle, illustrated in figure 3-13, is also a parallelogram with parallel opposite sides, equal opposite angles, and equal opposite sides. The broken diagonal line divides the rectangle into two equal right triangles. To find the area of a rectangle, multiply the base by the height.

Example: What is the area of a rectangle that is 8 inches wide and 6 inches high?

$A = bh$
$A = 8 \times 6$
$A = 48$ square inches

The rhomboid, illustrated in figure 3-13, is a parallelogram in which the opposite sides are parallel and equal and opposite angles are equal; however, there are no right angles in the rhomboid. The height or altitude is the perpendicular distance between two parallel sides as indicated by the broken lines. Notice in the illustration how a rhomboid can be divided into a rectangle and two right triangles. To find the area of a rhomboid, multiply the base by the height ($A = bh$).

The rhombus, illustrated in figure 3-13, is a parallelogram with parallel opposite sides that are equal in length and opposite angles that are equal. In the illustration, the altitude or height is represented by the broken line. To find the area of a rhombus, multiply the base by the height ($A = bh$).RH

The trapezoid, shown in figure 3-13, is a quadrilateral with only two of the sides parallel; therefore, it is not a parallelogram. In the illustration, the altitude or height is represented by the broken lines. To find the area of a trapezoid, take one-half the sum of the length of the parallel sides and multiply by the height.

Example: What is the area of a trapezoid that has a height of 12 inches and parallel sides that are 23 inches and 30 inches long?

$$A = \frac{(b + b') \times h}{2}$$
$$A = \frac{(23 + 30) \times 12}{2}$$
$$A = \frac{53 \times 12}{2}$$
$$A = \frac{636}{2}$$

$A = 318$ square inches

The trapezium, illustrated in figure 3-13, is a quadrilateral without any parallel sides. Notice how the broken lines have divided the trapezium into four triangles. To find the area of a trapezium or any other irregular

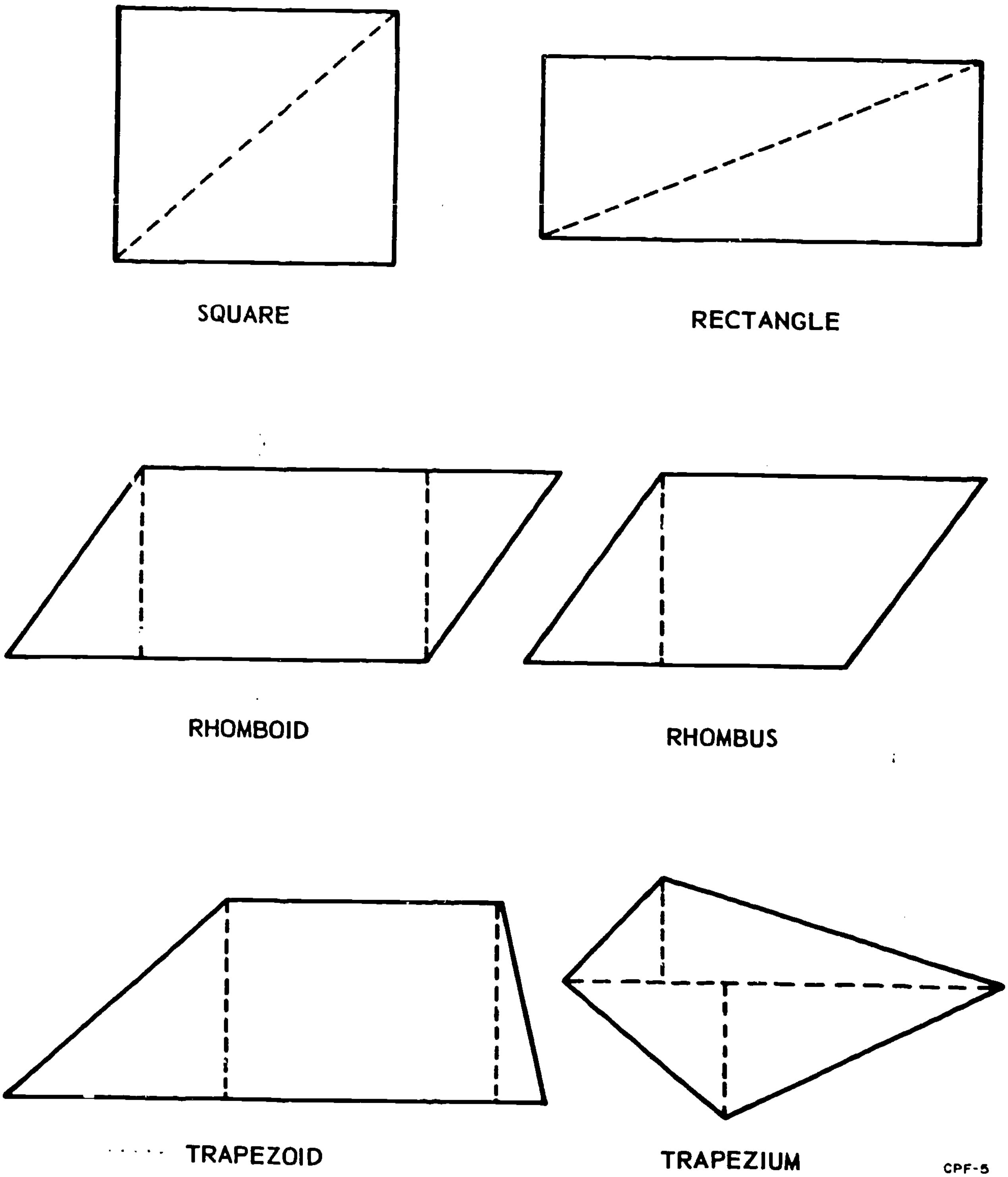

Figure 3–13. Quadrilaterals.

polygon, divide it by diagonals into simpler forms, such as triangles. The areas of these parts may then be calculated by the rules given, and the sum of the various areas will be the total area of the figure.

Polygons. Although triangles and rectangles are polygons, they are not commonly called polygons, since we usually consider polygons to be figures with more than four sides. Some of the most common polygons are illustrated in figure 3-14 and include the pentagon (five sides), the hexagon (six sides), the heptagon (seven sides), and the octagon (eight sides).

Polygons such as those shown in figure 3-14 have sides of equal length and are called regular polygons. If perpendicular lines are drawn to all sides of a regular polygon at the middle points, these perpendiculars will meet at a common point in the center of the polygon. In sheet metalwork it is sometimes necessary to make a pattern for a regular polygon. This is a simple process if you draw a circle the same size as the polygon, then draw the polygon inside the circle, as shown in figure 3-15.

The usual way to construct a regular polygon inside a circle is to divide the circumference of the circle into the same number of equal parts as the sides of the polygon. For example, in figure 3-15, a hexagon has been inscribed inside a circle. Any circle can be divided into the desired number of equal parts by stepping a compass around the circumference of a circle and adjusting the compass until a distance is found that produces the correct number of sides for the desired polygon. (Use of the compass is discussed in Volume 3.) In figure 3-15, the lines forming the sides of the hexagon, such as line CD, are called chords of the circle. Therefore, this method for constructing a regular polygon can be used to divide a circle into equal parts and chords.

To save time in finding the exact length of the chords that divide a circle, the following constants are furnished. The distance between the points on the circumference of a circle can be found by multiplying the diameter of the circle by the constant (k) corresponding to the number of sides of the desired polygon. To divide a circle into equal chords, multiply the diameter by the appropriate constant (k) to find the length of one chord:

k for a pentagon = 0.58779
k for a hexagon = 0.500000
k for a heptagon = 0.43388
k for an octagon = 0.38268

Examples: Construct a hexagon, similar to the one shown in figure 3-15, with a diagonal of 3 inches. First, construct a circle with a 3-inch diameter; then use the constant for a six-sided polygon and find the chord length 3 X 0.50000 = 1.50000 inches, which is the length of each of the six chords. Now, adjust the compass to a spread of 1½ inches, step the compass around the circle, and mark off six equidistant points. Use a straight edge and draw chord lines between the six points. The resulting figure will be like the one shown in figure 3-15.

A simple way to find the area of a regular polygon is to square the length of a side and multiply a constant (k) corresponding to the number of sides. The constants for a common polygon are as follows: k = 1.7205 for a

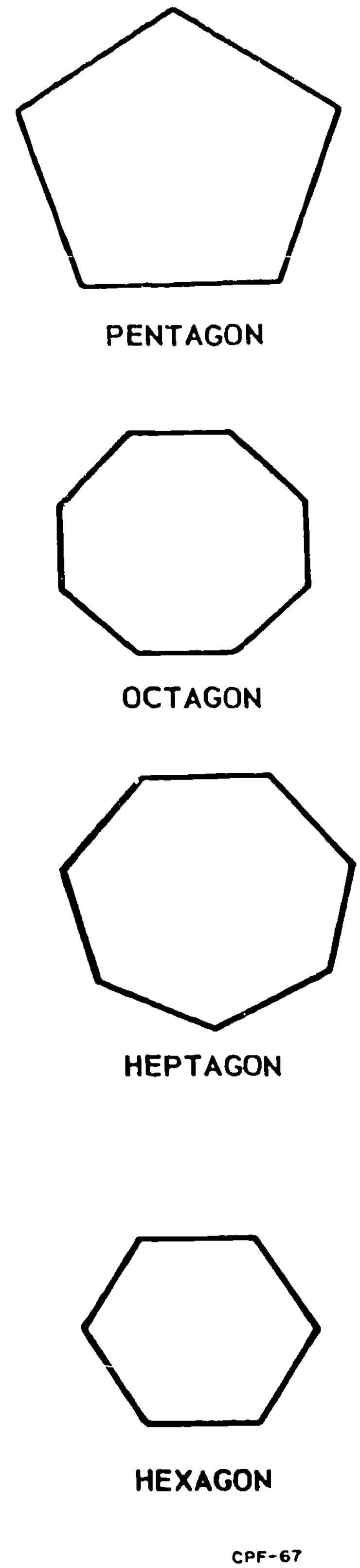

Figure 3–14. Regular polygons.

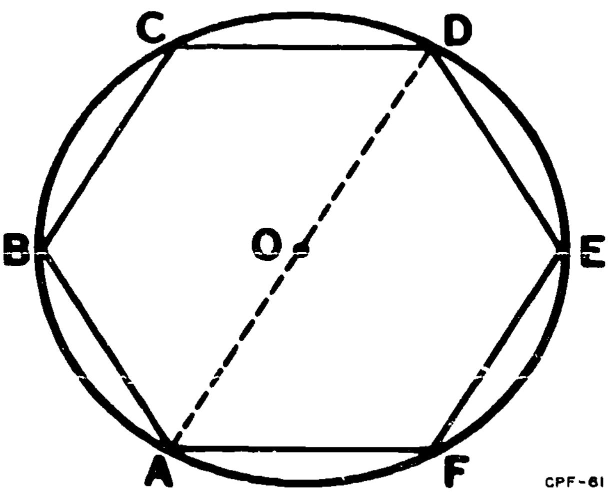

Figure 3-15. Hexagon inscribed in a circle.

pentagon; $k = 2.5981$ for a hexagon; $k = 3.6339$ for a heptagon; and $k = 4.8284$ for an octagon.

Example: What is the area of an octagon with 4-inch sides?

$$A = s^2k$$
$$A = s^2 \times 4.8284$$
$$A = 16 \times 4.8284$$
$$A = 77.2544 \text{ square inches}$$

To find the area of an irregular polygon (polygon whose sides are not all equal), it can generally be divided by means of diagonals into simpler forms, such as triangles and squares. The areas of these parts can then be calculated, and the sum of the various areas will be the total area of the irregular polygon.

Exercises (037):

1. A figure having four sides is a ____________.

2. Match the figures in Column A to the descriptions in Column B.

Column A *Shapes*	*Column B* *Description*
______ (1) Rhomboid.	a. Equal, parallel sides intersecting at 90°.
______ (2) Rectangle.	b. Equal, parallel sides and equal opposite angles not 90°.
______ (3) Square.	c. Parallel, equal opposite sides with equal opposite angles not 90°.
______ (4) Rhombus.	d. Parallel, equal opposite sides intersecting at 90°.

3. Find the area (to the fourth decimal place) of the following polygon?

   a. 6-inch (diagonal) heptagon.

   b. 21-inch (diagonal) pentagon.

038. List the parts of a circle and specify formulas used to find the area of circles.

Circles. A circle is a plane figure bounded by a curved line called the circumference. All points on the circumference are equidistant from the center. Figure 3-16 illustrates the lines and parts of circles.

The circumference of a circle is the length of the curved line that forms the circle; it may be referred to as the perimeter of a circle. Generally speaking, the letter C is used to designate circumference in a formula. The circumference of any circle is divided into 360 equal units of measurement called degrees (360°); however, in sheet metalwork, we most often use linear measurements, such as inches and feet and soon, the meter. When figuring the circumference of a circle, you will use the predetermined number 3.1416, called pi (), which is the ratio of the distance around the perimeter of the circle to the diameter of the circle. The circumference of a circle can be found by multiplying the diameter by pi.

Example: What is the circumference of a circle that has a diameter of 5 inches?

$$C = d$$
$$C = 3.1416 \times 5$$
$$C = 15.7080 \text{ inches}$$

The diameter of a circle is a line drawn through the center and ended by the circumference. The letter d, shown in figure 3-16, is used to identify the diameter. The diameter of a circle can be found by dividing pi (3.1416) into the circumference.

Example: What is the diameter of a circle that has a circumference of 18.8496 inches? $C = \pi d$, then:

$$d = \frac{C}{\pi}$$
$$d = \frac{18.8496}{3.1416}$$
$$d = 6 \text{ inches}$$

The radius of a circle is one-half the diameter (d) or the distance from the center to a point on the circumference. The letter r, shown in figure 3-16, is used to identify the radius, then:

$$r^2 = \frac{d^2}{4}$$

The area of a circle can be determined by two formulas. If r is known, square the radius and multiply by ($A = \pi r^2$). If d is known, then use

$$A = \frac{\pi d^2}{4} = \frac{3.1416d^2}{4} = 0.7854d^2$$

or square the diameter and multiply by the number 0.7854, since

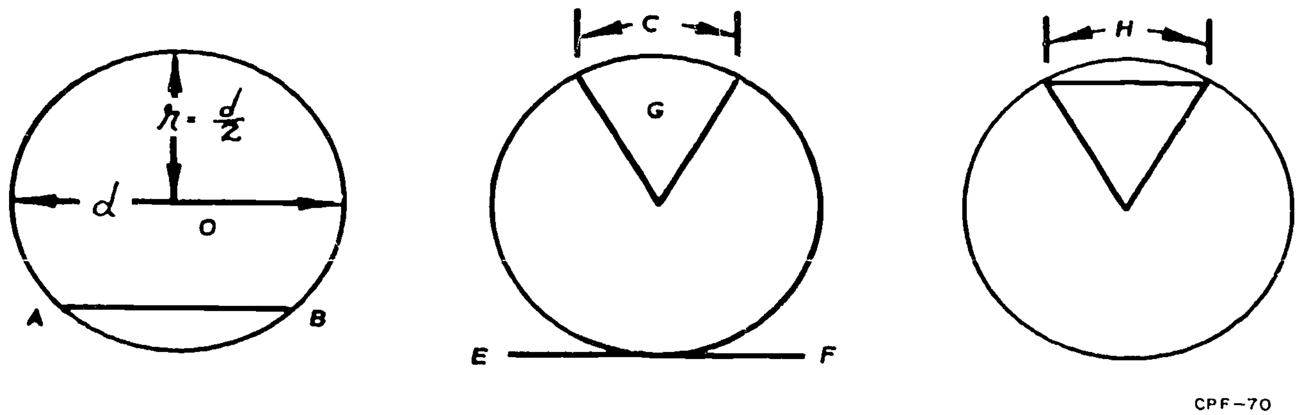

Figure 3-16. Parts of a circle.

$\frac{\pi}{4} = 0.7854,$

a constant (k).
Either way is correct.

Examples: What is the area of a circle that has a radius of 2 inches? What is the area of a circle having a diameter of 4 inches?

$$A = \pi r^2$$
$$A = 3.14416 \times 2 \times 2$$
$$A = 12.5664 \text{ square inches}$$
$$A = \frac{d^2}{4} = d^2k$$
$$A = d^2 \times 0.7854$$
$$A = 16 \times 0.7854$$
$$A = 12.5664 \text{ square inches}$$

An arc is any part of the circumference of a circle, such as C and H in figure 3-16. Letters or numbers may be used to identify various arcs. A major arc is larger than a semicircle, and a minor arc is less than a semicircle.

A chord is a straight line joining any two points on a circle of an arc, as shown by AB in figure 3-16. Whenever one chord is drawn within a given circle, it forms two arcs—a major arc and a minor arc.

A tangent is a straight line drawn in such a manner that it touches only a single point of the circumference of a circle. Line EF in figure 3-16 is tangent to the circle.

A sector of a circle is the part bounded by two radii and an arc. In figure 3-16, the letter G is used to identify the sector of a circle bounded by the arc C.

A segment of a circle is that part which is bounded by an arc and a chord, connecting the ends of the arc. In figure 3-16, the letter H identifies a segment.

Exercises (038):

1. State two formulas used to find the area of a circle.

2. What are the parts of a circle?

039. Compute the surface area and volume of solids in given problems.

Solids. A solid is any surface or a series of surfaces that incloses a section of space such as a cube, sphere, or cylinder. All solids have length, thickness, and width; and the space within the solid is called volume. Because of the three dimensions of solids, volume is identified as cubic inches, cubic feet, etc. (This differs from the plane figures, studied in the previous paragraphs, which had only two dimensions, and the space they contained was identified as area in square inches, square feet, etc.).

Prisms. A prism such as that shown in figure 3-17 is a solid whose ends are equal parallel polygons and whose sides (faces) are parallelograms. Remember that polygons, as well as parallelograms, can have several shapes. Therefore, you will find that prisms can be of various shapes and still comply with the definition. For example, figure 3-17 illustrates a rectangular prism. Others include triangular prisms whose ends are triangles, hexagonal prisms whose ends are hexagons, etc.

The rectangular prism shown in figure 3-17 has ends (bases) that are square; however, rectangular prisms may also have ends of other rectangular shapes if all angles are right angles and the opposite surfaces are parallel. To determine the volume of a rectangular prism, simply multiply the length times the width times the thickness ($V = lwt$). For example, if a rectangular prism has the dimensions of $l = 10$ inches, $w = 5$ inches, and $t = 5$ inches, the volume will be $10 \times 5 \times 5 = 250$ cubic inches.

The cube shown in figure 3-18 is a rectangular prism whose ends and faces are square. Stated in another way, a cube is a solid object with all sides equal. The volume of a cube can be determined by the same formula that you have learned for rectangular prisms; however, since all sides of a cube are the same, the formula $V = lwt$ can be shortened to simply $V = s^3$. For example, if the length of one side of a

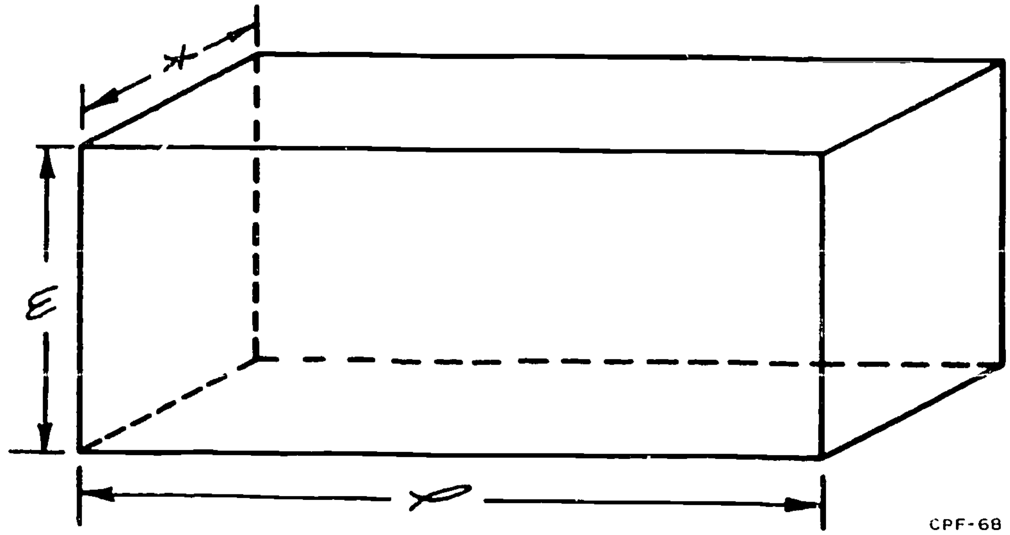

Figure 3–17. Rectangular prism.

cube is 4 inches, then the volume can be computed as $4 \times 4 \times 4 = 64$ inches.

Cylinder. A cylinder is a solid figure bounded by a lateral curved surface with flat ends or bases equal in size. The end on which the cylinder is shown to rest in figure 3-19 is called the base, and the distance between the two ends is called the altitude or height.

The volume of a cylinder can be determined by multiplying the area of the base times the height ($V = A_b h$). Notice that you must know the area (A_b) before solving for the volume. In previous paragraphs of this chapter, you learned how to figure the area of a circle. Since the ends of a cylinder are circles, the same formula(s) applies; therefore, we can change the formula

$$V = A_b h \text{ to } V = r^2 h = 0.7854d^2h.$$

Example: Assume that a cylinder has a diameter of 2 inches and a height of 10 inches. What is the volume?

$$V = kd^2h$$
$$V = 0.7854d^2h$$
$$V = 0.7854 \times 2^2 \times 10$$
$$V = 0.7854 \times 4 \times 10$$
$$V = 31.416 \text{ cubic inches}$$

$V = 0.7854 \times 4 \times 10$ The curved area of a cylinder (area of the outside surface not including the base) can be determined by multiplying the circumference of the base by the height of the cylinder.

Example: Assume that the cylinder illustrated in figure 3-19 has a diameter of 1 inch and a height of 10 inches. What is the curved area?

$$A = Ch$$
$$A = d \times h \ (C = \pi d)$$
$$A = 3.1416 \times 2 \times 10$$
$$A = 62.832 \text{ square inches}$$

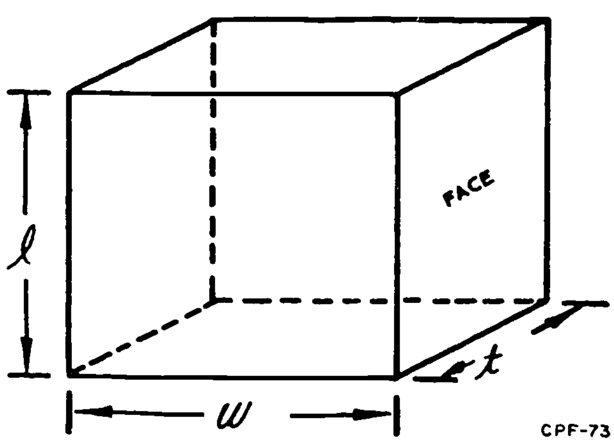

Figure 3–18. Cube.

Pyramid. A pyramid is a solid figure whose base may be a plane triangle, rectangle, or other polygon. Its sides form several triangles with a common vertex. The pyramid shown in figure 3-20 is a right pyramid, because a perpendicular line from the vertex to the base passes through the center of the base.

The volume of a right pyramid, as shown in figure 3-20, can be determined by multiplying the area of the base (A_b) by one-third of its height.

Example: What is the volume of a pyramid that is 18 inches high and has a base 12 inches square?

$$V = 1/3h \times A_b$$
$$V = 1/3 \times 18 \times 12^2$$
$$V = 1/3 \times 18 \times 144$$
$$V = 864 \text{ cubic inches}$$

The surface area of a pyramid (area of the outside surface not including the base) can be determined by multiplying the perimeter (P) of the base by one-half of the slant height. The slant height of a pyramid is the same as the altitude of any one of the triangular faces of the pyramid.

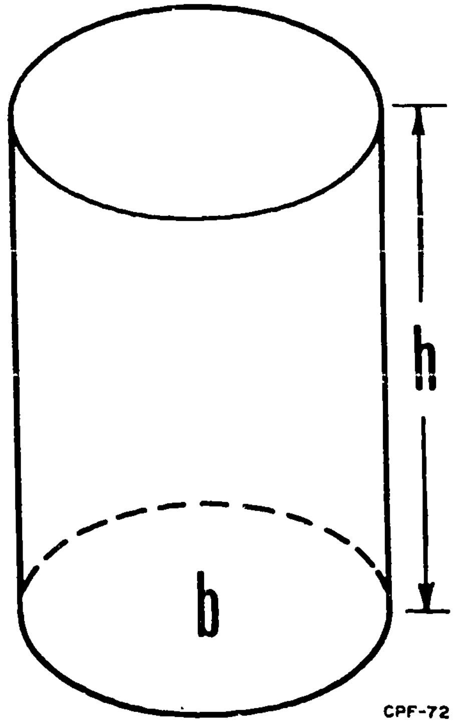

Figure 3–19. Cylinder.

Example: What is the surface area of a pyramid that has a slant height of 20 inches and has a base of 12 inches square?

$A = 1/2h_s \times P$
$A = 1/2 \times 20 \times 48$
A = 480 square inches

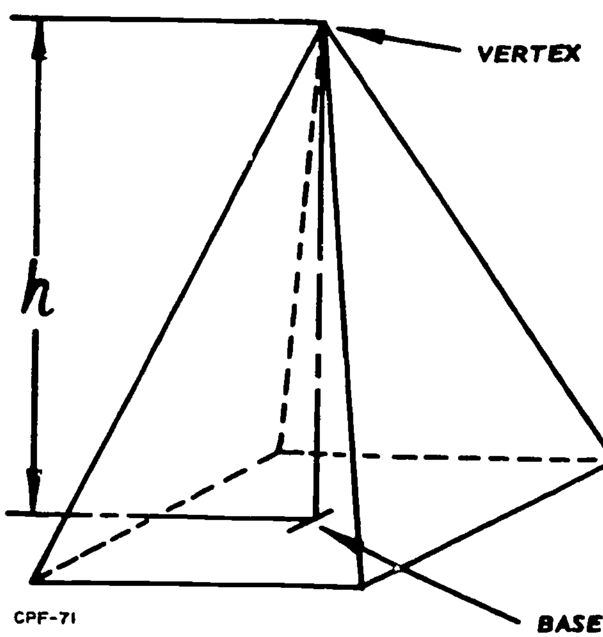

Figure 3–20. Pyramid.

Cone. A cone is a solid figure attained when a right triangle is rotated about one of its legs. The leg is commonly referred to as the axis. The base of the cone is the circle formed when the horizontal leg is rotated completely around the axis, as shown in figure 3-21.

The volume of a cone can be found by multiplying the area of the base (Ab) by one-third of the height.

Example: What is the volume of a cone that is 9 inches high and has a diameter of 6 inches?

$V = 1/3h \times A_b$
$V = 1/3hkd^2$
$V = 1/3 \times 9 \times 0\ 7854 \times d^2 (A_b = 0.7854 \times d^2)$
$V = 1/3 \times 9 \times 0\ 7854 \times 36$
V = 84.8 cubic inches

The curved area of a cone (area of the outside surface not including the base) can be determined by multiplying the circumference of the base by one-half the slant height.

Example: What is the curved area of a cone that has a circumference of 16 inches and a slant height of 10 inches?

$A = 1/2h_s = C$
$A = 1/2 \times 10 \times 16$
A = 80 square inches

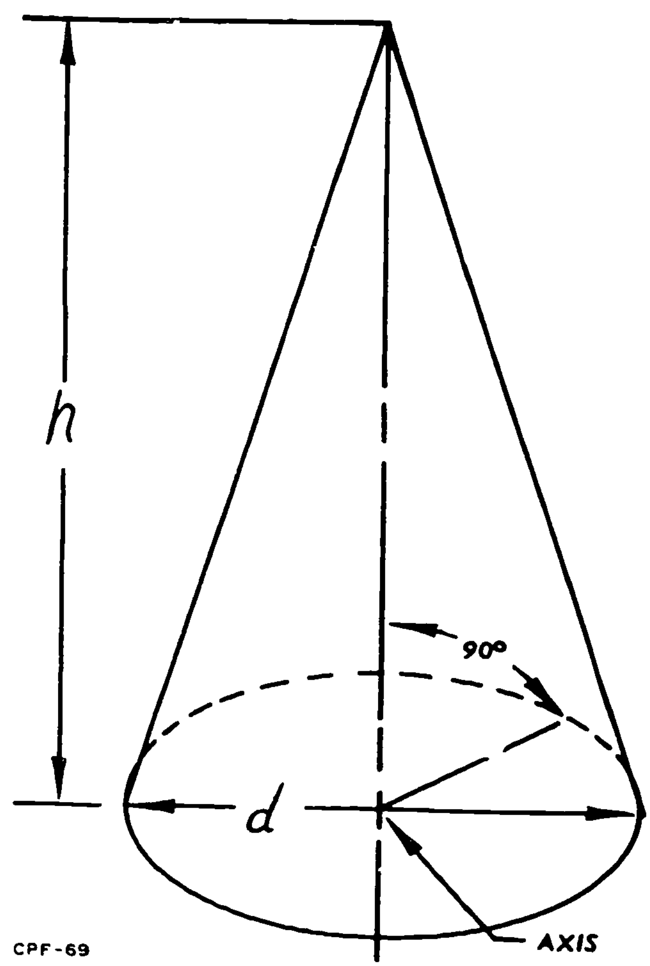

Figure 3–21. Cone.

Sphere. A sphere is a ball-shaped solid figure bounded by a uniformly curved surface, every point of which is equidistant from the center.

The volume of a sphere is the cube of the diameter multiplied by the constant k or 0.5236.

$$V_s = \frac{4\pi r^3}{3} = \frac{4}{3}\frac{d^3}{8} = 0.5236d^3$$

Example: What is the volume of a sphere that has a diameter of 2 inches?

$V = d^3k$
$V = d^3 \times 0.5236$
$V = 2^3 \times 0.5236$
$V = 2 \times 2 \times 2 \times 0.5236$
$V = 4.1888$ cubic inches

The surface area of a sphere is the square of the diameter multiplied by pi.

$$A_s = \pi d^2$$

Example: What is the surface area of a sphere with a diameter of 2 feet?

$A = d^2$
$A = 3.1416 \times 2^2$
$A = 3.1416 \times 4$
$A_s = 12.5664$ square feet

Exercises (039):

1. How many cubic yards of concrete will it take to fill a pyramid with a base of 72 inches by 72 inches and a height of 9 feet?

2. Determine the outside area of an 8-inch diameter cone with a slant height of 18 inches.

3. What is the volume of a rectangular prism 12 inches high, 16 inches wide, and 35 inches long?

4. What is the volume of a 5-inch diameter cylinder that is 27 inches long?

Characteristics of Metals

THE MORE you know about metals, the better you will be able to do your job. It is not enough to be able to layout, cut, form, weld, and harden metal, you must also know why these operations are performed, and what effect they have on metal. With this in mind, we discuss types, uses, properties and compositions of metals as well as chemical corrosion methods and health hazards.

Very few metals found in nature are in usable form. A metal is usually found in combination with other elements. Before it can be used, it must be refined either to reduce or remove undesirable elements and impurities or to add alloying elements that will develop desirable properties in the metal. The metal comes out of the refining process in a molten state; it must then be formed into a usable shape.

As you passed through the food serving line in the dining hall, did you ever wonder why the metal of the serving line was shiny or why the surface remained shiny? Or maybe you have noticed several buildings with gutters made of different metals and wondered why they are different. You may have asked yourself how the metal was formed into shapes of gutters without breaking. And what about the internal stress when metals are welded. Can all metals be welded?

The information in this chapter will help to answer these and other related questions.

4-1. Metals

Selecting the metal is another step forward in preparing you to fabricate metal components. To select the metals, you will have to know something about them. Therefore, we discuss properties of metals, such as hardness, toughness, and elasticity, as well as changing properties. To select metals, you will have to know the size, the finish, the composition, and the forming qualities, which we will discuss.

Since you are assigned to metalworking, you need to know metals—their properties, composition, and forming qualities. Also, you need to know the differences in metals so that you can select the correct one for the job requirement. You need to know metals that are corrosion-resistant, since selecting the wrong material could result in your having to do the job over. You need to know the forming qualities of metals, since most jobs require that the metal be formed.

040. Specify common manufacturing process used for producing steel, cast iron, and nonferrous metals.

Steel Refining Process. Several different types of furnaces are used in steel refining processes.

Blast furnace. The first step in changing iron ore to steel takes place in the blast furnace. Here the iron is separated from most of the impurities in the iron ore. The molten iron that is tapped off is called pig iron. It may be poured into a ladel and taken to other furnaces for further refining, or it may be cast into bars. Pig iron contains many impurities and has a high-carbon content.

Open-hearth furnace. About 90 percent of all steel made in the United States is refined in the open-hearth furnace. Pig iron, scrap iron, and limestone are put into the furnace and heated. The limestone, as well as other materials that may be added, help to remove impurities. Alloying elements, such as chromium, nickel, and molybdenum, may be added. The molten steel is tapped off and poured into large rectangular molds where it solidifies into blocks called ingots.

Bessemer converter. The Bessemer converter is used to produce machinery steel and structural steel. Molten pig iron is poured into the furnace. The hot air that is forced through the molten metal burns off most of the carbon and other impurities. The molten steel is then poured into an ingot mold to harden.

Electric furnace. High-grade alloy steel, tool steels, and stainless steels are produced in the electric furnace. Selected alloy scrap and alloying elements are added to the molten steel in the furnace. Carbon electrodes, positioned just above the surface of the metal, create an arc that heats the metal. No oxygen is necessary in the electric furnace; in fact, a controlled atmosphere, which will not react with the metal, is used. Alloys are added to remove impurities and to produce the desired properties. The steel is then poured into ingot molds to harden.

Induction furnace. The induction furnace is a type of electric furnace used to produce steel of uniform quality. High-frequency alternating current passes through a coil around the metal. The collapsing action of the magnetic line of force heats the metal. In addition to melting the metal, the collapsing action thoroughly stirs the metal. The furnace is charged with high-grade solid steel and high-grade alloys. After proper melting and mixing, the molten metals are poured into molds. Some of the finest quality tool steel is produced in the induction furnace.

The steel ingots produced by the open hearth furnace, Bessemer converter, and electrical furnace are removed from the molds and placed in an underground furnace called a soaking pit, where they are soaked and heated uniformly all the way through at approximately 2200° F.

Manufacture of Cast Iron. Cast iron is made from pig iron in a specially designed furnace called a cupola. The furnace is forced through the charge to burn the charcoal and melt the pig iron. The burning charcoal and gases

remove some of the impurities from the pig iron. The molten iron is then tapped off and poured into molds to harden. Cast iron contains many impurities and has a high-carbon content.

Manufacture of Nonferrous Metals. Many nonferrous metals are refined by an electrolytic process in which an electric current separates the metal from the ore. The process varies in detail with different metals, but it is essentially as follows:

(1) The ore of the metal is dissolved in an electroyte.

(2) Electrodes are placed in the solution containing the electrolyte and the ore.

(3) The current is turned on. This causes the metal to move to one of the electrodes, called the cathode. As the metal collects, it is tapped off.

(4) After the metal is separated from its ore, it may be further refined, alloyed, and cast.

Nonferrous metals are often used in the cast condition (permanent mold, sand mold, or die cast). However, higher strength properties are often obtained by working the metal.

Exercises (040):

1. How many furnaces must steel be processed through before it can be used? Name them.

2. When molten pig iron is tapped from a cupola furnace, what does it become?

3. How is nonferrous metal separated from its ore?

4. After steel has been refined in an electric furnace and ignots are made, what is done?

041. Specify the various means of shaping metals.

Shaping. The next step after refining is to change the metal into a usable shape. All methods of shaping a metal may be classified as either casting or wrought.

Casting. A casting is a metal part that has been formed by pouring or forcing molten metal into a mold. The liquid metal solidifies into the shape of the mold. The mold is then removed. There are three types of casting: permanent mold, sand mold, and die.

A permanent mold is used to form parts of fairly simple design. The mold is usually made of metal or ceramic. After the molten metal has hardened, the mold is removed, cleaned, and resued. Molten metal hardens and cools fairly fast in a permanent mold. White cast iron is formed in a permanent mold.

A sand mold is made of sand that has been packed to hold its shape. The sand is either formed around a pattern or in sections. The sections are put together, and molten metal is poured into the openings. After the metal hardens, the sand is shaken off the part. Very complicated shapes may be made by sand casting. Motor blocks for cars are sand castings. Gray cast iron is made by sand casting. The sand holds the heat in and causes the metal to cool slowly—in contrast to a permanent mold, which causes the molten metal to cool faster.

Diecasting is usually used for low-melting-point metals. In a permanent mold and in a sand mold, pot metal, zinc, aluminum, and magnesium would cool and get hard before getting to all areas of the mold. The metal would flow into thin sections. In diecasting, the molten metal is forced into the mold under pressure. This completely fills the mold before the metal hardens.

Casting is the only way that some parts can be formed. It is a relatively cheap process. Castings are usually not as strong as wrought parts. In a casting, the grains are large and there may be inclusions of slag or impurities that weaken the part, as shown in figure 4-1. Working the metal to form the wrought parts causes the grains to become smaller and elongated, as shown in figure 4-2. Working gives a grain pattern to the steel sometimes like the grains of wood. These long grains help to strengthen the part. Any inclusions are broken up so that they will not be harmful. During welding, these long grains are melted and recast; this tends to reduce the strength if the metal is not properly heat-treated after welding.

Wrought products. A wrought product is any metal that has been shaped by force while it is in solid form. Most metals can be shaped by either hot or cold-forming. In hot-forming, the metal is worked above a temperature known as the critical temperature; in cold-forming, it is worked below this temperature. Each metal has its own critical temperature. Hot-forming softens metal and leaves it almost stress-free. Cold-forming increases the strength and hardness, but it sets up stresses in the metal. In many manufacturing processes, the metal is first hot-worked and then cold-worked into final shape. Cold-working metal too long will cause it to fracture. When severe cold-forming is required, it is done in stages; each stage is followed by annealing to relieve some of the internal stresses.

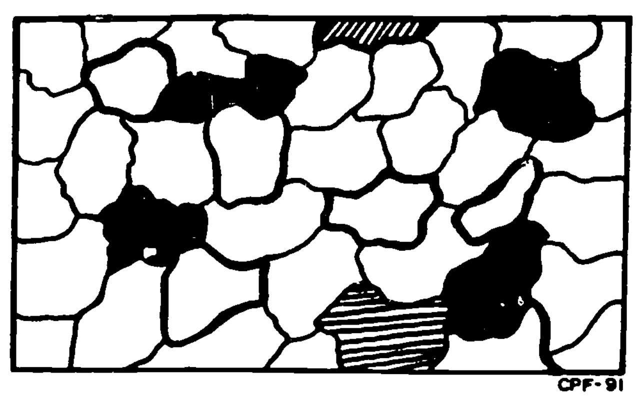

Figure 4–1. Grain structure in cast steel.

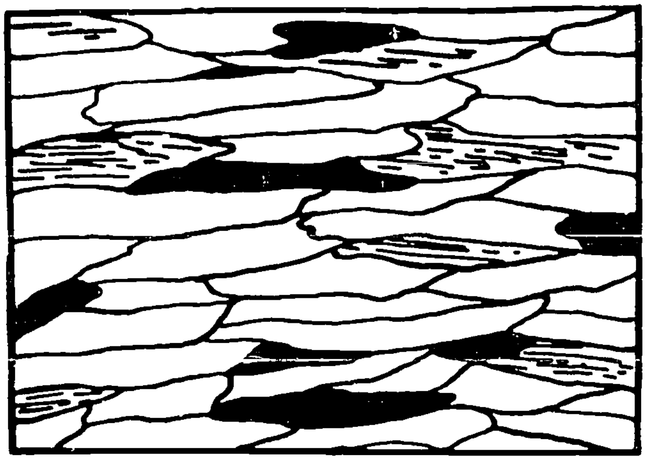

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Figure 4-2. Grain structure in wrought steel.

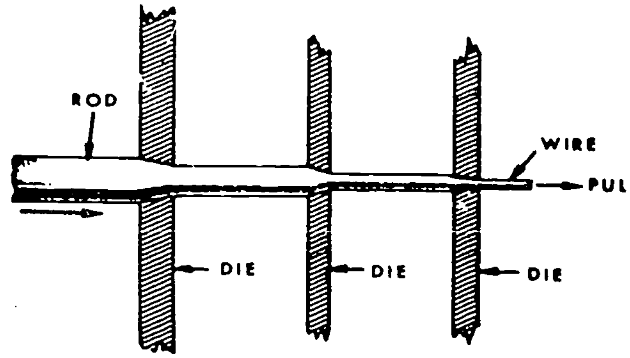

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Figure 4-4. Forged parts.

Most wrought products are formed by one or more of the following methods: rolling, forging, drawing, extruding, or piercing. All parts start as a casting when the metal is cast as an ingot. The next step in hot-rolling forms the ingots into large bars or billets. These bars or billets are then further reduced by rolling or other forming methods, either hot or cold.

In rolling, the metal is passed between two rolls to reduce the metal to a designated thickness. Special shapes may be rolled on rolls made for this purpose. Figure 4-3 shows some of the shapes that may be made by rolling.

Forging is done by heating the metal until it is plastic and hammering it into shape. The metal may be forged by a huge machine, hammered into a die, or hammered into shape on an anvil. You may be required to forge simple parts with a hammer and anvil. Figure 4-4 shows some forged parts.

In drawing, the part is formed by pulling it through a die so that the part takes the cross-sectional shape of the die. A series of dies may be used, each one smaller than the last. The metal starts out hot but cools during the drawing. The final stage of the process is cold-forming. Wire is made by drawing, as shown in figure 4-5.

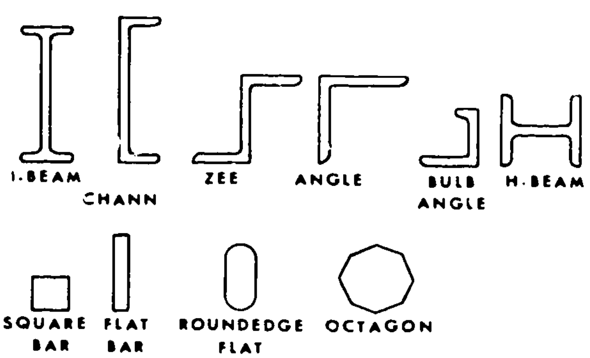

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Figure 4-3. Rolled steel shapes.

Extruded parts are made by pushing metal through a die. The metal is shaped in a manner similar to toothpaste being forced out of a tube. The metal takes the cross-sectional shape of the opening. Very complex shapes may be made in this way. Some of these shapes cannot be made in any other way. Aluminum, copper, and magnesium are often extruded. Long lengths of seamless tubing are made by extrusion.

In piercing, a bar of hot metals is rolled lengthwise between rolls so that the center opens up. The bar is then fed over a mandrel. The mandrel opens up the center to a given diameter to form tubing. This tubing is then drawn through a die to give it the proper size and smoothness.

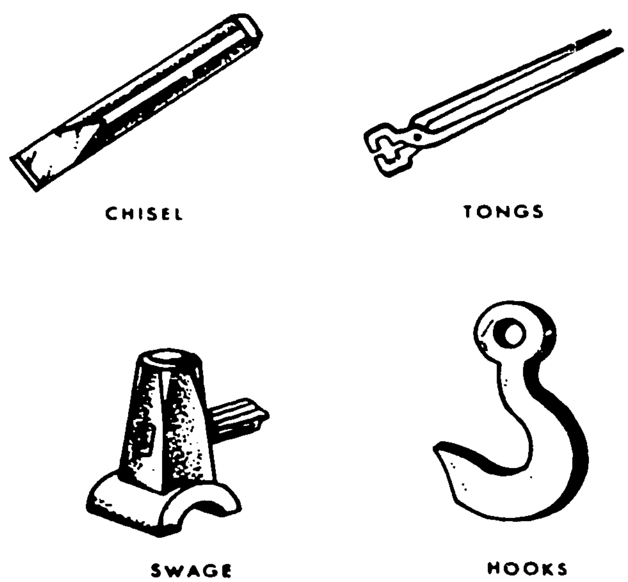

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Figure 4-5. Drawing.

Exercises (041):

1. List the three types of casting.

2. Metal pulled through a die is shaped by a process known as what process?

3. What is the best method to cast an intricate part of aluminum?

4. Name the methods of shaping.

5. What is a wrought product?

6. List five methods of shaping wrought products.

042. Identify the mechanical properties of metals and state the relationship of properties of metal when one property has changed.

To select a metal for a job, you will have to know something about properties of metals. In this section, we discuss the properties of metals and shop methods for testing various metals.

Mechanical Properties. The internal reactions of a metal to external forces are known as mechanical properties. The mechanical properties are directly related to each other. A change in one property will usually cause a change in one or more additional properties. For example, if you increase the hardness of a metal, the brittleness usually increases and the toughness usually decreases. We briefly review the properties of metals before discussing their composition.

Tensile strength. Tensile strength is the resistance that a metal offers to being pulled apart. Tensile strength increases or decreases as the hardness increased or decreases. The tensile strength of metal is usually stated in pounds per square inch of cross-sectional area.

Ductility. Ductility is the property of metal that allows it to be permanently bent, stretched, or formed without breaking. A good ductile material is one that can be permanently deformed without breaking or cracking and yet remain in the formed stage after the force has been removed. A material that is ductile is also malleable or pliable. Ductile and malleable metals can be thinned by rolling or hammering; however, most metals become hard when worked, and the tensile strength is increased. An example of a metal that is very ductile and malleable is copper.

Hardness. Hardness is the penetration resistance of a metal to an applied force. The "hard" also implies that the metal is solid or firm. A good example of a hard metal which you will be using is stainless steel. The hardness of a metal can usually be controlled by heat treatment.

Brittleness. Brittleness is the property of metal that allows very little bending before breaking. You are familiar with how a piece of glass will break when enough pressure is applied. A piece of metal that is brittle will act much the same way. A metal that is brittle is not ductile. A good example of brittle metal is cast iron, which breaks very easily when bent or struck with a hammer. Normally, the harder a metal, the more brittle it is.

Toughness. Toughness is the ability of a material to absorb sudden shock without breaking. You have, no doubt, used this term for something that was very strong but pliable. Toughness is a property that allows a metal to bend, twist, etc., without tearing or breaking. Usually, the harder the material, the less tough it is.

Elasticity. Elasticity means how much force of pull, bend, twist, or squeeze a piece of material will stand and yet return to its original shape. When a piece of rubber is stretched, it will return to its normal shape. And most metals will stretch and return to their original shape but not as much as rubber. When metals are stretched beyond their elastic limits, they usually remain in the stretched condition. The elastic limit is the point just before the metal reaches the permanent stretched condition. A metal that is between its elastic limit and breaking point is in a stage called the yield point. An example of this stage is when the metal has been bent or changes shape.

Shear strength. Shear strength is the resistance to an action similar to the cutting of a pair of scissors. A shear action is a force acting in a manner which tends to cause the particles of a body to slide over each other. The shear strength of steel is approximately 60 percent of the tensile strenth. Shear strength can be controlled in the same manner as tensile strenth—i.e., by varying the hardness of the metal.

Wear resistance. Wear resistance is the ability of a material to resist the cutting or abrasive action, resulting from a sliding motion between two surfaces under pressure. A hard material will usually have good wear resistance.

Stress. Stress is the reaction within a material to an externally applied force.

Strain. Strain is the change in the length each unit of length within a material subjected to a stress.

Exercises (042):

1. Match the defining phrases in column B with the correct mechanical properties listed in column A.

Column A	Column B
______(1) Hardness.	a. Breaks before deforming.
______(2) Tensile strength.	b. Ability to stretch.
______(3) Brittleness.	c. Result of stress.
______(4) Shear strength.	d. Fights abrasive action.
______(5) Ductility.	e. Doesn't permit deformation.
______(6) Toughness.	f. Inner reaction to force.
______(7) Elasticity.	g. Resists breaking from shock.
______(8) Stress.	h. Resistance to stretch.
______(9) Strain.	i. Resistance to cutting.

2. State the relationship of properties of metals when one property has changed.

3. What are you testing for when you pull (with weight) a piece of material apart?

4. What property does a metal have when it is bent, twisted, or pulled and then returns to its original shape?

5. When a metal is brittle, why can't it also have ductility?

6. Stainless steel is an example of a metal with which mechanical property?

4-2. Metal Identification

There are many ways in which we identify metals. We identify them by class, as ferrous or nonferrous, by numerical codes, color codes, or by testing them. In this section, we discuss all these ways of identifying metals.

043. Give the meaning of the ferrous and nonferrous classifications and identify metals within each.

All metals may be classified as "ferrous" or "nonferrous." A ferrous metal is any metal that contains iron. A metal is considered nonferrous if it contains no iron.

Ferrous metals include cast iron, steel, and the various steel alloys. The only difference between cast iron and steel is in the amount of carbon. Cast iron contains more than 2-percent carbon, while steel contains less than 2 percent. An alloy is a substance composed of two or more elements. Therefore, all steels are an alloy of iron and carbon, but the term "alloy steel" normally refers to a steel that also contains one or more other elements. For example, if the main alloying element is tungsten, the steel is a tungsten steel, tungsten alloy. If there is no alloying material, it is a carbon steel.

Alloy steels have been developed to meet the needs of modern industry for tougher, stronger, and harder steels than can be obtained in simple carbon steels. Alloys, such as nickel, chromium, tungsten, vanadium, manganese, and molybdenum give distinct properties to the steel; but, in most cases, the principal qualities are the increase in hardness and toughness.

Nonferrous metals are those composed primarily of elements other than iron. These metals include a great many metals that are used mainly for metal plating or as alloying elements, such as tin, zinc, silver, and gold. We are primarily concerned with the metals used in the manufacture of parts, such as aluminum, magnesium, titanium, nickel, copper, and their alloys.

Exercises (043):

1. Define the term "ferrous."

2. Define the term "nonferrous."

3. Identify the following metals as ferrous or nonferrous.
   a. Bronze.
   b. Copper.
   c. Gray cast iron.
   d. Chrome-molybdenum steels.
   e. Carbon steel.
   f. Magnesium.

g. Brass.

4. What does the term "alloy steel" generally refer to?

044. State the characteristics of ferrous metals and alloys.

In this section, we help you identify ferrous metals and alloys. Each ferrous metal is explained separately.

Ferrous Metals. Ferrous metals are composed chiefly of iron and include pig iron, cast iron, wrought iron, carbon steel, and various steel alloys.

Alloy Steels. Alloy steels have elements other than carbon added to improve the properties of the base metal. Some of the elements that are added to iron include nickel, chromium, zinc, tungsten, and silicon. Generally, alloys are harder than the base metal and have better corrosion resistance than the base metal. For instance, nickel and chromium have good resistance to corrosion.

Carbon Steel. Carbon is added to metals to make them harder without using one of the alloys described earlier. A metal having low-carbon content is ductile and easy to bend. Metals having high-carbon content are hard to bend. The properties of high-carbon steel can be changed by annealing, hardening, or tempering. We discuss these later in the section.

Carbon steels are listed in a numerical code, according to the amount of carbon they contain. The numerical code for carbon steel is listed in the SAE code (Society of Automotive Engineers).

Carbon steels are listed with a four-digit number in the 1000 series. The first number of 1030 steel, identifies the metal as a carbon steel. The second number identifies the amount of alloy; in this case, none. The third and fourth numbers identify the carbon content in one-hundredths of one percent; in this case, 0.30 percent carbon. So, steel listed with a number of 1096 is high in carbon, while 1010 is low in carbon.

Dead soft steel. Dead soft steel, or wrought iron as it is sometimes called, is a low-carbon steel. It is commonly called black iron. Dead soft steel corrodes quickly and must be painted or coated with zinc or tin. It has good forming qualities and is used often in the sheet metal shop.

Black iron. Black iron is a dead soft steel available in sheets of various sizes and thicknesses. You will probably use it in thicknesses ranging from 30 to 16 gage; in sheet widths of 30, 36, and 48 inches, and in sheet lengths of 8 and 10 feet. Sheets thicker than 16 gage can also be obtained in widths of 48 inches and lengths of 8 or 10 feet. (Gage is a thickness measurement for sheet metal. The thickness gage is discussed in Volume 3. Black iron can be worked cold on the machines in the shop and may be bent up to 180° without breaking.

Galvanized iron. Galvanized iron is the same basic metal as black iron, except that galvanized iron has a coating of zinc to protect the base metal from corrosion. Like black iron, it has good forming qualities—and you will probably use it more than any other sheet metal. The bench stock in your shop will probably have several sheets of different gages and in widths of 36 inches and lengths of 10 feet.

Tin plate. Tin plate is tin-coated iron that has good corrosion-resistant qualities; however, it is considerably less resistant to corrosion than stainless steel or galvinized iron. Extensive exposure to corrosive conditions will require the tin-plated surface to be painted. Tin plate has good forming qualities and is available up to 20 inches in width and 28 inches in length.

Stainless Steels. The stainless steel that you will be using is a hard metal, resists scratches and corrosion, and will usually have a shiny finish. Stainless steel is an alloy of iron and other metals such as chromium, nickel, and small parts of silicon and manganese.

18-8 stainless steel. The 18-8 stainless steel is 18-percent chromium and 8-percent nickel. It is used in the sheet metal shop for jobs that require a metal that is resistant to corrosion. There are three types of 18-8 stainless steel, as shown in figure 4-6. Notice the percentages of carbon, manganese, silicon, chromium, and nickel.

The 18-8 stainless steel is used where resistance to chemicals, ease of cleaning, and freedom from contamination of food and dairy products are required. This stainless steel is resistant to organic substances, such as fruit and vegetable juices. It is also resistant to zinc sulphate and X-ray developing solutions.

The 18-8 stainless steel has good forming qualities. However, some springback will be noticed during forming. The machinery in the shop should be checked before cutting or forming stainless steel, since the machines are rated for dead soft metals. Types of 18-8 stainless steel can be obtained in sheet sizes up to 48 inches wide and 144 inches long, depending upon the gage thickness. For instance, 8 to 18 gage is available in widths of 24, 36, or 48 inches, and in lengths up to 144 inches. The following surface finishes are available:

Hot Rolled Annealed and Pickled	(No. 1)
Full Finish Bright Cold Rolled	(No. 2B)
Full Finish Dull Cold Rolled	(No. 2D)
Intermediate Polish	(No. 3)
Standard Polish	(No. 4)
Standard Polish Tampico Brushed	(No. 6)
Highly Polished	(No. 7)

Type 302 of 18-8 stainless steel can be joined by almost all methods used in sheet metalworking. It can be riveted, spot-welded, soldered, or arc-welded. However, when arc welding is used to join the metal, you should not allow the metal to be overheated for long periods. The 18-8 stainless steel resists oxidation if the metal is not allowed to overheat. (You will learn about these fastening methods in later volumes of this course). Many jobs around food serving equipment will require welding, and different types of 18-8 stainless steel may be used. During welding, the carbon in the metal precipitates, and the welded seam

18-8. Stainless Steel Variations and Composition					
Type	Maximum % Carbon	Maximum % Manganese	Maximum % Silicon	% Chromium	% Nickel
302	.15	2.00	1.00	17-19	8-10
304	.08	2.00	1.00	18-20	8-12
304 L	.03	2.00	1.00	18-20	8-12

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Figure 4–6. Stainless steel variations and compositions.

becomes exposed for corrosion to set in. Therefore, you should select the type (302, 304, or 304L) with the lowest carbon content.

In figure 4-6 you can see that type 304 stainless steel has a lower carbon content, and the chromium and nickel content is raised. This lowers the carbon precipitation during welding.

You will also notice that type 304L is another variation of 18-8 stainless steel. The carbon content is lowered to 0.03 percent. This variation is used when jobs require that the seams be welded and where maximum corrosion resistance is desired. All variations of 18-8 stainless steel have the same forming qualities and can be obtained in the same finishes and sheet sizes. This completes our discussion of stainless steels; however, since monel resembles stainless steel, we will discuss it next.

Monel. Monel is an alloy that is sometimes mistaken for stainless steel because it resembles stainless steel and has many of its characteristics. Monel contains from 65- to 68-percent nickel: about 30-percent copper; and small quantities of iron, manganese, and cobalt. Monel is harder and stronger than nickel or copper, is ductile, and has good working qualities. Like stainless steel, it is corrosion resistant and can be worked cold; a it is worked, its tensile strength is increased.

Exercises (044):

1. What do the third and fourth numbers of the SAE code for carbon steels tell you?

2. How is dead soft steel protected from corrosive actions?

3. What is the chief alloy used in 18-8 stainless steel?

4. What are galvanized sheets made of?

5. To bend black iron 180° without breaking it, how hot does it have to be?

6. What must be done to tin plate that is constantly exposed to the corrosive conditions?

7. Do monel sheets have good working qualities?

8. What effect does carbon have when added to ferrous metal?

9. What is a characteristic of black iron?

10. How does tin-coated iron compare with stainless steel or galvanized iron?

11. List three characteristics of stainless steel.

045. Define metal composition, cite the various types of grain structures, and specify common chemical compositions.

The composition of a metal (the chemical composition and the grain structure) determines the properties of the metal, the properties that can be changed, and the amount of change that is possible. A knowledge of the composition of metal will help you determine the type of metal to use for a specific application and the heat treatment required to obtain the desired mechanical properties.

Chemical. The chemical composition refers to the elements, and the exact percentage of each element in the metal. It is often referred to as the che. ·cal analysis or, more simply, as the analysis. The chemical composition and the grain structure of a metal determine the properties that can be developed in the metal. Metal may be in the form of a pure metal, mechanical mixture, solid solution, or combination of a mechanical mixture and a solid solution.

Pure metal. Pure metals are rarely used outside of laboratories. Pure metals cannot be hardened by heat treatment because there is little change in its structure when it is heated.

Mechanical mixture. A mechanical mixture can be compared to concrete. Just as the sand and gravel are visible and held in place by the cement, the elements and compounds in a mechanical mixture are clearly visible and are held together by a matrix of the base metal. An alloy in the form of a mechanical mixture at room temperature may change to a solid solution or to a partially solid solution when it is heated. When it is cooled to room temperature, the alloy may return to its original structure, remain a solid solution, or form a combination of a solid solution and a mechanical mixture.

Solid solution. When two or more metals are absorbed, one into the other, they form a solution. You are probably most familiar with liquid solutions, but solutions may also be gaseous or solid. When an alloy is in the form of a solid solution, the elements and compounds are absorbed into each other in much the same way that salt is dissolved in a glass of water. The separate elements cannot be identified even under a microscope. The solubility of various metals often increases when the temperature is increased. Thus, a metal in the form of a mechanical mixture at room temperature often goes into solution when it is heated.

When it is cooled, a metal may remain in a solid solution, form a combination solid solution and mechanical mixture, or return to a mechanical mixture.

Combination solid solution and mechanical mixture. An alloy that consists of a combination solid solution and mechanical mixture at room temperature may change to a solid solution when it is heated. When it is cooled, it may remain a solid solution, revert to its original form, or form a complex solution.

Grain Structure. Metals consist of millions of small particles called grains or crystals. The arrangement of the grains is the grain structure. The grain structure, which determines the properties of a metal, can be controlled by the heating and cooling procedures and by using various temperatures.

Types. The grains assume several forms as the metal is heated and cooled. We will briefly discuss the most important types of grain structure in ferrous metals.

Ferrite is a compound of iron and various other elements that are found in steel. Ferrite is soft and ductile. Low-carbon steels contain a large amount of ferrite.

Pearlite is a fingerprint-like structure consisting of alternate layers of iron and iron carbides. Pearlite is normally soft and easily machined.

Cementite is the iron carbide structure that forms in steel that has a carbon content of 0.80 percent or higher. Cementite forms a mechanical mixture with austenite at room temperature.

Austenite is the solution formed by combining either cementite or ferrite witl pearl· . Austenite is present only when steel is in a partial or complete solid solution. *Martensite* is the structure that is formed when steel containing austenite is rapidly quenched. A martensitic structure is hard and brittle, but it can be tempered to produce the hardness and tensile strength that is desired.

Size. When metals are heated, the grain boundaries prevent the grains from expanding until the recrystallization temperature is reached. At that temperature, the grain boundaries collapse and small grains are formed from the original large grains. The recrystallization temperatures vary for different metals and for different chemical compositions.

As the temperature increases beyond the recrystalization temperature, the grain size continues to increase until the melting point is reached. The grain size will also increase if the soaking period is lengthened. A numerical code (1 through 8) is used to indicate the grain size of metal. The higher the number, the finer the grain. For example, a NO. 3 grain size consists of 3 to 6 grains each square inch, and a No. 6 grain size contains 24 to 48 grains each square inch. The grain size of most aircraft steel is a No. 5 (12 to 24 grains each square inch) or finer. A fine grain structure is usually desirable.

Exercises (045):

1. What is metal composition?

2. List the various types of grain structures.

3. What effect does the chemical composition and grain structure have upon a metal?

4. Give the three chemical compositions usually found in the field.

5. What effect does heat have upon the grain size?

6. You must choose between two pieces of metal for the same job: one has a No. 2 grain size and the other a No. 8. Which would you choose?

046. State the characteristics of aluminum and aluminum alloys.

In this segment, we discuss nonferrous metals which have no iron [illegible] se Copper, aluminum, zinc, and lead are nonferrous [illegible] that you will probably use in the metal shop. Nonferrous metals have good resistance to corrosion; the surface will oxidize or tarnish (change color) when exposed to weather but will not rust.

Aluminum and Aluminum Alloys. Commercially pure aluminum is a white, lustrous metal that ranks high in its resistance to corrosion. Commercially pure aluminum has tensile strength of about 13,000 psi, but by rolling or using other cold-working processes, its strength may be approximately doubled. When it is combined with various percentages of other metals (generally copper, manganese, magnesium, and chromium), aluminum alloys are formed.

Aluminum alloys in which the principal alloying ingredients are either manganese, magnesium, chromium, or silicon show little sign of attack in a corrosive environment. Alloys in which a substantial percentage of copper is used are more susceptible to corrosive action. The total percentage of alloying elements is seldom more than 6 or 7 percent in the wrought alloys.

One disadvantage in using aluminum alloys is the difficulty of making reliable soldered joints. Oxidation of the surface of the heated metal prevents soft solder from adhering to the metal. There are special solders and fluxes that may be used to seal [illegible] nts, or sometimes sealants are used.

Wrought aluminum and wrought aluminum alloys are divided into two general classes—heat treatable and nonheat treatable alloys. Nonheat treatable alloys are those in which the mechanical properties are determined by the amount of cold-work introduced after the final annealing operation. The mechanical properties obtained by cold-working are destroyed by any subsequent heating and cannot be restored except by additional cold-working, which is not always possible. The "full-hard" temper is produced by the maximum amount of cold-work that is practical.

Wrought aluminum and wrought aluminum alloys are designated by a four-digit index and are shown in figure 4-7. The system is broken into three distinct alloy groups: 1xxx, 2xxx through 8xxx and 9xxx (which is, at present, unused). In the 1xxx group, the first number indicates that the alloy contains at least 99-percent pure aluminum. The second digit of the group indicates controls over the impurities contained in the alloy. Should the second

	AA Number
Aluminum--99.00% minimum and greater	1xxx
Aluminum Alloys, Grouped by Major Alloying Element	
Copper	2xxx
Manganese	3xxx
Silicon	4xxx
Magnesium	5xxx
Magnesium and Silicon	6xxx
Zinc	7xxx
Other element	8xxx
Unused Series	9xxx

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Figure 4-7. Aluminum alloy groups.

number be zero, it would indicate no special control over individual impurities. Digits 1 through 9, however, when assigned consecutively [illegible] the second number in this group, indicate tha[illegible] number of controls over individual impurities in the metal.

The last two digits in the 1xxx group are used to indicate the hundredths of 1 percent above the original 99 percent designated by the first digit. Thus, if the last two digits are 30, the alloy would contain 99 percent plus 0.30 percent of pure aluminum, or a total of 99.30-percent pure aluminum. Examples of alloys in this group are:

- 1100—99.00-percent pure aluminum with one control over individual impurities.
- 1130—99.30-percent pure aluminum with one control over individual impurities.

In the 2xxx through 8xxx groups, the first digit indicates the major alloying element used in the formation of the alloy, as shown in figure 4-7.

In the wrought aluminum form, commercially pure aluminum is known as 1100. It has a high degree of resistance to corrosion and is easily formed into intricate shapes. Like other metals, aluminum becomes stronger and harder as it is rolled, formed, or otherwise cold-worked. Since the hardness depends upon the amount of cold-work done, 1100 and wrought aluminum alloys are available in several strain-hardened tempers. The soft or annealed condition is designated 0, and the fu[illegible] hard is designated H18, with intermediate tempers fro[illegible] H12 to H16. The aluminums you will use are 1100 and 3003, which we will discuss in the following paragraphs.

1100 aluminum. The 1100 aluminum is 99-percent pure and has a tensile strength of 13,000 psi in the annealed condition. The 1100–H16 aluminum has a tensile strength of 20,000 psi and is used often for the fabrication of duct work, since the same tools that are used for galvanized iron can be used. Some metalworkers prefer 1100–H12 that has a tensile strength of 15,500 psi, or 1100–H14 that has a tensile strength of 17,500 psi, for duct fabrication. These three alloys have good forming qualities.

3003 aluminum. The 3003 aluminum is used often in the fabrication of ducts. In the annealed condition, it has a tensile strength of 16,000 psi. The 3003–H14 (half-hard), which has a tensile strength of 21,500 psi, and 3003–H16, which has a tensile strength of 25,000 psi, are used when

extra strength is required. These two 3003 types do not have the forming qualities of 1100–H14 and 1100–H16, and the joining method to be used should be considered when choosing the type. Alloys 1100–H18 and 3003–H18 (full–hard) are good for jobs that do not require forming. Many shops use these types for signs, since aluminum resists corrosion much better than galvanized iron.

Aluminum is much lighter than black iron or galvanized iron and has replaced them for many jobs where weight is concerned. Your shop will probably stock a few sheets of aluminum in the 1100 or 3003 types, which are usually 30, 36, or 48 inches wide; 8 or 10 feet long; and in various thicknesses. The thickness of aluminum sheets is measured in decimals rather than gage. Here are some examples of the comparison of gage and decimal equivalents: 16 gage is 0.050, 20 gage is 0.032, 24 gage is 0.020, and 26 gage is 0.015. These are a few of the popular thicknesses that you will probably use from time to time.

A guide to bending aluminum may be found in figure 4-8. The type of alloy is listed in the left column, and the bend radius is listed to the right under the thickness columns. As you can see, only a few thicknesses are listed, as this is a guide. The bending radii are identified as numbers from 0 to 6. This means to allow for that number times the thickness of the material. The far right column identifies alloys recommended as weldable.

Exercises (046):

1. In its pure state, aluminum has a tensile strength of 13,000 psi. How is the tensile strength increased?

2. What is the recommended setback for the bend radii for a 1/4-inch sheet of 6041 T4 aluminum?

3. What is one disadvantage in using aluminum alloys?

4. What are the two classes of wrought aluminum?

5. How does aluminum compare to black iron or galvanized iron?

6. What is the alloy in aluminum coded 5250?

7. What is the alloy in aluminum coded 3003?

8. What determines the mechanical properties of nonheat treatable aluminum alloys?

047. Interpret the metal identification codes and cite their parts and uses.

Numerical Codes. The terms "steel" and "aluminum" are general in meaning. There are many different types of steel and aluminum. They vary greatly in their chemical composition and physical properties. This is true of all metals. Every piece of metal is manufactured to meet certain specifications. Since it is not possible to mark all of this data on each individual piece of metal, it is represented by a specification number. The ideal situation is to have the specification number marked on each piece of metal in the metal racks in the shop. When this is not possible, each piece should be either tagged or color coded.

Unfortunately, there is no single, unified numerical code for metals. Each manufacturer has his own code or specification number system. This is confusing, since there is no uniformity among manufacturers. In an attempt to correct this situation, several agencies of the metals industry and the Federal Government have developed specification number systems. As a result, you may find any one of seven different specification code numbers stamped on a piece of metal or written on an identification tag. Five of the seven codes cover both ferrous and nonferrous metals. The Aluminum Association code is restricted to aluminum. The American Iron and Steel Institute code is restricted to ferrous metals.

SAE code. Perhaps, the best known numerical code is the Society of Automotive Engineers (SAE) code. This organization pioneered in developing a uniform code for the metals industry, based on chemical analysis. SAE specifications are rather broad and are not complete procurement specifications; however, they cover the basic industrial metals. SAE specification numbers are now used less widely than in the past; however, the SAE numerical code is the basic code for ferrous metals. It is especially useful in identifying metals, such as steels, by chemical composition. You will often hear welders talk about 1030, 1080, or 5120 steel. These are SAE numbers. They have meaning, not so much as particular specification numbers, but in terms of carbon content (low, medium, or high) or in terms of nickel steel, chromium steel, etc. SAE specifications are nearly always restricted to chemical composition.

The SAE system is based on the use of four- or five-digit numbers. The first number indicates the type of steel; for example, 1 indicates a carbon steel, 2 nickel steel, etc. In the case of alloy steels, the second number—and sometimes the third—usually indicates the approximate percentage of the principal alloying element. The final two numbers—

REQUIRED SET BACK FOR 90° BEND

ALLOY AND TEMPER	THICKNESS						
	.0156	.0313	.0625	.1250	.1875	.2500	
1100—O							W
1100—H12					1	1	W
1100—H14					1	1	W
1100—H16			1	1/2–1 1/2	1–2	1 1/2–3	W
1100—H18	0–1	1/2–1 1/2	1–2	1 1/2–3	2–4	2–4	W
2024—O					0–1	0–1	
2024-T3	1 1/2–3	2–4	3–5	4–6	4–6	5–7	
2024-T36	2–4	3–5	4–6	5–7	5–7	6–10	
3003—O							
3003—H12					0–1	0–1	W
3003—H14				0–1	0–1	1/2–1 1/2	W
3003—H16	0–1	0–1	1/2–1 1/2	1–2	1 1/2–3	2–4	W
3003—H18	1/2–1 1/2	1–2	1 1/2–3	2–4	3–5	4–6	W
5250—O					0–1	0–1	W
5250—H32				0–1	0–1	1/2–1 1/2	W
5250—H34			0–1	1/2–1 1/2	1–2	1 1/2–3	W
5250—H36	0–1	1/2–1 1/2	1–2	1 1/2–3	2–4	2–4	W
5250—H38	1/2–1 1/2	1–2	1 1/2–3	2–4	3–5	4–6	W
6061—O					0–1	0–1	W
6061-T4	0–1	0–1	1/2–1 1/2	1–2	1 1/2–3	2–4	W
6061-T6	0–1	1/2–1 1/2	1–2	1 1/2–3	2–4	2–4	W

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Figure 4–8. Required setback for 90° bend.

sometimes three—indicate the approximate carbon content in one-hundredth of 1 percent (0.01 percent). The SAE series numbers are given in figure 4-9. The following examples will help you understand this system.

SAE–1045
1............Type of steel (carbon).
0............Percent of alloy (none).
45..........Carbon content (0.45 percent).

SAE–2330
2............Type of steel (nickle).
3............Percent of alloy (3-percent nickle).
30..........Carbon content (0.30 percent).

SAE–71650
7............Type of steel (tungsten).
16..........Percent of alloy (16-percent tungsten).
50..........Carbon content (0.50 percent).

SAE–50100
5............Type of steel (chromium).
0............Percent of alloy (less than 1-percent chromium).
100.........Carbon content (1-percent).

AISI code. The American Iron and Steel Institute numerical code (AISI) is essentially the same as the SAE code. For example, SAE–1030 and AISI–C1030 are carbon steels of identical chemical composition. The two organizations have worked together in the past in expanding the SAE code to cover a greater number of specifications for ferrous metals. One difference between the two codes is that the prefix of an AISI number indicates the process used in the manufacture of the metal. The C in AISI–C1030 indicates that the steel is a basic open-hearth carbon steel.

AMS code. The aeronautics division of the SAE Standards Committee has developed the Aeronautical Material Specifications (AMS) code. These specifications are complete procurement specifications for materials used in the manufacture of aircraft, aircraft engines, propellers, and other aircraft accessories. The chemical and physical composition of AMS metals are coordinated as closely as possible with SAE general standards for similar metals. An example of an AMS number is AMS–5054B. The specification numbers indicate many detail requirements in addition to the chemical analysis of the material. Revised or amended specifications are indicated by letter suffixes: e.g., AMS–5054B is the second revision of AMS–5045.

ASTM code. The American Society for Testing Materials numerical code (ASTM) has much in common with the Aeronautical Materials Specification code. The ASTM specifications are also complete procurement specifications and [illegible] detailed requirements in addition to the [illegible]n of the materials. For example, [illegible] ASTM specification number in which the A denotes ferrous material. The 5 in A5 is the serial number for high-carbon steel joint bars, and the 55 following the dash indicates that the specification was adopted or last revised in 1955. A "T" suffix would indicate that the specification is tentative.

Federal specification numerical code. The federal specification numerical code was developed to aid in the procurement of supplies used by the departments and independent agencies of the Federal Government. Each specification number is divided into three elements: (1) the group of materials or supplies to which the specification relates; (2) the initial letter of the title of the material; and (3) a serial number determined by the alphabetical location of the file. Two groups in this numerical code are QQ, metals; and WW, pipe, pipe fittings, tubes, and tubing (metallic). For example, the federal specification number of corrosion resistant steel, bars and forgings (except for reforging) is QQ\nS763a (\n1). The small letter suffix "a" indicates the first division of QQ–S–763a. Each division completely supersedes the earlier issues and all amendments thereto. Federal specifications are complete procurement specifications and have many detail requirements in addition to the chemical analysis of the material.

MIL and JAN code. The Department of Defense has developed a numerical code which consists of two series: military specifications (MIL) and Joint Army-Navy specifications (JAN). They can be used as procurement specifications and may have other detail requirements in addition to those of chemical composition.

We have discussed seven different numerical codes or specification number systems. The Department of Defense has developed a master code which ties all of these codes or systems together. It is explained in Military Handbook H1B, Cross-Index of Chemically Equivalent Specifications and Identification Codes (Ferrous and Nonferrous Alloys). The master code groups materials of similar chemical composition which may be represented by one or more specifications. The five-digit code numbers cover both ferrous and nonferrous alloys but are not specification numbers and cannot be used to procure materials. This identification code is extremely valuable because it provides a reference for comparing the material composition of various specifications. Steel code numbers correspond closely to SAE–AISI specification numbers, except that a zero is placed in front of the standard SAE–AISI designations. For example, the corresponding code number of SAE–1070 and AISI–C1070 is 01070. If you should look at a page from a chart on chemical analysis of specifications, you would find a group of SAE, AISI, ASTM, AMS, DOD, and federal specifications for steels with similar chemical compositions. The chemical content (percent by weight) listed provides a basis for comparison. H1B should be in your technical order file. It will help you to find answers to many questions regarding the chemical composition, identification, selection, and procurement of metals.

Exercises ([illegible]):

1. What does the number 75 mean in SAE number 1075?

2. Give the AISI number for 1040 carbon steel.

TYPE OF STEEL	SAE NUMBERS
Carbon Steels	1XXX
Plain Carbon	10XX
Free Cutting, Manganese	X13XX
Free Cutting, Screw Stock	11XX
High Manganese	T13XX
Nickel Steels	2XXX
.50% Nickel	20XX
1.50% Nickel	21XX
3.50% Nickel	23XX
5.00% Nickel	25XX
Nickel-Chromium Steels	3XXX
1.25% Nickel : .60% Chromium	31XX
1.75% Nickel : 1.00% Chromium	32XX
3.50% Nickel : 1.50% Chromium	33XX
3.00% Nickel : .80% Chromium	34XX
Corrosion and Heat Resisting	30XXX
Molybdenum Steels	4XXX
Chromium-Molybdenum	41XX
Chromium-Nickel-Molybdenum	43XX
Nickel Molybdenum	46XX & 48XX
Chromium Steels	5XXX
.60% to 1.10% Chromium	51XX
1.2% to 1.5% Chromium	52XXX
Corrosion and Heat Resistant	51XXX
Chromium-Vanadium Steels	6XXX
Tungsten Steels	7XXXX & 7XXX
Silicon-Manganese Steels	9XXX

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Figure 4-9. SAE numbering system.

3. What is the AMS code used for?

4. Give the third revised specification number for −5095.

5. Explain the nur ' ...ng and breakdown for SAE 9235.

6. What identification codes are designed for the Department of Defense use?

7. What handbook shows the relationship of all the various metal identification codes?

048. Identify metals by shop tests and cite steps in tests.

Shop There are several methods of identifying unknown metals; however, you cannot use any of these methods to accurately determine the chemical composition of a metal. You can determine, however, whether a metal is ferrous or nonferrous and whether steel has a low- or high-carbon content. The methods of shop identification that we discuss are the spark, flame, heat and quench, and chemical tests.

Spark test. In the spark test, you hold a piece of metal against a grinding wheel. Ferrous metals will spark; nonferrous metals will not usually spark. Some nonferrous metals, such as titanium, nickel, and tungsten, will spark slightly. You can achieve fair results in spark testing in determining the amou t of carbon in stee' and the alloying elements in steel, ... the shape and the pattern of the spark stream vary with carbon content and with the alloy. Sp... has its limitations, however, since several steels have similar spark streams. The best way to identify an unknown steel is to compare its spark stream with the spark stream of a known sample of steel.

Flame test. The flame test also has its limitations. However, you can use it in certain situations. For example, to determine whether a metal is an aluminum alloy or magnesium alloy, cut a small chip from the metal and heat it with an acetylene torch. Aluminum alloy will melt and form a ball of molten metal. Mag..esium alloy will ignite, burn with a brillant white light, give off white smoke, and leave a white ash.

Heat and quench test. You use the heat and quench test to indicate the carbon content or the degree of hardness of a metal. Heat sample pieces of the metal to various temperatures above the critical range and quench them in different cooling media. Then, check the hardness of each sample. Hardness increases as the carbon content increases. Usually, a carbon content of 0.50 percent or more is necessary for a piece to be hard enough so that a file will not cut it. Usually, a carbon content of 0.80 percent is necessary to produce a maximum hardness o... 56.

You can use the tube test to distinguish lo... on steel tubing from low-alloy steel tubing. Heat a 1 to 2 inch length of tubing to a bright-red color and quench it in water. Place the piece of tubing in a vise and apply pressure. Low-carbon steel tubing will deform or bend before breaking. Low-alloy steel tubing will break easily before deforming.

Chemical test. You can use chemical tests for various purposes. For example, you can use the caustic soda test to determine whether aluminum is weldable or nonweldable. Submerge the edge of a test sample in a 10-percent caustic soda test solution and allow it to stand for a few minutes. Test the edge of the sample, since the sample might be clad, and, thus, give an incorrect indication. The caustic soda solution will clean weldable aluminum and make it bright and shiny. Nonweldable aluminum alloy will turn black. A piece of nonweldable clad aluminum will come out shiny on the surface and black on the edge.

You can use the cupric chloride acid test to distinguish between nickel-base alloys (inconel) and iron-base alloys (18-8 stainless steel). The test solution consists of 10 grams of cupric chloride dissolved in 100cc of hydrochloric acid. (You can use cupric sulphate instead of cupric chloride.) Clean the metal thoroughly with emery paper; then place one drop of the acid test solution on the metal and allow it to remain there for 2 minutes. A green color will appear. Slowly add 4 drops of water to the acid on the metal until the green color disappears. Rinse and dry the sample. The acid solution will leave a small copper spot on steel or stainless steel. It will leave a bright shiny spot on nickel-base alloys, such as inconel or monel.

The application of a drop or two of nitric acid will enable you to distinguish between stainless steel and hardened carbon or alloy steels. Nitric acid attacks hardened ste... very rapidly; it attacks stainless steel very ...

Exercises (048):

1. List the four shop tests tha. are used to identify metals.

2. What type of test is the best method of distinguishing aluminum from magnesium?

3. How can aluminum be identified as weldable or nonweldable?

4 Which test would you use to indicate the degree of hardness?

5. What metals can be distinguished using nitric acid? How?

6. What should you have to identify unknown steel using the spark test?

049. Given SAE, AISI, and AA numbers, determine location and type of marking.

Marking. When a piece of metal stock is received in the shop, it is usually identified by a specification number, or by a national stock number. If it is not identified, you must mark it in accordance with Technical Order 42D–1–3. There are three approved methods. In order of preference they are: stenciling, color coding, and stamping.

Stenciling. White or black paint, whichever shows up better on the metal, should be used when the size of the metal permits. The national or military specification number should be stenciled on the metal in vertically and horizontally aligned rows. The distance between the vertical rows should not exceed 36 inches, and the distance between the horizontal rows should not exceed 10 inches.

Air Force color coding. For ease in identifying metals in storage, the material designation numbers are represented by stripes of paint at each end of the stock. The stripes are parallel and of equal width, 1/2 to 3/4 inch wide, and placed side by side and in sequence. When they are read from either end of the bar toward the center, the material designation numbers are shown in proper order. A space is left between stripes of the same color appearing side by side. This space is 1/4 inch or less in width. Ten colors are used to represent the various numbers and letters; they are shown in figure 4-10. Figure 4-11 shows the color coding for SAE–1045 steel and figure 4-12 for AA–2025-T6 aluminum. Note that, if they are read from either end toward the center, the numbers are in correct sequence. Note also that the temper designation colors are separated from the number designation colors by 3/4 inch. Two colors have been added recently to the color code. Aeronautical material specification and military specification metals of aircraft quality each require an additional stripe to indicate the condition of the quality of the metal. Gold is used to represent the letter Q and indicates aircraft quality. The commerical designation, American Iron and Steel Institute (AISI), Society of Automotive Engineers (SAE), and Aluminum Association (AA) numbers are used as the designation numbers.

Stamping. Stamping the specification number into the metal is permitted only when it is impossible to use the stencil or color-code methods. It is usually necessary to cut

COLOR	NUMBER	LETTER
BLUE	1	F
GREEN	2	H
OLIVE DRAB	3	O
YELLOW	4	T
ORANGE	5	W
RED	6	A
MAROON	7	B
WHITE	8	C
GRAY	9	D
BLACK	0	S

CP-11

Figure 4–10. Color code identification.

or eliminate the marked portion out of the metal before using the material for work stock; therefore, the marking should be located where waste will be held to a minimum. Gothic style numerals and letters should be used; the height may be 1/16 inch, 1/8 inch, or 1/4 inch, depending upon the size of the material being marked.

Exercises (049):

1. If you were given a piece of SAE–1080 carbon steel 2-inch round stock and had to stamp it with 1/4 [illegible] numerals, where would you stamp it: along the length or across the diameter?

2. What is the preferred method of identifying AA–204–T6 sheet?

3. Give the applicable color code or SAE, AISI, or AA number for the following:

   a. SAE–7015.

   b. Blue, blue, black, black, (aluminum).

   c. AISI–C1065.

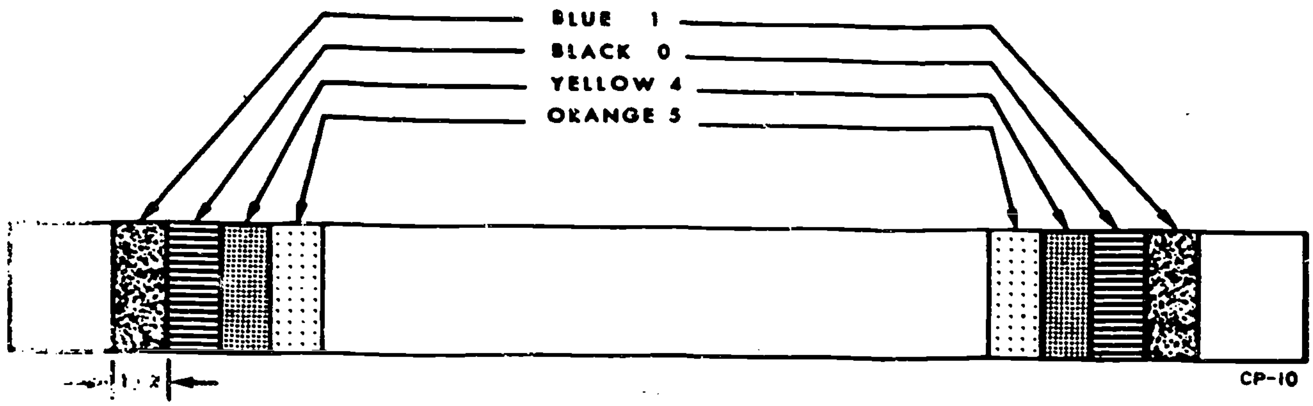

Figure 4–11. Color code for SAE–1045 steel.

d. AA–6300.

e. Green, black, green, yellow, space, silver, aluminum.

f. Maroon, blue, red, orange, black, space, gold, SAE.

050. State the composition of brass, the uses of lead and zinc, and properties of each.

Copper and Copper Alloys. Copper is very malleable and is easily worked. As it is worked, it becomes hard (work hardened) but can be softened by annealing, a process that we will discuss later in this section. Its thickness is referred to as weight in ounces per square foot. In figure 4-13, you can see the gage and decimal equivalents, ounces per square foot, and sizes of various copper sheets. Some of the popular sizes that are used in sheet metal shops are included. Copper resists corrosion and is used where long life of the metal is required. Copper is often added to other metals to increase the corrosion resistance of the metal. Copper holds heat well; you have probably noticed that the soldering coppers (irons) in the shop are made of copper. Copper is expensive, and consideration should be given to the job before deciding to use it.

Brass. Brass is an alloy of copper and one of the most widely used copper alloys. Brass is resistant to corrosion, since it is usually composed of 50-percent copper and 32- to 50-percent zinc. It has a bright-yellow color and is easily formed; it is available in sheets of various sizes and thicknesses. The thickness is measured in gage rather than weight. Brass is soft and can be cold-worked.

Bronze. Bronze is another copper alloy and is composed of copper with tin or zinc. Bronze is harder than brass and is expensive because of the tin content. You will usually find bronze in bar or round stock rather than in sheets.

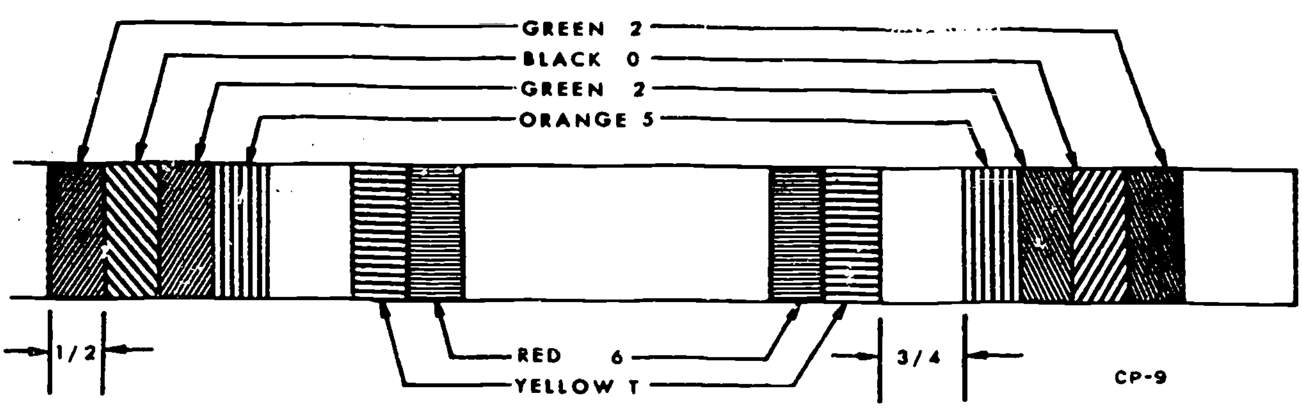

Figure 4–12. Color code for AA–2025–T6.

Nearest Gage	Decimal Thickness	Ounce Per Sq Ft	Sheet Weight in Pounds, Size and Thickness				
			14"x48"	24"x48"	30"x60"	36"x72"	48"x72"
31	.0107	8	2.33	4	6.25	9	12
29	.0134	10	2.91	5	7.81	11.25	15
26	.0188	14	4.08	7	10.93	15.75	21
24	.0215	16	4.66	8	12.50	18	24
22	.0269	20	5.83	10	15.62	22.50	30
18	.0538	40	11.66	20	31.25	45	60
16	.0645	48	14	24	37.50	54	72

CP-7

Figure 4–13. Copper sheet—[illegible]ss, weight and size.

Lead. Lead is a very soft metal that works much more easily than any of the metals we have already discussed. It is alloyed with tin to make solder, which you will use often. Solder is discussed in Volume 3. As a metalworker, you may be required to line an X-ray room with lead, since it resists radioactive rays. Lead also resists chemicals and is used around sewer vents. Lead can be purchased in various sizes, by roll or sheet. It has very little strength and should not be used where strength is required. Lead is very heavy, and its weight should be considered when used.

Zinc. Zinc is a medium-soft metal used chiefly to alloy with other metals and to coat black iron for corrosion resistance. When iron is dipped in melted zinc and allowed to cool, the zinc forms crystals which make a spotted appearance on the surface You have probably observed a GI can that is zinc-coated to resist corrosion. Zinc hardens when worked; it can be annealed by heating and slow cooling. Zinc is also used to cut raw acid (soldering flux), which is covered in Volume 2.

Each of these metals discussed can be treated or worked to change its properties. It is important that you are able to identify each of these metals and are aware of the effects of heat upon them. Figure 4-14, which shows the melting point and color of ferrous and nonferrous metals, will help you understand the next section on annealing, hardening, and tempering.

Exercises (050):

1. Brass is composed of what two metals?

2. List three main uses of lead.

3. Which metal is used to cut raw acids (soldering flux)?

4. Why is copper alloyed with other metals?

051. List ways to change the properties of metals, and identify the hardening and tempering processes.

Heat treating of metals is done to change the properties of the metal. It is done by annealing, hardening, and tempering. In this section, we discuss each of these processes and give examples of treating some of the metals you learned about earlier in this chapter.

Name	Symbol	Melting Point	Color
Aluminum	Al	1219° F	Silvery White
Iron	Fe	2700° F	Black
Nickel	Ni	2646° F	Shiny Silvery
Chromium	Cr	2939° F	Bluish White
Copper	Cu	1981° F	Reddish Brown
Silicon	Si	2588° F	....
Zinc	Zn	787° F	Bluish White
Lead	Pb	621° F	Bluish Gray
Tin	Sn	449° F	Shiny Silver

CP-6

Figure 4–14. Symbols, melting point, and color of ferrous and nonferrous metals.

Annealing. The annealing of metals is a process of heating the metal to a cherry-red color and cooling slowly. Annealing reduces brittleness, since it restores ductility, relieves stresses, and controls grain size. Copper can be annealed to increase its electrical conductivity. Copper is a metal that is cooled quickly as it is annealed by quenching (dipping) it in water; however, most other metals are cooled slowly. Don't confuse annealing with tempering, which we will discuss later.

To anneal steel, it is heated to a high temperature, approximately 1375°. (Since an approximate degree is being reached, a cherry-red effect will appear on the heated area as the metal reaches approximately 1375°). It is important that the steel reach this temperature so that the hardness will be removed.

The steel is allowed to cool slowly, and the slower the metal cools, the more effective the annealing process will be. The thickness of the materials has some effect on the cooling time, which can range from 5 to 24 hours. To cool metals slowly, a sand pit or insulated annealing box will more than likely be used in your shop. The piece being annealed should be allowed to cool in the annealing box until it reaches room temperature before being removed. The piece should be well buried in the annealing box so that the cool air in the room will not reach the hot metal.

Hardening. Hardening is a process of changing the property of metals to make them harder. Hardening steels, especially high-carbon steel, is done by heating the metal to a cherry-red color and cooling fast. The metal is cooled fast in a quench tank of oil, salt brine, or water. As the piece is quenched, it is circulated in the solution to insure even cooling. The heating and quenching process gives the piece of metal a fine-grain structure, extreme hardness, greater strength, and less ductility. Metal quenched in water is hard but brittle; salt brine makes a good quench solution, but oil is better than salt brine or water.

Tempering. Tempering is a process of restoring temper to a metal or adding temper to a metal to change the property. Tempering is also done to reduce the excessive hardening that is often produced during the hardening process. Tempering is done by heating the metal to a specific temperature. In figure 4-15, you can see a chart of the tools that may require tempering. You should learn to recognize the surface appearance of the material when it reaches the desired temperature.

A clean surface is important when you are tempering metals. If the surface is not clean, you will not get an accurate surface color as the material is heated. The surface can be cleaned with a piece of abrasive cloth or paper until it has a bright finish. After the surface has been cleaned and heated to the desired temperature, the metal is dipped in water or oil and circulated.

Exercises (051):

1. What factor must you control when heat treating metals?

2. Explain the quenching process.

3. Explain how to anneal a piece of steel.

4. How do you reduce the excessive hardness of a metal?

5. Why should the surface of a metal be clean when tempering?

4-3. Corrosion Control

Corrosion can be defined as the deterioration of a metal by reaction to its environment. The corrosion occurs because of the natural tendency for most metals to return to

For Tempering		
Degree Farenheit	Color For Related Degree	Kind of Material
430	Yellow	Scrappers, Hammers
470	Straw	Punches, Twist Drills, Reamers
500	Brown	Drift Punches
540	Purple	Cold Chisels, Center Punches, Rivet Sets
570	Blue	Screw Driver

CP-5

Figure 4-15. Heat and color for tempering tools.

their natural state. An example of this is iron reacting with moisture and oxygen from the air to revert to iron oxide (iron ore). Those metals which are found in the pure state are the least likely to corrode.

Not all corrosion is caused by just moisture and oxygen. Sometimes it may be caused by a chemical attack on the metal surface. Some of these chemicals may be acids, alkalis, or salts.

Sometimes, when two unlike metals are connected together in a moist atmosphere, corrosion will occur on one of the metals.

One of the appearances of corrosion may be a tarnish or discoloration to a shiny metal. Stainless steel will become black. Aluminum may become dull or coated with a white powdery residue. Copper will be greenish white in color. Iron or carbon steel will develop reddish-to-black color (rust). Severe rusting will be scaly and may flake.

052. Cite factors concerning the use of common corrosion removers.

Chemical Corrosion Removers. The primary consideration in removing corrosion is that removal must be complete. Failure to clean away all residue lets corrosion continue even after the affected surfaces are refinished.

There are two methods of removing corrosion; mechanically or chemically. The mechanical method includes abrasive blasting, filing, wire brushing, grinding, or abrasive ruts. The chemical method includes the use of various acids or alkaline solutions. The method used will depend on the metal/alloy, degree of corrosive damage, and the accessibility of the area. The chemical method should not be used if chemicals may become entrapped.

Phosphoric acid corrosion remover (Mil–M–10578). This corrosion remover contains a strong acid. Protect hands, face, and eyes. Wear protective clothing. Avoid prolonged breathing of vapors. Inhibited (Type III) phosphoric acid base rust remover is intended for removing rust (on ferrous metals) and conditioning the metal surface prior to painting. This material should always be rinsed off with water after application. This acid comes in a concentrated form and must be diluted for use. The correct dilution is 1:1; that is, 1 part acid to 1 part water. When you do this, always mix the solution in an acid resistant container. Always add the acid to the water; otherwise, there may be a violent reaction that will cause the solution to emit globules of material.

Apply this solution to the corroded area with a brush or swab. Allow the solution to remain long enough to loosen rust (2 to 10 minutes, depending on the degree of rusting). Rinse well to remove all solution residue thoroughly, dry the part well, and immediately apply a protective coating.

Pasa-Jell No. 101. This corrosion remover is used on stainless steel in liquid oxygen storage and transfer systems because it is compatible with liquid oxygen. The solution is applied with an acid-resistant brush and can be agitated with an abrasive mat.

Remove Pasa-Jell with a clean, lint-free cloth rinsed frequently in clean water. Use a clean, lint-free dry cloth for a final wipe. Do not use aluminum or steel wool to agitate Pasa-Jell because a combustible reaction will occur. This solution contains strong acids which requires that you wear protective clothing and avoid breathing fumes.

Alkali corrosion remover (Mil–C–14460). This corrosion remover is highly alkaline and is used on ferrous metals. It is very harmful to skin and eyes, so you should wear rubber gloves, aprons, and goggles, and insure adequate ventilation when working with this material.

Metal to be cleaned should be immersed in the solution. Rust removal time varies with the extent of the rust and temperature of the solution—a warmer solution removes rust at a faster rate. When the part is clean it must be rinsed thoroughly with clean water, then dried and coated with a suitable protective coating. This corrosion remover dissolves aluminum and thus should not be used as a corrosion remover on aluminum surfaces.

Exercises (052):

1. Why must chemical corrosion removers be completely cleaned from the surface of the metal after use?

2. When shouldn't you use chemical corrosion removers and why?

3. How is phosphoric acid prepared for use and what metal is it used on?

4. What is used to remove corrosion from stainless steel in liquid oxygen storage systems and why?

5. What precautions must be taken when applying Pasa-Jell No. 101?

6. What is alkali corrosion remover (Mil–C–14460) used on, what shouldn't it be used on, and how can you speed its action?

053. Identify potential health hazards caused by exposure to chemical compounds.

Potential Health Hazards. You are exposed to chemical compounds if you breathe their fumes or handle them. Any procedure that may produce a health hazard must be evaluated and controlled.

Breathing air containing solvent vapors. Inhaling solvent vapors in a high enough concentration can injure the body. The organ or body system affected depends upon the solvent involved. Some solvents act as irritants to the nose, throat, or eyes; others act as anesthetics and produce varying degrees of narcosis. In cases of narcosis, your manual dexterity and alertness may be affected. Your ability to do your work efficiently and without accident may be decreased. This can be important in all types of maintenance operations that require a high degree of skill and alertness.

Toxicity. Toxicity degree of being poisonous data for individual solvents or chemical compounds are difficult to apply to a mixture. Various additives and mixtures can affect toxicity. Some industrial solvents used in the Air Force are mixtures containing numerous organic compounds.

Absorbency through the skin. Many chemical compounds can be absorbed through the skin in large enough quantities to cause poisoning. Skin absorption must be considered a possible method of ingestion for all solvents.

Ingestion by swallowing. Swallowing toxic chemicals is the least important means of industrial exposure, but swallowing should not be overlooked as a contributing factor in occupational disease. People handling toxic chemical compounds must be careful to avoid contaminating their food, hands, or other objects that they might place in their mouths, intentionally or unintentionally.

Dermatitis. Cleaning compounds can also irriate the skin, resulting in dermatitis. Chemical compounds act in two ways to produce occupational dermatitis—as primary irritants and as skin sensitizers. A skin sensitizer is an agent that does not cause noticeable changes on the first contact, but on subsequent or prolonged contact, produces dermatitis.

A primary irritant is an agent that causes dermatitis by direct action where it touches the skin if it is permitted to act long enough in sufficient intensity or quantity. A primary irritant forms chemical combinations with the skin or removes essential ingredients from the skin, destroying the skin, burning it, or inflaming it. The type and concentration of the chemical and the period of exposure determines the type of damage that occurs.

Exercises (053):

1. List five potential health hazards.

2. How do some solvents affect the body?

3. What is the method of solvent ingestion that might not be considered?

4. What is the least important means of industrial exposure?

5. How is an agent classified that doesn't necessarily cause noticeable changes on first contact?

6. How does a primary irritant cause dermatitis?

054. Cite methods and procedures for controlling chemical health hazards.

Control of Health Hazards. The health hazards you face while you are cleaning metal surfaces are controlled by one or more of the following methods.

Selection of chemical. Use the least toxic chemical compound that will do the job satisfactorily. The relative toxicity of a compound, although not the only factor influencing the degree of hazard involved, is an important consideration. Selecting kerosene in place of benzine is an example of substituting less toxic materials for cleaning.

Selection of equipment. Select a type of equipment that prevents the escape of chemicals into the breathing zone of the worker. Whenever closed processes are economically and operationally possible, use them. If maximum health hazard control is built into equipment, operate and maintain the control element carefully. An inadequately designed or maintained health hazard control is frequently more dangerous than an uncontrolled process because of the false sense of security it creates.

Ventilation. Supply clean air to a work area to dilute the toxic vapor concentration to a point below the threshold limit value. The uncontaminated air can be provided by natural draft, open doors, open windows, or preferably by forced ventilation. Use this method of control only when the chemical is of low toxicity or when only small quantities of toxic vapor are escaping into the air.

Using exhaust ventilation to capture the contaminants and remove them from the workroom air is the most effective method of controlling toxic concentration. The exhaust system must produce enough air movement to capture the contaminant as near to its source as possible. The system must then convey the contaminant to some safe discharge point, while removing only a minimum amount of workroom air and not interfering with the normal ventilation system.

No method of controlling toxic compounds is foolproof. You need to learn certain hygienic fundamentals concerning the materials you are using, and you must remember to prevent excessive exposure. If you are indifferent or uninformed, the control devices can't keep you from producing the maximum amount of atmospheric contamination.

Protective clothing. Use respiratory devices only for emergency and supplementary protection; rarely, if ever, rely upon them as your primary protection. There are occasional, isolated, or emergency jobs where you must depend on respiratory protective devices for the prevention of injury, but your first lines of defense should be one or more of the control measures discussed above.

A variety of respiratory devices are available, each with its specific uses and limitations. Be sure that you are using the proper one for the particular job. Keep respiratory protective devices clean and in good repair, and change filters, canisters, or cartridges as necessary. Respirators can be divided into two main groups: air-supplied and air-purifying.

Air-supplying respirators provide you with air from a source of supply that is independent of your working environment. You use them where there is a possible oxygen deficiency—for example, inside a tank or in a high-atmospheric concentration of a chemical contaminant.

Air-purifying respirators provide safe air by removing the toxic components from the workroom air with mechanical or chemical filtration. You cannot use these in an oxygen-deficient atmosphere or in high atmospheric concentrations of contaminants.

Protective clothing, shown in figure 4-16, protects the skin against toxic, irritant, and corrosive chemicals. Some chemicals can be absorbed through the skin in harmful quantities, many are primary irritants, and a few are sensitizing agents. When other control measures fail to protect your skin adequately, use protective clothing. Such items as rubber and plastic gloves, aprons, suits, boots,

Figure 4–16. Protective clothing.

hoods, and face shields are available. Keep these items clean and in good repair.

Occupational dermatitis can result from exposure to any of the compounds used in metal cleaning. Protecting yourself by the control methods discussed above prevents these irritants from reaching your skin, thus preventing dermatitis as well as intoxication.

Next to avoiding exposure, personal cleanliness is the most important control measure for preventing dermatitis. Make sure you have adequate washing facilities, including hot and cold water and a good industrial skin cleanser. Allow yourself enough time for a thorough cleansing before lunch and at the end of the shift. Protective ointments have some value as preventative measures but their usefulness is frequently overemphasized. However, if the use of your bare hands is essential to the operation, or you cannot cover your face with a protective device, ointments may be the only means of protection available.

Exercises (054):

1. List four methods of controlling health hazards.

2. What rule should you remember when selecting a chemical for corrosion removal?

3. What is the most effective method of controlling the concentration of toxic materials and removing contaminants from the workroom?

4. Name the two types of respirators.

5. What items of equipment protect your skin from chemicals?

6. Next to avoiding exposure, what is the most effective control measure for preventing dermatitis?

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

001 – 1. No.
001 – 2. Yes.
001 – 3. Yes.
001 – 4. No.
001 – 5. Yes.
001 – 6. Yes.
001 – 7. No.
001 – 8. Yes.
001 – 9. Yes.
001 – 10. No.
001 – 11. Yes.
001 – 12. Yes.

002 – 1. Mechanical.
002 – 2. Sanitation.
002 – 3. Resources and Requirements.
002 – 4. Operations.
002 – 5. Pavements and Grounds.
002 – 6. Civil Engineer.
002 – 7. Civil Engineer.
002 – 8. Civil Engineer.
002 – 9. Structures.
002 – 10. Structures.
002 – 11. Pavements and Grounds.
002 – 12. Pavements and Grounds.

003 – 1. (1) a.
(2) b.
(3) c.
(4) c.
(5) d.
(6) e.
(7) g.
(8) b.
(9) f.
(10) c.

004 – 1. C.
004 – 2. C.
004 – 3. I.
004 – 4. C.
004 – 5. C.
004 – 6. I.

005 – 1. Base Engineer Emergency Force.
005 – 2. You should have written BEEF in a, c, d, e, g, and h.

006 – 1. 55212.
006 – 2. a. Basic Pavements and Soils Course.
b. Basic Const. Equip. Course.
006 – 3. a. 55230.
b. 55231.
c. 55232.
006 – 4. a. 55255.
b. 55350.
006 – 5. a. Pavements Maintenance Technician, 55170.
b. Construction Equipment Technician, 55171.
006 – 6. Pavements Superintendent, 55191.

007 – 1. (1) i.
(2) f.
(3) b.
(4) d.
(5) c.
(6) d.
(7) e.
(8) c.
(9) j.
(10) h.
(11) a.
(12) g.

008 – 1. (1) T.
(2) S.
(3) S.
(4) T.
(5) T.
(6) S.
(7) T.
(8) T.
(9) S.
(10) S.
008 – 2. Intelligence indicators.
008 – 3. Only those people with a "need to know."
008 – 4. Aircraft loadings, takeoffs and landings; information about materials and specific military operations.

009 – 1. To determine the effectiveness of formal schools and career development courses.
009 – 2. (1) When the graduate can't meet the proficiency requirements of the STS, (2) when the STS lists tasks not performed in that AFS, and (3) when the STS code levels are too high.
009 – 3. 6 months.

010 – 1. (1) b.
(2) d.
(3) c.
(4) a.
(5) a.

011 – 1. AFM–85–3.
011 – 2. Resources and Work Force Management.

012 – 1. 34C2, I–2.
012 – 2. 34C2–3, I–4.
012 – 3. 34W8, I–73.
012 – 4. 34Y1–1, I–73.

013 – 1. (1) Spark plugs.
(2) Ignition wiring and battery connection.
(3) Engine distributor timing.
(4) Wear or pitting of distributer breaker points.
(5) Engine generator belt.
014 – 1. No.
014 – 2. Yes.
014 – 3. No.
014 – 4. Yes.
014 – 5. Yes.

CHAPTER 2

015 – 1. Inservice work plan.
015 – 2. Facility surveys.

015 – 3. Recurring labor-hours and equipment maintenance labor-hours.
015 – 4. Work authorization documents.
015 – 5. By post work and the use of a computer.
015 – 5. BEAMS.

016 – 1.
- a. Requester's name and phone number.
- b. Building or facility number.
- c. Work requested.
- d. Date signed.
- e. Signature of base civil engineer.

016 – 2. On the back of the form.
016 – 3.
- a. New work.
- b. Self-help work.
- c. Repair of damages to real property caused through neglect or abuse.
- d. Inservice minor construction costing less than $1000.00 for base work or over 100.00 for military family housing.
- e. Projects that are accomplished by contract.

017 – 1. AF Form 1135.
017 – 2. AF Form 332.
017 – 3. AF Form 332.
017 – 4. AF Form 1135.
017 – 5. AF Form 1135.

018 – 1. F. Initiate AF Form 1135.
018 – 2. T.
018 – 3. F. Emergency situations.
018 – 4. T.
018 – 5. T.
018 – 6. T.

019 – 1. Self-help.
019 – 2. Hopper.
019 – 3. Service call.
019 – 4. SMART.
019 – 5. Service call.
019 – 6. IWP.

020 – 1. Recommend that a larger storage area be constructed.
020 – 2. BCE Work Order (AF Form 327).

021 – 1. To compute man-hour requirements.
021 – 2. To compute allowed time for a job.
021 – 3. The planner.
021 – 4. The front side.

022 – 1. T.
022 – 2. F.
022 – 3. F.
022 – 4. T.

023 – 1.
- (1) To provide a uniform reporting system.
- (2) To identify direct labor cost against work orders.

023 – 2. ATA and ETA.
023 – 3. AF Form 1734.
023 – 4. Handprinted on AF Form 1734 below the first group of names.

024 – 1.
- (1) c.
- (2) f.
- (3) d.
- (4) e.
- (5) a.
- (6) f.
- (7) e.
- (8) e.
- (9) d.
- (10) b.
- (11) c.
- (12) e.

025 – 1. You should have placed an x by (1), (3), (4), (5), (6), and (7).

026 – 1. AFR 67–23.
026 – 2.
- a. Requisition equipment initially.
- b. Request replacement.
- c. Increase authorization.
- d. Reduce authorization.
- e. Turn in equipment.
- f. Receipt for equipment.

026 – 3. Nomenclature, unit of issue, and quantity.
026 – 4. It is used to order materials.

027 – 1. Materiel Control.
027 – 2. Stock number.
027 – 3. Turkey.

028 – 1. To make a visual check to see if property listed on paper is actually there.
028 – 2. Obeying a set of rules necessary to conserve and protect Air Force equipment and supplies.
028 – 3. (1) AF equipment must be operational; (2) adequate supplies in good condition must be on hand; (3) use equipment and supplies only for their intended purposes; (4) safeguard equipment and supplies; and (5) keep accurate records.

029 – 1. Yellow.
029 – 2. Unserviceable but reparable.
029 – 3. Condemned—do not use.

030 – 1. Expendable items.
030 – 2. Place I (initial), R (recurring), or N (nonrecurring) in the Issue block.
030 – 3. No.
030 – 4. A justification for the issue.
030 – 5. Unit of issue, quantity, unit price, and total cost.
030 – 6. Receipt for AF materials issued on a temporary basis.
030 – 7. 24 hours.
030 – 8. Custody receipt and hand receipt.

CHAPTER 3

031 – 1.
- a. Improper fraction.
- b. Mixed number.
- c. Proper fraction.

031 – 2.
- a. 2.
- b. 32.
- c. 2.
- d. 7.

031 – 3.
- a. $6\frac{3}{4}$.
- b. $16\frac{6}{8}$
- c. $1\frac{1}{64}$
- d. Cannot be converted.

032 – 1.
- a. 7/2.
- b. 201/32.
- c. 47/8.
- d. 5/4.
- e. 73/16.

032 – 2.
- a. 77/96.
- b. 161/9.
- c. 5/12.

032 – 3.
- a. 5.
- b. 16/27.
- c. $5\frac{2}{3}$.
- d. $4\frac{25}{26}$

032 – 4. Items b, c, e, and f contain improper fractions.
032 – 5.
- a. $21\frac{16}{24}$
  $7\frac{15}{24}$
  $18\frac{18}{24}$
  $11\frac{6}{24}$
  $15\frac{21}{24}$
  $4\frac{20}{24}$
- b. $1\frac{3}{32}$
  $1\frac{4}{32}$
  $6\frac{14}{32}$
  $14\frac{8}{32}$
  $3\frac{20}{32}$

032 – 6.
- a. 80.
- b. $26\frac{17}{32}$

032 – 7.

a. $21\frac{32}{64} = 20\frac{96}{64}$

$\underline{-14\frac{55}{64}}$ $\underline{-14\frac{55}{64}}$

b. $14\frac{3}{16} = 13\frac{19}{16}$

$\underline{-5\frac{10}{16}}$ $\underline{-5\frac{10}{16}}$

032 – 8. a. $6\frac{41}{64}$
b. $8\frac{9}{16}$

033 – 1. 46.4858.
033 – 2. a. 83.824
b.
c. 9.66

034 – 1. 53 inches = 1346.2 mm
034 – 2.

a. 6" = 152.4 mm
9" = 228.6 mm
21" = 533.4 mm
54" = 1371.6 mm
68" = 1727.2 mm

b. 12" = 304.8 mm
14" = 355.6 mm
23" = 584.2 mm
28" = 711.2 mm
39" = 990.6 mm
89" = 2260.6 mm

034 – 3.

a. $6\frac{7}{8}$" = 174.6245 mm
$29\frac{47}{64}$" = 755.237 mm
$86\frac{11}{32}$" = 2193.08 mm
$1\frac{3}{4}$ = 44.4491 mm
$36\frac{13}{16}$" = 935.019 mm

b. 98 miles = 157.72 km
61 miles = 98.17 km
984 miles = 9584.24 km

034 – 4. a. 4 feet 4½ inches = 1333.50 mm
b. 3 pounds = 1.36 kg
c. 5½ gallons = 20.82 l
034 – 5. a. 3531.4 cubic feet.
b. 130.79 cubic yards.

035 – 1. An equation.
035 – 2. π, 3.1416
035 – 3. Transposition.
035 – 4. Add 4.
035 – 5. An equal (=) sign.

036 – 1. The branch of geometry that deals with the measurement of lines, angles, surfaces, and solids.
036 – 2. Triangle.
036 – 3. Right, obtuse, acute.

037 – 1. Quadrilateral.
037 – 2. (1) c.
(2) d.
(3) a.
(4) b.
037 – 3. a. 24.6272 square inches.
b. 262.1426 square inches.

038 – 1. $A = \pi r^2$ or $A = \frac{d^2}{4}$

038 – 2. Arc, chord, tangent, sector, and segment.

039 – 1. $V = 1/3\,(9) \times A_b = 4$ cubic yards.
039 – 2. 226.2 square inches.
039 – 3. 6,720 cubic inches.
039 – 4. 137,445 cubic inches.

CHAPTER 4

040 – 1. Two. All steel goes through the blast furnace; then it must go through either the open-hearth furnace, Bessemer converter, electric furnace, or induction furnace.
040 – 2. Cast iron.
040 – 3. By electric current.
040 – 4. The inglots are placed in an underground furnace called a soaking pit and heated uniformly all the way through at approximately 2200° F.

041 – 1. Permanent mold, sand mold, and die.
041 – 2. Drawing.
041 – 3. Die casting.
041 – 4. Casting or wrought.
041 – 5. Any metal that has been shaped by force while it is in the solid form.
041 – 6. Forging, extruding, rolling, piercing, and drawing.

042 – 1. (1) e.
(2) h.
(3) a.
(4) i.
(5) b.
(6) g.
(7) d.
(8) f.
(9) c.

042 – 2. A change in one property will usually cause a change in one or more additional properties.
042 – 3. Tensile strength.
042 – 4. Elasticity.
042 – 5. A brittle metal *will not* bend without breaking, and a ductile metal *will* bend without breaking.
042 – 6. Hardness.

043 – 1. A ferrous metal is any metal that has iron as its main element.
043 – 2. A nonferrous metal is any metal that contains no iron.
043 – 3. a. Nonferrous.
b. Nonferrous.
c. Ferrous.
d. Ferrous.
e. Ferrous.
f. Nonferrous.
g. Nonferrous.
043 – 4. Alloy steel refers to steel that contains one or more elements other than the iron and carbon which comprises steel.

044 – 1. The percent of carbon content.
044 – 2. Painted or coated with zinc or tin.
044 – 3. Chromium 17–20 percent.
044 – 4. Black iron dipped in hot zinc.
044 – 5. Heating is not required.
044 – 6. It must be painted.
044 – 7. Yes.
044 – 8. Makes them harder without using alloys.
044 – 9. Can be worked cold on the machines and may be bent up to 180°.
044 – 10. Less resistance to corrosion.
044 – 11. Hard metal, and resists scratches and corrosion.

045 – 1. The combination of the chemical composition and grain structure.
045 – 2. Ferrite, pearlite, cementite, austenite, and martensite.
045 – 3. Determines the properties of the metal, the properties that can be changed, and the amount of change that is possible.
045 – 4. Mechanical mixture, solid solution, and a combination of mechanical mixture and solid solution.
045 – 5. Heat increases the size of the grain.
045 – 6. Metal with No. 8 grain size.

046 – 1. By cold-working.
046 – 2. 2 to 4 times the thickness or 1/2 to 1 inch.
046 – 3. The difficulty of making reliable soldering joints.
046 – 4. Heat treatable and nonheat treatable.
046 – 5. It is much lighter.
046 – 6. Magnesium.
046 – 7. Manganese.
046 – 8. Amount of cold-work.

047 – 1. The 75 in 1075 means that there is 0.75-percent carbon in that steel.
047 – 2. SAE–1040 is equivalent to AISI–C2040.
047 – 3. To give complete procurement specifications for materials used in the manufacturing of aircraft, aircraft engines, propellers, and other aircraft accessories.
047 – 4. AMS–5095C.
047 – 5. SAE–9235 indicates:
9—Type of steel (silicon managanese).
2—Percent of alloy (2 percent).
35—Carbon content (0.35 percent carbon).
047 – 6. MIL (military specifications) and JAN (Joint Army and Navy specifications).
047 – 7. Military Handbook H1B, Cross-Index of Chemically Equivalent Specifications and Identification Codes (Ferrous and Nonferrous) Alloys.

048 – 1. Flame test, heat and quench test, spark test, and chemical test.
048 – 2. Flame test.
048 – 3. Use the caustic soda test. Weldable aluminum will become bright and shiny, while nonweldable aluminum will turn black.
048 – 4. Heat and quench test.
048 – 5. The nitric acid test will distinguish between stainless steel and hardened carbon or alloy steels. Nitric acid will attack the hardened carbon or alloy steel very rapidly but attacks stainless steel slowly.
048 – 6. Known samples of steel to use for comparison.

049 – 1. Across the diameter.
049 – 2. Stenciling.
049 – 3. a. Maroon, black, green, orange.
b. AA–1100.
c. White, blue, black, red, orange.
d. Red, olive drab, black, black.
e. AA–2024–Q.
f. SAE–71650–N.

050 – 1. Copper and zinc
050 – 2. Solder, X-ray shield, and sewer vents or acid tanks.
050 – 3. Zinc.
050 – 4. To increase corrosion resistance.

051 – 1. Temperature.
051 – 2. Place a hot piece of metal in water, salt water, or oil and circulate for even cooling.
051 – 3. Heat it to red hot and let it cool slowly.
051 – 4. By heating it to a specific temperature and allowing it to cool slowly.
051 – 5. To observe the color change of the metal as it is heated.

CHAPTER 4

052 – 1. To prevent continued corrosion after refinishing.
052 – 2. When the chemicals may become entrapped and cannot be completely removed, thus allowing corrosion to continue.
052 – 3. Use an acid resistant container and mix in a ratio of 1:1 with water. Add the acid to the water and apply to ferrous metals only.
052 – 4. Pasa-Jell No. 101 because it is compatible with liquid oxygen.
052 – 5. Wear protective clothing, avoid breathing fumes, and *DO NOT* apply with aluminun or steel wool.
052 – 6. Use on ferrous metals, never on aluminum. Its action can be accelerated by increasing the temperature of the solution.
053 – 1. Breathing air containing solvent vapors, toxicity; absorbing solvents throught the skin; ingestion by swallowing; and dermatitis.
053 – 2. By irritating the nose, throat, or eyes, or by acting as anesthetics.
053 – 3. Absorption through the skin.
053 – 4. Swallowing.
053 – 5. A skin sensitizer.
053 – 6. By direct action where it touches if it is permitted to act long enough in sufficient intensity and quantity.

054 – 1. Selection of chemicals selection of equipment, ventilation.
054 – 1. Selection of chemicals, selection of equipment, ventilation, and protective clothing.
054 – 2. Use the least toxic chemical that will satisfactorily do the job.
054 – 3. Exhaust ventilation.
054 – 4. Air-supplied and air-purifying.
054 – 5. Rubber and plastic gloves, aprons, boots, hoods, and face shields.
054 – 6. Personal cleanliness.

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STOP - 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

55252 01 22

GENERAL SUBJECTS

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (001) Which of the following items *best* describes the primary mission of civil engineering?

   a. Maintain base facilities.
   b. Supply utilities and repair base facilities.
   c. Maintain roads and runways, and keep buildings operational.
   d. Acquire, construct, maintain, and operate real property facilities.

2. (002) Which of the following operates as a staff function to the Chief of Operations?

   a. Engineering and Environmental Planning.
   b. Electrical Power Production.
   c. Resources and Requirements.
   d. Industrial Engineering.

3. (003) Which of the following descriptions *best* fits the Industrial Engineering function?

   a. IE evaluates work performed by all CE personnel.
   b. IE is responsible for engineering activities.
   c. IE is the liaison between the base and CE.
   d. IE activities are all automated.

4. (003) What are two responsibilities of Financial Management?

   a. Directs and controls all work performed by CE.
   b. Prepares budgets and financial plans.
   c. Evaluates work and implements automated system.
   d. Distributes communications and maintains library.

5. (004) When Army of Navy units are *not* available, what unit provides heavy equipment and construction support for base CE major projects?

   a. RED HORSE.
   b. Prime BEEF.
   c. Field Maintenance.
   d. Base Repair Squadron.

6. (005) Which of the following descriptions *best* fits the meaning for BEEF under Project Prime BEEF?

   a. A unit capable of major construction for 4 to 6 months using Army or Navy equipment.
   b. A unit on permanent duty doing heavy construction work with its own equipment.
   c. Any unit doing heavy construction work while on temporary duty.
   d. A base engineer emergency force.

7. (006) What is the grade for an apprentice in the 55 career field?

   a. E-1.
   b. E-2.
   c. E-3.
   d. E-4.

8. (006) What is the title of AFSC 55255?

   a. Plumbing specialist.
   b. Plumbing technician.
   c. Carpentry specialist.
   d. Carpentry technician.

9. (007) What is an important duty of the protective coating specialist?

   a. Construct concrete walks.
   b. Test construction materials.
   c. Apply markings to runways.
   d. Apply plaster to the exterior of buildings.

10. (007) What is an important duty of the engineering assistant specialist?

a. Construct concrete walks.
b. Apply markings to runways.
c. Test construction materials.
d. Apply plaster to the exterior of buildings.

11. (008) Which of the following jobs is required by the metal fabricating technician but *not* by the specialist?

a. Forges metal to required shape.
b. Conducts and supervises OJT.
c. Drills and punches holes.
d. Cuts and trims metal.

12. (008) Facts concerning your duties can be told to

a. anyone.
b. anyone senior in rank.
c. only your commander.
d. only people with a need to know.

13. (009) Who makes job performance evaluations?

a. Trainee.
b. Trainer.
c. Immediate supervisor.
d. Unit commander.

14. (010) What type material do Air Force supplements contain?

a. Directive.
b. Informative.
c. Additional.
d. Procedural.

15. (010) What type material do Air Force pamphlets contain?

a. Directive.
b. Additional.
c. Procedural.
d. Informative.

16. (011) Besides a basic number, what other item determines the sequence of listing of Air Force Standard publications?

a. Subject.
b. Data of publications.
c. Major command to which it applies.
d. Difficulty of work with which they are concerned.

17. (011) What does "M" mean in AFR 0-2 reference M85-1?

a. Air Force Manual.
b. Methods and procedures.
c. Maintenance publication.
d. Mechanical series publication.

18. (012) What are technical orders (TOs)?

a. Official government directives stating how equipment is operated.
b. Suggestions on how to operate equipment.
c. Manufacturer's directions on the best method of operating equipment.
d. Booklets which the technician uses as a guide for operating Air Force equipment.

19. (012) What TO is the key to the technical order system?

a. 31-1-75.
b. 1-1-8.
c. 0-1-32.
d. 0-1-01.

20. (013) What publication should you use for operation of a new type of pavement saw that has *not* been incorporated into the TO system?

a. Regulation.
b. Air Force Pamphlet.
c. Manufacturer's manual.
d. Time Compliance TO.

21. (014) For what are TO improvement reports used?

a. All errors found in TOs.
b. Errors which change the meaning of information.
c. Errors not requiring supervisory appraisal.
d. Only errors concerning safety.

22. (015) Which of the following activities is used to gather information for the inservice work plan?

a. Base Engineer Automated Management Performances.
b. Performance evaluations.
c. Facility surveys.
d. IG inspections.

23. (016) Which Air Force form serves as a requesting, approval, and disapproval document for types of work?

a. AF Form 332.
b. AF Form 327.
c. AF Form 1131.
d. AF Form 1135.

24. (017) Which of the following work requests should *not* be requested on a Real Property Maintenance Request, AF Form 1135?

a. Install wall with self-help work.
b. Repair screen door on MFH.
c. Repair leaky water faucet.
d. Replace broken window panes.

25. (018) Select from the choices below the situation that would be applicable to the service call method of requesting work.

a. a cellar window is broken.
b. a dish washer will not start.
c. a garage door in MFH cannot be lowered.
d. electrical power has been lost to a facility.

26. (019) What is the primary mission of the SMART team?

a. To undertake highly complex repair jobs.
b. To perform unscheduled work that is generally done by various work centers.
c. To perform routine maintenance and repair work on high-use facilities.
d. To be deployed in time of emergencies to augment the Prime BEEF teams.

27. (020) The base Civil Engineer Work Order, AF Form 327 would be used for which of the following situation?

a. Repairing loose door hinges.
b. Adding to the floor area.
c. Adjustment on a self-closing door.
d. Replacing a faucet in a latrine.

28. (021) Who uses the nomograph side of the AF Form 2167, Job Phase Calculation Sheet?

a. The planner.
b. The supervisor and craftsman.
c. The scheduler.
d. The craftsman.

29. (022) Who directs the preparation of Part II of the AF Form 561?

a. Chief of Programs.
b. Chief of Work Control.
c. Chief of Material Control.
d. Chief of O&M.

30. (023) What are the two methods of time accounting?

a. Actual time accounting and proposed time accounting.
b. Actual time accounting and exception time accounting.
c. Proposed time accounting and exception time accounting.
d. Actual time accounting and labor time accounting.

31. (024) What does the word pecuniary mean?

a. Money.
b. Peculiar.
c. Personal.
d. Neglegence.

32. (024) What is the *least troublesome* way to settle a monetary obligation when pecuniary liability is admitted?

a. Report of survey.
b. Statement of charges
c. Cash collection voucher.
d. Transfer and acceptance of military property.

33. (025) What document prescribes exact items and quantities that each unit may draw to perform its mission?

a. Equipment authorization.
b. Stocklist authorization.
c. Table of allowance.
d. US Air Force Supply Manual.

34. (026) What form should be used by shop personnel to requisition shop equipment?

a. AF Form 158, Equipment Authorization Inventory Data.

b. AF Form 601b, Custodian Request/Receipt.

c. AF Form 1420, Purchase Order/Voucher.

d. AF Form 1441, Real Property Voucher.

35. (027) Who is responsible for maintaining bench stock?

a. Work Control and Material Control.
b. Material Control and Base Supply
c. Base Supply and Work Control.
d. The shop foreman.

36. (028) What is the cause of *most* deficiencies found during inventories?

a. Loss.
b. Theft.
c. Human error.
d. Deliberate falsification.

37. (029) What is the color of the tag used to show material that is unserviceable but repairable?

a. Red
b. White.
c. Green.
d. Yellow.

38. (030) When using material on AF Form 1297, Temporary Issue Receipt, what is the normal time period for issue?

a. 12 hours.
b. 24 hours.
c. 60 days.
d. 120 days.

39. (031) Fractions that have a denominator that is small than the numerator are called

a. improper fractions.
b. inverted fractions.
c. common fractions.
d. proper fractions.

40. (032) When two sections of metal are needed to form an item 53-3/4 inches long, if one section is 22-1/8 inches long, what is the length of the other section?

a. 31-3/8".
b. 31-1/2".
c. 31-5/8".
d. 32".

41. (033) What is the decimal equivalent of 5/16?

a. .250.
b. .275.
c. .3125.
d. .325.

42. (033) When working problems with decimals, it is important to keep the decimals aligned vertically when doing

a. multiplication and subtraction.
b. subtraction and addition.
c. addition and multiplication.
d. addition and division.

43. (034) Using figure 3-6 find the metric size of a 15/16 diameter twist drill.

a. .09375 cm.
b. 0.234375mm.
c. 11.9060mm.
d. 23.8120mm.

44. (034) The metric system of measurement is based on the unit of

a. ten.
b. one.
c. the dollar.
d. the French franc.

45. (035) Which formula listed below is used to find the area of a rectangle?

a. $A = \frac{bc}{2}$
b. $A = \frac{bh}{2}$
c. $A = bh$.
d. $A = bc$.

46. (036) Mensuration deals with the measurement of angles, linges,

a. surfaces, and solids.
b. surfaces and cylinders.
c. curved lines and squares.
d. none of the above.

47. (036) Two lines that intersect and form 90 degree angles are said to be

a. acute.
b. obtuse.
c. parallel.
d. perpendicular.

48. (037) What is the area of a rhomboid whose sides are eight inches and five inches and whose height is four inches?

a. 32 sq in.
b. 36 sq in.
c. 40 sp in.
d. None of the above.

49. (038) Which of the following is the formula for finding the area of a circle?

a. $A = \pi r^2$.
b. $A = \pi d$.
c. $A = \pi c$.
d. All of the above.

50. (038) The part of a circle that is straight and intersects the circle at two points is a

a. chord.
b. sector.
c. tangent.
d. segment.

51. (039) How many square inches of area are there on the curved area of a 7-inch diameter cylinder with a height of 9 inches.

a. 49.4802 square inches.
b. 63 square inches.
c. 153.9384 square inches.
d. 197.9208 square inches.

52. (039) What is the volume of a cone that has a diameter of 14 inches and a height of 21 inches?

a. 109.956 cubic inches.
b. 153.9384 cubic inches.
c. 1077.5688 cubic inches.
d. 1616.3532 cubic inches

53. (040) The first step in changing iron ore to steel takes places in a

a. cupola furnace.
b. blast furnace.
c. bessemer converter.
d. induction furnace.

54. ((040) The Bessemer converter furnace is used to produce

a. machinery steel and structural steel.
b. high-grade alloy tool steel.
c. pig iron, cast iron and iron alloys.
d. about 90 percent of all steel.

55. (041) Complicated shapes in metal work may be made by

a. sand casting.
b. die casting.
c. drawing.
d. hot working.

56. (041) Extruded parts are made by

a. pushing metal through a die.
b. drawing metal through a roll.
c. piercing a bar of hot metal.
d. pulling metal through a die.

57. (042) When the hardness of a metal is increased which of the following usually increases?

a. Ductility.
b. Brittleness.
c. Shear strength.
d. Machanical properties.

58. (042) The elastic limit of a piece of metal is the point

a. just before the permanent stretched condition.
b. just after a metal is bent.
c. a metal returns to when bent.
d. all of the above.

59. (043) Which of the following contain only nonferrous metals?

a. Aluminum, copper, and titanium.
b. Magnesium, nickel and stainless steel.
c. Titanium, stainless steel, and magnesium.
d. Cast iron, copper and alloy steel.

60. (044) What metal is coated with zinc to form galvanized iron?

a. Pig iron.
b. Black iron.
c. Carbon steel.
d. Tin plate alloy.

61. (045) The two major factors that determine the properties of a metal are

a. the ferrite and austenite content.
b. the pearlite and cementite content.
c. chemical composition and gain structure.
d. chemical composition and mechanical mixture.

62. (045) When do the grain boundaries collapse forming smaller grain structure in metals?

a. When the recrystallization temperature is reached.
b. When carbon is mechanically mixed in.
c. When the temperature goes above recrystallization.
d. Only when a chemical solution is made.

63. (046) What prevents soft solder from adhering to aluminum?

a. Oxidation of the surface when heated.
b. Lead solder will not allow with aluminum.
c. The difference in heat expansion.
d. Too wide a variation in grain structure.

64. (046) Aluminum identified with the number 1130-H14 contains what percent of pure aluminum?

a. 30.00
b. 99.00
c. 99.30
d. 11.30

65. (047) Steel listed in the SAE (Society of Automotive Engineers) code as 1077 steel contains what percent of carbon?

a. 0.77
b. 7.7.
c. 1.7.
d. 1.0

66. (048) To identify an unknown steel by the spark test, you should

a. watch for white smoke while grining.
b. watch for a black spot and long slender sparks.
c. compare its spark stream with that of a known steel.
d. compare the luster of the ground area to an unground area.

67. (048) Which of the following tests are used to identify weldable and nonweldable aluminum?

a. Flame.
b. Caustic soda.
c. Nitric sulphate.
d. Heat and quench.

68. (049) Color code on metal stock can be read

a. from the end of the stock.
b. from the center of the stock.
c. from either end towards the center
d. from the long portion of the stock.

69. (050) Copper is often added to other metals in order to

a. increase corrosion resistance.
b. give it a crystal appearance.
c. lower the melting point.
d. increase elasticity.

70. (051) The process of hardening metal is used to increase its hardness, strength and lessen its

a. ductility.
b. brittleness.
c. tensile strength.
d. all of the above.

71. (051) Why is it important to clean a cold chisel before tempering it?

a. Cleaning is not necessary.
b. To insure accurate surface color.
c. To insure proper cooling when it is quenched.
d. To reduce the amount of heat required to reach the proper temperature.

72. (052) Phosphoric Acid (Mil-M-10578) is intended to be used to remove corrosion from

a. aluminum.
b. non-ferrous metals.
c. ferrous metals.
d. all of the above.

73. (052) Why shouldn't you use Alkali Corrosion Remover Mil-C-14460 on aluminum?

a. It discolors the metal.
b. It dissolves he metal.
c. It reduces metal corrosion resistance.
d. It reduces metal weldability.

74. (053) What determines what organ or body system that may be affected by solvents?

a. The specific solvent involved.
b. The amount of exposure.
c. Protective clothing used.
d. Individual tolerance.

75. (054) How should you select a chemical for corrosion removal?

a. Always select a non-toxic chemical.
b. Always select acid base compounds.
c. Always select alkali base compounds.
d. Always select the least toxic compound that will produce satisfactory results.

END OF EXERCISE

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STUDENT REQUEST FOR ASSISTANCE

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AUTHORITY: 10 USC 8012 and EO 9397. PRINCIPAL PURPOSES: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package. It is utilized by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's need. Failure to provide all information would result in slower action or inability to provide assistance to the student.

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1 THIS REQUEST CONCERNS COURSE (1 6)	2 TODAY'S DATE	3 ENROLLMENT DATE	4 AUTOVON NUMBER

5 SOCIAL SECURITY NUMBER (7 15)	6 GRADE/RANK	7 NAME *(First initial, second initial, last name)* (17) (18) (19-32)
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4	Request Grade/Rank change/correction.	K	Vol 33 - 35 GR 36 - 38
5	Correct SSAN. (List incorrect SSAN here) (Correct SSAN should be shown in Section I)	M	33 - 34 35 - 40
6	Extend course completion date. (Justify in REMARKS)		
7	Request enrollment cancellation.	N	33 - 38
8	Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 Originals were: [ ] Not received [ ] Lost [ ] Misused	P	Vol 33 - 35 TC 36 37
9	Send course materials. (Specify in REMARKS) [ ] Not received [ ] Lost [ ] Damaged	Q	33 34 00 Volume 35 37
10	Course exam not yet received. Final VRE submitted for grading on ______ (date).	38	
11	Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 not yet received. Answer sheet(s) submitted ______ (date).	1	39 42
12	Results for CE not yet received. Answer sheet submitted to ECI on ______ (date).	2	39 - 42
13	Previous inquiry (☐ ECI Fm 17, ☐ Ltr, ☐ Msg) sent to ECI on ______ (date).	3	39 - 42
14	Give instructional assistance as requested on reverse.	16	
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METAL FABRICATING SPECIALIST

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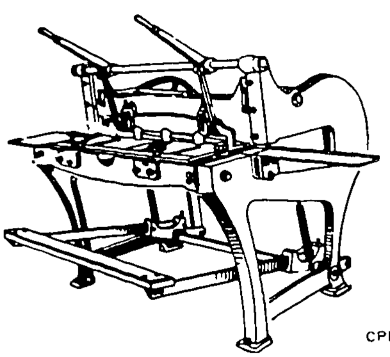
Volume 2

Sheet Metal Tools and Equipment



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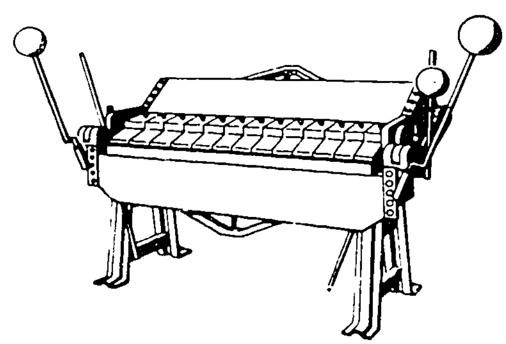

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Air University

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Preface

IN THIS VOLUME, we study the sheet metal tools and equipment that you will use in your future work on the job. We discuss proper care and maintenance of the tools and equipment as well as how to use them.

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Figure 4-4	Goodheart-Wilcox Co. Inc. South Holland, Il 60473

Contents

Cutting Tools and Equipment

IN THIS CHAPTER, you will study about many of the specialized tools and machines used for cutting sheet metal. The chapter contains objectives which concern maintenance of tools and equipment: hand snips and shears; shearing equipment; saws; and files, chisels, and grinders. The large shearing equipment includes the manually operated squaring shears, power operated squaring shears, and gap squaring shears. The small shearing equipment includes utility shears, throatless shears, scroll shears, circle shears, ring and circle shears, and unishears. Safety precautions are discussed where applicable.

The text, illustrations, and questions will help you increase your knowledge and understanding of the purpose, function, use, and maintenance of sheet metal cutting equipment as specified in your Specialty Training Standard. This chapter will also help you understand and apply safety practices and rules which are important. By following accepted accident prevention techniques, you can eliminate accidents when working with sheet metal equipment. In fact, safe operation of equipment may save your hands, fingers, or eyes.

The information you learn from this chapter will not only help you answer examination questions correctly but will also be used frequently during and after your training period. For example, you will be selecting cutting devices to cut various shaped articles from flat sheets, round stock, and angle iron. You must be able to select the proper equipment and use it correctly in order to produce articles of acceptable size and shape. You will repeatedly find that proper operation and maintenance of tools and equipment are important. There is an old saying among sheet metalworkers: "You can tell the way a person does a job by the condition of the tools."

1-1. Maintenance of Tools and Equipment

To get the maximum benefit from any tool or piece of equipment, we need two things—a trained operator and equipment that has been well maintained. As you gain experience, you will learn how to maintain specific tools and equipment. For example, cutting equipment must be oiled, sharpened, adjusted, and used only for jobs for which it was designed. You should never overload a machine by cutting or bending material that is heavier than the capacity of the machine. The care and maintenance of most tools and equipment is discussed in the various objectives concerning each specific item. General and specific rules should be posted (and enforced) in every shop as to the use, care, and repair of all tools and equipment. These general and specific rules should also include safety precautions from such sources as manufacturer's handbooks, and technical manuals.

200. State the effects of improper storage and care of tools.

Most of the suggestions of "don't" and "do" which follow are self-evident; nevertheless, they serve to emphasize the importance of proper tool use and care.

Don't pile handtools on top of one another on the workbench or in the toolbox. When tools, such as snips, files, hacksaws, chisels, and hammers, are scattered and piled on the bench, they may become damaged. If tools are piled upon each other, the tool you want always seems to be on the bottom of the pile; therefore, time is lost.

Don't put a tool away without first cleaning it, especially if the tool is wet or has been used on oily material. Excess oil will pick up dirt and dust, and moisture will cause the tool to rust. Remember, too, that some greases and oils have corrosive properties that may damage the finish on the tool.

Don't leave tools or any other articles on beams, rafters, or any other overhead location. The least that could happen (besides forgetting where you left it) would be a broken tool, and the worst thing could be injury, should it drop on anyone below.

Don't use screwdrivers for chisels.

Don't overload cutting machines by exceeding the recommended cutting capacity.

Do keep hand, bench, and power tools sharp, properly adjusted, and in top mechanical condition at all times.

Do have a regular and definite time every day to inventory your tools and check their condition.

Do sharpen, adjust, and/or repair (if the tool is reparable) any tool needing such maintenance. If tools are not reparable, have them replaced.

The items of cutting equipment in your shop should have maintenance performed on them at different intervals. A maintenance record folder is kept on the equipment to log any maintenance that has been performed and when it was performed. Manufacturers' handbooks or technical manuals for the equipment contain detailed instructions concerning frequency of inspections and servicing procedures. For example, the inspection on a power cutoff saw is usually accomplished every 90 days and includes inspection for damage, wear, and fluid condition. Maintenance of a typical power cutoff saw includes lubrication where required, making adjustments as needed, cleaning the

cutting fluid strainer and reservoir, refilling with clean fluid of the correct mixture, cleaning all unpainted parts with a slightly oiled rag, and cleaning all painted parts with a dry rag or with a rag moistened with soap and water. The power cutoff saw blade may or may not be replaced during preventive maintenance, since it is usually replaced by the operator as needed.

The preventive maintenance performed on other sheet metal cutting equipment is similar to the items listed for the power cutoff saw except for the cutting fluid and strainer.

Other repair on pieces of sheet metal cutting equipment may be performed by personnel from civil engineer shops or at a depot.

Exercises (200):

1. What will probably result if tools are stored on top of each other?

2. What damage may be caused if tools are left with excessive oil on them?

201. Identify unsafe work area safety practices, and relate various flammable materials with classes of fire.

Work Area Safety Practices. Your work area may contain many potential hazards if you fail to apply the safety rules established for your protection. These rules will make you aware of some of the things you should or should not do. The following rules are of a general nature. Your shop will have specific rules which are an extension of these general rules.

Housekeeping. Poor housekeeping is not keeping your work area clean and orderly; it can result in broken bones, cuts, bruises, burns, and other injuries. To prevent these injuries, you must practice good housekeeping. Some of the important items to consider in keeping your house in order are:

a. Keep all floors and walkways clean, dry, and free from spilled oil, fuel, or other contaminants. If these items are spilled, clean them up immediately. Slipping and falling could result in a serious injury to you or someone else.

b. Make sure that your shop or any area you work in is adequately ventilated. Vapors from fuels, oil, gases, acids, and chemicals are injurious to your health.

c. Keep occupied working areas well lighted. You cannot work efficiently and safely without sufficient lighting. Replace burned-out lamps and fuses immediately.

d. Don't leave tools scattered about on floors, workstands, or other places. Always use the cabinets and toolboxes provided for them.

e. Don't struggle with a toolbox that is too heavy to handle conveniently. People have been known to rupture themselves handling excessively heavy toolboxes. Divide your tools so that you can handle them without strain.

f. Don't clutter your work area with unnecessary equipment. If you do not intend to use an item immediately, store it in its proper place.

g. Keep all ropes, chains, cables, hoses, and electrical extension cords properly stowed when not in use.

h. Provide suitable waste containers and insure that waste is disposed of properly. Extra care is required in disposing of glass.

i. Inspect your shop frequently for protruding nails, bolt ends, and other sharp points that might cause injury. Have broken window and door glasses replaced promptly.

j. Insure that water fountains, lunch areas, and personnel clothing lockers are kept clean and sanitary. Illness caused by contaminated water and food can often become more serious than most accidents.

Horseplay. Some of the common varieties of horseplay are pushing, tripping, directing compressed air toward a friend, shocking a friend with electricity, or applying the hotfoot. Any kind of horseplay can result in sudden and serious injury or death. Injuries or deaths resulting from horseplay cannot be justified or even explained. Horseplay in any Air Force shop or on any job is strictly forbidden.

Improper working methods. Equipment with exposed moving parts (belts, chains, flywheels, moving arms, etc.) can be a serious safety hazard unless care is exercised during its operation and maintenance. While most moving parts of machinery are inclosed in protective guards, alertness on the part of the operator is essential. Gloves and loose clothing, particularly large loose sleeves, should not be worn around moving machinery. Just stop for a moment and visualize what would happen if your sleeve should become caught in a drivebelt or chain. You would be lucky to escape with your life.

Any adjustment, cleaning, lubrication, or repair of moving machinery should be done with the device stopped if at all possible. If it is not possible to stop the device, you must take extreme care to prevent serious injury.

Fire Hazards. Materials that burn readily or quickly can constitute a fire hazard if not controlled. As a metal fabricating specialist, you must work around flammable materials. These materials may be solids, liquids, or gases. Good housekeeping is essential in the effective prevention of fires. If you let waste, rubbish, and other residue accumulate, they are a source of fire. Oily rags, for example, can ignite by spontaneous combustion. You can prevent fires of this type by storing oily rags in a covered metal container.

Another serious fire hazard is the accumulation of asphalt and tar vapors, fuel vapors, sewer gases, paint vapors, and other items of this nature. To minimize this type of hazard, follow safety rules and keep the facility you work in clean and well ventilated. Prevent fires whenever you can, but you must also know something about the four classes of fires and the extinguishers used to fight them. Your prompt action might make the difference between a followup check by the fire department and a major fire that endangers many lives.

Classes of Fires and Extinguishers. Fires are grouped into four general classes, each of which can be extinguished

by a particular agent. Because all fire extinguishing agents cannot be used on all types of fires, this classification lets you use the agent best suited for fighting a particular fire. If you use a class A extinguisher, for instance, on a class B fire, instead of putting the fire out, you spread it.

Class A fires are fires occurring in wood, clothing, paper, rags, and other items of this nature. This type of fire can usually be handled effectively with gas and water. Water provides the cooling and quenching effect to put out the fire. The gas merely forces the water out through the hose. You may also use the soda-acid type extinguisher or the foam type extinguisher on class A fires.

Class B fires occur in flammable liquids such as asphalts, tars, gasoline, fuel oil, lube oil, grease, some solvents, paints, etc. The agents for extinguishing this type of fire dilute or eliminate the air by blanketing the surface of the fire. This action creates a smothering effect. The types of fire extinguishers for use on class B fires are foam, carbon dioxide, and dry chemical. The dry chemical units contain a dry powder, usually sodium bicarbonate, and an activating agent of carbon dioxide or nitrogen gas. The dry chemical extinguisher is also used on class C and class D fires.

Class C fires are fires in electrical equipment and facilities. The extinguishing agent for this type of fire must be a nonconductor of electricity and provide a smothering effect. The dry chemical extinguisher is used for this purpose.

Class D fires occur in combustible metals such as magnesium, potassium, powdered aluminum, zinc, sodium, titanium, zirconium, and lithium. The extinguishing agent must be a dry-powdered compound which creates a smothering effect.

In the case of any fire, there are certain actions required of the individual who discovers the fire. The first action should be to sound the alarm and alert all personnel. Second, call the installation fire department and give them exact directions to the location of the fire. These first two actions must be taken quickly. After they have been done, apply the most effective measures available to extinguish or to contain the fire. When you are assigned to a new section, locate the fire extinguishers in the area and be sure you know what kinds are available and how to operate them.

Exercises (201):

Write true or false beside the following work area safety practices. Correct false statements.

____ 1. Keep occupied working areas well lighted.

____ 2. Since you will be using a portable drill in 2 hours, its alright to leave it on the workbench.

____ 3. Replace broken windows promptly.

____ 4. A clean shop means an inefficient shop.

____ 5. Keep some windows open in winter when needed for ventilation.

____ 6. Leave your tools in the places where you will use them.

____ 7. If possible, stop a machine before adjusting it.

8. Match the items in column A with their respective fire class in column B.

Column A	*Column B*
____ (1) Magnesium.	a. Class A.
____ (2) Electrical equipment.	b. Class B.
____ (3) Paper and rags.	c. Class C.
____ (4) Gasoline and grease.	d. Class D.

1-2. Sheet Metal Cutting Tools and Equipment

There are many uses for hand snips and shears, such as cutting out light gage sheet metal parts. Many times, when working away from the shop, your handtools will be your only help in doing a job. Therefore, it is necessary for you to know how to use the tools in your toolkit. Use the appropriate snips or shears with the correct capacity for the job. The snips and shears you will be using are for cutting straight lines, inside and outside circles, and irregular curves.

202. Select the types of hand cutters to use for given situations.

Hand Snips and Shears. Snips and shears are designed to cut only sheet metal cutting wire or rod can damage the cutting blades. Keep snips in good working condition by proper use, sharpening when necessary, applying a light coat of oil to prevent rusting, and oiling the hinge bolt to make operation easier. Hinge bolts in snips and shears should be kept snug but not too tight since a tight hinge bolt makes operation harder, while a loose hinge bolt prevents a clean cut because the metal folds rather than cuts. Sometimes snips or shears with a loose bolt cut but leave a rolled edge.

Straight snips. Straight snips are designed to cut straight or long curved lines in sheet metal. The straight snips shown in figure 1-1 are available with right-hand cut for right-handed people and with left-hand cut for left-handed people. Use straight snips for cutting sheet metal for such items as pans, rectangular ducts, and other similar jobs.

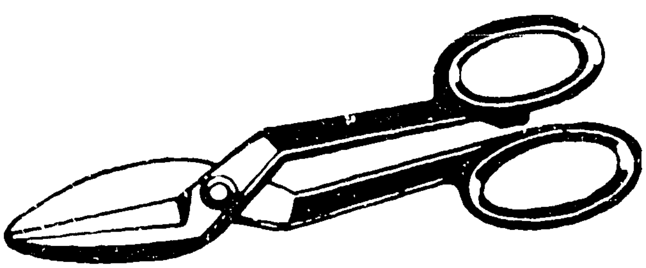

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Figure 1-1. Straight snips.

With straight snips you can cut sheet metal from 30 to 20 gage with very little effort. Bulldog snips (not illustrated) can be used for cutting sheet metal from 20 to 16 gage, although it is difficult to cut these heavier gages with hand operated snips.

Double-cutting shears. Double-cutting shears have a cutting edge on both sides of the blade and can cut on either side, as their name suggests. These shears are useful when cutting sections of vents or round conductors for gutters. For instance, if you need to cut a 3-foot piece of vent pipe from a 10-foot joint, start a hole large enough to insert the cutting blade. A 1/2-inch cold chisel easily cuts the starter hole. The hole should be made close to the seam since the metal is stiff at this point and cuts easier. When making cuts away from the shop, you normally have to crimp one end of the joint so it will slip inside another. Double-cutting shears usually have a crimping device which can be used. These shears are for light gage metal, so do not attempt to cut through the seam where the metal is much thicker. Straight snips should be used to cut the seams.

Aviation snips. The aviation snips which you will be using are illustrated in figure 1-2. They are available in left- or right-hand cut. This means two pairs of snips are required, one for cutting to the left and one for cutting to the right. It does not mean that they are made for left- and right-handed people as in the case of straight snips. The blades of aviation snips are designed to cut small holes and irregular outlines in heat-treated aluminum alloy or stainless steel. The handles are of the compound lever type and can cut mild steel as thick as 16 gage. You will find these snips very useful in the field for cutting any shape of hole in ducts, panels, and similar jobs.

Exercises (202):

From the list of hand shears and snips select the type of hand cutter you should use for the situation.

Situation	*Snips and Shears*
____ 1. You must cut a 5-inch 26-gage vent pipe in half.	a. Aviation snips.
____ 2. You must cut a small hole in 16-gage steel.	b. Straight snips.
____ 3. A rectangular duct must be cut from 30-gage sheet metal.	c. Bulldog snips.
____ 4. You must notch some 16-gage sheet metal.	d. Double-cutting shears.

203. Identify the parts of a squaring shear by their function, and cite the steps in operating a squaring shear.

Although handtools are indispensable for the sheet metalworker, a person is very limited in the amount of material he or she can produce by hand; therefore, one continually strives for greater production or easier ways to turn out work. Because of this necessity for increased production to meet demands, laborsaving machines are constantly being perfected. Within each field, every sheet metalworker is a machine operator in addition to having other skills.

One thing to remember when you are using any sheet metal machine is that it has a specific limit as to what materials it can process. If the metal is too thick, the machine can be damaged. Posted on each machine is the manufacturer's data plate which tells the capacity of the machine. Read this information carefully and follow the instructions.

Do not attempt to use shearing equipment unless you have received checkout instructions and are authorized to operate such equipment.

Power-Operated Squaring Shear. Squaring shears, illustrated in figure 1-3, provide a convenient means of cutting and squaring sheet metal. It is important to learn how to use this tool because it will, among other things, increase production.

This machine consists of a lower blade that is stationary on the bed of the shear, an upper blade that is attached to the crosshead, and holddown clamps (fig. 1-3,A) to hold the metal securely during cutting. The holddown clamp allows you to get your hands out of the way during the cutting operation. The bed of the power shears has extension arms (fig. 1-3,B) which provide support for long sheets of metal.

At the left end of the bed is a guide (side gage, fig. 1-3,C) graduated in sixteenths of an inch. This guide can be used as a measuring scale for cutting short lengths of metal. It also keeps the metal square with the blade. The on-off switch (fig. 1-3,D) is mounted on the control box. The on-off switch should always be in a handy location.

The back gage is not shown in figure 1-3 but is a very useful part of the shear. The back gage is adjustable forward and backward, depending on the length of metal required. There is no need to measure between the back gage and the

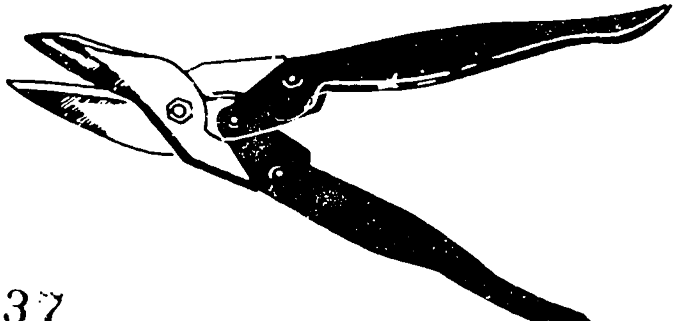

Figure 1-2. Aviation snips.

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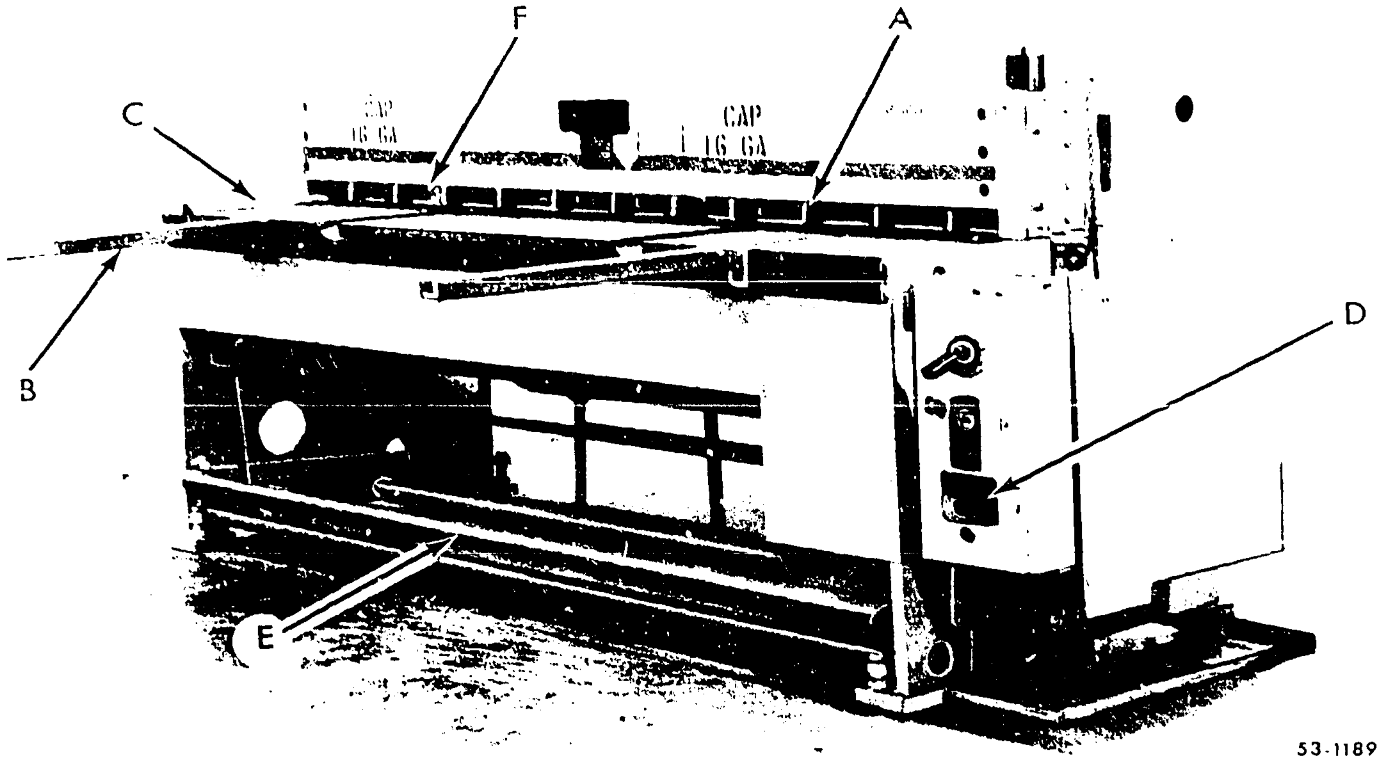


A. Holdown
B. Extension arms
C. Side gage
D. ON-OFF switch
E. Treadle
F. Safety guard

Figure 1-3. Power-operated squaring shear.

fixed horizontal blade because all measurements can be read on the back gage, which is graduated in sixty-fourths of an inch.

Before operating power shears you should check the machine to see that it is clear of material and personnel. For instance, someone might be making repairs behind the machine. If power to the machine is turned off, there is usually a reason; therefore, check with your supervisor for the cause. In some shops a "Caution Repair" tag may be used to identify the status of the machine. If there is such a tag on the machine, do not attempt to remove the tag. The person making repairs will do the removing when the work has been completed. The machines you use are equipped with guards for your protection, and they should never be removed, except when the machine is being repaired. The blade guard is not visible in figure 1-3,F; because it is located between the holddown and cutting blade. The blade guard is designed to keep your hands and fingers away from the cutting blades during operation of the machine. Wheel and belt guards are provided to protect personnel and to keep foreign objects from being caught in the moving parts.

The steps in sequence to cut a piece of metal are: make certain the cutting blades are clear, set the back gage, start the motor by depressing the on switch and allowing the motor to reach full rpm. Then place the metal to be cut in the shear, and depress the treadle (fig. 1-3,E) to make the cut. Be sure to turn off the shears after all cuts are made and remove the material that has just been cut.

By depressing the treadle, you engage an automatic clutch which sets the shearing blade in action. When set for single the shears go through only one cycle of action each time the treadle is depressed and released. If continuous operations are desired, move the clutch shift crank to multicut, and simply continue to hold the treadle in the DOWN position. Once the treadle is released, the machine stops when it completes the cycle of operation.

Manually Operated Squaring Shear. These shears are a great deal like power-operated squaring shears except that the foot supplies the action and power required to operate the cutting blade. In addition, the back gage and holddown handles are manually operated. True, there are quite a variety of foot operated shears manufactured, but basically they are all made the same. If you can operate one succesfully, you can operate the others.

The shear illustrated in figure 1-4 has a large spring at each end of the housing which raises the blade when pressure is removed from the treadle. A scale, graduated in fractions of an inch, is scribed on the bed as a guide for cutting correct lengths. At each end of the bed there is a side gage which aids in keeping the metal square with the blades. If, after several cuts are made, the cut is not square, the error could be yours or the side gage. If it's the latter, have your supervisor readjust the side gage. If it is necessary to cut long sheets of metal that must be pushed from the back side, the extension arms can be used in conjunction with the front gage. The sheet metal gage limit

of this particular shearing machine is usually 16-gage mild carbon steel. If the metal is heavier, use power shears.

The holddown attachment on foot-operated shears can be either spring actuated or manually controlled. These holddowns, if adjusted properly, have a decided advantage over handholding the materials, which usually allows the material to slip, causing inaccurate cuts.

The squaring shears perform many necessary operations which save a great deal of work. These jobs are cutting to a line, squaring, and multiple cutting to a specific size. When cutting to a line, place the sheet on the bed of the shear in front of the cutting blade. Place the cutting line even with the cutting edge of the bed. Pull the holddown handles forward to lock the metal in place. Then cut the material by stepping on the treadle, which initiates the cutting cycle.

Squaring a piece of metal requires several steps, the first of which is the trimming of one edge. This is done by inserting the metal between the blades of the shears and cutting off approximately one-quarter of an inch of metal. The remaining edges are squared by holding a trimmed edge against the side gage and making the remaining cuts, one edge at a time, until all edges have been squared.

When cutting several pieces of metal to the same dimensions, use the back gage (production gage). This gaging device, shown in figure 1-4, consists of two support rods graduated in fractions of an inch, and a square fence that can be set at any point on the support rods. To use the gage, set the squaring fence at the desired distance from the cutting blade by loosening the locking knobs and turning the adjusting knobs. Lock the fence in position after all adjustments have been made, and insert the metal between the blades of the shears until the edge of the metal comes in contact with the squaring fence. To insure accuracy of cut, be sure that the edge of the metal is flush all along the fence. When this is done, pull the holddown handles to clamp the metal. The successful use of this gage depends upon a few predetermined adjustments, and once the gage adjustments are made, many pieces of metal can be cut to the same dimension without additional measuring.

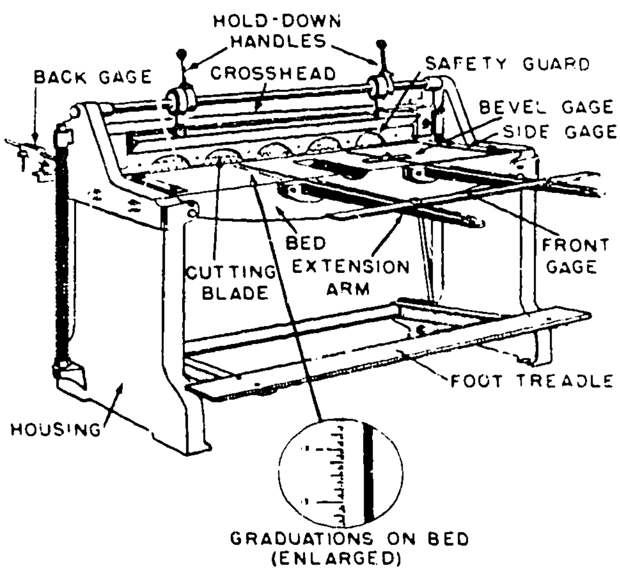


Figure 1-4. Manually operated squaring shear.

Safety precautions to be observed when using manually operated squaring shears are practically the same as those for power operated squaring shears. One exception is that when pushing down on the foot treadle, which requires considerable force, be sure your other foot is clear of the foot treadle.

Exercises (203):

1. What step was performed out of sequence if a piece of metal is cut when the power shear is turned on?

2. What parts of the power shear are safety items that you should not remove?

3. List the last step in a power shear cutting operation.

4. On a manual squaring shear, what is the purpose of the large springs mounted on each end of the blade?

5. What must you depress to begin the cutting action of the power shear?

6. True or False. The holddown on a manual squaring shear works as the treadle is depressed.

7. On a manual squaring shear, of what component is the squaring fence a part?

204. Specify advantages and disadvantages of the gap squaring shear.

Gap Squaring Shears. The gap squaring shears, illustrated in figure 1-5, resemble manual squaring shears except that the frame is built to accommodate any width or length of sheet metal for slitting. The front opening or gap is usually about 18 inches deep for shears with a capacity of 16-gage mild steel. Due to its construction, the gap squaring shear is considerably larger than a squaring shear of the same capacity. Constructed as they are, these shears can be used to cut one piece or several pieces from a sheet of metal longer than the machine itself. You do this by first adjusting the front gage to the desired width, making sure that the gap is deep enough to allow easy passage of the metal. Then move the metal between the cutting blades from left to right and make a cut about three-quarters the

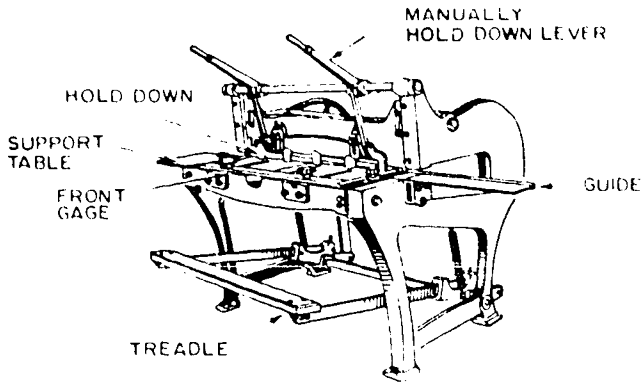


Figure 1-5. Gap squaring shear.

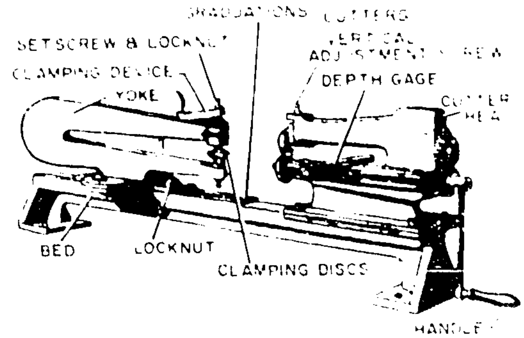


Figure 1-7. Circle shears.

length of the blade. Release the holddown lever and move the sheet to the right so that the edge of the metal rides against the guide. Repeat this step until the cut is completed. Most cutting jobs that can be done on a squaring shear can be done on a gap squaring shear, but the gap squaring shear makes more types of cuts than the squaring shear.

Safety precautions to observe when operating gap squaring shears are similar to those precautions for manually operated squaring shears.

Exercises (204):

1. What is one of the disadvantages of a gap squaring shear?

2. What is one of the advantages of a gap squaring shear?

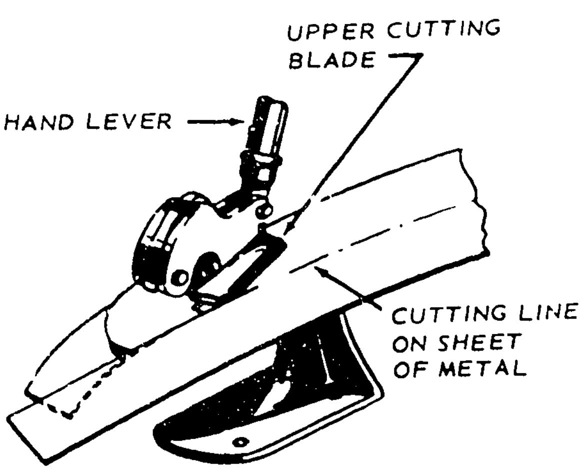


Figure 1-6. Throatless shears.

205. Differentiate between pieces of bench-mounted cutting equipment by their construction and use.

Throatless Shears. These shears, illustrated in figure 1-6, get their name from their construction because the frame is "throatless," and there are no obstructions during cutting. Therefore, a sheet of any length may be cut, and the metal can be turned in any direction to allow for cutting irregular shapes. The cutting blade (top blade) is operated by a hand lever. An example of the use of throatless shears is the cutting of a rectangular elbow from 16-gage sheet metal. Radius cuts in this heavier gage metal can be made easily with throatless shears. Safety precautions include keeping fingers away from the cutting blades, returning the handle to the full UP position after the cutting operation, and protecting fingers and hands from burrs when guiding metal through the cutting blade.

The bottom (fixed) blade should be kept in proper adjustment; if the blades are too close, they lose their sharpness and may be damaged. If the blade gap is too wide, the metal will have a tendency to fold, causing a bad cut. The lower blade is adjusted with setscrews.

Circle Shears. Circle shears, illustrated in figure 1-7, are used to greatest advantage when cutting circular blanks for such items as buckets, cans, and the usual run of cylindrical objects. These shears can also be used for slitting sheets and are equipped with a guide for that purpose. They are best suited for cutting discs from mild steel, copper, and aluminum.

The principal parts of the circle shears are the bed, yoke, and rotary cutters. The bed, since it must absorb and withstand the majority of the load and shock, is made of strong steel plate. On the top of this bed are graduations marked every sixteenth of an inch to indicate the approximate diameter of the circle you are cutting. The yoke, or sliding circle arm, centers and holds the sheet. The position of the yoke is governed by the diameter of the cut. To adjust the yoke, loosen the locknut (usually located at the base of the yoke) and slide it along the bed. Attached to the yoke is the clamping device, which is operated by a clamping handle. Setscrews and locking nuts are used to adjust the pressure on the clamping devices. There is also a hardened center pin in the lower disc which aids you in centering blanks of center punched metal.

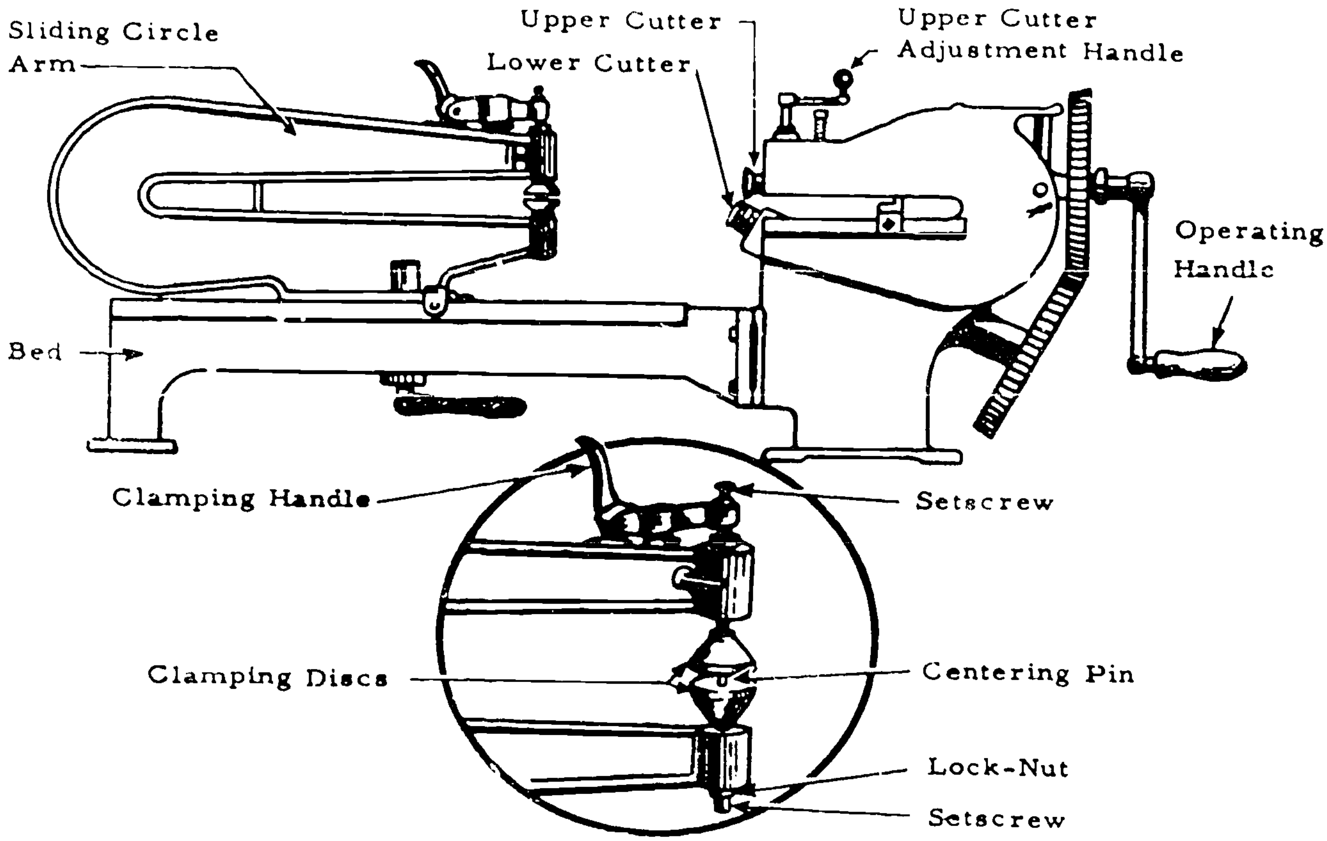


Figure 1-8. Ring and circle shears.

The upper rotary cutter on this machine can be adjusted in a vertical position and should overlap enough to cut through the metal in one cut. Usually the adjusting screw is located directly above the upper cutter. The bottom cutter can be adjusted in the same manner but in a lateral direction. For light gage metal, the cutters should just touch and operate freely. When cutting heavy material the cutters should be separated slightly, but this opening should be limited to a maximum of 10 percent of the metal thickness.

When you are cutting circular blanks with circle shears, the first job is to cut the metal to the approximate size. Place the blank between the clamping discs and adjust the yoke so that the distance from the center of the clamping discs to the cutting wheels is one-half the diameter of the blank desired. Then adjust the upper cutting blade with the vertical adjustment screw. You should stand to the side of the shears with the cutting head to your left when operating the machine with the handle so that the sheet metal will feed away from you. Do not attempt to cut inside circles with this machine, and always start the cut from the edge of the sheet. Safety precautions when using circle shears include such items as keeping fingers from the cutters, gears, and burrs.

Ring and Circle Shears. The basic construction of ring and circle shears, illustrated in figure 1-8, is similar to that of rotary circle shears. The main difference lies in the lower cutting head, which is set at an angle to the upper cutter to permit the cutting of inside circles as well as discs and shallow concave curves. The lateral adjustment between the cutters is the same for the circle shears. Turning the adjustment handle to the left or right will obtain proper clearance between the cutters. Before you cut the outside discs with the ring and circle shears be sure to read the operational procedure for the circle shears.

To cut an inside circle (hole) in a sheet of metal, adjust the yoke of the ring and circle shears so that the distance from the center of the sheet to the cutter wheels is one-half the diameter of the desired circle. Place the metal between the clamping discs, and secure it by lowering the clamping handle. Turn the upper cutter adjustment handle slowly in a clockwise direction. When cutting with the ring and circle shears, turn the operating handles so that the material is fed away from you. Do not lower the upper cutter any farther than is necessary to cut through the metal. Set the locknuts on the upper cutter adjustment handle so that the upper cutter produces a clean cut.

Safety precautions when you are using ring and circle shears are very similar to those listed for circle shears; however, some ring and circle shears are power operated, and the additional safety precautions include keeping clear

of the sheet metal as it revolves during the cutting process. The foot switch can be moved away from the machine to help you stay clear. This foot switch is a source of possible danger, since it may be accidentally depressed by the foot or by a falling object. If the switch is accidentally actuated, the power-operated ring and circle shears may start operating and cause damage to the material and danger to the operator. Still another source of danger to the operator is loose clothing which can snag on burrs or corners of the revolving metal, causing hands or fingers to be drawn into the cutter heads.

Exercises (205):

1. What shears are best adaptable for cutting irregular shapes in heavy sheet metal?

2. Which shears should you use to cut outside circular blanks from mild steel, copper, or aluminum?

3. Which shears should you use to cut an inside circle in a sheet of metal?

4. Which bench-mounted shears have the lower cutting heads set at an angle to the upper cutting heads to allow clearance for concave curves?

206. Give operational characteristics of unishears.

Unishears. You will find unishears useful equipment in the sheet metal shop. Figures 1-9 and 1-10 illustrate two types—stationary and portable. Both are designed to cut along irregular lines on sheet metal and will save you much time since they cut faster than hand snips or shears.

The *stationary unishears*, illustrated in figure 1-9, are powered by an electric motor which moves the lower cutting blade up and down to cut sheet metal as it is guided through the blades. It is possible to make straight or irregular cuts through sheet metal as heavy as 16 gage. The upper cutting blade does not reciprocate during cutting; however, the upper blade positioning assembly can be raised with the upper blade positioning lever when it is necessary to open the throat of the shears to make inside cuts. The blade is lowered before the machine is operated. The cutting blades are adjusted for clearance when new blades are installed; therefore, they do not need readjustment, in most cases, for different gages of sheet metal. A red safety light located near the on-off switch is

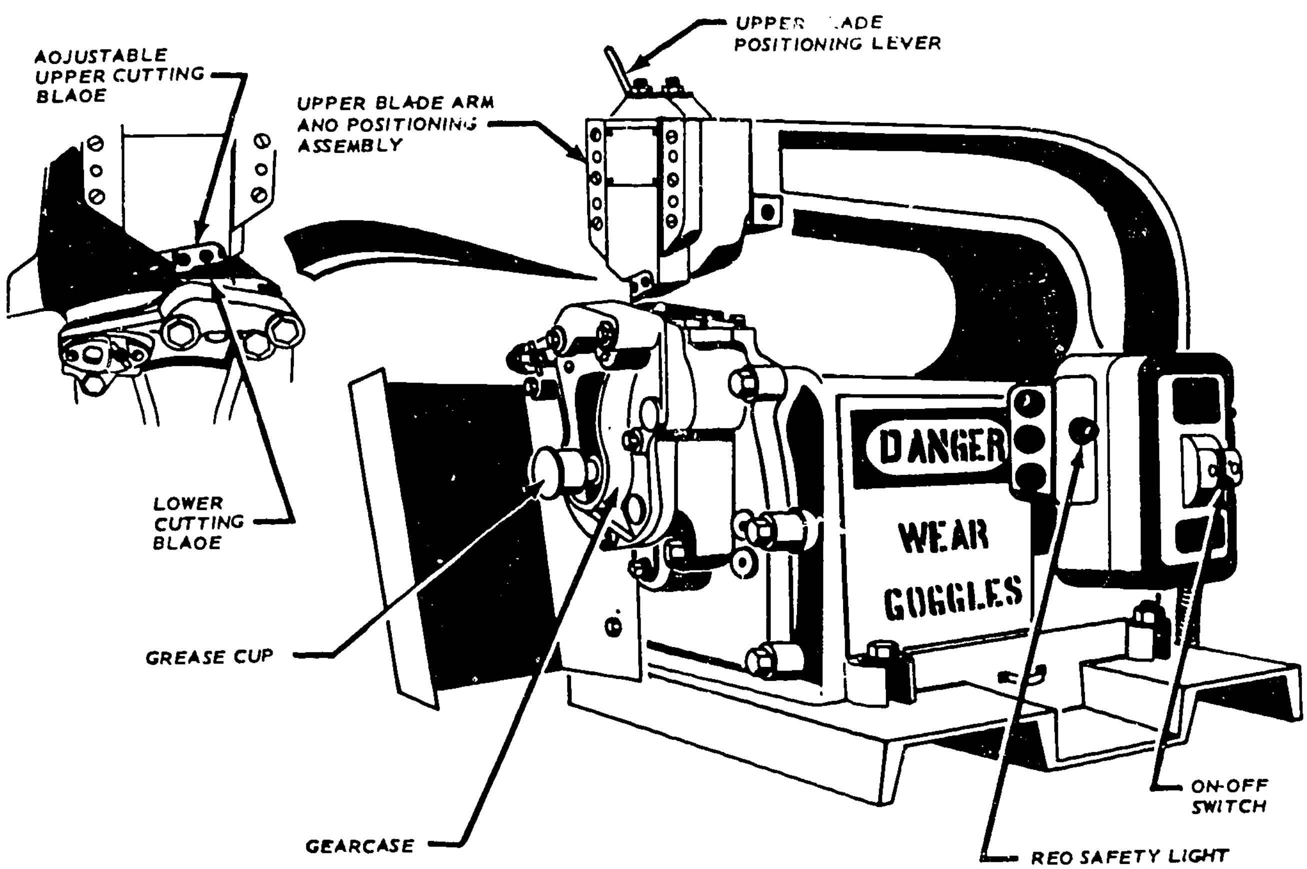


Figure 1–9. Stationary unishears.

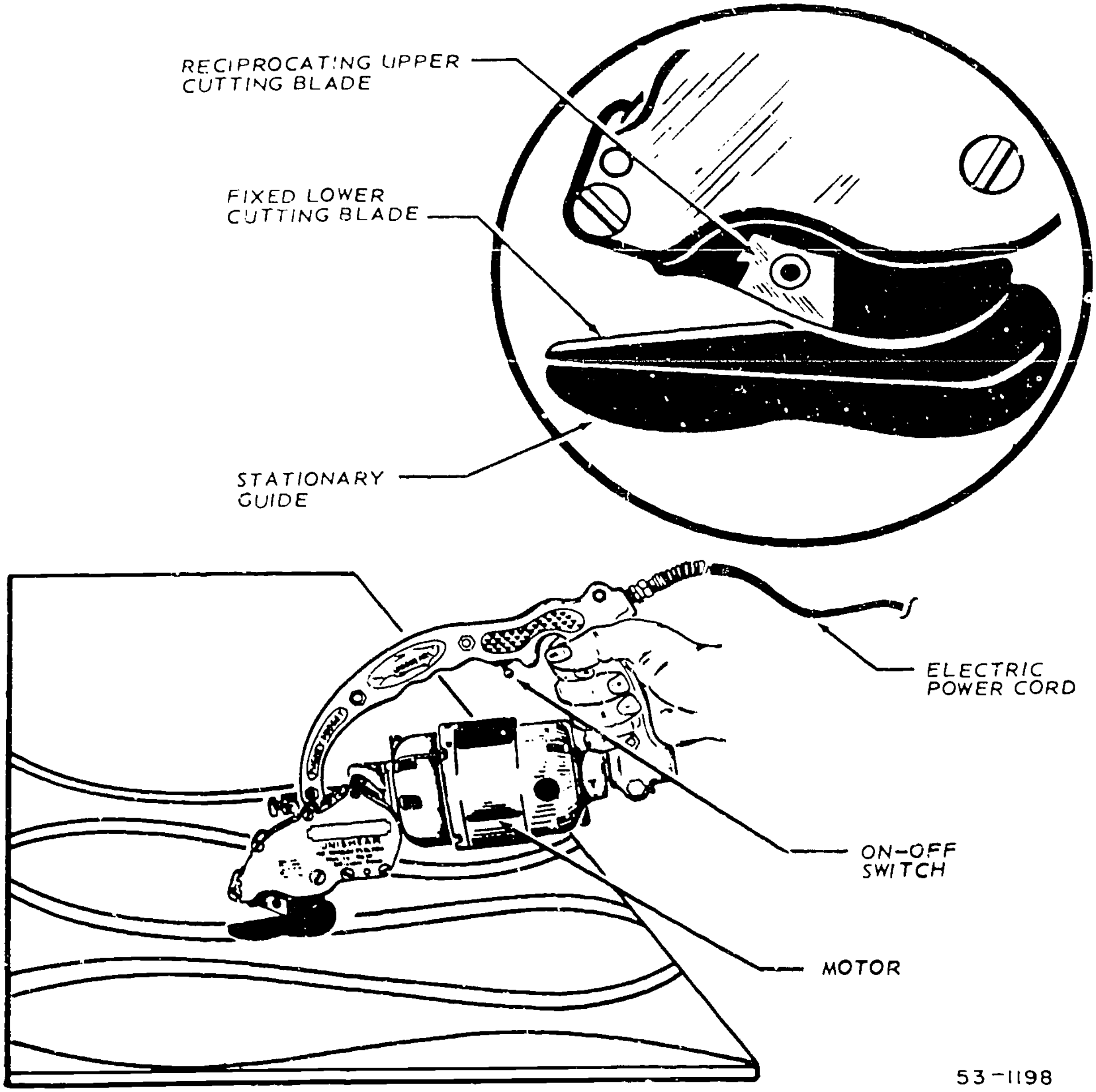


Figure 1-10. Portable unishears.

illuminated when the motor is operating. The grease cup located in the gearcase is packed with gear lubricant and must be tightened by hand to lubricate the moving parts.

In figure 1-10 you can see how irregular cuts in sheet metal are made with the electrically driven *portable unishears* on which the upper blade moves up and down. Notice how the shears are guided through the metal. This is rather easy to do because they are throatless and can be turned to the right or left without releasing the forward pressure. Portable unishears are held in your right or left hand and used in the shop or at the job if electrical power is available.

Cutting accuracy with either the stationary or portable unishears depends on the operator, so remember to always align the upper cutting blade with the line being cut in the metal. If you look a few inches ahead of the cutting blades, rather than at the blades, you should get better results. Apply just enough pressure to insure that the blades are cutting smoothly at all times. Too much pressure overloads the machine, and too little pressure causes the machine to jump from side to side, resulting in very sharp burrs.

There are several safety precautions you should observe when using either of the unishears. Always keep your hands and fingers clear of the cutting blades, and avoid the sharp

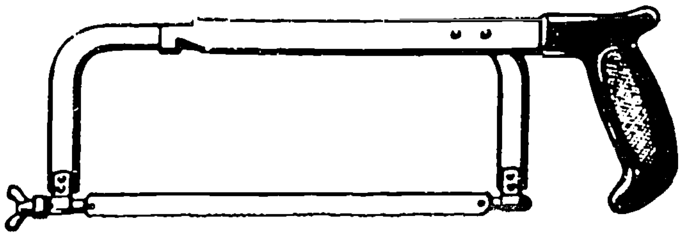


Figure 1-11. Hacksaw.

burrs. Also, keep the power cord of the portable unishears clear of the burred edges to prevent damage to the insulation. Check the three-prong connector on the power cord before connecting it to a properly grounded power receptacle.

Exercises (206):

1. What must be adjusted on a stationary unishear before using it to cut a slot for a louver?

2. What difference is there in cutting action between a stationary and portable unishear?

207. State procedures for using hand and portable hacksaws, and specify the correct blades to use for given situations.

Saws used in the sheet metal shop include bandsaws, hole saws, hand hacksaws, and power operated hacksaws. These saws are used to cut light and heavy gage sheet metal, angle iron, pipe, and thin wall tubing. Each has certain characteristics that make it better than other saws for certain jobs. As with other tools, you should select the right saw for the job. In the following four objectives we discuss saws used in sheet metalwork, including their uses, maintenance, and safety precautions. We will also discuss various saw blades with respect to materials selected for cutting.

Hand Hacksaws. The hacksaw, illustrated in figure 1-11, consists of a frame, handle, and blade. Hacksaw blades come in lengths 6 to 16 inches, although the 10-inch size is most commonly used. These blades are identified by their length and number of teeth per inch (or pitch). Blades with 14, 18, 24, and 32 teeth per inch are available. Blades are made of high-grade tool steel which may be flexible or all hard. The flexible blades have only hardened teeth, whereas all-hard blades have hardened teeth and blades. Blade selection involves finding the right type for the job at hand, as illustrated in figure 1-12. An all-hard blade is best suited for sawing brass, tool steel, cast iron, and heavy cross sections of material. Flexible blades are recommended for sawing hollow shapes and material having thin cross sections. The selection of a blade by its pitch is important, as illustrated in figure 1-12. A blade with 14 teeth per inch is recommended for cutting cold roll and structural steel. The 18-teeth-per-inch blade is recommended for solid stock aluminum and cast iron. The 24-teeth-per-inch is recommended for cutting thick wall tubing, pipe, channel iron, and angle iron, as well as brass and copper. The blade you will use most often is the 32 teeth per inch, which is recommended for thin wall tubing and light gage sheet metal.

Always remember to install the blade in the frame with the angle of teeth forward (away from the handle). When sawing, hold the saw at an angle that will allow at least two teeth to contact the cutting surface at all times. Use long strokes and apply just enough pressure on the forward stroke to cause each tooth to cut. Forty or fifty strokes per minute are sufficient to insure a good cut.

Portable Power Saw. There are several types of portable power saws on the market. We discuss only one, the two-speed Porta-band, shown in figure 1-13. This is a 110-volt 60-cycle electric power bandsaw that is as portable as any electric drill. This item, if used properly, may save many hours, both on the job and in the shop. The blade is installed with the teeth pointing toward the work rest. To select the proper blade, follow the same rules as you do for a hand hacksaw. For most cuts, use the high speed, and for problem cuts use the low speed. To make a cut with a Porta-band saw, position the item to be cut so that it touches both the blade and work rest. Next, lift the saw just enough to raise the blade off the work and depress the switch trigger, then let the weight of the saw do the cutting. Keep the work rest against the work. A slight pressure may be needed on some jobs. Too much pressure results in an improper cut.

While the saw does the cutting, you must keep it straight. When the cut is completed, release the switch trigger. This saw, as with many other items in the metal shop, can be operated left or right handed. Always store this item in a case or cabinet to protect the blade and not damage other tools.

Exercises (207):

1. How should you install the blade in a hand hacksaw?

2. How do you use the hand hacksaw to cut a piece of metal?

3. How do you use the portable hacksaw?

4. What is the pitch of the blade you should use to cut cold roll and structural steel?

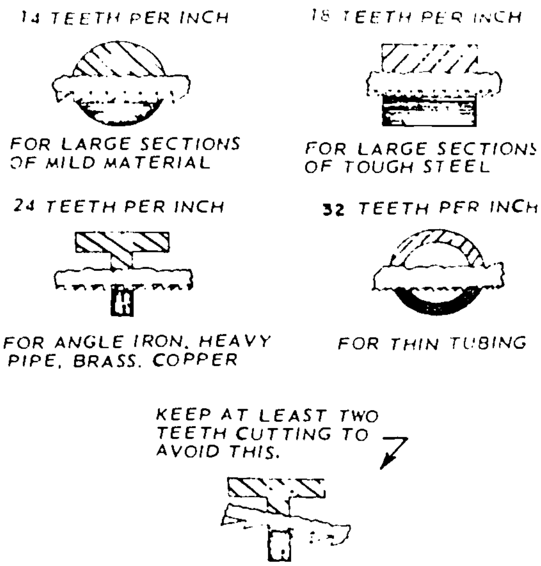


Figure 1–12. Correct sawtooth selection.

5. What is the pitch of the blade you should use to cut thick wall tubing, pipe, channel iron, angle iron, brass, and copper?

6. When you must cut thin wall tubing and light gage sheet metal, which blade should you use?

208. State operating procedures of the power hacksaw and cutoff saw.

Power Hacksaws. Power hacksaws are designed to cut pipe, angle iron, bar stock, and heavy plate. The power hacksaw is equipped with an adjustable viselike clamp to secure the material being cut. The clamp can be set for various miter cuts but is used to make 90° cuts most of the time. The blades are approximately 1 inch wide and come in various lengths. The number of teeth per inch for power hacksaw blades is selected by the same criterion as for hacksaw blades. As with other machines, you should read the operator's instructions or the technical manual before using this machine.

Before starting the power hacksaw, be sure that the material is clamped securely to prevent binding and breaking of the blade. The material thickness adjustment is set in various notches according to the material thickness. A blade broken while the saw is operating may shatter and endanger personnel. If your power hacksaw is equipped with a blade lubricating device, be sure to keep the fluid strainer clean and to mix the cutting oil according to the

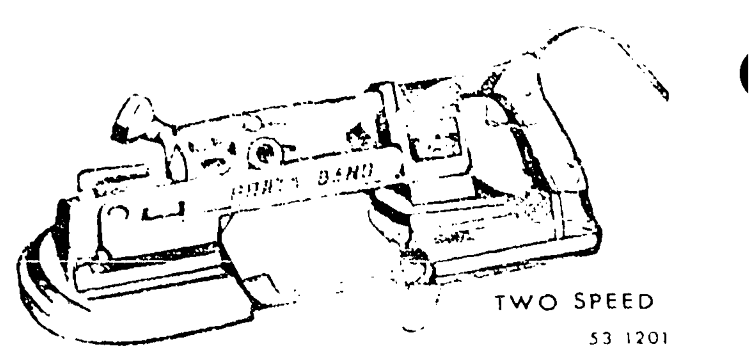
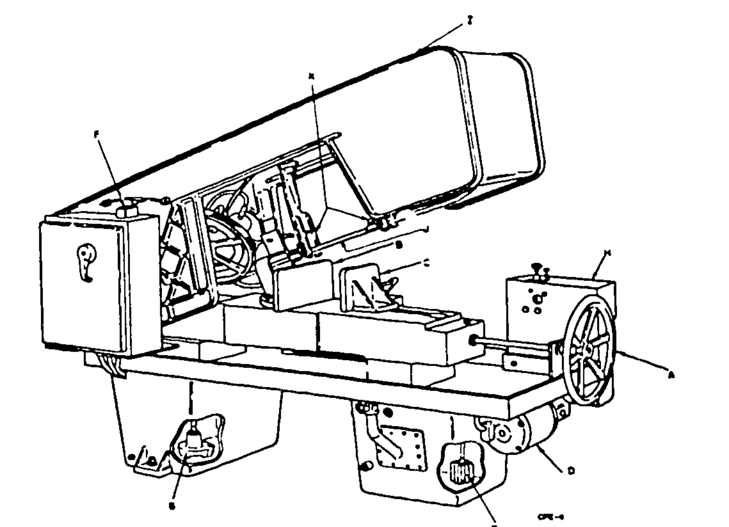


Figure 1–13. Porta-band saw.

manufacturer's specifications. Proper use of cutting oil means longer blade life and improved performance of the saw.

Cutoff Bandsaw. The cutoff bandsaw illustrated in figure 1-14 is used to cut the same type of material as the power hacksaw.

To make a cut, with a cutoff saw like the one illustrated in figure 1-14, raise the blade and secure material between the vise jaws (fig. 1-14,B, and C) by turning the vise handwheel so as to apply pressure on the jaws. Start the saw and adjust the raise and lower handle to bring the blade down slowly until it starts to cut. Adjust the feed pressure control if necessary for the proper cutting speed for the job. As with the power hacksaw, angle cuts can be made by changing the position of the vise jaws. This type of saw is operated by hydraulic pressure supplied by the motor and pump assembly (fig 1-14,D). Hydraulic pressure powers the hydraulic cylinder used to raise and lower the cutting blade and apply feed pressure. When the cut is complete the limit switch should turn the machine off automatically. Remove the cut material from the saw and clean the saw and area.



A. Vice handwheel
B. Stationary vice jaw
C. Moving vice jaw
D. Pump and motor assembly
E. Oil filter
F. Limit switch
G. Coolant pump
H. Control panel

Figure 1–14. Power cutoff saw.

Be sure to follow the manufacturer's recommendation for saw blade coolant fluid, used to cool the blade. When multiple cuts are made you can save time by using the adjustable stop.

Exercises (208):

1. When using the power hacksaw or cutoff saw, what must you do to prevent the material from binding and breaking the blade?

2. What must you do to lengthen the life of the blade on the power hacksaw?

3. How do you control the cutting speed on the power cutoff saw?

4. What must you adjust before making angle cuts on a power cutoff saw?

209. State the use of an upright bandsaw, and cite factors controlling the quality of its products.

Upright Bandsaw. One of the most versatile machines your shop could have is the upright bandsaw (sometimes referred to as a contour machine), such as the one in figure 1-15. This machine can be used to cut irregularly shaped objects from sheet metals, various extrusions, and blocks of metal, as well as most nonmetallic materials (wood plastics, etc.). The quality and precision of the work produced on this machine depends almost entirely on the skill and knowledge of the operator. If it is properly set up for a particular job and the work is properly guided and fed into the blade, a high degree of accuracy can be obtained easily. In the objective to follow, we will discuss some of the basic parts of the upright bandsaw, how to set it up, and how to operate the butt welder (used to weld new blades).

Exercises (209):

1. What types of material can be cut on an upright bandsaw?

2. On what does the quality and precision of work produced on an upright bandsaw depend?

210. Cite procedures for setting up an upright bandsaw for use.

Upright Bandsaw Operation and Setup. Before operating the machine, you should thoroughly understand its operating features. Make sure that you are familiar with all the controls and their functions (study fig. 1-16). A thorough knowledge of the machine is required to avoid damaging it or injuring yourself. For personal safety, certain rules must be followed. You should never wear watches or rings. Your should roll up your sleeves and wear eye protective devices Personal safety hazards and precautions will be explained as various machining operations are covered.

Cutting action. The saw band passes over the upper saw wheel and below the drive wheel, as shown in figure 1-16. As the saw band passes down past the work table the teeth are pointing down and as work is pressed against the teeth they will cut.

Guide blocks. Guides are provided to guide and support the saw band above and below the section where the cutting action occurs. The saw guide block assembly consists of a cast iron guide block, hardened steel inserts, and a roller.

The upper guide block has two screw holes and is mounted on the saw post. The lower guide block has one screw hole and one aligning pin and is mounted on a keeper block below the saw table. The saw guide inserts are mounted in grooves machined in the guide block. Two thrust rollers, one on the upper guide block and another on the lower guide block, prevent the saw band from springing under the pressure of the cut.

Guide inserts. The saw guide inserts are made of hardened tool steel and are available for every size of saw band. The size of the inserts must correspond to the size of the saw band. When the ends of the inserts become worn, they can be reground to an angle of 45°.

To mount saw guide inserts in the guide block, first mount the left-hand insert in the block by using an insert gage, as shown in figure 1-17, to position the insert. Then, use an insert gage as a thickness gage and position the right-hand insert, as shown in figure 1-18. Finally, mount the upper guide block on the saw post and the lower guide block on the keeper block.

Positioning. When you place the saw band over the upper wheel and below the drive wheel, it should align directly in the slots between the saw guide inserts. Tilting the upper wheel causes the band to "track" or move into the desired location. Tilt the upper wheel by means of the tilt screw until the back of the saw band just touches the thrust roller. Then, lock the wheel in place with the tilt locknut, which is the large diameter nut that encircles the smaller sized tilt screw.

Tension. You adjust the tension of the saw band by raising or lowering the upper wheel by means of the handwheel, shown in figure 1-16. Keep the saw band tight to prevent it from twisting and to keep it sawing straight. A new saw band stretches slightly after use and must be readjusted for the proper tension adjustment. You must rely on your experience to guide you. Generally speaking, it is better to have the band too tight than too loose. (NOTE:

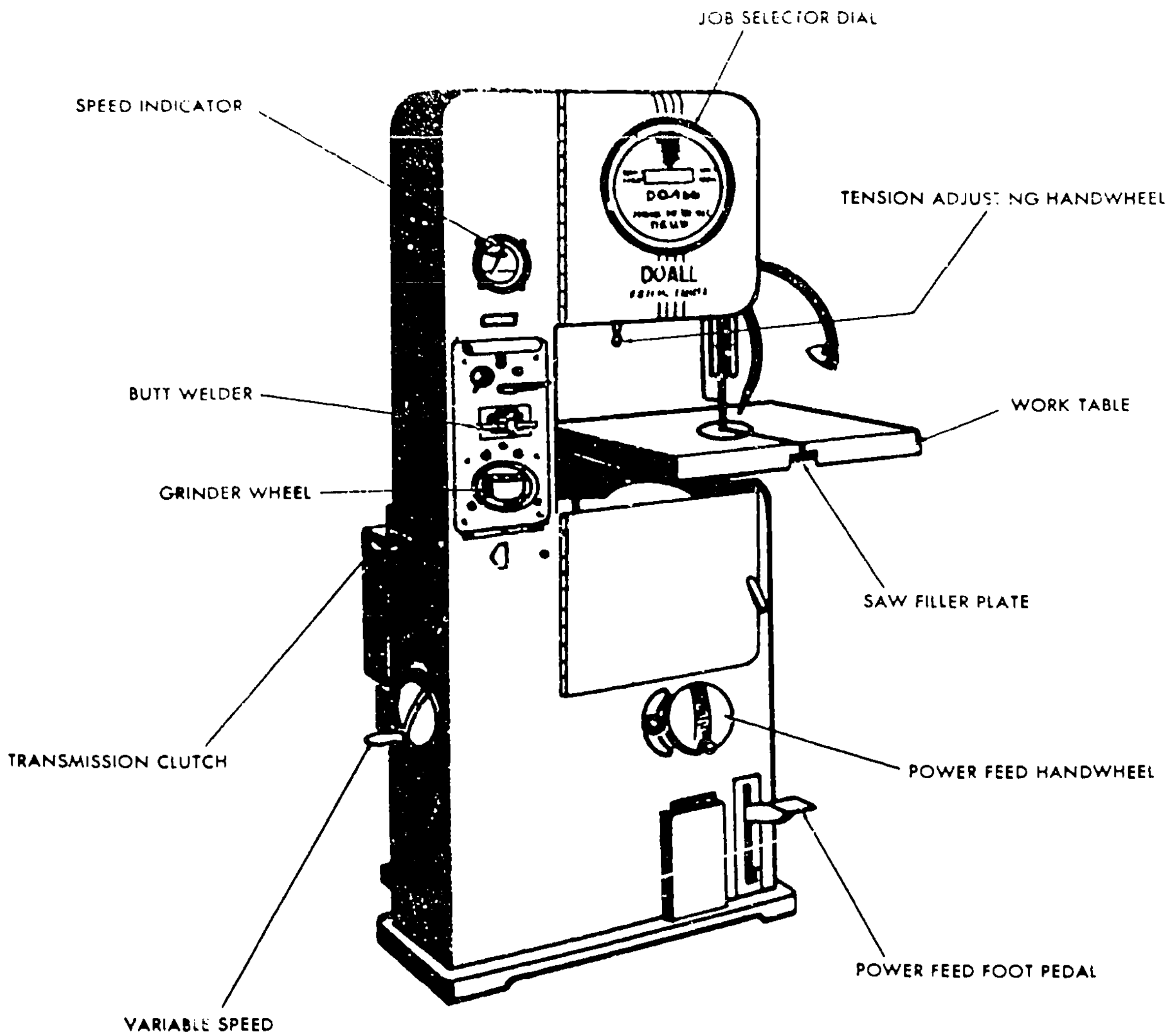
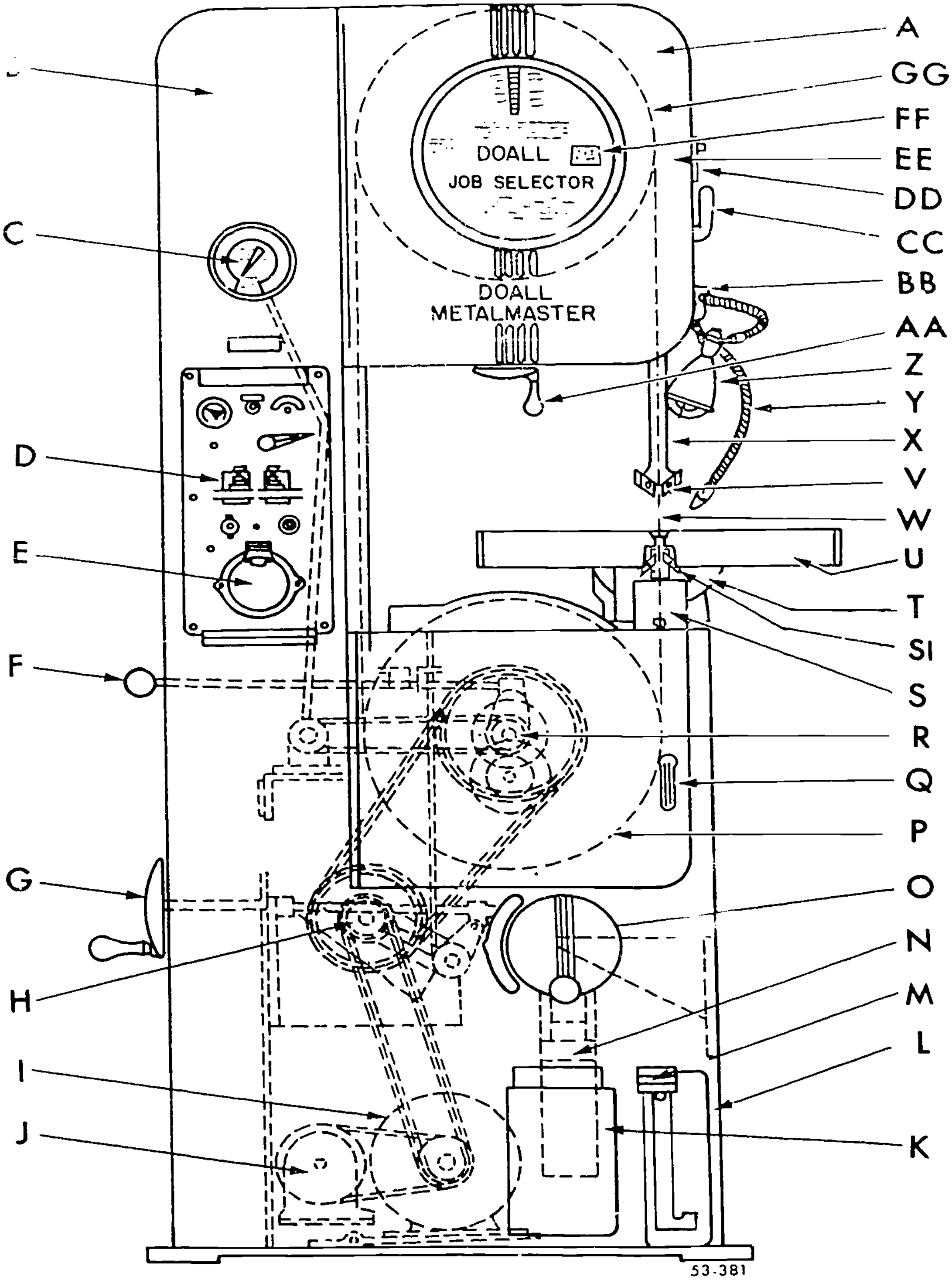


Figure 1–15. Upright bandsaw.



A. Head
B. Column
C. Speed indicator
D. Butt welder
E. Grinder
F. Shift lever
G. Speed change handwheel
H. Variable speed unit
I. Drive motor
J. Air pump
K. Chip box
L. Base
M. Power feed foot pedal
N. Power feed weight
O. Power feed adjustment handwheel
P. Drive wheel
Q. Lower wheel door
R. Gear transmission
S. Chip baffle
T. Graduated plates for table tilt
U. Table
V. Upper saw guides
W. Saw band
X. Post
Y. Air jet
Z. Table lamp
AA. Band tension handwheel
BB. Magnifier outlet
CC. Door latch
DD. Drive motor switch
EE. Upper door
FF. Job selector
GG. Upper saw wheel
SI. Lower saw guides

Figure 1–16. Components of an upright bandsaw.

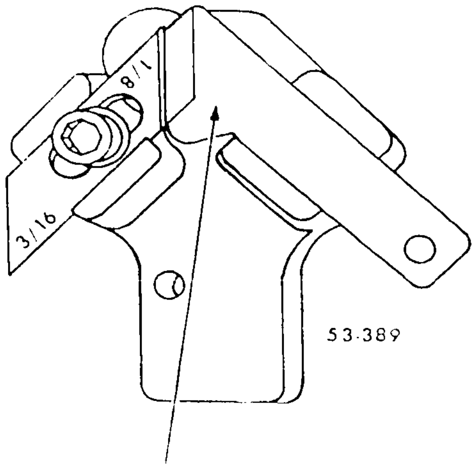


Figure 1–17. Installing left insert.

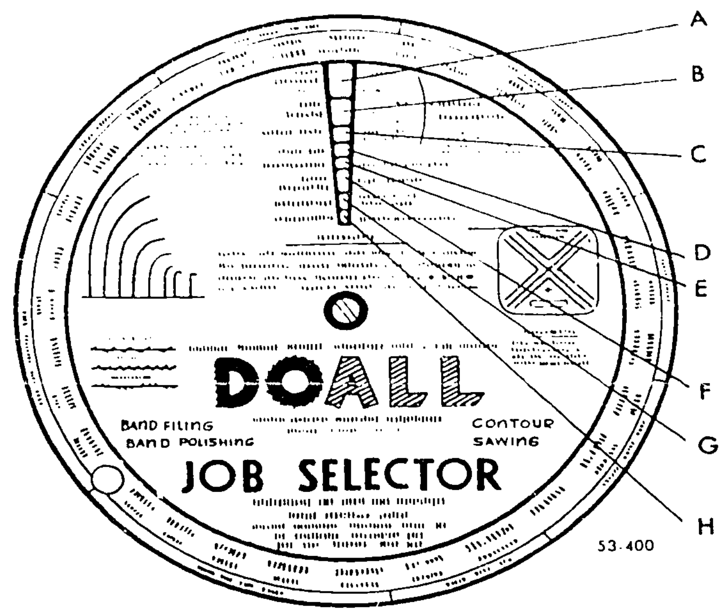


Figure 1–19. Job selector dial.

Overtightening the saw band can cause it to break or cause excessive wear on the wheel tires. Use extra care when you adjust the tension of bands less than 3/16 inch in width.)

Mounting. The first step in mounting a saw band is installing the proper size inserts on the upper and lower guide blocks, as shown in figures 1-17 and 1-18. Open the upper and lower wheel access doors, remove the filler plate from the table slot, and mount the upper and lower guide blocks shown in figure 1-16. Place the right-hand portion of the saw band over the upper wheel and below the drive wheel. Use the handwheel to set the tension just tight enough to keep the band on the wheels. Then, check to insure that the saw band is positioned between both the upper and lower sets of inserts. After loosening the tilt locknut, raise the upper wheel by hand and use the tilt screw to tilt the upper wheel until the back edge of the saw band contacts the thrust roller on the guide block. The moving band should cause the roller to turn, but light finger pressure should stop the roller from turning. (NOTE: The transmission should be in NEUTRAL so that it can be turned by hand.) Once the band is tracking (moving between the inserts and rotating the thrust roller) correctly, lock the tilting wheel by means of the tilt locknut. Adjust the tension of the saw band, replace the filler plate in the table, and close the upper and lower doors.

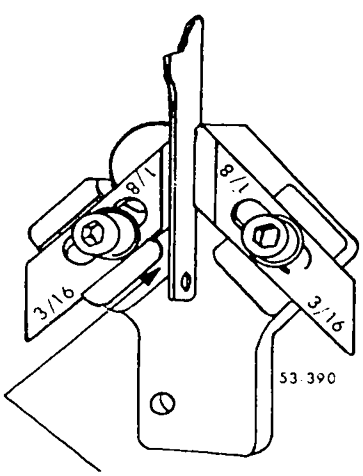


Figure 1–18. Installing right insert.

Job selector. To pick the right blade and velocity (blade speed), check the job selector as shown in figure 1-19. The job selector will indicate the velocity, pitch, set, and temper for each type of work. Other information that can assist you in selecting the proper blade is located on the job selector.

Variable speed unit. The variable speed unit is located within the base of the machine, as shown in figure 1-16. This unit consists of two V-type pulleys which are mounted on a common bearing tube. The two outside cones of the pulleys are fixed, but you can shift the middle cone by turning the speed change handwheel. The variable speed unit can only be adjusted with the motor running. When you shift the middle cone, you cause the diameter of one pulley to increase and the diameter of the other pulley to decrease. This slowly changes the ratio between the two pulleys and permits you to gradually increase or decrease the speed of the machine. The variable speed unit is connected to a transmission which has high- and low-speed ranges. You can obtain a greater number of speeds by shifting the transmission gears and the inner cone of the variable speed unit.

Now that the machine is ready, are YOU? To operate a contour machine, you should first insure that the transmission shift lever is in NEUTRAL. Only then should you start the drive motor and shift the transmission lever to the desired position.

CAUTION: Never attempt to shift the transmission selection lever except at the very lowest speed in the range being used (50 fpm or less).

Turn the speed change handwheel clockwise until the desired speed is indicated on the speed indicator. Never turn the speed change handwheel unless the motor is on and the transmission is engaged. When you stop the machine, reduce the speed as low as possible and shift the transmission lever to neutral. *Then* turn the motor off.

Exercises (210):

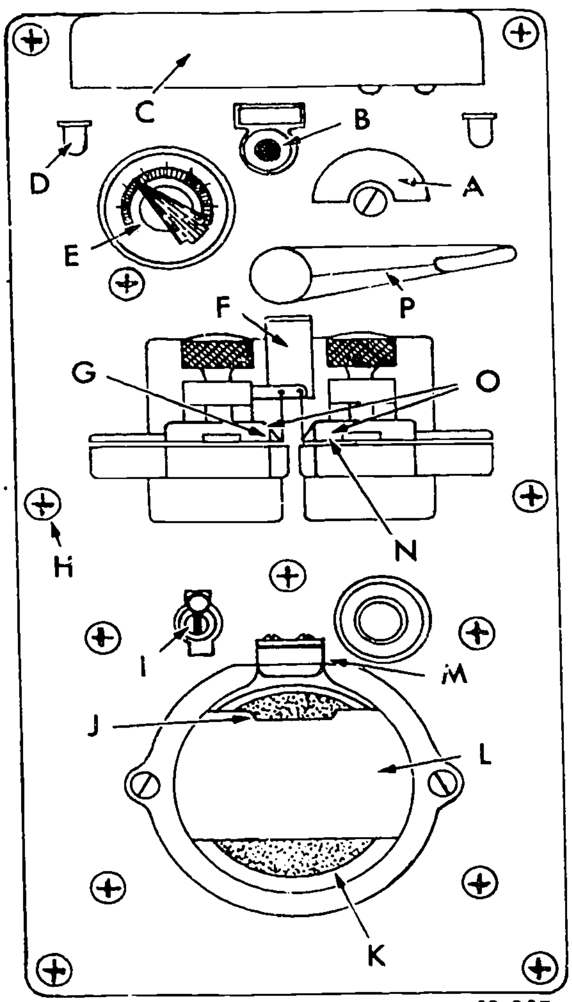
1. On what is the lower guide block mounted?

2. What three items are mounted on a guide block?

3. What is the first step in mounting a saw band?

4. What is the hard-and-fast rule for setting tension?

5. What part of the pulley moves when you adjust the speed change handwheel?



53-387

A. Line voltage regulator
B. Etching pencil ground bushing
C. Lamp
D. Oil cups (for grinder)
E. Tension control
F. Flash guard
G. Stationary jaw
H. Mounting screws
I. Lamp and grinder switch
J. Step for squaring saw bands
K. Grinding wheel
L. Grinding wheel guard
M. Weld thickness gage (2 gaps)
N. Movable jaw
O. Welder jaws
P. Welding operating lever

Figure 1–20. Butt welder.

211. Identify parts of the butt welder by their function, and state procedures to follow when using the butt welder.

Welder. Saw blades are usually received in the shop in 100-foot-long strips. They must be cut to the required length, and the ends must be welded together to form an endless loop. The length required for a particular saw may be found in the instruction manual or in the technical order for the machine. It is sometimes given on a data plate that is mounted on the machine column.

The butt welder, which is built into the column of the machine, is used to weld new bands and to rejoin bands that have been broken. The butt welder panel assembly, shown in figure 1-20, shows the general arrangement of the panel as viewed by the operator. A 15-watt lamp (C) is housed at the top of the panel. On either side of the panel, you will note two oil fillers (D). The spring cap oil fillers are connected by means of copper tubing to the sleeve bearings of the grinder motor. Below the oilers is the tension control dial (E) or weld selector, which regulates the tension of the movable jaw for each width of saw you are welding. This dial is mechanical and enables you to control the force with which the movable jaw (N) moves toward the stationary jaw (G). Wider saws require greater force than smaller ones. Too much force on small saw bands will cause the ends to overlap. To the right of the tension control is the line voltage regulator switch (A). The line voltage regulator compensates for voltage variation in the electrical power supply. The voltage regulator permits the proper amount of heat to be generated at the weld by controlling the current flow between the saw clamps. Use a screwdriver to change the voltage regulator setting. Move the index point on the regulator switch toward the MORE position to increase the heat. Move it toward the LESS position to decrease the heat. The line voltage regulator seldom needs to be reset if the current supply remains fairly constant.

Directly below the line voltage regulator switch is the welder operating lever (P). The operating lever turns the current on and moves the movable clamping jaw toward the stationary clamping jaw. The movable jaw travels approximately 0.040 inch, forcing the molten ends of the saw together and welding them into a solid unit. The

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clamping jaws hold the ends of the saw band during the welding operation and the welded portion of the saw band during the annealing operation.

The annealing switch button, which is usually red, is located below the clamping jaws. You hold this springloaded button in the depressed position to heat the weld to the annealing temperature.

You use the grinding wheel (K) on the welder to square the ends of the saw band before welding them together and to remove the excess metal from the weld after the welding so that its thickness is no greater than that of the rest of the band. A gage (M) located above the grinding wheel is used to check the saw band thickness. The portion of the saw band behind the sawteeth will pass freely through the gage when the weld is correctly ground. (CAUTION: Always wear eye protection when using this grinder.)

To weld a saw band, first cut off the band to the required length and follow this procedure:

a. Always cut the band from the back toward the teeth. Grind the ends of the band square against the side of the grinding wheel. Then, insert the ends of the band into the jaws of the butt welder with the teeth pointed toward you and clamp them in this position by turning the thumb screws. Set the tension control switch for the width of band and the line voltage regulator for the required welding heat. After placing the flashguard down, depress the operating lever to complete the weld and hold it down until the weld has cooled. BEFORE releasing the operating lever, loosen the stationary jaw thumbscrew and then release the band from the movable jaws. Move the band forward (toward the operator) to the wide gap annealing position. Reclamp the band just behind the saw teeth, with the newly welded joint centered between the jaws.

b. Turn off the welding panel light so that the correct annealing heat is visible. Now press the annealing switch button until the welded area becomes a dull cherry red. Cool the annealed portion gradually by pressing the annealing button several times during the cooling period. After it has cooled enough to be safely handled, remove the band from the jaws and grind the excess weld off both sides of the band. Grind until the welded joint is the same thickness as the band. Use the gage directly above the grinding wheel to check for correct thickness.

c. Do not grind the teeth. When you finish welding a saw band, you should coil and store it in the storage cabinet. Coil the saw band by holding the band in one hand with the other end of the loop just touching the floor. Then place your foot on the portion of the band in contact with the floor just hard enough to prevent the band from moving. At the same time, twist the band by rotating your wrist 1½ to 2 times while lowering your arm. The band will automatically coil itself, usually into three loops.

Exercises (211):

1. Which component compensates for voltage variation in the electrical power supply?

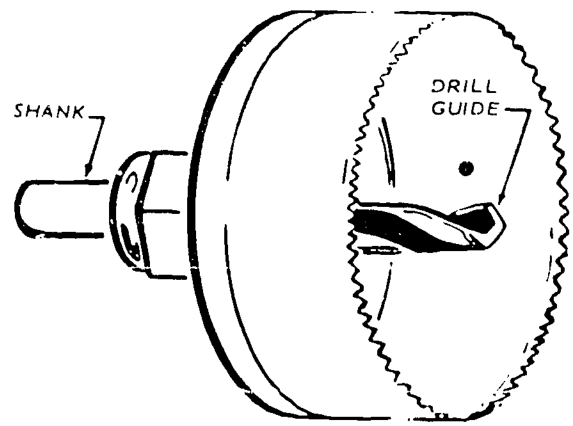

Figure 1-21. Hole saw.

2. What controls the tension of the movable jaw for each width of saw you are using?

3. What should you do before releasing the weld operating lever after a weld is made?

4. What two steps must you do after the welding step?

212. State the purpose of a hole saw and tell how to use a circle cutter.

Hole Saws. Hole saws such as that illustrated in figure 1-21 are used to cut holes in light gage sheet metal and wood. They may be purchased in sizes up to 4 inches in diameter. A 1/4-inch electric drill is recommended for hole saw sizes up to 1½-inches and a half inch electric drill is recommended for sizes up to 4 inches in diameter. The hole saw is useful for jobs such as venting hot water heaters, because most heater vents are 3 inches in diameter. Another use is for cutting holes in fire doors or partitions, since these items are usually covered with light gage metal. When drilling with hole saws, use only enough pressure to cut evenly. Too much pressure causes the saw to bind and create excessive strain on the electric drill motor.

Circle Cutters. Circle cutters, like that illustrated in figure 1-22 are used with drill presses in a similar manner and purpose as hole saws. However, the circle cutter differs from the hole saw in that the circle cutter may be ajusted for different sizes and depths of cuts. In figure 1-22, you can see the setscrew wrench, which is used to loosen and tighten the setscrews or to remove the twist drill. The adjustable arm enables the circle cutter to be used for cutting circles of different sizes, and raising or lowering the cutting blade makes it possible to regulate the depth of the

cut. During use, the circle cutter must be perpendicular to the material being cut, and the material must be held securely or clamped. Circle cutters are sometimes called fly cutters.

Exercises (212):

1. What are the use(s) of a hole saw?

2. Briefly, tell how to use a circle cutter.

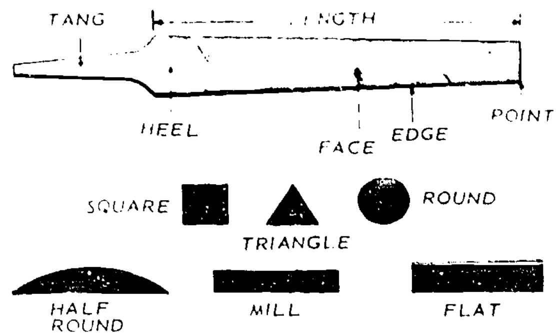

Figure 1-23. Shapes of files.

213. Identify the types of files by their uses.

In previous sections, we have frequently mentioned the metal burrs that are often produced by cutting equipment. You were cautioned to avoid cutting your hands and fingers or snagging your clothing on these burrs. These rough edges can be removed with files or grinders. Other uses for files and grinders are discussed in this section.

Files. No shop nor individual toolkit is complete without several files. Figure 1-23 illustrates six shapes of files most used by sheet metalworkers, as follows:

(1) Flat file—used to file flat surfaces and for other fast-cutting operation.

(2) Mill file—especially adapted for finish filing.

(3) Triangular, or "three-cornered", file—used in filing internal angles and cleaning out corners.

(4) Square file—most useful in finishing the bottom of slots.

(5) Round file (or rattail)—used for enlarging round holes.

(6) Half-round file—used where other files will not fit.

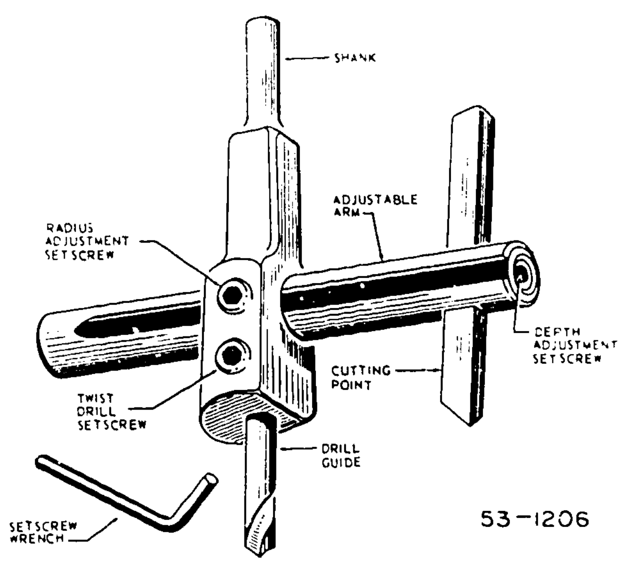

Figure 1-22. Circle cutter.

Files are very useful tools, but their life and usefulness depend a great deal upon the way they are used and maintained. They should be cleaned frequently with a file card or brush and kept separate from other tools to prevent damage to the other tools.

Files are usually made in two types of cut—single-cut and double-cut—as shown in figure 1-24. The single-cut file has a single row of teeth extending across the face at an angle from 65° to 85° to the length of the file. The size of the cuts depends on the coarseness of the file. The double-cut file has two rows of teeth which cross each other. For general work, the angle of the first row is from 40° to 45°.

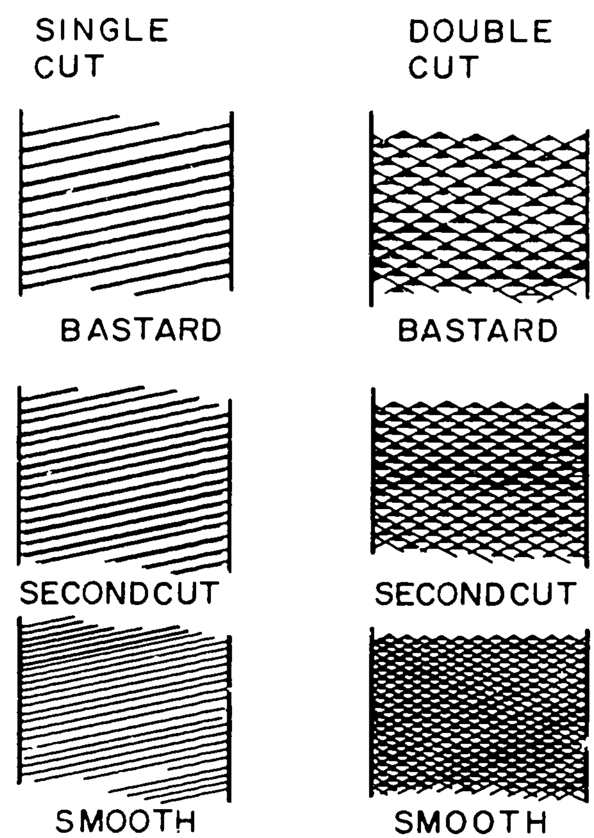

Figure 1-24. Types of file cuts.

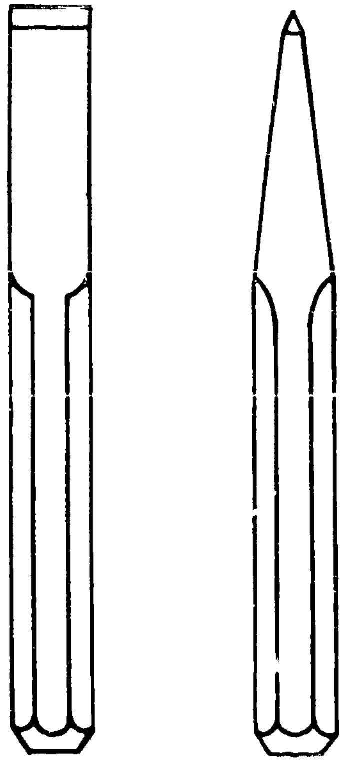

Figure 1-25. Flat cold chisel.

The first row is generally referred to as "overcut", the second row as "upcut," the upcut being somewhat finer and not so deep as the overcut.

Single-cut files are recommended for sharpening cutting tools, such as shear and snip blades. Light pressure should be applied to single-cut files to obtain a smooth finish. Double-cut files are used when a rough finish is permissible and heavy pressure may be applied for fast cutting. One of the factors in selecting a file is the composition of the metal to be filed. An example is stainless steel, which is hard and requires a file with a deep upcut and a fine overcut.

Exercises (213):

1. What type of file would you use to clean out a rough slot in 1/4 inch-thick black iron?

2. What type file would you use for finish work that is to be exposed?

214. State characteristics of chisels, and tell how to dress chisels and grinders.

Chisels. If you can't use snips or a hacksaw for cutting, the cold chisel will probably do the job. Although cold chisels come in a variety of blade shapes, you will most often use the flat blade type, which is illustrated in figure 1-25. This chisel can be used in restricted areas for such jobs as making a slot or starter hole in sheet metal for snips or shears. Other uses for cold chisels include splitting rusted nuts from bolts and cutting wire, strap iron, small bars, and rods. A cold chisel may be used to cut any metal softer than itself. The size of a cold chisel is identified according to the width of the cutting blade. In sheet metalwork the cold chisels most often used include the 1/4-inch, 1/2-inch, and 1-inch sizes. Cold chisels are usually made of octagonal (eight-sided) tool steel bar stock and are carefully hardened and tempered.

Keep your chisels sharp and the edges ground at the proper angle (60° to 70°). When sharpening a chisel, hold it against the wheel with very little pressure to avoid overheating. Dip the point in water often enough to keep it cool. Otherwise, the heat generated will "draw" the temper of the steel. If this happens, the cutting edge will become soft and useless until rehardened and tempered.

Through normal use, the head of the cold chisel will spread out until it looks like a ragged mushroom. This spreadout head is rough and can "ream out" the inside of your hand if the chisel slips. Also, blows of the hammer may break off pieces from the overhanding mushroom and cause injury. Keep the head of the chisel dressed to eliminate these hazards.

Grinders. Electrically driven grinders, such as that illustrated in figure 1-26, may be attached to workbenches or mounted on floor stands. These grinders should be equipped with eyeshields, wheel guards, work rests, power cord with ground, and good abrasive wheels. They normally have medium and fine abrasive wheels—the medium for heavy cuts and the fine for finish work. Bench grinders are usually equipped for grinding twist drills, chisels, and other small jobs. The cooling tank is filled with water so that the object being ground can be kept cool.

Grinders are very hazardous; therefore, you should be careful when operating them. You should not grind on the side of wheels, and you must not use the work rest more than 1/8 inch from the grinding wheel. Even if the grinder is equipped with an eyeshield, you should wear a face shield during operation. When grinding, use only enough pressure to cut the material. Too much pressure causes undue wear to the wheel and unnecessary heating of the material being ground.

Preparing the Abrasive Wheel. Before grinding a twist drill, you should check the wheel and dress it, if necessary. The terms "dressing" and "trueing" are frequently confused. Dressing is the reconditioning of the abrasive surface of a wheel that has lost some of its cutting ability. This is caused by glazing or loading up (filling the spaces between abrasive particles) or dulling the abrasive particles. Trueing is restoring the abrasive wheel to its correct geometrical shape. Trueing is not required as frequently as dressing. The Huntington-type dresser (fig. 1-27), which consists essentially of a number of circular metal cutters mounted on a spindle in a holder, is the most commonly used type of offhand dressing tool. Figure 1-27 shows this tool The dulled abrasive grains and any loading of metal or foreign material are being removed so that sharp grains will

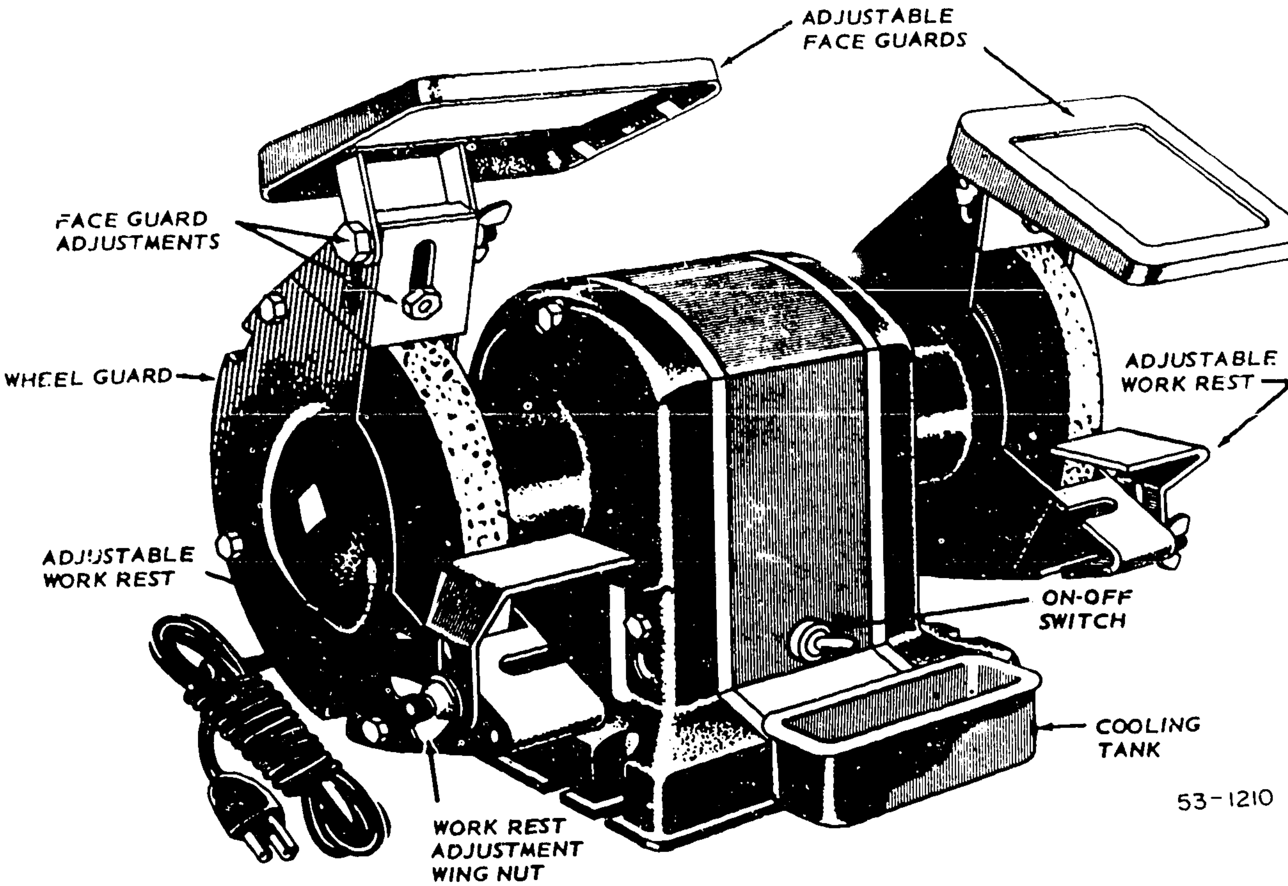

Figure 1–26. Bench grinder.

be presented to the work. Before using the wheel dresser, position the tool rest so that the legs of the dresser may be hooked over it, as shown in figure 1-27. When you turn on a grinder, always stand aside until it attains operating speed. If there is a defect in a wheel, it will disintegrate. To dress a wheel as in figure 1-27, you hold the dresser firmly against the rest and as you raise the handle of the dresser to make contact with the wheel, move it in a steady motion back and forth across the face of the wheel. Too much pressure causes excessive sparking and rapid cutter wear.

Exercises (214):

1. How is the size of a cold chisel identified?

2. What would happen if you overheated a cold chisel when you sharpened it?

3. When you dress the head of a chisel, what do you grind?

4. While dressing an abrasive wheel, how should the wheel dresser be held?

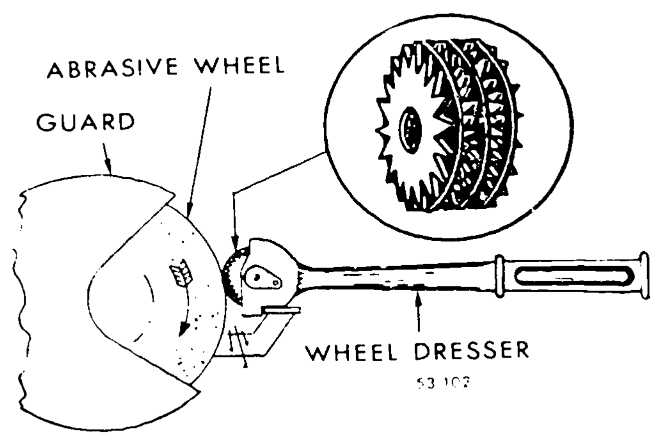

Figure 1–27. Wheel dresser.

Drilling, Punching, and Fastening

NEARLY ALL fabrication and installation of sheet metal components involve the drilling or punching of holes, and the use of various fastening devices. When blueprints are furnished, you must identify the fasteners and sizes specified. If they are not furnished, you must be able to determine which fasteners and tools are suitable for the job.

This chapter concerns the tools and equipment used to drill and punch holes in sheet metal. The drilling equipment includes twist drills, masonry drills, hand drills, portable electric drills, and drill presses. The hole punching equipment includes hand punches and rotary punches. Related equipment that we also discuss includes countersinks, reamers, and rotary files. It is important that you learn the proper use of each of these items. We also discuss a number of common fasteners and fastening systems that you must select from.

You can apply the information you gain from this chapter later in this CDC when you study fabricating, installing, and repairing sheet metal components. Following the completion of on-the-job training, you will frequently use this information as you perform the various work assignments in the metal fabricating shop.

2-1. Drilling Equipment

It is important for you to use the correct terms when speaking or writing about drilling equipment. For example, the word "drill" when used loosely may cause some confusion in communication. A twist drill is the part that cuts the hole, whereas the hand drill, portable drill (air or electric), or drill press supplies the rotary motion and torque to rotate the twist drill.

215. State structural characteristics of a twist drill, and tell how to use and sharpen the twist drill.

Twist Drills. Twist drills may be made of carbon steel or of high-speed alloy steel. Although carbon steel twist drills are satisfactory for general work, high-speed twist drills are recommended for most jobs in sheet metalwork, since they stay sharp longer and do not dull from the heat generated during the drilling operation. If you are drilling holes in hard or thick metal, you should apply a few drops of cutting oil in the hole to lubricate and prevent excessive heating. If a cutting oil is used, high-speed twist drills will keep right on cutting, even though they are hot. Excessive heating will also result from using a dull twist drill or from too much or too little pressure on the twist drill. If a high-speed twist drill becomes overheated, it should be allowed to cool slowly. Do not try to cool it in water, oil, or fast moving air, because the metal may crack.

Twist drill sizes are expressed in terms of millimeters, decimals, fractions, numbers, and letters, as shown in figure 2-1. The size is stamped on the shank of the twist drill. For example, a 3/16-inch twist drill, which is often used in sheet metalwork, has a decimal equivalent size of a 0.1875 inch.

Figure 2-2 shows a twist drill with the nomenclature of its parts, including the shank, body, heel, flute, and land. A twist drill for most uses will have a lip angle of 59° and a heel angle of 12° to 15°. However, a lip angle of 68° is recommended for hard materials, such as stainless steel. Soft metals, such as brass or bronze, can be drilled with a twist drill having a lip angle between 50° to 60°. In all cases of sharpening a twist drill, both cutting edges must have the same lip angle and the same length cutting edge.

When you are drilling a hole with a twist drill installed in a hand or power drill, the chuck must be tight enough to prevent slippage. The twist drill must make a hole with its center at the exact spot desired; therefore, you should use a center punch to sink a mark deep enough to prevent the twist drill from "walking" away from the center point. (Be careful not to dimple the material by striking the center punch too hard.) Next, secure the work and place the point of the twist drill into the punch mark. After drilling is begun, you must make certain to keep the drill at right angles to the surface of the work throughout the operation. You should ease the pressure the instant the twist drill breaks through the material but continue drilling until the hole is finished. Be sure to follow appropriate procedures to keep the twist drill from overheating.

Correct twist drill grinding is an absolute must. A sharp twist drill performs more efficiently and you can attain a higher quality of work with less physical application on the drill. You cannot turn a twist drill in to Supply just because the point is dull. Drills, at this time, are classified as expendable items and can be replaced only after normal wear or breakage. We will cover one method of *sharpening* twist drills, free-hand grinding.

Free-hand grinding is done without the aid of any fixtures on the grinder. The success of this operation depends upon your skill in using various techniques.

Adjust the tool rest of the grinder to a convenient height for resting the back of your left hand while grinding. Hold the drill between the thumb and index finger of one hand and grasp the body of the drill near the shank with the other hand. Place your left hand on the tool rest, with the centerline of the drill making the desired angle with the

Milli-Meter	Dec. Equiv.	Fractional	Number	Milli-Meter	Dec. Equiv.	Fractional	Number	Milli-Meter	Dec. Equiv.	Fractional	Number	Milli-Meter	Dec. Equiv.	Fractional	Number	Milli-Meter	Dec. Equiv.	Fractional
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.15	.0059			....	.0700		50	4.0	.1575			6.9	.2716			11.0	.4331	
.2	.0079			1.8	.0709			....	.1590		21	....	.2720		I	11.11	.4375	7/16
.25	.0098			1.85	.0728			....	.1610		20	7.0	.2756			11.5	.4528	
.3	.0118			....	.0730		49	4.1	.1614			....	.2770		J	11.51	.4531	29/64
....	.0135		80	1.9	.0748			4.2	.1654			7.1	.2795			11.91	.4687	15/32
.35	.0138			....	.0760		48	....	.1660		19	....	.2811		K	12.0	.4724	
....	.0145		79	1.95	.0767			4.25	.1673			7.14	.2812	9/32		12.30	.4843	31/64
.39	.0156	1/64		1.98	.0781	5/64		4.3	.1693			7.2	.2835			12.5	.4921	
.4	.0157			....	.0785		47	....	.1695		18	7.25	.2854			12.7	.5000	1/2
....	.0160		78	2.0	.0787			4.37	.1719	11/64	...	7.3	.2874			13.0	.5118	
.45	.0177			2.05	.0807			....	.1730		17	....	.2900		L	13.10	.5156	33/64
....	.0180		77	....	.0810		46	4.4	.1732			7.4	.2913			13.49	.5312	17/32
.5	.0197			....	.0820		45	....	.1770		16	....	.2950		M	13.5	.5315	
....	.0200		76	2.1	.0827			4.5	.1771			7.5	.2953			13.89	.5469	35/64
....	.0210		75	2.15	.0846			....	.1800		15	7.54	.2968	19/64		14.0	.5512	
.55	.0217			....	.0860		44	4.6	.1811			7.6	.2992			14.29	.5625	9/16
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.6	.0236			2.25	.0885			4.7	.1850		13	7.7	.3031			14.68	.5781	37/64
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....	.0250		72	2.3	.0905			4.76	.1875	3/16	...	7.8	.3071			15.08	.5937	19/32
.65	.0256			2.35	.0925			4.8	.1890		12	7.9	.3110			15.48	.6094	39/64
....	.0260		71	....	.0935		42	....	.1910		11	7.94	.3125	5/16		15.5	.6102	
....	.0280		70	2.38	.0937	3/32	...	4.9	.1929			8.0	.3150			15.88	.6250	5/8
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.75	.0295			2.45	.0964			5.0	.1968			8.2	.3228			16.5	.6496	
....	.0310		68	....	.0980		40	....	.1990		8	....	.3230		P	16.67	.6562	21/32
.79	.0312	1/32	...	2.5	.0984			5.1	.2008			8.25	.3248			17.0	.6693	
.8	.0315			....	.0995		39	....	.2010		7	8.3	.3268			17.06	.6719	43/64
....	.0320		67	....	.1015		38	5.16	.2031	13/64	...	8.33	.3281	21/64		17.46	.6875	11/16
....	.0330		66	2.6	.1024			....	.2040		6	8.4	.3307			17.5	.6890	
.85	.0335			....	.1040		37	5.2	.2047			....	.3320		Q	17.86	.7031	45/64
....	.0350		65	2.7	.1063			....	.2055		5	8.5	.3346			18.0	.7087	
.9	.0354			....	.1065		36	5.25	.2067			8.6	.3386			18.26	.7187	23/32
....	.0360		64	2.75	.1082			5.3	.2086			....	.3390		R	18.5	.7283	
....	.0370		63	2.78	.1094	7/64	...	....	.2090		4	8.7	.3425			18.65	.7344	47/64
.95	.0374			....	.1100		35	5.4	.2126			8.73	.3437	11/32	...	19.0	.7480	
....	.0380		62	2.8	.1102			....	.2130		3	2.75	.3445			19.05	.7500	3/4
....	.0390		61	....	.1110		34	5.5	.2165			8.8	.3465			19.45	.7656	49/64
1.0	.0394			....	.1130		33	5.56	.2187	7/32	...	....	.3480		S	19.5	.7677	
....	.0400		60	2.9	.1141			5.6	.2205			8.9	.3504			19.84	.7812	25/32
....	.0410		59	....	.1160		32	....	.2210		2	9.0	.3543			20.0	.7874	
1.05	.0413			3.0	.1181			5.7	.2244			....	.3580		T	20.24	.7969	51/64
....	.0420		58	....	.1200		31	5.75	.2263			9.1	.3583			20.5	.8071	
....	.0430		57	3.1	.1220			....	.2280		1	9.13	.3594	23/64	...	20.64	.8125	13/16
1.1	.0433			3.18	.1250	1/8	...	5.8	.2283			9.2	.3622			21.0	.8268	
1.15	.0452			3.2	.1260			5.9	.2323			9.25	.3641			21.03	.8281	53/64
....	.0465		56	3.25	.1279			....	.2340		A	9.3	.3661			21.43	.8437	27/32
1.19	.0469	3/64	...	....	.1285		30	5.95	.2344	15/64	...	....	.3680		U	21.5	.8465	
1.2	.0472			3.3	.1299			6.0	.2362			9.4	.3701			21.83	.8594	55/64
1.25	.0492			3.4	.1338			....	.2380		B	9.5	.3740			22.0	.8661	
1.3	.0512			....	.1360		29	6.1	.2401			9.53	.3750	3/8		22.23	.8750	7/8
....	.0520		55	3.5	.1378			....	.2420		C	....	.3770		V	22.5	.8858	
1.35	.0531			....	.1405		28	6.2	.2441			9.6	.3780			22.62	.8905	57/64
....	.0550		54	3.57	.1406	9/64	...	6.25	.2460		D	9.7	.3819			23.0	.9055	
1.4	.0551			3.6	.1417			6.3	.2480			9.75	.3838			23.02	.9062	29/32
1.45	.0570			....	.1440		27	6.35	.2500	1/4	E	9.8	.3858			23.42	.9219	59/64
1.5	.0591			3.7	.1457			6.4	.2520			....	.3860		W	23.5	.9252	
....	.0595		53	....	.1470		26	6.5	.2559			9.9	.3898			23.81	.9375	15/16
1.55	.0610			3.75	.1476			....	.2570		F	9.92	.3906	25/64	...	24.0	.9449	
1.59	.0625	1/16	...	....	.1495		25	6.6	.2598			10.0	.3937			24.21	.9531	61/64
1.6	.0629			3.8	.1496			....	.2610		G	....	.3970		X	24.5	.9646	
....	.0635		52	....	.1520		24	6.7	.2638			....	.4040		Y	24.61	.9687	31/32
1.65	.0649			3.9	.1535			6.75	.2657	17/64	...	10.32	.4062	13/32	...	25.0	.9843	
1.7	.0669			....	.1540		23	6.75	.2657			....	.4130		Z	25.03	.9844	63/64
....	.0670		51	3.97	.1562	5/32	...	....	.2660		H	10.5	.4134			25.4	1.0000	1

CP 2

Figure 2–1. Hole and twist drill sizes.

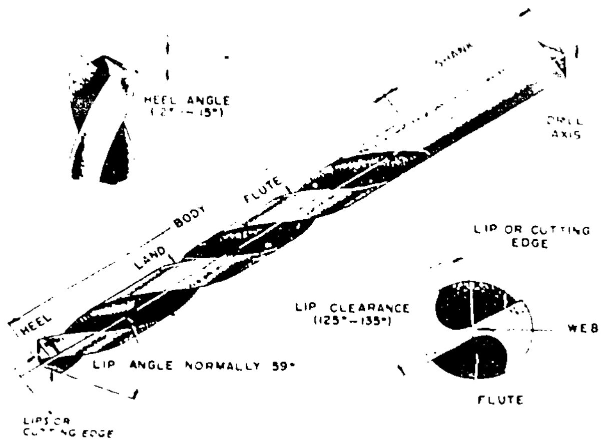

Figure 2–2. Twist drill nomenclature.

cutting face of the grinding wheel, and then slightly lower the shank end of the drill as illustrated in figure 2-3.

There are two ways of rotating the drill when grinding—counterclockwise and clockwise. The method used depends upon the individual. When rotating the drill in a counterclockwise direction, slowly place the heel of the drill against the grinding wheel. Then gradually raise the shank end of the drill and twist it in your fingers in a counterclockwise direction as the grinding wheel contacts the cutting edge. Exert only enough pressure to grind the drill without overheating.

Frequently cool the drill in water while grinding. As you rotate the drill in a clockwise direction, hold the drill in the right hand with the point against the grinding wheel at the proper angle. The left hand should hold the body of the drill in the same manner as for counterclockwise grinding. With the drill lip bearing against the grinding wheel, the right hand should push the shank of the drill slightly clockwise and push it forward slightly. Remember to dip the drill in water often enough to prevent overheating. Check the results of the grinding with a gage or equivalent tool to determine whether the cutting edges are the same length (both cutting edges must be the same length) and at the desired angle. Also, notice whether the heel is ground to an angle of 12° to 15° for cutting speed and clearance.

The thickness of the web of a drill increases as the flute approaches the shank; this adds strength to the drill. As the drill point wears away through normal use, the web at the point becomes thicker. The web at the point should be no thicker than 1/32 or 1/16 inch. Web thickness can be controlled by grinding (thinning) the web on a thin, round, or beveled edge wheel. If a special grinding machine is not available, use free-hand grinding. However, such operation requires skill and experience. Improperly sharpened twist drills are those with unequal cutting edge lengths and they will tend to produce holes with poor diameter and directional control. With these factors in mind, thin the web only when necessary. When thinning the web, grind the web from the fute while being careful not to grind on the cutting edge. Grind on the heel up close to the web and grind so as to produce a cutting edge with your grind that will intersect the main cutting edge.

Exercises (215):

1. Of what two steels are twist drills made?

2. Where is the size stamped on most twist drills?

3. In drill size, what unit of measurement is indicated by the number, letter, or fraction stamped on the shank?

4. What step in drilling was omitted if the drill tends to "walk"?

5. When should you ease off on the amount of pressure required to make a twist drill cut?

6. In what direction is a twist drill rotated in free-hand grinding?

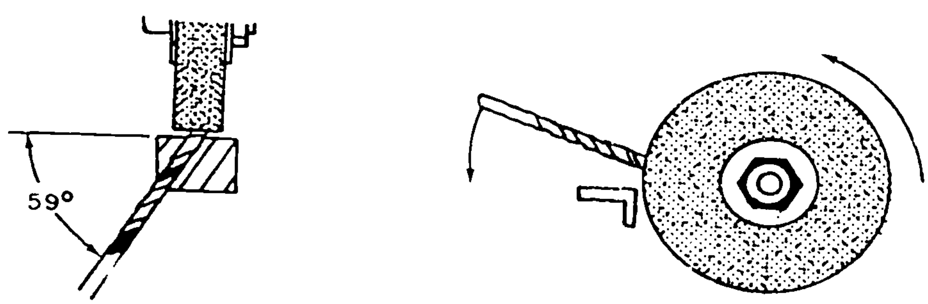

Figure 2–3. How to sharpen a twist drill.

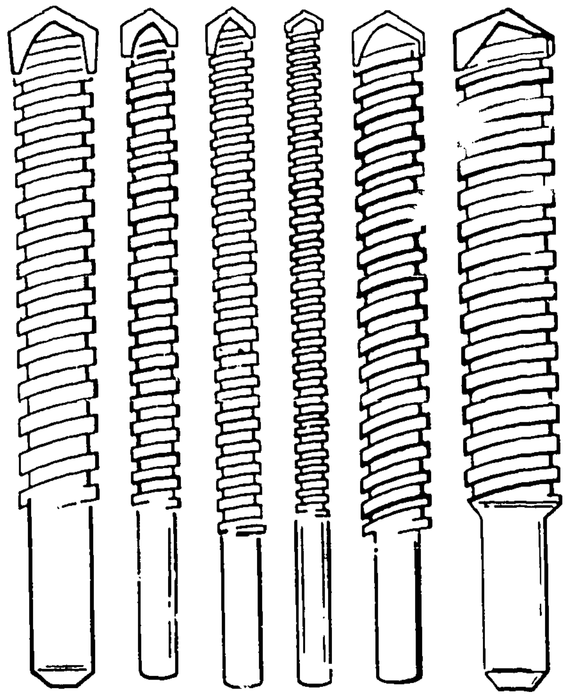

Figure 2–4. Masonry drills.

7. What two surfaces should be ground when sharpening a twist drill?

216. State the uses of masonry drills and countersinks.

Masonry Drills. Several types of masonry drills are available for drilling holes in concrete, brick, and cinder block. Holes are needed when attaching sheet metalwork, such as downspouting, duct work, and metal awnings. One type of masonry drill is the star drill (not illustrated) that somewhat resembles a chisel except that the cutting tip forms a cross. Star drills are available in various sizes and are driven by hand with a heavy ball peen hammer. Another type of masonry drill, which is illustrated in figure 2-4, is designed to fit in the chuck of portable power drills. These masonry drills have tungsten-carbide cutting tips and are available in sizes 1/4 to 3/4 inch. A 1/2-inch portable drill should be used with masonry drills that are 3/8 inch and larger.

Countersinks. Countersinks are used to bevel edges of holes so that rivets or bolts with countersunk heads can be inserted. This allows the rivet or bolt heads to be flush with the surface of the metal. Figure 2-5 shows a countersink that can be used with hand or power drills. These countersinks are available in various bevel angles, which should match the bevel of the rivet or bolt to be installed.

Exercises (216):

1. List at least two types of materials that can be drilled with a masonry drill.

2. For what purpose are countersinks used?

217. Specify those conditions when you would use hand drills, and state how to use portable electric drills.

Hand Drills. Hand drills are used to drill holes in light gage sheet metal, and the chuck normally accommodates a twist drill up to 1/4-inch diamater. Hand drills are often used on jobs where only one or two holes are to be drilled, and the holes can be drilled in less time than it would take to install a power cable for an electric drill. Also there are times when holes must be drilled at locations where the power cable cannot reach the job.

Portable Electric Drills. Portable drills are manufactured in several sizes which include 1/4, 3/8, and 1/2 inch, as illustrated in figure 2-6. The 1/4-inch drill is used extensively when drilling holes for rivets, sheet metal screws, and machine screws. A 3/8- or 1/2-inch drill should be used to drill holes larger than 1/4 inch. Portable electric drills are often used on jobs away from the shop, so be sure that an adequate electrical ground connection is made before beginning the drilling operation.

When using a portable electric drill, be sure the twist drill (or masonry drill) is firmly tightened in the geared chuck of the drill to prevent the twist drill from turning in the chuck. This action may damage the shank of the twist drill. This is done by first tightening the chuck handtight, then by inserting the chuck key and tightening in each of the three holes. Do not overtighten with the chuck key, because the chuck threads can be damaged.

When using the portable power drill, hold it firmly. Insert the twist drill in the chuck and test it for trueness and vibration. You may check the trueness visibly by running the motor freely. Do not use a twist drill that wobbles or is slightly bent, because such a condition causes enlarged holes. Always hold the drill at right angles to the work, regardless of the position or curvature. Tilting the drill at any time when drilling into or withdrawing from the material can cause elongation (egg shape) of the holes.

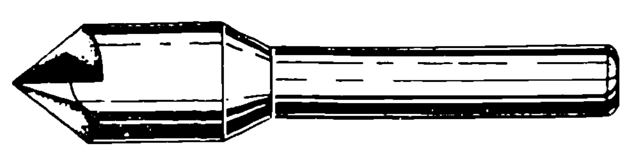

Figure 2–5. Countersink.

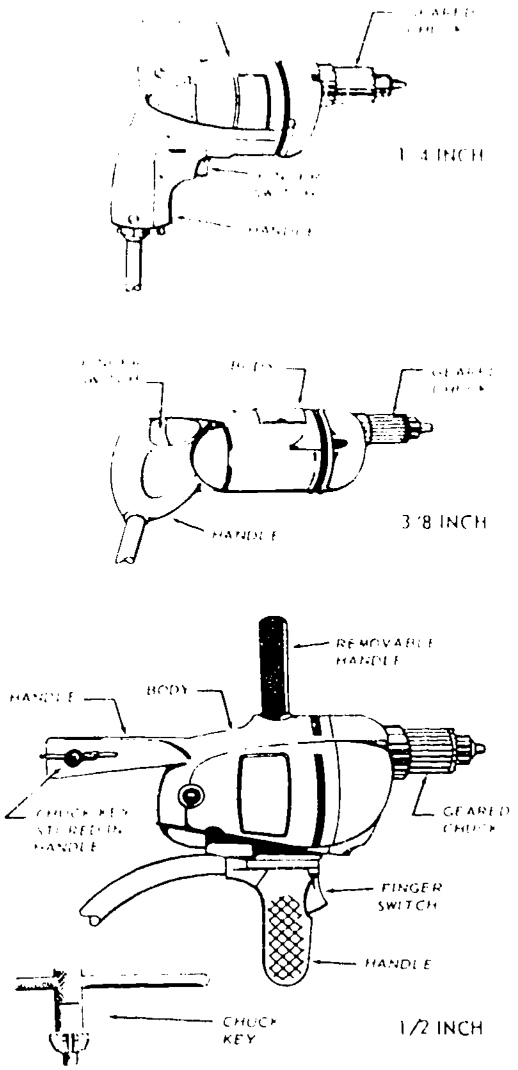

Figure 2–6. Portable electric drills.

When drilling through sheet metal, small burrs are found around the edge of the hole. You must remove these burrs to prevent scratching and to allow rivets or bolts to fit snugly. Burrs may be removed with a countersink, a reamer, or a twist drill larger than the hole. If one of these is used to remove burrs, rotate it by hand.

Exercises (217):

1. Normally hand drills are used where only one or two holes are to be drilled. When else are they used?

2. At what angle to the work should you always hold the drill?

3. Why should you test a drill after installing a twist drill?

218. State the safety and operating procedures to follow when using the drill press.

Drill Press. The drill press is a precision machine used for drilling holes that require a high degree of accuracy. It serves as an accurate means of locating and maintaining the direction of a hole that is to be drilled, and it provides the operator with a feed control lever to regulate the drilling pressure and make the task of feeding the drill into the material easier. A variety of drill presses are available; however, the most common type is the ordinary upright drill press, shown in figure 2-7.

When using a drill press, adjust the height of the working table to accommodate the height and thickness of the part to be drilled; then clamp the material into position so that the center punchmark is directly in line with the twist drill. Material or parts that are not properly clamped may bind on the drill and start spinning, which can possibly cause the loss of fingers or hands or cause serious cuts to the operator's arms or body. Always make sure the part to be drilled is properly clamped to the drill press table before starting drilling operations. You must wear goggles, safety glasses, or a face shield in accordance with the safety rules of your shop. While we are on safety, there is one unsafe act that has been with us for years, but now you see it in writing. *Don't leave the chuck key in the chuck*, as shown in the insert in figure 2-7. It is a safety hazard. Remove it before someone turns on the drill press and gets injured!

Most drill presses are equipped with gears or multistep pulleys to provide a means of increasing or decreasing the speed of the spindle. The drill press shown in figure 2-7 is illustrated with the belt guard removed. The drill press can be adjusted for different spindle speeds by changing the V-belt to different steps on the V-pulleys. Be sure to stop the motor before moving the belt from one step to another, and don't forget to check the belt adjustment before operating the drill press.

Installing V-belts. To obtain adequate power, V-belts must be of the correct size for the pulleys, and they must be adjusted and installed properly. There are many sizes of V-belts. For maximum power, the belt must fit the pulleys as shown in figure 2-7. Make sure that the belt matches the pulley so that it will not ride the bottom of the sheave grooves. The sides of the belt pulling against the pulley provide the traction. Another important factor to consider is to select a belt so that the motor will be as close to the machine as practical. This will prevent some power loss. To obtain efficient operation, the tension of V-belts must be adjusted properly. As a general rule, allow 3/4 inch of sag for each foot of distance between pulley centers when you apply thumb pressure to the belt.

Some equipment requires multiple belts for sufficient traction. If one belt becomes worn or breaks, replace all of the belts, so that a "matched" set of belts is operating. Never roll the belt onto the pulley, because that will break the cords in the belt. Rather, release the takeup adjustment before you install the belt.

Continued use of too heavy a feed or too fast a speed overworks the machine and may break the twist drill or damage the machine. The speed of the chuck and rate of feed vary depending on the material you are drilling.

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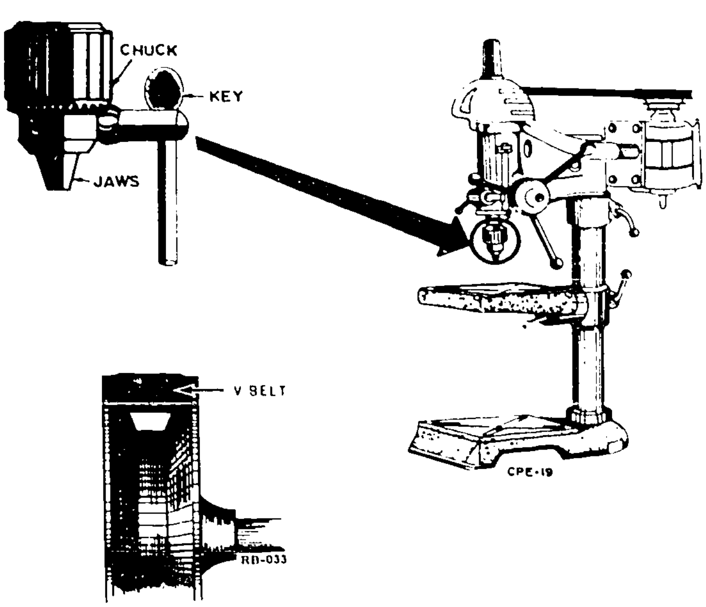


Figure 2-7. Drill press.

Always check the manufacturer's handbook or the technical manual for information concerning the feed and speed recommended for various drilling operations. When drilling hard metal or steels, use a cutting oil to cool and prevent dulling the twist drill. With proper feed and speed, the drill usually produces a spiraled shaving; however, granular cuttings are produced when drilling cast iron or other porous materials. To prevent binding or breakage, always reduce feed or pressure just before going through the metal.

Preventive maintenance procedures for a drill press consist mainly of keeping it cleaned, adequately lubricated, and properly adjusted. Like other machines in the sheet metal shop, the drill press should have a maintenance record folder which specifies the items to be inspected and serviced, the intervals of inspection, and a place to record and initial the maintenance accomplished. A drill press, such as that illustrated in figure 2-7, should be inspected. Be sure that the belt guard is installed, that the V-belt has the correct tension, that the machine is clean, and that all parts operate and are serviceable. The motor of the drill press illustrated has sealed bearings and does not require oiling; however, the spindle and the depth adjustment feed handle have oil cups for lubrication. Lubricate the support column with an oiled rag to prevent corrosion and to allow the working table and head assembly to move up and down freely.

Exercises (218):

1. What item must you wear when using the drill press?

2. What item used on a drill press should never be left in its working position?

3. Where should you check for the spindle speed for various drilling operations?

4. What extra step must you follow when drilling hard metal?

5. How many inches of deflection should be in a properly adjusted V-belt?

2-2. Punching Equipment

There are several types of punches that you will use in sheet metalwork, including those for marking metal before drilling, for removing pins, for aligning holes, and for piercing holes. Each punch is designed for a specific job. Hand punches that are driven with a hammer which you use in sheet metalwork include the center punch, prick punch, starting punch, drift punch, pin punch, and hollow punch. Lever-type punches that you will also use are the Whitney punch, iron hand lever punch, and rotary punch.

219. State the type of punch to use in a given situation.

Hand Punches. There are many types of hand punches that can be used in sheet metal shops; however, the punches illustrated in figure 2-8 are used more often than others. The heads and points should be kept in good condition in the same manner as chisels. The *center punch* is used to make a small depression in metal prior to drilling or punching. This depression prevents the twist drill from "walking" during the drilling operation. The *prick punch* is used to establish location points when laying out patterns on sheet metal. The *starting punch* is tapered for strength, has a blunt tip, and is used to loosen tight-fitting pins that are removed from a hole. A *drift punch* (taper punch) is also used to loosen tight-fitting pins, although its slender taper is not as strong as the starting punch. The drift punch is often used to align holes in two pieces of metal prior to installing screws, bolts, or rivets. The *pin punch* has no taper; it is used to drive out rivets which have had the heads drilled off and to drive pins out of holes too deep for the starting punch or drift punch. The starting punch, drift punch, and pin punch are blunt end punches and are sometimes called solid punches. *Hollow punches* when used with suitable backup material are used to pierce holes in thin metal.

Whitney Punch and Iron Hand Lever Punch. The Whitney punch and the iron hand lever punch have interchangeable dies for piercing holes in metal. The Whitney punch, shown in figure 2-9, is used to punch light gage metal and is available with dies ranging in size from 1/16 to 3/32 inch. When making holes in exact locations, set the centering point in the center punch mark. The iron hand lever punch is similar to the Whitney punch except that it has longer handles; it is available with dies ranging in

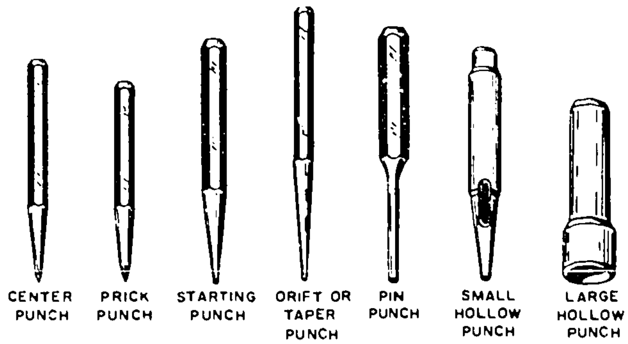


Figure 2–8. Hand punches.

size from 3/32 to 1/2 inch. Both punches have short throats and are used when hole locations are near the edge of the material. Both punches will pierce holes much faster in light gage metal than it is possible to do so with twist drills. When changing punches and dies, be sure to match the sizes. Too large a punch for a die damages the cutting edges, and too small a punch pierces the hole but dimples the material.

Exercises (219):

1. Which hand punch is sued to loosen tight-fitting pins?

2. Which punch should you use to mark points on sheet metal layouts?

3. Which punch should you use to punch 2/16-inch holes 1⅛ inches from the edge of 26-gage sheet metal?

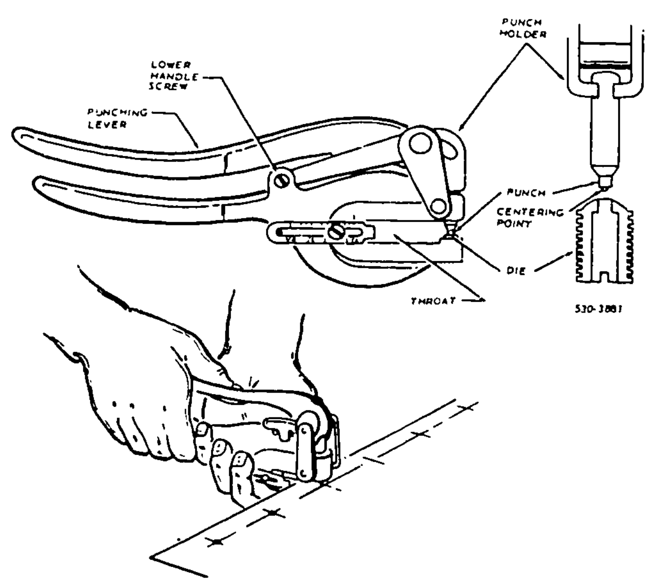


Figure 2–9. Whitney punch.

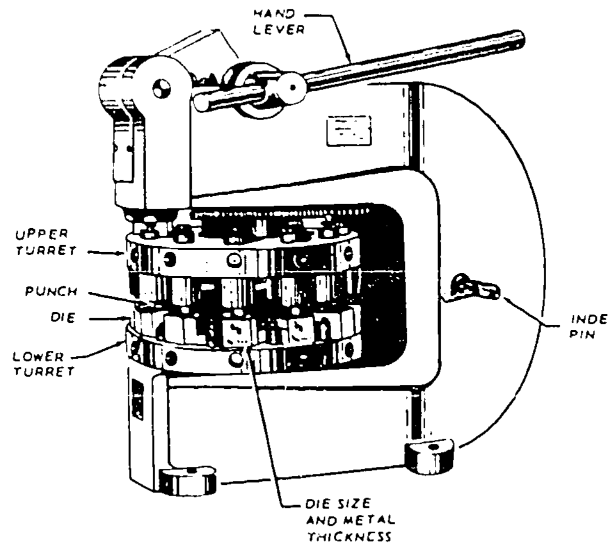


Figure 2–10. Rotary punch.

220. State the factors controlling the use of the rotary punch, and specify the uses of reamers and rotary files.

Rotary Punch. This large punch is used in the sheet metal shop to punch holes in metal parts such as baffle plates and tops for drain tables. It can also be used for cutting radii in corners and for making washers. The rotary punch shown in figure 2-10, is found in many Air Force sheet metal shops. It is composed of two cylindrical turrets, one mounted over the other and supported by the frame. Both turrets are synchronized so that they rotate together, and the index pins maintain correct alignment at all times. To release the index pins from their locking position, the lever, which is located on the right side of the machine, is rotated 180°. This action will withdraw the index pins from the tapered holes and allow you to turn the turrets to any size punch desired.

To operate this rotary punch, place the metal between the die and punch. Then pull the hand lever, which is on the top right side of the machine, towards you. This forces the punch through the metal. When the lever is returned to its original position, the metal will be stripped off the punch.

Stamped on the front of each dieholder is the diameter of the punch and its maximum capacity for punching mild steel. Each punch is made with a point which can be placed in the center punch mark. This point assures you of the definite location to be pierced.

To accurately align the punch and die, you must determine where the adjustment is necessary by punching through several thicknesses of stiff paper. This will show which side of the die has the greatest clearance. If the cut is uneven, loosen the lockscrews and tap the die in the opposite direction. When the paper is cut evenly all around, tighten the punch securely with the lockscrews. The lockscrews are located between each set of dies.

The principal safety precaution to observe when operating the rotary punch is to keep your fingers away from the punch and die and to return the hand lever to the full UP position after each operation has been completed. Be sure the operating instructions and safety precautions for the rotary punch are legible and posted in the most obvious location.

Reamers. Tapered reamers, such as those illustrated in figure 2-11, have several uses in sheet metalwork. They are useful for enlarging holes and removing burrs. These reamers have tapered spiral flutes with cutting edges somewhat similar to the countersink you saw in figure 2-5. One of the reamers illustrated in figure 2-11 is turned by hand, and two are used with a carpenter's brace. The size and shape to select for enlarging holes or removing burrs from sheet metal is determined by the diameter of the holes. Tapered reamers are frequently used to ream the ends of tubing or pipe which have been cut. Earlier in this course, you learned that burrs should be removed from holes prior to installing rivets. Removing burrs is also a good safety practice because they are sharp and may snag flesh and clothing. When using reamers to enlarge holes or to remove burrs, be careful not to use too much force, because this causes the reamer to take too large a "bite" and remove too much metal which results in a hole that is oversized or beveled.

Rotary Files. Rotary files, such as those illustrated in figure 2-12, have 1/4-inch diameter shanks which can be "chucked" in a hand drill, a portable electric drill, or a drill press. Rotary files with spiral cutting flutes, which are smaller than the spiral flutes of reamers, are used more often to ream or enlarge holes than to remove burrs.

Figure 2–11. Reamers.

Preventive maintenance for the rotary punch consists mainly of keeping it cleaned, adequately lubricated, and properly adjusted. At intervals specified on the maintenance record folder, the rotary punch, such as illustrated in figure 2-10, is inspected to see that the index pin works freely and locks the upper and lower turrets easily. If necessary, clean and oil the index pin and aligning holes in the turrets. Next, inspect each punch and die to see if it lowers and raises freely when the hand lever is pulled forward. Cleaning and oiling are necessary for any punch that sticks. To thoroughly clean this piece of equipment, you must remove any sticking punch. Then clean the punch and its sleeve, and lightly coat them with oil before reassembly. Next, inspect the hand lever and connecting linkage for cleanliness and freedom of operation; if necessary, clean and oil the moving parts. Now, inspect each punch for proper alignment with its corresponding die by punching several thicknesses of stiff paper. Finally, wipe off all excess oil, clean all painted surfaces with a dry rag or a rag moistened with soap and water, and wipe all unpainted surfaces with a slightly oiled rag. The final step is to make the appropriate entries in the maintenance record folder.

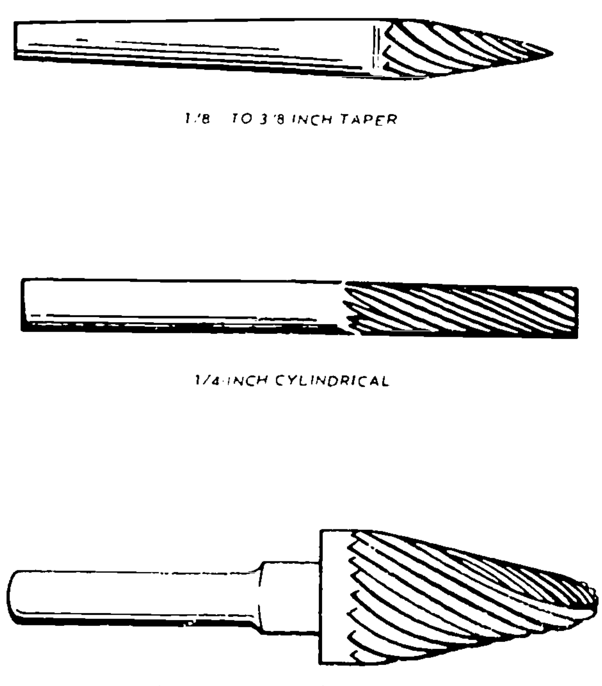


Figure 2–12. Rotary files.

Although in most cases you use a twist drill to enlarge a hole in sheet metal, sometimes it is desirable to use a rotary file instead. Selection of the size and shape of the rotary file to use depends upon the job. For example, the rotary files illustrated in figure 2-12 can be used to ream holes, to elongate slots, and to file irregularly shaped edges.

Exercises (220):

1. How are reamers used?

2. When rotary files are used, where may they be mounted?

3. What type of material is used when testing a rotary punch for correct punch die alignment?

4. Can the top turret of the rotary punch, shown in figure 2-10, be set to punch through a die that is too large? Why?

5. How are rotary files are used most often?

2-3. Rivets and Riveting Tools

In this section, we discuss rivets, their properties, uses, and steps to properly install.

221. Describe tinner's rivets in terms of weight, usage, advantages, installation procedures, and types of joints; and determine the size of rivets for different thicknesses and material.

Rivets are used considerably in sheet metalwork and are satisfactory for fastening sheet metal from both the standpoint of strength and neatness, if properly used. Riveting can be done by hand or by machine; however, in the type of work you do, most riveting is done by hand.

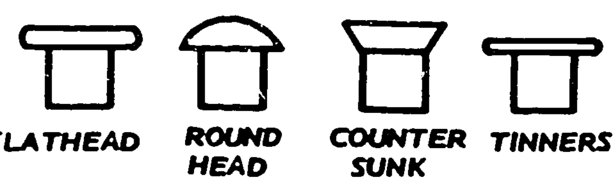


Figure 2-13. Typical rivet heads.

Rivets vary in the following respects: the kind of metal from which they are made, type of head, diameter, and length. Figure 2-13 illustrates some of the various shapes of rivet heads you may encounter. The rivet most often used in the sheet metal shop is the tinner's rivet; however, you may also use Monel, aluminum, and blind rivets of various shapes and styles.

Tinner's Rivets. As a sheet metalworker, you use tinner's rivets more than any other type. They are made of mild (soft) steel, are easily formed with a hand riveting set, and are usually tinned. The tinner's rivet illustrated in figure 2-13 is available in various diameters and lengths. The rivet sizes are identified according to the weight per thousand. For example, 1,000 of the smallest tinner's rivets (which are identified as 8-ounce rivets) weigh 8 ounces. Tinner's rivets are available in the following sizes: 8 oz, 1 lb, 1¼ lb, 1½ lb, 1¾ lb, 2 lb, 2½ lb, 3 lb, 4 lb, 5 lb, 6 lb, 7 lb, 8 lb, 10 lb, and 12 lb. You can see there are many sizes available; however, in the sheet metal shop, the sizes in the following list are used more than the others:

Size of Rivet	*Diameter of Shank*	*Length*	*Gage of Sheets Being Joined*
1 lb	0.109"	3/16"	26
2 lb	0.148"	9/32"	24
2½ lb	0.1607"	5/16"	22
3 lb	0.165"	21/64"	20
4 lb	0.176"	11/32"	16

Monel Rivets. Monel rivets, like other rivets, vary in diameter, length, and head shape. These rivets are harder to drive than tinner's rivets because of the hardness of the metal. In sheet metalwork, you use Monel rivets when manufacturing or repairing parts and components such as stainless steel trays, pans, hoods, and serving equipment in dining facilities.

Aluminum Rivets. There are many types and shapes of aluminum rivets available; however, the aluminum sheets you may be riveting will be soft aluminum and will require soft aluminum rivets. Two general-purpose aluminum rivets, identified as the 1100–F and 3003, are recommended for use on nonstructural parts fabricated from soft aluminum. The 1100–F and 3003 are available with flat countersunk, round, or universal heads. The main advantage of these rivets in the sheet metal shop is that they can be used without further treatment and are easily driven with a handset.

Blind Rivet. Blind rivets are very popular and have made their way into industry as approved fasteners. The word "blind" refers to the fact that access with a bucking bar to the back side of the material being riveted is not necessary. Imagine trying to buck rivets on the inside of a pipe handrail that was embedded in a concrete step. Figure 2-14 shows some blind rivets which are set with a special tool called a *rivet gun*.

There are several types and varieties of rivet styles available as listed in figure 2-14. Notice that there are also several different sizes and lengths. Some rivets with large diameter heads are used when fastening materials other than metal (wood, leather, plastic, or fabric). The use of a washer on the back side of soft material will allow you to rivet two or more pieces of soft material together.

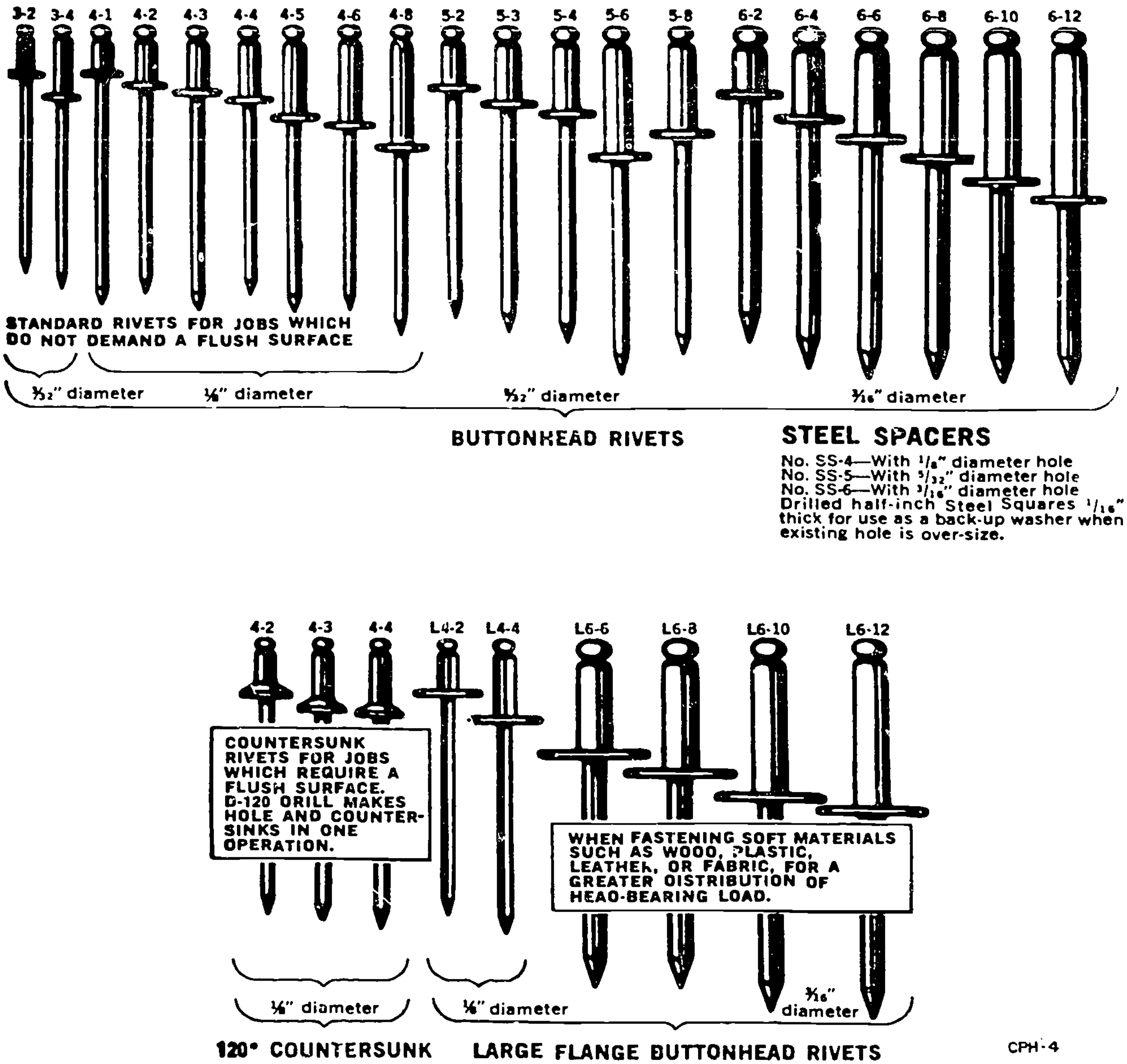


Figure 2–14. Blind rivets.

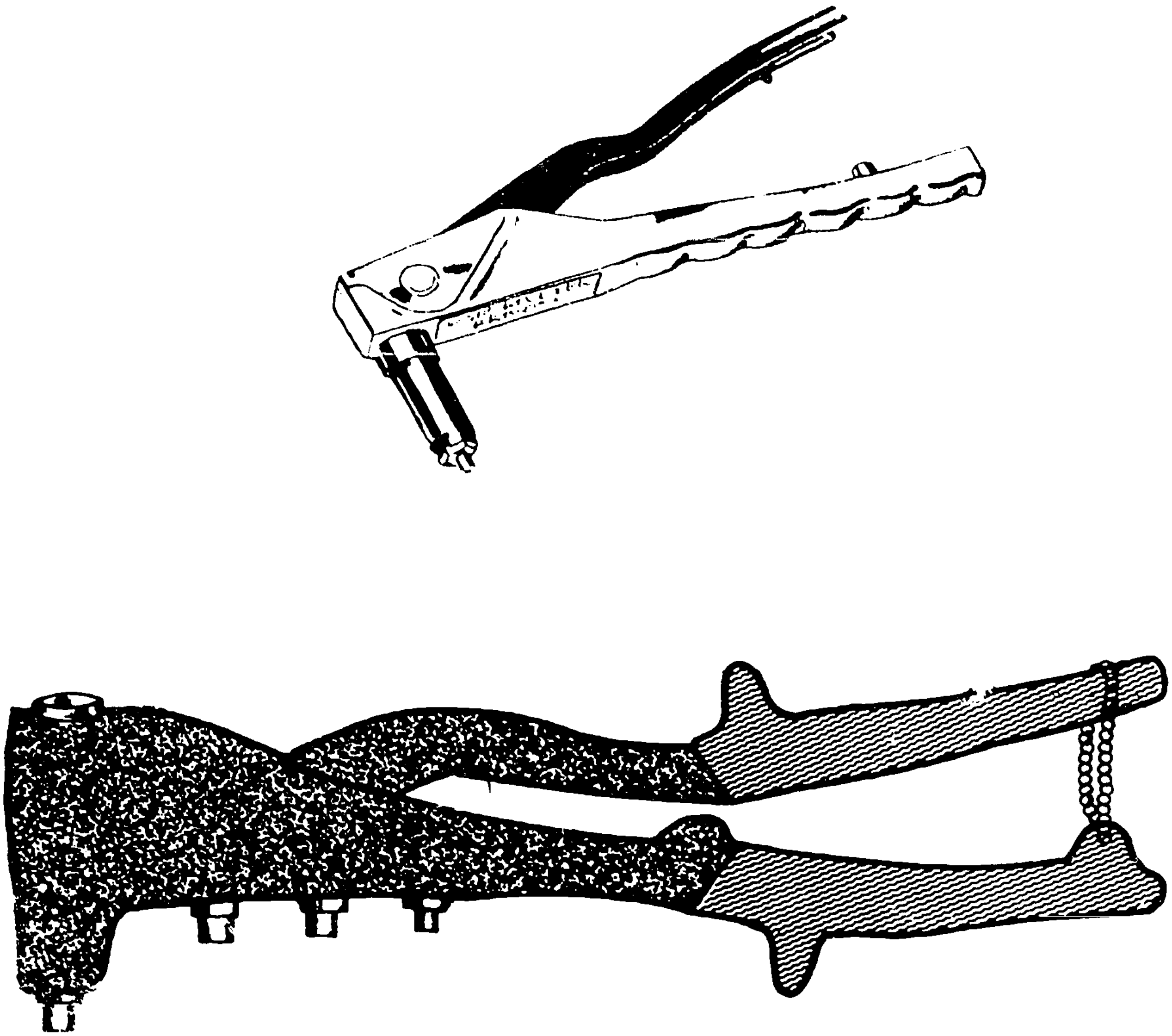


Figure 2–15. Blind rivet guns.

To use a blind rivet gun, as shown in figure 2-15, place the rivet stem into the rivet gun and then place the body of the rivet through a predrilled hole. Hold the rivet firmly against the work and squeeze the handle until the stem breaks off. The blind rivet pulling head in figure 2-16 shows the internal parts of a pulling head and rivet installed and set. Most all pulling heads work on the same principle; that is the jaws grip the mandrel as they are pulled upward and the upward motion continues until the mandrel breaks in two. Maintenance on the pulling head lies with the jaw When they get loaded, they slip. So when your rivet gun begins to slip, it is telling you to clean the teeth on the jaws. This can usually be done with a wire brush after disassembly of the pulling head.

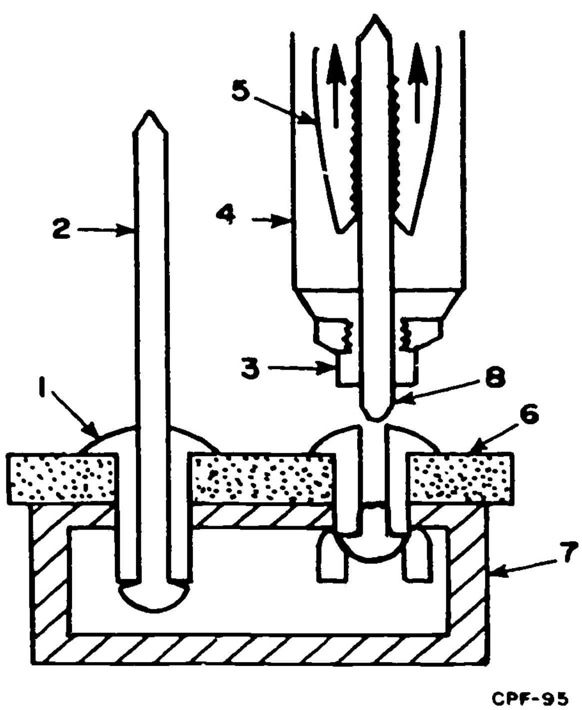
Design of Riveted Joints. Riveted joints are of two general types—lap joints and butt joints. The lap joint is made by placing the sheets of metal so that one sheet overlaps the other. The butt joint is made by butting the plate or sheet ends together and using one or more cover plates. Both types of joints can be single riveted, double riveted, or triple riveted, depending upon whether one, two, or three rows of rivets are used. If more than one row of rivets is used and the rivets are directly behind each other, they are said to be chain riveted. If they are diagonally behind each other, they are stagger riveted. Chain or stagger riveting can be used both in lap and in butt joints when more than one row or rivets is used.

Rivet spacing for the joint can be obtained from the drawing or blueprint. If the spacing is not specified, the type of seam will serve as a guide in determining whether the rivets are spaced close together or far apart. For instance, a joint that must be liquidtight has many more rivets per inch than a joint that need not be liquidtight. Whatever the rivet spacing, the center of the rivet hole is

located twice the diameter of the rivet head from the edge of the sheet (some sheet metalworkers prefer to use two and one-half times the shank diameter). The number of rows of rivets used in making a joint depends on the amount of strength needed in the joint. The distance between rows of the rivets is known as the transverse pitch, and the distance between the rivets in the same row is called the *rivet pitch*.

Determining Rivet Size. The diameter of the rivet is usually determined by the thickness of the plate or sheet stock from which the part is made. Unless otherwise specified, the diameter of the rivet shank is approximately three times the thickness of the sheet metal. The length of the rivet shank is determined by the combined thickness of the sheet to be fastened. The shank should protrude through the metal sheets, as shown in figure 2-17, about one and one-half times the diameter of the rivet to permit the forming of a good shaped head and for maximum holding strength.

Making a Rivet Hole. After the rivet size is determined and the layout completed, the center of the hole is marked. This is done by placing a sharp pointed punch on the center and striking it lightly with a hammer, then completing the operation of making the hole by using a drill or punch. The hole should be slightly larger than the rivet. If the location of the holes is near the edge of the sheet, use the Whitney hand punch for piercing the holes. If the location of the holes is not near the edge of the metal, use a hand drill or power drill for piercing the holes. Whichever way you make the holes, remember that the edges of the holes must be smooth and the holes slightly larger than the rivet.



1. Rivet
2. Mandrel
3. Nose piece
4. Body
5. Jaws
6. Material
7. Frame
8. Expended Mandrel

Figure 2–16. Pulling head.

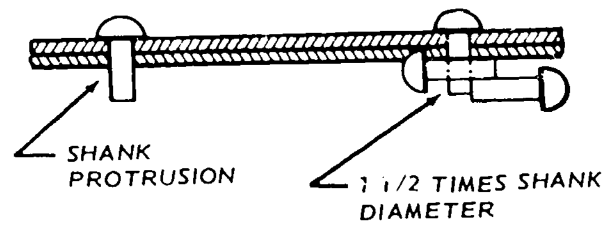


Figure 2–17. Pop rivet length.

When several sheets are to be drilled or punched, use a template to locate the holes. On individual sheets, you can use a pencil, compass, scriber, or dividers. However, you should not use a scriber on aluminum or stainless steel, because this scratches the metal and may cause aluminum to crack when being formed. A soft, pointed pencil is recommended for marking aluminum and stainless steel.

Before driving rivets, remove any burrs and chips to prevent marring the metal. This also permits the sheets to seat tightly against each other. Burrs can be removed by inserting the point of a larger size twist drill in the hole and turning it. A countersink may be used in the same manner.

To insure proper alignment or rivet holes, the sheets must be held in proper relation to each other while the rivets are being inserted. A holding device, called a *Cleco*, is the tool to use for this job. A Cleco in every third or fourth hole along the seam is usually sufficient. Figure 2-18 shows how the Cleco is used.

Exercises (221):

1. If you had 2 pounds of 3-lb tinner's rivets, how many rivets would you have?

2. What length of rivet is needed for joining two sheets of 16-gage metal?

3. What type of rivets are used in manufacturing or repairing items in a dining facility?

4. What is the rivet seam called on a joint that has double row rivets and the rivets in each row are not behind each other?

5. What are the main advantages of blind rivets?

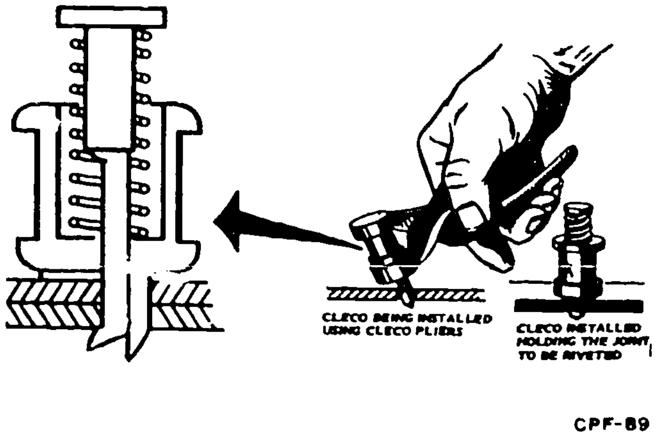


Figure 2–18. Rivet installation.

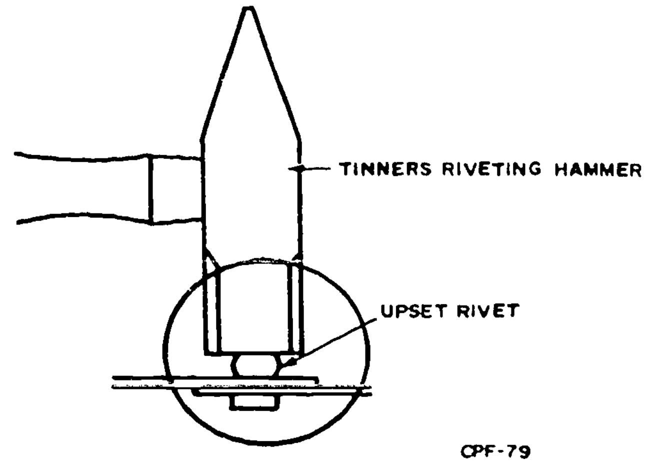


Figure 2–20. Upsetting rivets.

6. List the factor or rule to determine the size of rivet to use.

7. What size of twist drill is recommended for a 1/8-inch pop rivet?

8. What is a Cleco and why is it used?

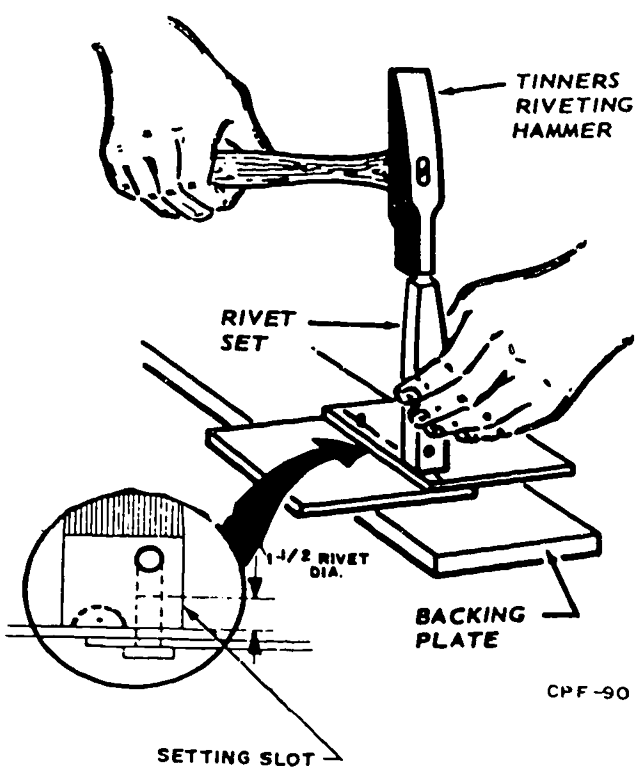


Figure 2–19. Setting rivets.

9. List the three steps, in sequence, for installing a tinner's rivet.

10. What causes the blind rivet pulling head to slip on the mandrel?

222. List steps and name tools used to install or remove rivets.

Rivets are usually installed by placing the manufactured head against a solid surface, such as a backing plate, and following the steps shown in figures 2-19, 2-20, and 2-21. This procedure is used when setting rivets with a hand riveting set. The steps illustrated are necessary to insure a strong rivet with a proper head and to prevent the joint from being distorted.

If the setting step, illustrated in figure 2-19, is not performed correctly, the sheets may not seal tightly against each other and may cause the rivet to swell between the sheets during the upsetting step, as shown in figure 2-20. A second problem often appears when the rivet head is not seated up tight against the metal. This causes the rivet to swell below the metal as shown in figure 2-22. Either problem makes the rivet too short to form a proper head, causes the metal around the hole to dimple (bulge), and fails to form a strong joint.

Upsetting the rivet, as shown in figure 2-20, is also very important, since it is the beginning of the heading process. If the rivet is struck too hard, the rivet shank will be flattened too much to form a good head during the heading step.

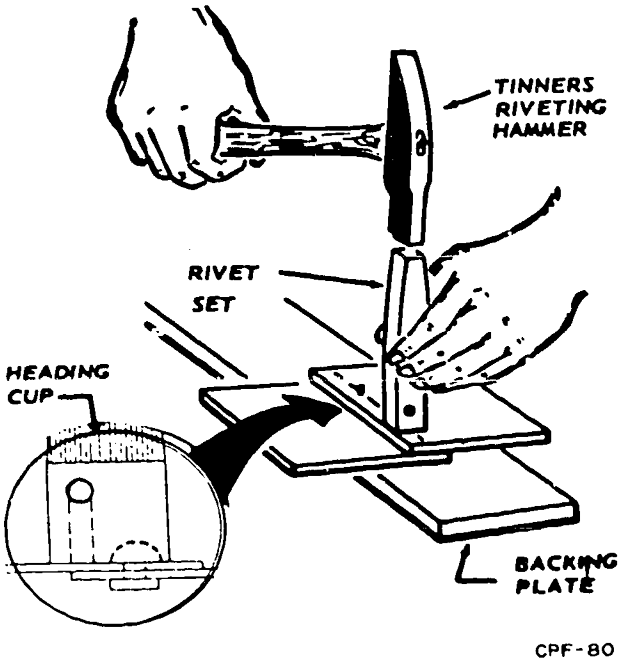


Figure 2-21. Heading rivets.

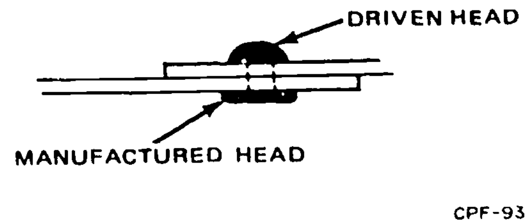


Figure 2-23. Properly set rivet.

The heading step, illustrated in figure 2-21, uses the head-forming depression of the rivet set to form a strong well-shaped head. Heading the rivet enlarges the head to provide a holding surface all around the hole, as shown in figure 2-23.

The tools needed for hand riveting are a riveting hammer, a rivet set, and a backing surface, such as a backing plate, hand dolly, or bench stake. Rivet sets 3/16-inch in diameter and under are available in most sheet metalworker toolkits. A rivet set is required to form a good shaped head on the rivet. The size of the set depends upon the size of the rivet. The shape and size of the backing plate, hand dolly, or bend stake depend on the size of the rivet, thickness and size of the material, location, and conditions under which the driving is taking place. Therefore, many shapes and sizes of hand dollies and bench stakes are available in most sheet metal shops. A piece of square, cold-rolled steel bar of the proper weight can be used as a backing plate when no interference exists. Where riveting is not so simple, hand dollies or bench stakes of various shapes are used. They are designed to overcome the interference and still have enough weight to support setting, upsetting, and heading. Hand dollies are sometimes called *bucking bars*. When riveting flat sheets where no interference exists, use a flat steel plate secured to the workbench.

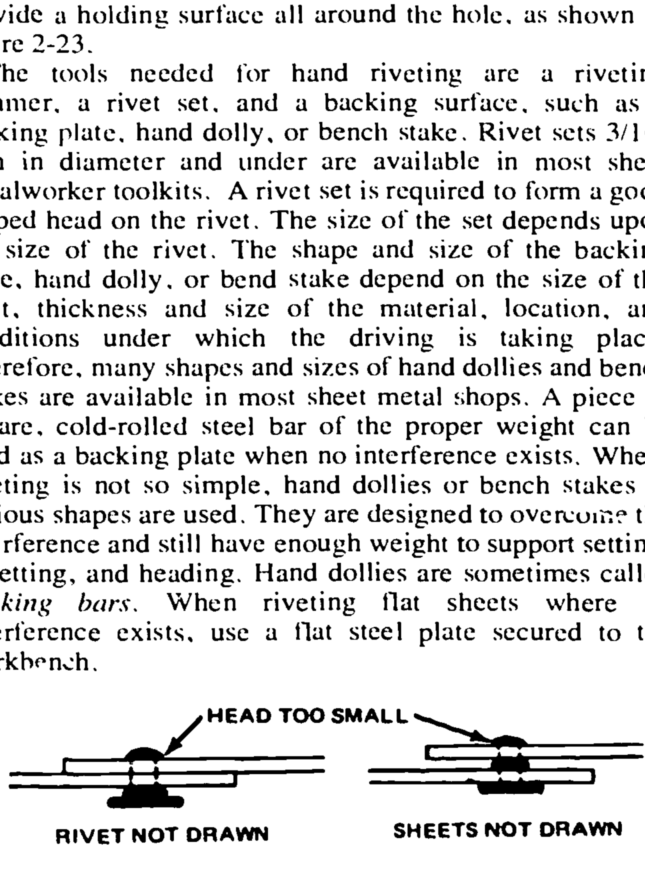


Figure 2-22. Improperly set rivet.

Drawing Rivets. Drawing rivets is a process where drilling or punching holes is not necessary. This procedure is used with light gage sheet metal, such as 30, 28, and 26 gage. A solid rivet is placed head down on a bench plate or stake with the joint placed over the rivet. The joint is tapped lightly with a mallet to make an impression of the rivet shank. The set, shown in figure 2-19, is placed over the impression in the joint, and the set is tapped with a riveting hammer to draw the rivet through the light sheet metal. This method is useful when manufacturing funnels and cylinders and joining light sheets.

Removing Rivets. When removing a rivet, take care to maintain the original size and shape of the rivet hole so that replacement with a larger rivet is not necessary. If the rivet is not removed properly, the strength of the joint is weakened and replacement of additional rivets is made more difficult.

When removing a rivet, drill the manufactured head, because it is more symmetrical than the shop-made head and there is less chance of damaging the rivet hole or the metal around it. Rivets are removed with handtools, a power tool, or a combination of both. The round manufacture head of a rivet should be filed flat and center punched for drilling, as shown in figure 2-24. (When center punching on thin sheet stock, back up the rivet on the upset head to avoid depressing or buckling the metal.)

Select a twist drill of the same size as the rivet shank and drill the rivet head out, as shown in figure 2-24. When a power drill is used, the point of the drill is set on the rivet and the shuck rotated several times by hand before turning on the power. This helps the drill cut a good starting spot, which eliminates the possibility of the drill slipping off the rivet head and tracking the metal. Then, the rivet is drilled the depth of the head, making sure the drill is held at a 90° angle to the rivet head. The rivet head usually breaks away and climbs the drill as soon as the head is completely pierced. This is a good signal to cease drilling. Do not drill too deep as the rivet shank may fail to turn with the drill and cause the metal to tear. If the rivet head should fail to come loose of its own accord, insert a drift punch in the hole, as shown in figure 2-24, and twist slightly to either the left or right until the head comes off the rivet.

The final step is to drive the rivet out with a pin punch slightly smaller than the diameter of the rivet shank. Support light gage metal with a solid object, such as a bucking bar, when you drive out the shank of the rivet.

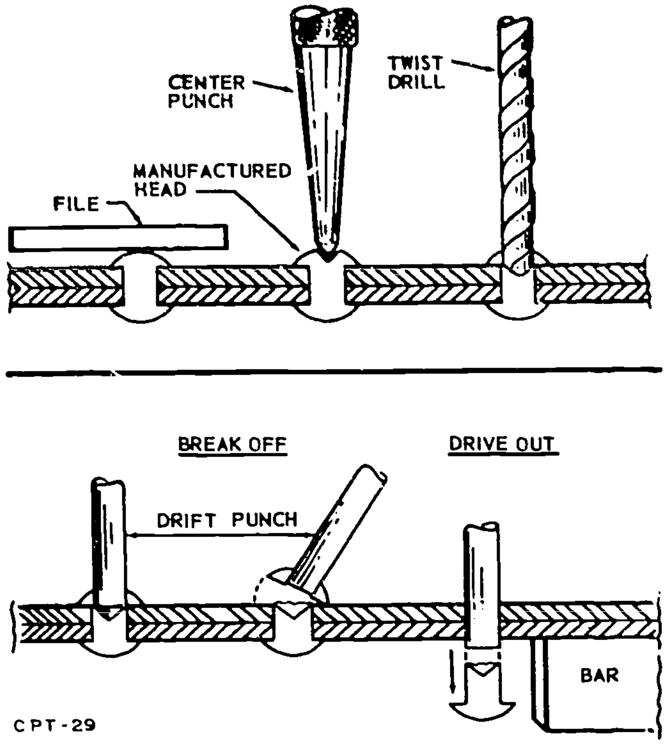


Figure 2–24. Removing a rivet.

Exercises (222):

1. What are the three steps of installing tinners rivets?

2. What procedure should you use to remove a solid rivet?

3. How do you "draw" a rivet, and what tools are required?

2-4. Fastening Sheet Metal Components with Screws, Bolts, and Nails

You need to know the kinds of screws, bolts, and nails that are used in sheet metalwork, including their names, sizes, shapes, type of metal, and uses. This information will enable you to use the proper fastener for the job and help you to obtain the correct fasteners from supply. Bolts and screws used in the sheet metal shop are usually made from iron, steel, aluminum, or stainless steel.

223. Specify the types and uses of sheet metal screws, stove bolts, machine screws, nuts and nails.

Sheet Metal Screws. Sheet metal screws are frequently used in locations that make riveting difficult or for fastening sheet metal parts that may later be disassembled. If the hole is drilled or punched to the proper size, sheet metal screws are easily installed as they form their own threads in the metal during installation. If the hole is too small, the sheet metal screw, which is hardened, may break, making removal difficult. Three types of sheet metal screws (type A, type Z, and self-tapping) are illustrated in figure 2-25. Notice that type A and type Z have several different head styles; reading from left to right, they are roundhead, pan head, stove head, countersunk flathead, and countersunk ovalhead.

Type A sheet metal screws. Type A sheet metal screws have a sharp point and resemble a wood screw except that the threads are more course and extend to the head of the screw. These type A screws are recommended for joining and fastening light gages of sheet metal.

Type Z sheet metal screws. Type Z sheet metal screws have blunt points and the same threads as type A; they are recommended for joining and fastening light or heavy-gage metal.

Self-tapping sheet metal screws. Self-tapping sheet metal screws illustrated in figure 2-25 are recommended for heavier gage sheet metal, since they form threads while being screwed into the proper size hole. This sheet metal screw is also available with a hex head for use with socket wrenches.

Stove Bolts. Stove bolts, illustrated in figure 2-26, were originally developed for use on stoves, as the name suggests. They are small and can be used for many jobs where accuracy and strength are not required and where vibration does not shake the nuts loose. Stove bolts have coarse threads and are normally made of iron; they may be plated to prevent corrosion. Stove bolts may be obtained with roundheads, flatheads, or ovalheads. When you order or draw stove bolts from supply, the kind of head, diameter, threads, length, and finish are required to determine the stock number. *For example:* bolt, stove, steel, roundhead, 1/4"–20 by 1" cadmium plated.

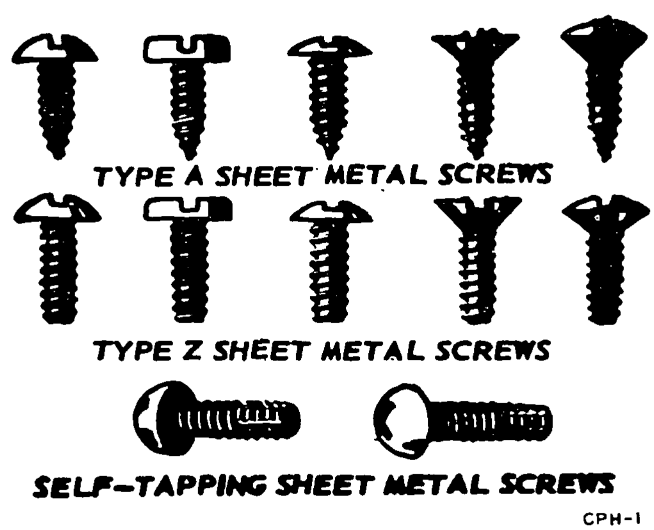


Figure 2–25. Sheet metal screws.

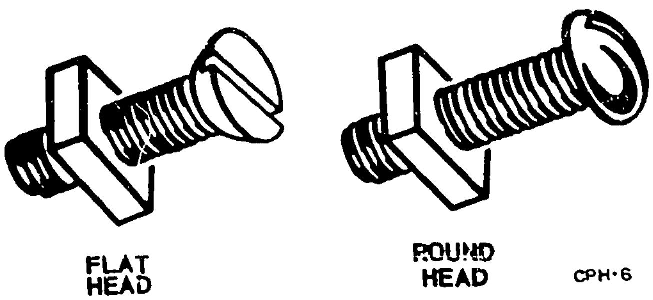


Figure 2–26. Stove bolts.

Machine Screws. The term "machine screw" is the general term used to designate small screws that may be used in tapped holes or with nuts. Most machine screws have fine threads and are made of steel or brass; they may be plated to prevent corrosion. A variety of diameters, lengths, and head shapes are manufactured, some of which are shown in figure 2-27. When you order or draw machine screws from supply, the kind of head, diameter, threads, length, and finish are required to determine the stock number. For example: screw, machine, roundhead, 3"–32 by 1", cadmium plated. Figure 2-28 is a list of American (National) screw thread sizes and tap drill sizes.

Nuts. When sheet metal parts are being fastened with stove bolts or machine screws, it is necessary to use nuts of the same size and thread. The size of the nut is determined by the diameter of the bolt or screw it is to fit. For example: a 3/16-inch nut will fit a 3/16-inch bolt or screw if the threads are the same. Nuts may be made of brass, steel, or iron, or they may be plated the same as the bolt or screw. Nuts are made in several shapes, such as square, hexagon, wing, self-locking, and sheet spring. Many other shapes are available, but these are the most common in sheet metalwork.

Square nuts are square shaped, as the name implies, and are rightened with an open end wrench or adjustable wrench. Stove bolts usually have square nuts.

Hexagon nuts, commonly called *hex nuts*, have heads with six sides and are tightened with an open-end wrench, adjustable wrench, box end wrench, or socket wrench. The box-end and socket wrenches are recommended because they fit tighter and reduce the chance of rounding the corners of the nut. Machine screws normally have hex nuts.

Wing nuts, illustrated in figure 2-29, are identified by the wings extending from the two sides of the body of the nut. They are tightened by hand and used when easy or repeated removal is desirable.

Self-locking nuts differ from the nuts already described because they have a locking device built in or secured to the nut to act as a binder. They are usually hexagon shaped and are held in place while the machine screws are installed. Self-locking nuts are used when vibration is encountered.

Sheet spring nuts are manufactured from sheet spring material, usually steel, into varying flat, concave, bent, or curved designs. The hole in the spring nut has internal lugs or prongs that are capable of securing and gripping the threads of a screw or bolt. Flat spring nuts must be held in place while a bolt or screw is installed. Other spring nuts are folded like a clip and stay in place while a bolt or screw is installed. Folded spring nuts can be used only near the edges of sheet metal; the metal parts being joined must have a hole drilled or punched to allow a bolt or screw to pass through.

Nails. Nails are manufactured in many sizes and shapes and are used with many types of material. Some are coated for resistance to corrosion and for increased holding power in wood. The shank of the nail may be spiraled, such as the screw nail illustrated in figure 2-30. The screw nail has replaced the common nail for attaching sheet metal to wood, since it has greater holding power. Also, the screw nail is made from harder material than ordinary nails and can be driven through light-gage sheet metal without first drilling a hole. The size and type of nail is determined by the strength desired and the thickness and location of the material into which it is driven.

Exercises (223):

1. Where are sheet metal screws used?

2. What type sheet metal screw has a point?

3. Stove bolts are used where strength is not required and they are not subjected to ______________.

4. With what are machine screws used?

5. What are the most common types of nuts used in the metal shop?

6. What type of nail is used to secure sheet metal to wood? Why?

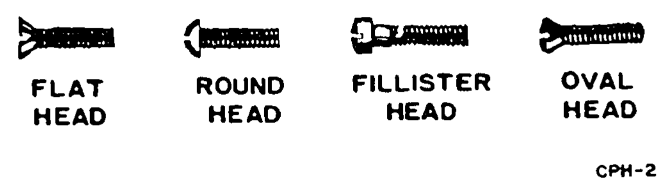


Figure 2–27. Machine screws.

American (National) Screw Thread Series							
NATIONAL COARSE THREAD SERIES MEDIUM FIT. CLASS 3 (NC)				NATIONAL FINE THREAD SERIES MEDIUM FIT. CLASS 3 (NF)			
Size and Threads	Dia. of body for thread	Tap Drill		Size and threads	Dia. of body for threading	Tap Drill	
		Pref'd dia. of hole	Nearest Stand'd Drill Size			Pref'd Dia. of	Nearest Stand'd Drill Size
				0-10	.060	.0472	3/64
1-64	.073	.0575		1-72	.073	.0591	#53
2-56	.086	.0682	#51	2-64	.086	.0700	#50
3-48	.099	.078	5/64	3-56	.099	.0810	#46
4-40	.112	.0866	#44	4-48	.112	.0911	
5-40	.125	.0995	#39	5-44	.125	.1024	#38
6-32	.138	.1063	#36	6-40	.138	.113	#33
8-32	.164	.1324		8-36	.164	.136	#29
10-24	.190	.1472	#26	10-32	.190	.159	#21
12-24	.216	.1732	#17	12-28	.216	.180	#15
1/4-20	.250	.1990	# 8	1/4-28	.250	.213	# 3
5/16-18	.3125	.2559	# F	5/16-24	.3125	.2703	I
3/8-16	.375	.3110	5/16"	3/8-24	.375	.332	Q
7/16-14	.4375	.3642		7/16-20	.4375	.386	W
1/2-13	.500	.4219	27/64"	1/2-20	.500	.449	7/16"
9/16-12	.5625	.4776		9/16-18	.5625	.506	1/2"
5/8-11	.625	.5315	17/32"	5/8-18	.625	.568	9/16"
3/4-10	.750	.6480	41/64"	3/4-16	.750		11/16"
7/8-9	.875		49/64"	7/8-14	.875		51/64"
1-8	1.000		7/8"	1-14	1.000		59/64"

CP-14

Figure 2–28. American (National) screw thread sizes.

Figure 2–29. Wing nut.

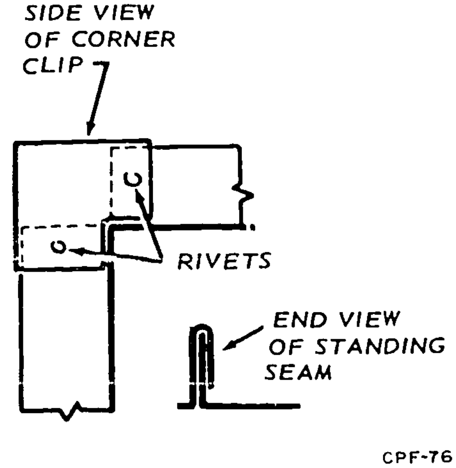


Figure 2–31. Clips.

224. List some of the uses of clips, cleats, hangers, and braces.

In the previous two sections, you learned how rivets, bolts, screws, and nails are used for fastening sheet metal components and assemblies. In this section, we discuss clips, cleats, hangers, and braces that are used to fasten sheet metal components and assemblies. These fastening devices are usually fabricated in the sheet metal shop to fit a particular assembly or component. Although only a few of the many variations of these devices are described here, the illustrations will give you a good idea of how the devices are used, and it will not be difficult for you to make adaptations for similar sizes, shapes, and uses.

Clips. Clips are used to dress and strengthen corners of sheet metal assemblies that have been notched or damaged. Figure 2-31 is an example of how a clip is used to strengthen the corner of a standing seam. The size and shape of the clip is determined by the size and shape of the corner, joint, or seam being strengthened.

Cleats. Cleats are fasteners used to secure metal flashing and roofing. The cleat is nailed at one end to the roof and the remainder is formed into the seams. Cleats may be used with standing or grooved seams. The length of cleats is determined by the seam being used; however, the width should not exceed 2 inches. Figure 2-32 is an example of one type of cleat used with galvanized sheets—notice the location of the holes. When you install soft copper roofs, the cleats should have nail holes located near the end so that 1/2 inch of the cleat can be folded back over the nailheads; this prevents the nail from backing out and damaging the copper sheet.

Hangers. Hangers are used to support the level heating and air-conditioning ducts. Figure 2-33 illustrates some of the types and shapes you may use. The size and shape of the hanger depends upon the size, weight, and material of the duct it supports. The location and the material of the structure supporting the hanger are other determining factors in selecting the type of hanger.

Braces. Braces are used when ducts are large and the sheet metal needs additional support and strength. Figure 2-34 illustrates three uses of braces; however, there are many other variations. The size and shape of the brace depends on the size and shape of the assembly.

Exercises (224):

1. Where are clips used?

2. Why are clips used?

Figure 2–30. Screw nail.

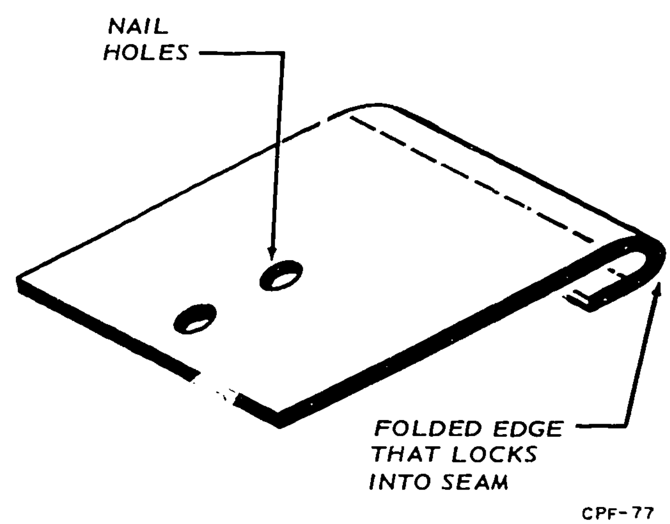


Figure 2–32. Cleat.

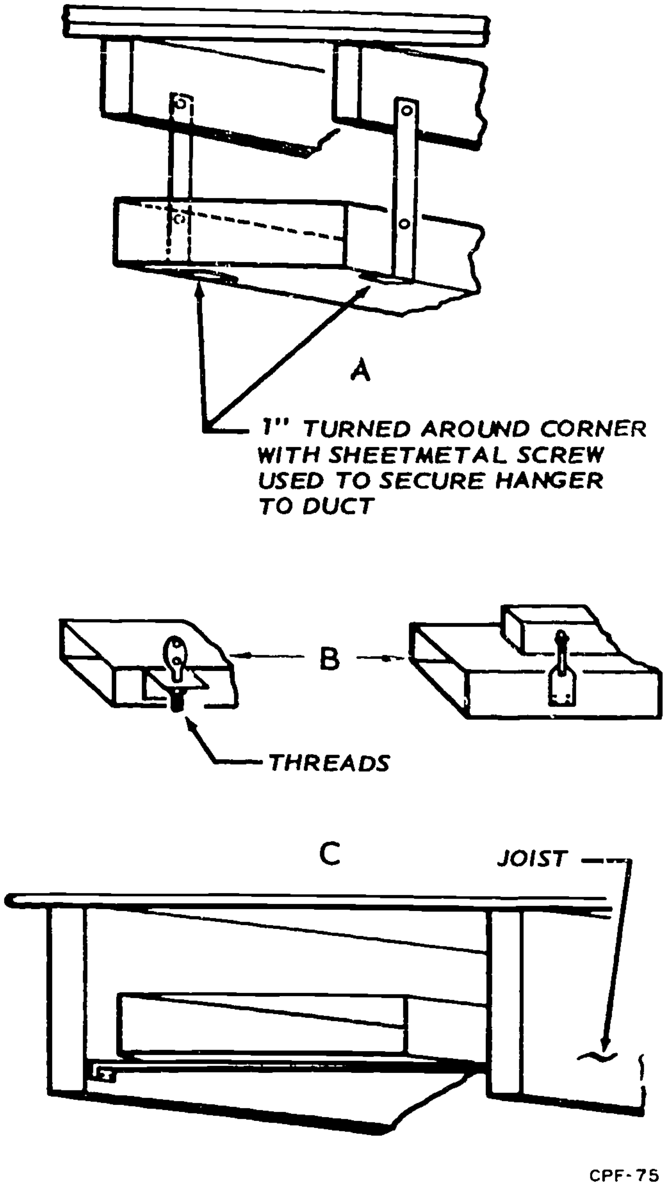


Figure 2–33. Hangers.

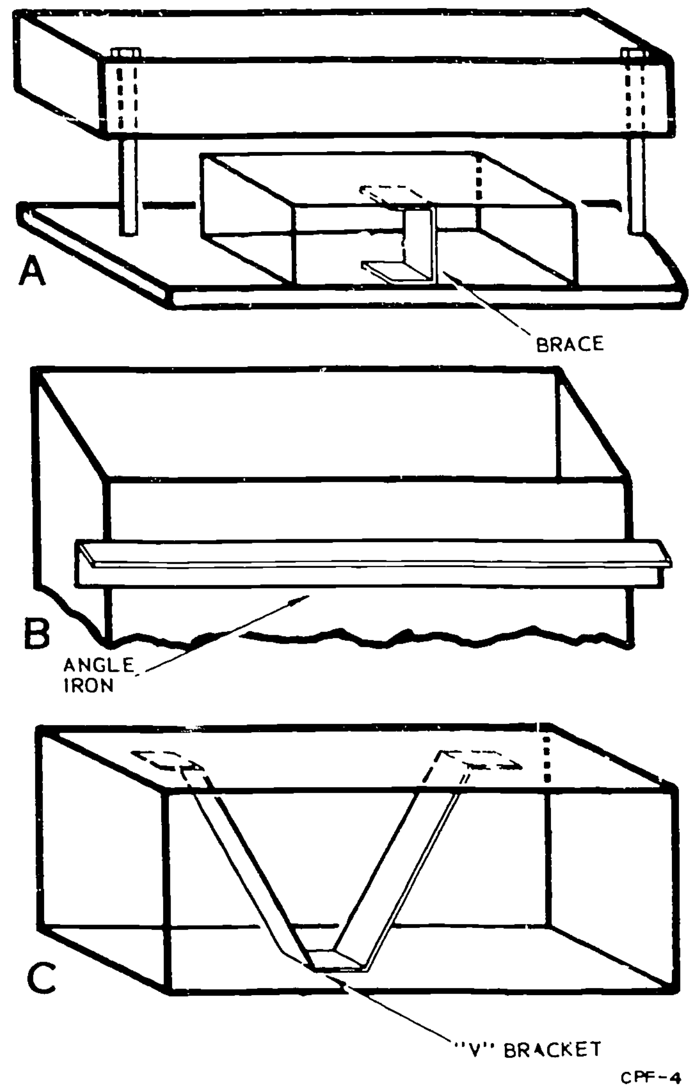


Figure 2–34. Uses of braces.

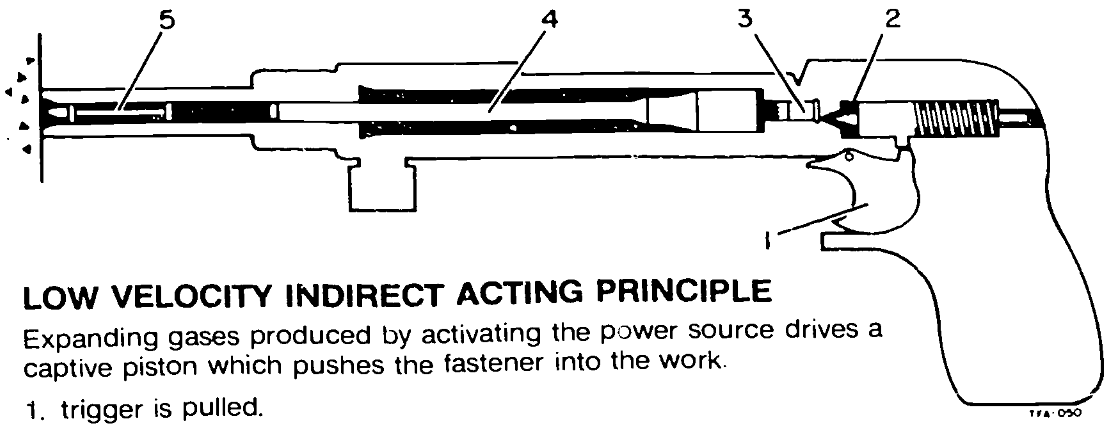


Figure 2–35. Indirect acting powder actuated tool.

3. On a flat metal roof, what keeps the roofing nails from damaging the roof?

4. When are the braces used?

5. How are hangers used?

2-5. Powder Actuated Tools

Powder actuated tools are more commonly known by their various trade names, for example, Ramset or Hilti. The use of these tools can greatly reduce the time required to install fasteners in many jobs, as well as make the job easier. There are, however, special precautions that must be taken and procedures to follow in the use of these tools. Because of the variety of brands available, and the variety of models available from each manufacturer, we discuss only general features, operating procedures, and safety precautions. These tools should be used only after proper hands-on training and after careful study of the proper operator's manual that accompanies each tool.

225. Identify specific components of powder-actuated tools, and cite safety factors involved in their use.

Powder Actuated Tool Components. There are two basic types of powder actuated tools - direct acting and indirect acting. The difference between them is in how the fastener is driven into the work. The indirect acting type is designed for light and medium duty fastening, while the direct acting type is designed for heavier duty fastening.

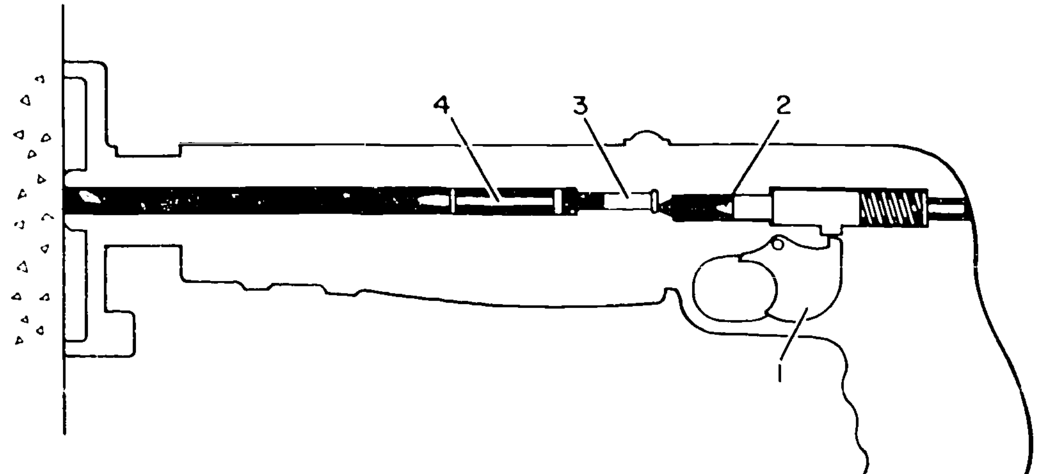
Indirect acting. The indirect acting tool as shown in figure 2-35 uses a powder charge to drive a piston which in turn drives the fastener into the work. An advantage this tool has over the direct acting tool is its barrel design which allows it to be used in confined areas.

Direct acting. This tool, shown in figure 2-36, is designed for heavier duty applications. The powder charge drives the fastener down the barrel of the tool and into the work, in the same way a handgun fires its projectile.

Fasteners. There are many fastener styles available to be used with either tool. The most common ones used are the pins and studs as shown in figure 2-37. The correct fastener to use depends on which tool and the materials being fastened. Always refer to the manufacturer's handbook for the proper selection.

Power loads. The loads or charges you select also vary from job to job. These charges are color coded and numbered to indicate their power level. To determine what load is right for the job you should always make a test fastening with the lowest power level recommended for the tool.

Applications and Safety. The wide variety of power loads and fasteners will help you on many jobs. Hanging ductwork from a concrete beam ceiling is one example of when this tool would save many man-hours work. It can be safely used to fasten through and into a wide variety of materials as shown in figure 2-38. Because of the nature of these tools, you must observe special safety precautions when using them. Following is a list of safety precautions from the Ramset owners manual; however, these precautions apply to all powder actuated tools.



STANDARD VELOCITY DIRECT ACTING PRINCIPLE

Expanding gases produced by activating the power source accelerate the fastener within the tool, generating the energy required to set the fastener into the work.

1. trigger is pulled.
2. firing pin released.
3. firing pin ignites power load.
4. expanding gases propel fastener down the barrel and into work surface.

Figure 2-36. Direct acting powder actuated tool.

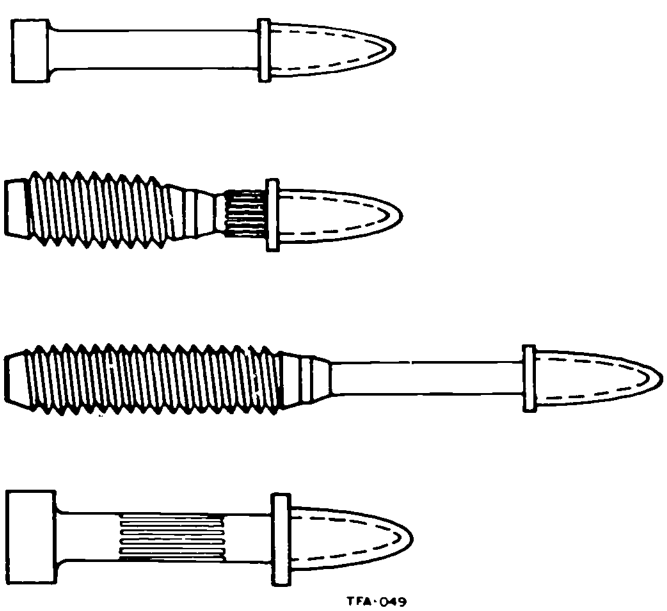


Figure 2-37. Common fasteners.

WARNING. Ramset powder actuated tools are to be used only by trained qualified operators according to Ramset's instruction manuals that are provided with each new Ramset tool.

Failure to obey Ramset's safety and operating instructions regarding the use of standard velocity tools can result in injury or death to the operator or bystanders due to escaping fastener.

Closing low velocity piston drive tools by placing hand over muzzle can result in discharge of tool and penetration of hand by fastener or piston.

GENERAL PRECAUTIONS. Do not operate any Ramset powder actuated tool unless you have been properly trained by a Ramset authorized instructor and have been issued a qualified operator's card.

Always read your operator's instruction manual prior to operating any Ramset powder actuated tool.

Use only Ramset fasteners, power loads and tool parts specifically designed for your application and the Ramset tool being used.

Do not alter tool parts or manufacture replacement parts for any Ramset powder actuated tool. If in doubt, call your Ramset representative.

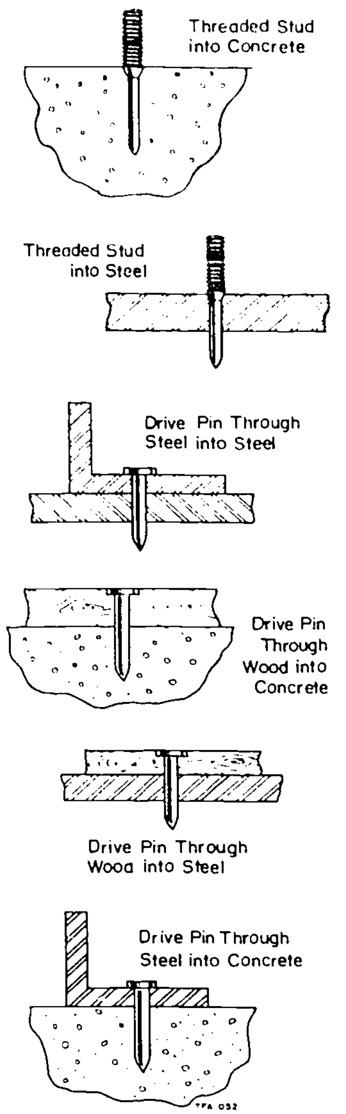


Figure 2-38. Fastener applications.

Always wear goggles when operating a powder actuated tool. Wear hearing protection when operating in a confined area. Never load a powder actuated tool until you are ready to make a fastening.

PRIOR TO LOADING. Perform safety checks of your tool as outlined in the instruction manual. In piston tools, barrel must be completely forward to properly position piston. Always check barrel of tool for obstructions before loading.

Analyze base material as described in your instructor's manual. A simple center punch test with a fastener and hammer will help avoid fastening into unsuitable materials that are very soft, brittle, or exceptionally hard.

When using the standard velocity tool make certain that the shield is in full position. Half shield position should be used only in corner applications or where physical restrictions provide protection from escaping fasteners.

LOADING PROCEDURES. Always load fastener before inserting power load. * Close tool manually. Never close tool against work surface. Never place hand over end of muzzle.

Loaded tools should close easily. If tool binds or otherwise fails to close, reopen and check for debris in breech or improperly seated breechplug or load.

OPERATING PROCEDURES. Read your operator's manual regarding operation of your specific Ramset tool. Always make a test fastening with the lowest power level recommended for use in your Ramset powder actuated tool. Always hold tool perpendicular to work surface. Do not attempt to operate tool at an angle.

Do not operate any powder actuated tool in an explosive or flammable atmosphere. Do not fasten into spalled or cracked concrete. Do not fasten through predrilled holes in concrete or steel. Observe proper edge and spacing distances.

If you decide not to make a fastening, unload your tool by removing powder load first, then the fastener.

Exercises (225):

1. What code is used to indicate the power level of a specific power load?

2. Which type powder actuated tool would be best to use for light fastening in a confined area?

3. What level powder load should be used as a test?

4. What should you look for before fastening into concrete?

Folding, Forming, and Seaming Equipment

IN THIS CHAPTER you will study pieces of equipment which are used to fold, form, and seam sheet metal; some of which are handtools, and others are machines. The straight line forming machines include such equipment as the bar folder, cornice brake, and box and pan brake. The machines are capable of making straight line folds or bends in sheet metal. Rotary forming equipment includes slip roll forming machines and a variety of rotary machines. Handtools used when forming sheet metal include such items as dollies, form blocks, vises, stakes, seamers, groovers, and various kinds of hammers and mallets. In this chapter you will also study safety precautions, maintenance tips, and the adjustment and use of folding, forming, and seaming equipment.

You will want to become well qualified in the use of this equipment, because the strength and general appearance of a completed job will be greatly affected. For example, suppose you have made a perfect transition layout. The next step is fabrication, which includes cutting, forming, and seaming. If you are to fabricate a component correctly, it will be necessary to use each machine correctly. In Chapter 1 we discussed cutting equipment; now we will discuss the specialized equipment used to fold, form, and seam sheet metal.

General safety procedures to follow when using folding, forming, and seaming equipment include such practices as keeping hands, fingers, and clothing clear of clamping devices, folding blades, bending leafs, and forming rollers. Make sure that materials and personnel do not interfere with proper operation of handles and levers of the machines. Specific safety procedures are discussed in the following sections along with the individual machines.

General maintenance requirements for folding, forming, and seaming equipment include keeping machines lubricated, cleaned, and properly adjusted for the gage of metal to be formed. These machines should not be overloaded by exceeding the recommended capacity. Like other large machines in the sheet metal shop, each piece of folding, forming, and seaming equipment should have a maintenance record folder which specifies the items to be inspected and serviced, the intervals of inspection, and a place to record and initial the maintenance completed. Specific maintenance procedures in the following sections along with the individual machines.

3-1. Folding Equipment

One of the most frequent and common operations in sheet metalwork is that of folding metal, and it is practically impossible to make these folds accurately without the aid of machinery. Folding machines that we discuss include the bar folder, cornice brake, box and pan brake, and brace and wire bender. The bar folder is used when the width of the fold to be made falls within the fold capacity of the machine. However, if the width of the fold is too great for the folder, the cornice brake is used. The box and pan brake is used to fold boxes and pans, as its name implies. The brace and wire bender is used to bend wire, round rod, and narrow widths of flat plate.

226. State procedures for using the bar folder.

Bar Folder. The bar folder, shown in figure 3-1, is designed to make bends and folds from 0° to 165° along the edges of sheets up to 43 inches in width. The thickness capacity of the bar folder illustrated is 20-gage material. This is the machine generally found in most sheet metal shops. The width of the folds, or gaging range, is usually from 3/32 to 1 inch, depending on the thickness of the material; the thinner the gage, the smaller the fold. The maximum diameter for wire edged folds is 1/4 inch. The bar folder is best suited for forming small hems (double or single), right-angle folds, rounded folds, and acute folds (less than 90°).

The bar folder is adjusted for different thicknesses of material by adjusting the wing pressure screws at each end of the folder. These adjustment screws are not visible in figure 3-1, but each consists of a threaded shaft with an adjusting nut and a locking nut which are tightened with a wrench to increase or decrease the distance between the wing and folding blade. After the folder has been adjusted, each end of the machine is tested separately by folding a small piece of metal. Take care not to adjust the bar folder to the extent that clamping pressure is excessive because too much pressure can damage the machine. Excessive clamping pressure is easily detected, because the machine does not operate freely.

The width of the fold is controlled by the gage adjusting screw (shown in fig. 3-1), which can be turned either clockwise or counterclockwise. This screw moves the slide and gage bar back and forth for the desired fold. The gage bar is under the folding blade and is not visible when you stand in front of the folder. Although the gage is graduated in fractions of an inch, a 6-inch rule is used for an accurate measurement by sliding the rule between the jaw and blade and holding it against the gage bar. After the measurement has been made, the gage is locked in place by tightening the lock screw, which is on the right side of the gage.

It is possible to make both sharp and round folds with this machine. Before the machine is adjusted, the wing must be

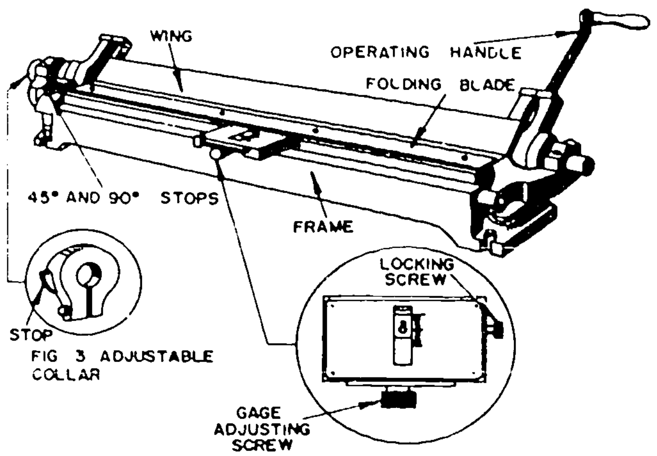


Figure 3–1. Bar folder.

perpendicular to the folding blade. Then a wedge which supports the wing must be properly adjusted by using the wedge adjusting knob located in the center back side of the folding bar. To make a sharp bend, set the wedge in such a manner that the wing stays in the same position through a cycle of operation. To make a round fold, adjust the wedge so that the wing falls back when it starts to swing.

There are two positive stops on the bar folder—one stop is set at a 45° bend and the other stops at a 90° bend. These stops are small pieces of flat bar that have been cut on the desired angle. To remove the stops, just swing (pivot) them out of the way.

Bends of other degrees can be made by setting the adjustable collar stop. This stop is located on one end of the bar folder and is set by loosening the bolt and rotating the stop to a 0° bend. Use a small piece of metal to make a test bend. Check the angle of the bend. When the desired bend has been achieved, tighten the bolt in the collar stop. (NOTE: When using the collar stop, pivot both positive stops out of the way.)

On the other end of the bar folder there should be a spring (not illustrated) attached in such a way as to aid in making the bend. The spring acts as a counter balance for the wing.

After the bar folder has been correctly adjusted, insert the metal between the folding blade and wing. Hold the metal firmly against the gage and pull the operating handle upward. The wing will automatically raise and hold the metal until the desired bend is made. This safety feature allows the left hand to be clear of the folding blade. When the handle has been returned to its original position, the wing and blade will return to their original positions and release the metal.

Exercises (226):

1. What item is adjusted for the different thicknesses of material?

2. To make a large number of identical folds, what should you set?

3. To make a round fold, what should you adjust?

227. State specific adjustments to make when using the cornice brake, and distinguish between the cornice brake and a box and pan brake.

Cornice Brake. The cornice brake, illustrated in figure 3-2, is a type of folding machine that has a much greater range than most folders. The cornice brake not only forms locks and bends, but it can do complicated jobs, such as forming complex seams and shapes, because of its construction. It also forms square, round, ogee bends. It can be used for many jobs, such as forming ducts, gutters, transitions, flashing, and gravel guards as well as joints, seams, and locks. For example, a Pittsburg lock can be formed very easily with the cornice brake if a Pittsburg machine is not available.

To get the most out of a cornice brake, it is necessary to know how to adjust it for various operations. These adjustments are very important because they save time and improve the quality of work.

The cornice brake must be level on the floor to prevent creeping of the top leaf when metal is clamped between the top leaf and the bed. If the top leaf creeps, screw P and screw O should be checked; both are shown in figure 3-2. If adjusting these screws does not remedy the creeping, put a wedge of wood or similar material under the rear leg on the side that creeps. The wedge should be forced until the creeping is eliminated. Then replace the wedge with a permanent block that is the proper height.

Next the bending leaf is checked when it is in the down position. The edge of this leaf should be 1/64 inch below the bed edge at the ends and 1/32 inch below the bed edge at the center. To obtain and maintain this alignment, the following adjustments are necessary:

a. Leaf ends adjusted with screw H (right-hand end view).

b. Leaf center adjusted with bolt 2 (front view).

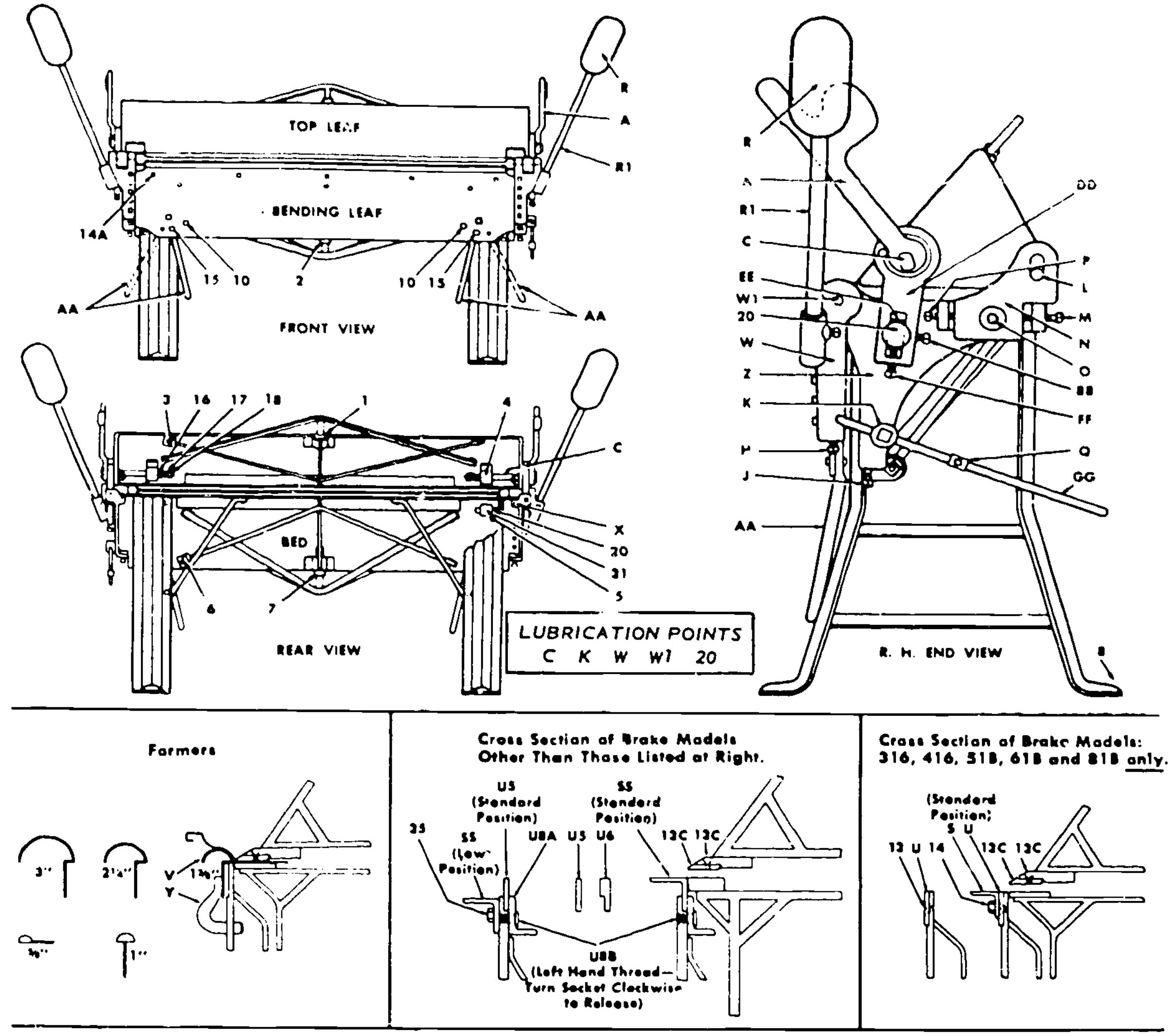
c. Bed ends adjusted with screws J (right-hand end view).

d. Bed center adjusted with bolt 7 (rear view).

When bending various thicknesses of metal the top leaf should be set back two times the thickness of the material being bent. Thus, to make neat sharp bends always make sure the set back is correct. To adjust the set back on the type brake illustrated, the top leaf adjustment is made as follows:

a. Screws O are loosened (shown on right-hand end view).

b. The top leaf is moved forward or backward by adjusting screw M or P (shown in right-hand end view); these screws have right-hand threads.



A—Clamping Handle
AA—Bending Leaf Handle
BB—Link Set Screw
C—Top Shaft
DD—Link
EE—Link Adj. Block
FF—Link Adj. Screw
GG—Stop Gauge Rod
H—Bending Leaf Hinge Adj. Screw
J—Bed End Adj. Screw
K—Stop Gauge Guide

L—Slot Casting Pin
M—Slot Casting Adj. Screw
N—Slot Casting
O—Slot Casting Lock Screw
P—Slot Casting Adj. Screw
Q—Adjustable Stop
R—Balance Weight
R1—Balance Weight Rod
S, SS—Bending Leaf Angle Bar
U—Bending Leaf (¼") Bar
U5—Bending Leaf (¼") Bar

U6—Bending Leaf (½") Bar
U8A—Bending Leaf Bar Holder
U8B—Bar Holder Screw
V—Formers (Specify Sizes)
X—Bed Adj. Screw
W—Bending Leaf Hinge
W1—Bending Leaf Hinge Pin
Y—Former Clamp
Z—Bed End Housing
2—Bending Leaf Adj. Bolt
7—Bed Adj. Bolt

10—Bending Leaf Tension Bolt
12C—Top Nose Bar
13C—Top Nose Bar Screw
14—(S) Angle Bar Screw
15—Bending Leaf Handle Screw
16—Clamping Handle Spring
17—Clamping Handle Washer
18—Clamping Handle Nut
20—Bottom Shaft
21—Bottom Shaft Set Screw
35—(SS) Angle Bar Screw

Figure 3–2. Cornice brake.

c. Once the correct adjustment is made, screws O are tightened

The clamping pressure should be tight enough to hold the metal in place while the bend is made. Different gages of metal require different adjustments; therefore, you must realize that every gage of metal has its own adjustment. Remember, the pressure should be equal on both ends of the machine. This clamping pressure can be changed by adjusting the link block (EE in right-hand view of fig. 3-2) To do this job:

a. Loosen screws BB which hold link adjustment blocks EE.

b. Adjust blocks EE to the thickness of metal with screws FF.

c. Lock adjustment blocks EE in position with screws BB.

d. Lock adjustment blocks EE in position with screws BB.

e. Use a test strip to make sure the machine is adjusted correctly.

After the cornice brake has been correctly adjusted, place the metal on the bed beneath the top leaf. Partially lower the top leaf by pulling the clamping handle (A in fig. 3-2) forward. Align the scribed break line on the metal (or prick points) with the nose bar (12C) on the top leaf; then pull the clamping handle until the metal is firmly clamped. To make the fold, pull the bending leaf handle (AA) forward and upward, which swings the bending leaf forward and upward as it pivots on the bending leaf hinge pin (W1). As the bending leaf swings up, the balance weights (R) move backward, acting as counterbalance weights for easier manual operation. When the desired angle of bend is reached, lower the bending leaf by movement of its handle or the balance weight. When the clamping pressure is released, remove the metal.

The capacities of machines like the one illustrated in figure 3-2 range from 22- to 16-gage sheet metal, and bending lengths range from 3 to 12 feet. However, the bending capacity of the cornice brake is determined by the bending edge thickness of the various bending leaf bars (S, SS, U, U5, and U6 in fig. 3-2). Bending leaf angle bars S and SS permit a smooth 1-inch flange to be made in a piece of material that is within the capacity of the cornice brake. Some pressure is released on the bending leaf bar identified as U when the S or SS bar is installed.

In figure 3-2, bending leaf bar U6 is a 1/2-inch bar for the bending leaf. When U6 is used to make flanges, the capacity of the brake is reduced by 4 gages. For example, if the cornice brake is rated at 16 gage, the capacity with a 1/2-inch U6 bending leaf bar will be 20 gage.

Suppose you are using the cornice brake to make small offset bends 1/4 inch wide. If your brake is like model 316, illustrated in figure 3-2, the bending leaf bar identified and U should be removed. If your brake is a model other than those like model 316, the 1/4-inch offset can be made by installing bending leaf bar U5. In both of these situations, the rated capacity of the cornice brake is reduced 7 gages. For example, a cornice brake rated at 16 gage is reduced to 24-gage capacity. You should remember this capacity change, because the bending leaf can easily be warped if the rated capacity is exceeded. Duplicate bends can be made with any of the models of brakes that you may have in your shop be setting the adjustable stop, Q, for the desired angle.

There are occasions when the material bends excessively or bends further on one end of the brake than on the other. To correct either condition:

a. Loosen screws O (shown in right-hand end view).

b. Readjust the top leaf with screws M and P.

c. Retighten screws O.

If the bending leaf becomes bowed after repeated heavy use, both bolts (10, front view) are tightened until the center is brought in line. This line should be straight and should be checked with a straight edge.

Molds or formers, as illustrated in figure 3-2, can be obtained in half-round sizes, such as 5/8, 1, 1⅝, 2¼, and 3 inches, and are used most often to make gutters. These formers are attached to the brake with clamps Y; usually three to five clamps are used.

To attach formers to the brake, there must be 1/2-inch clearance on the side of the formers against the bending leaf. The clamps are positioned vertically to the ground and tapped lightly with a mallet. This creates enough friction to hold the formers in place.

Some of the precautions to observe when operating a cornice brake include:

a. Always bend short pieces of material in the center of the brake to equalize the strain on the machine.

b. Always SS angle bars with U5 and U6 bars to make narrow offset bends.

c. Never bend seams unless you adjust links DD to clamp the full multiple thickness of the seam, and set the top leaf back for clearance of the same multiple thickness.

d. Never bend rod, wire, band iron, or spring tempered sheets on the cornice brake.

e. The counterbalance is very heavy and can cause serious injury to you or other personnel if released improperly. Always return the bending leaf slowly to its proper position after completing a bend.

Box and Pan Brake. The construction of the box and pan brake is a great deal like that of the cornice brake except that the clamping leaf of the box and pan brake is divided into removable sections called fingers or shoes. These fingers, as shown in figure 3-3, vary in width and are interchangeable. This machine is especially designed for making boxes of various sizes and shapes, because it permits the forming of all sides without distorting any of the finished bends. If the need arises, you can use this brake to do most of the same type of work that can be done on the standard cornice brake. The main advantage a box and pan brake has over the cornice brake is that you may form pans or boxes with four sides by using different combinations or arrangements of the fingers.

Since the machine is a great deal like the cornice brake, all adjustments such as radius and thickness can be made the same as for the cornice brake. The steel fingers are secured to the upper beam by means of thumbscrews. Before using the brake, securely seat the fingers and tighten the thumbscrews. To remove any of the fingers, raise the clamping bar, loosen, the thumbscrews, and pull the fingers

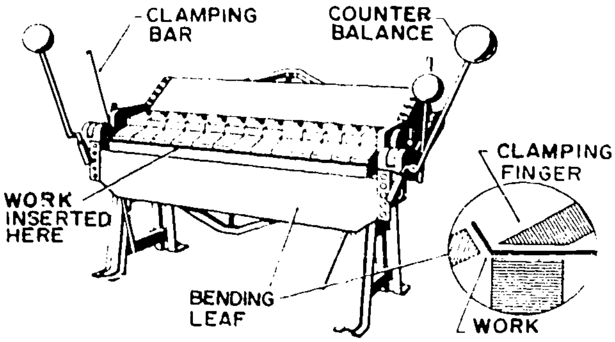


Figure 3–3. Box and pan brake.

forward. When installing the fingers, reverse the procedure.

Before starting any work on the box and pan brake, be sure all adjustments are made and are suitable for the gage of metal selected. Never bend rod, wire, band iron, or spring tempered sheets on the box and pan brake. Operation of the box and pan brake is similar to that of the cornice brake.

Exercises (227):

1. What adjusting screws are adjusted to change the set back?

2. If the bending leaf is too low in the center, what item should be adjusted?

3. What is mounted on the brake to assist in forming rain gutters?

4. What feature of a box and pan brake distinguishes it from a cornice brake?

3-2. Forming Equipment

The most frequently used machines in the sheet metal shop include squaring shears, cornice brake, and slip roll forming machine. Other forming equipment includes rotary machine, rotary burring machine, turning machine, wiring machine, elbow edging machine, setting down machine, crimping machine, bedding machine, dollies, form blocks, and sandbags.

228. State the operating procedures of a slip roll forming machine.

Hand Operated Slip Roll Forming Machine. The slip roll forming machine, illustrated in figure 3-4, is used to form sheets into cylinders of various diameters. The machine is simply constructed and consists of right- and left-end frames (housing) between which are mounted three solid steel rolls—two lower rolls and one upper roll. The two lower rolls are connected by gears operated by a handcrank. The lower front roll can be adjusted to the thickness of the metal by means of two knurled adjusting screws (one at each end of the roll). Once the metal is started into the machine, it is gripped between the lower front roll and the upper roll and is carried to the lower rear roll which bends it around the upper roll, thus forming a cylinder. Turning the adjusting screws at each end of the lower rear roll to the right, produces a smaller radius. Turning the screws to the left, produces a larger radius.

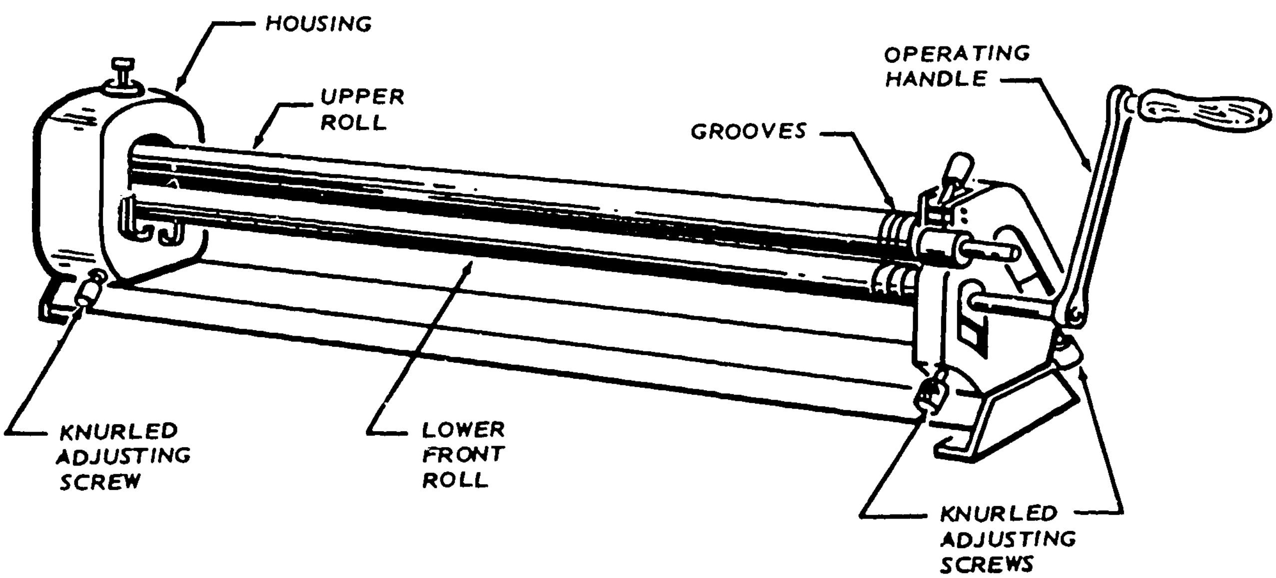


Figure 3–4. Hand-operated slip roll.

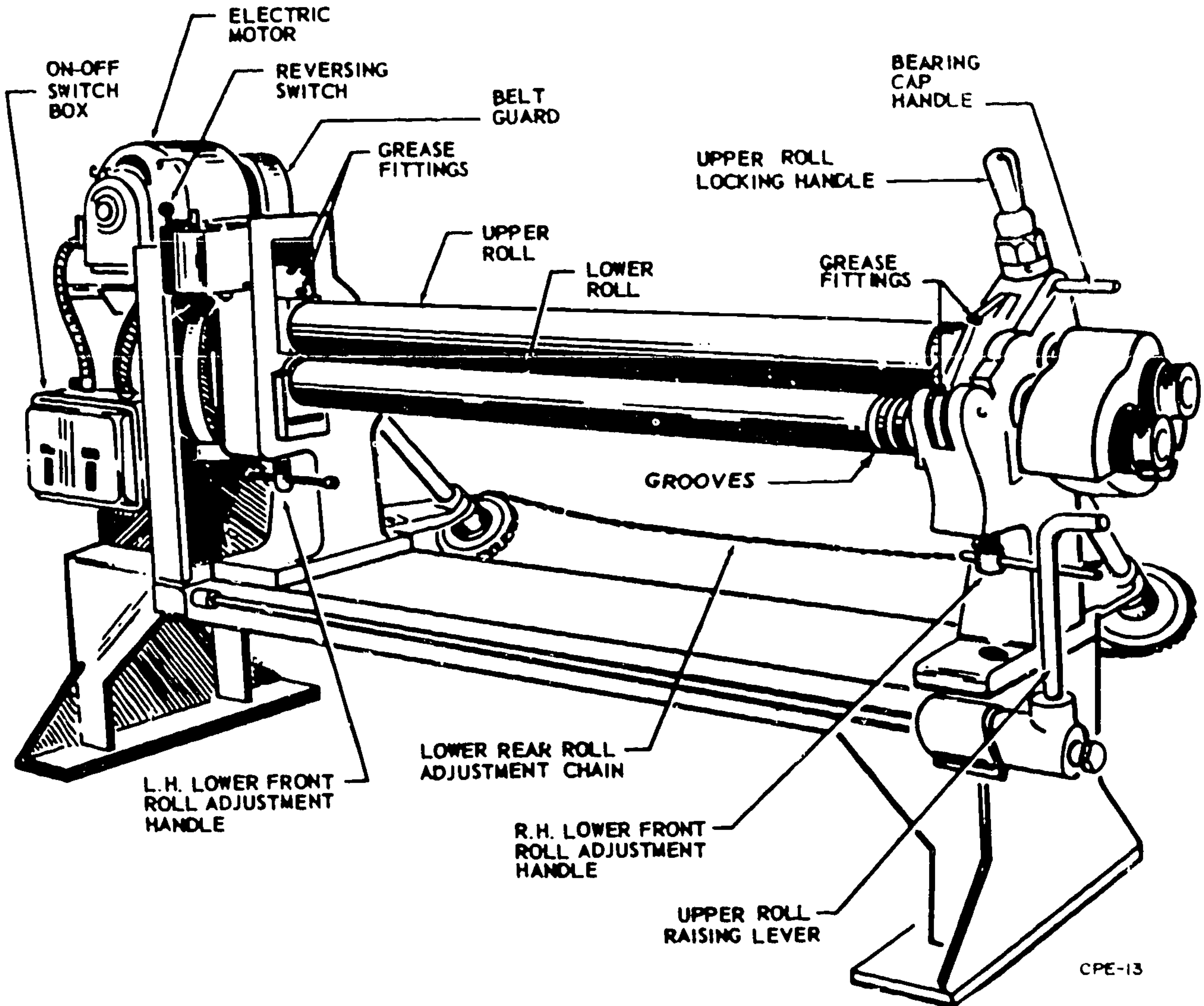


Figure 3–5. Power-operated slip roll.

On most hand-operated slip roll forming machines the upper roll can be released at one end which permits a formed cylinder to be removed from the machine without distortion. The rolls are grooved on the right end for forming wire and wired edges. The capacity of slip roll forming machines is determined by the manufacturer and must not be exceeded.

Slip roll operation is not a set procedure; however, the following is recommended: the lower front roll must be adjusted so that it and the upper roll will have a uniform grip on the metal. Once this adjustment has been made, the metal should ride smoothly through the rolls. In making a preliminary test it is best to select a piece of scrap material of the same gage as the metal you plan to form. Crank the test piece through the gripping rolls until it comes in contact with the lower rear roll. Then by means of adjusting screws, the lower rear roll is set for the desired radius. This adjustment must be the same on both ends to form cylinders unless a taper is desired. A truncated cone or frustum is formed when the screws have different adjustments. When the rolling process is completed, the upper roll is released and raised. The test piece is then removed and final adjustments made. Place the material square with the rolls, and turn the crank clockwise. The cylinder that is formed should be the finished product. No change of adjustments on the machine is necessary when more than one item of the same size is to be formed.

Power Operated Slip Roll Forming Machine. The power operated slip roll forming machine, shown in figure 3-5, is a great deal like the hand-operated slip roll machine in that it has two lower rolls and one upper roll. However, turning power for the rolls is supplied by an electric motor. Direction of the rolls is controlled with a reversing switch.

The power-operated slip roll machine, like the hand-operated version, has a limitation as to the diameter (radius) it can produce. When the machine is operating at maximum capacity (thickness and size of the sheet metal), the diameter of the cylinder formed should not be less than two

times the diameter of the upper roll. If this recommendation is not followed, the formed cylinder will have flat spots at the seam.

The front gripping rolls can be adjusted for clearance (according to thickness of metal to be formed) by turning screw handles located under the ends of the lower front roll. The lower rear roll can be adjusted for radius of bend by moving the endless chain. This chain turns adjustment screws at each end of the machine to keep the lower rear roll parallel with the gripping rolls. After the cylinder is formed, it can be removed by releasing the upper roll locking handle and pressing down the rai'ing lever located at the right hand end of the machine.

Before starting the electric motor, you must press the on button of the on-off switch. Then move the reversing switch lever from the OFF position to the FORWARD position. This starts the motor and sets the rolls in motion for normal operation. When it is necessary to reverse the direction of the rolls, move the reverse switch lever to the OFF position until the rolls stop rotating, then move the lever to the REVERSE position. When a job has been completed, stop the rolls and remove power by moving the reverse switch lever to the OFF position and by pressing the off button of the on-off switch.

Operation of the power slip roll machine is similar to that of the smaller, hand-operated slip roll except that the heavier gage metal can be formed. The heavier gages must be inserted and rolled for 7 to 9 inches, then backed out, turned around, and rolled from the other end in the regular way. This prevents a flat spot along the seam.

Similar maintenance is performed on hand-operated and power-slip roll machines, such as lubricating the moving parts, keeping the rollers clean, and keeping the machines clear at all times. When the rollers get dirty, clean them with steel wool and a dry rag; then wipe them with an oiled rag to prevent corrosion.

You should observe safety precautions, such as keeping hands, fingers, and clothing clear of the rollers and drive gears, at all times. As with other machines, handle metal carefully to keep burrs from cutting your hands. Never apply power to the rolls until you are certain the machine is clear. If you are working on large jobs that require assistance from another person, make certain that you both are qualified operators and that you understand which part of the operation each will perform.

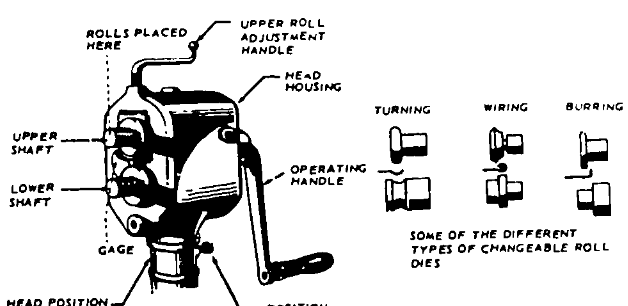


Figure 3–6. Rotary machine.

Exercises (228):

1. Which roll is adjusted to produce the desired radius?

2. How is the direction of the rolls in a power operated sliproll controlled?

3. Why is an endless chain used on a power slip roll forming machine?

4. To roll a truncated cone, how must you adjust the lower rear roller?

5. Which two rolls are geared together?

229. Distinguish among the types of rotary machines by the jobs they do.

Rotary Machines. The rotary machines, illustrated in figures 3-6 through 3-12, are designed to rotate various shapes of matched roll dies which press sheet stock into desired shapes. Sheet metal is fed between these rolls in a manner similar to that for sliproll machines. Basically, a rotary machine consists of two shafts mounted in a frame. The rolls are mounted on one end of the shaft, and a pair of mesh gears and a handle (or pulley) are mounted on the other. The distance between the two rolls can be adjusted by a small crank located on top of the machine. Rotary machines are manufactured to operate either by power or by hand and, like many others, are equipped with gages to guide the metal. Such gages can be set to determine the depth at which a sheet passes between the rolls. Most rotary machines have a head position adjustment and lock screw, as shown in figure 3-6.

Because some rotary machines are designed for one specific operation, the operator must be certain of what each machine can do. This will be easy for you since the name of each rotary machine, in most cases, defines the job that it does. Typical examples are burring, turning, elbow edging, setting down, crimping, and beading machines.

The rotary machine illustrated in figure 3-6 is a combination of several rotary machines since by changing roll dies this machine can perform several operations. This machine has a combination rotary head that will accept turning rolls, burring rolls, and wiring rolls. To change these rolls, loosen the nuts on the end of the shafts and remove the rolls and replace them with rolls that are desired. Some of the nuts have left-hand threads; therefore, you should be careful when changing the rolls.

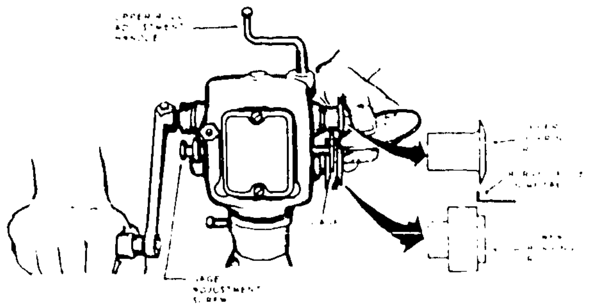


Figure 3–7. Rotary burring machine.

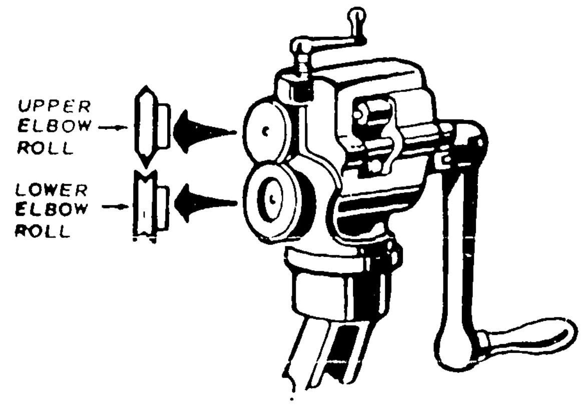


Figure 3–9. Elbow edging machine.

Rotary burring machine. A burring machine, such as that shown in figure 3-7, is used to turn flanges and edges on circular discs and cylinders. It is also used for turning edges on elbows and for making double seams and single hems when other machines are not available. An important thing to remember is that it will take considerable time, effort, patience, and practice to turn out a good job.

To operate the rotary burring machine, you must adjust and align it so that the side edge of the top roll protrudes over the shoulder of the bottom roll twice the thickness of the metal. The opening between the rolls should be equal to the thickness of the metal. Be sure these adjustments are correct because if the opening is too small, the top roll will act as a shear and cut the metal. The gage adjustment screw that controls the amount of metal turned up (flanged) is on the back side of the machine. Flange limits are from 1/8 to 1/4 inch.

To start the forming operation, place the disc in the machine and lower the top roll with the crank screw until the machine grips the metal and creases it slightly. Turn the crank slowly in a clockwise direction while keeping the edge of the disc firmly against the gate. Use caution to prevent injury to the hand when the disc is rotating between the thumb and forefinger. The first revolution of the rolls should be slow enough to permit the accurate starting of the burred edges. After the first revolution of the disc, it is possible to disregard the gage and follow the crease as the top pressure increases. Continue turning as before. Raise the disc slightly after each revolution until the full burred edge has been formed.

Turning machine. The turning machine, illustrated in figure 3-8, is used to form rounded flanges for wired edges.

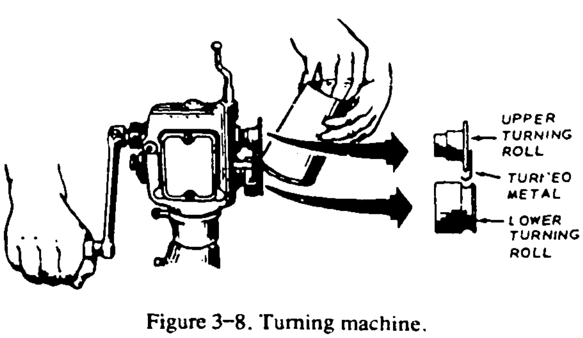


Figure 3–8. Turning machine.

The rolls of this machine may also be used to turn double seams on elbows when a elbow edging machine is not available. The turning rolls are removable. Thin turning rolls are available for light work and thick rolls for heavy work.

The first operation is to center the top and bottom rolls, then to adjust the gage so that it allows ample space for the wire. When the gage has been properly set, rest the cylinder to be wired on the lower roll, and press the edge against the gage. With the cylinder in place, lower the upper roll by turning the small crank screw located on top of the machine until a slight depression is formed in the metal. Turn the crank handle slowly until the cylinder has passed completely through the machine. Be sure to hold the metal firmly against the gage. After the first crease has been made, lower the upper roll, and pass the metal through the machine again with the work tilted upward. Repeat this process several times to obtain the desired groove.

Elbow edging machine. The elbow edging machine, shown in figure 3-9, has elbow edging rolls that fit most standard makes of turning and burring machines. The lower roll of the elbow edging machine is v-grooved and has a matching upper roll. The rolls are made in three standard types to permit the fabrication of interlocking edges used in fastening various pieces of elbows together.

For making various types of edges, the operation is much the same. First, you must determine what lock seam is best suited for the job; then, screw the guide bar (gage) away from the rolls until the desired seam allowance has been made. If the use of a guide bar is not practical, draw or scribe a line around the outside of the elbow section 1/8 inch from the edge to be joined. Make a similar line on the machine section inside the cylinder.

Place the first piece in the elbow edging machine so that the inside surface of the elbow rests on the lower roll. Keep the edge of the elbow snug against the guide bar, and tighten the top roll until it forms a slight crease in the metal. Turn the handle slowly as you carefully guide the piece through. After one complete revolution of the elbow, tighten the top roll slightly, and repeat the process until a deep groove has been made around the edge of the elbow section.

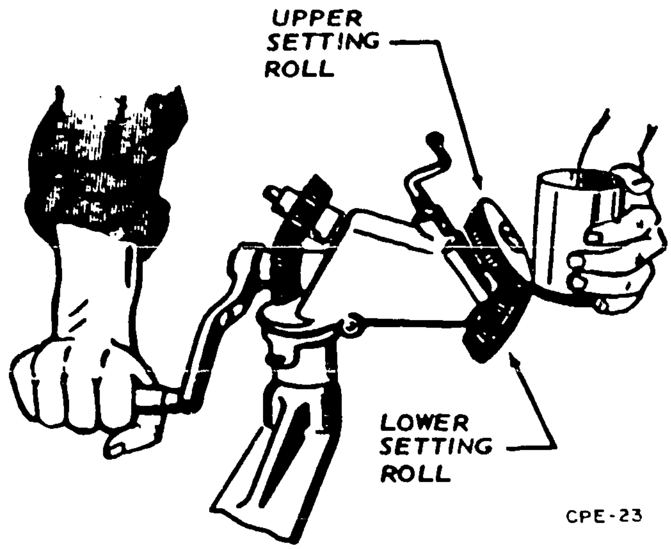


Figure 3-10. Setting down machine.

The second piece is made in the same manner; however, the upper roll is placed on the inside of the cylinder.

Once the job has been completed, the lock should snap together with very little, if any, difficulty. If the flanges are too loose, tighten them with a hammer and stake.

Setting down machine. The setting down machine, shown in figure 3-10, is used for tightening or setting down the edges prior to double seaming. Two styles of setting down machines are available—one has the upper roll perpendicular to the lower roll, and the other has both rolls sloping toward the machine.

When double seaming the bottom of a can or tank, hold the object in any convenient position, and run it between the rolls. The crank screw on top of the machine can be adjusted to any pressure necessary to close the seam.

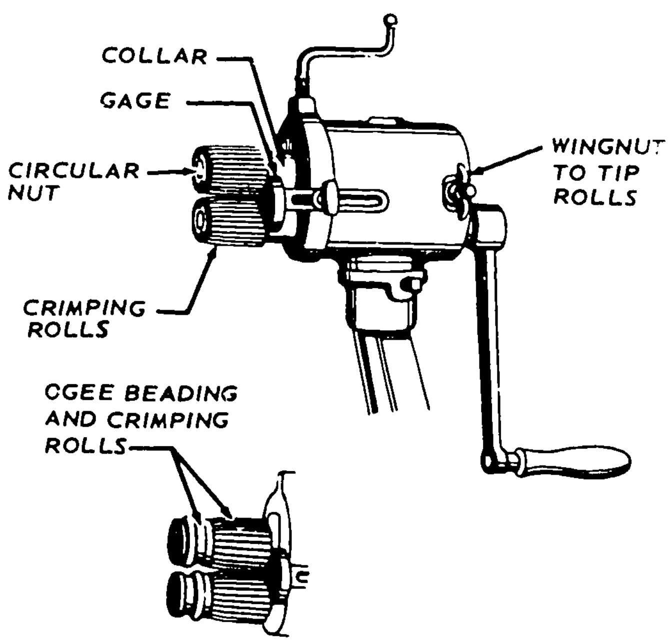


Figure 3-11. Crimping machine.

Machine operation consists of placing the object between the upper and lower rolls and lowering the top roll. Medium pressure is desirable for the first revolution around the bottom of the object and should be continued until all wrinkles are removed. After this setting down operation has been completed, the seam must be turned up tight against the side with a mallet and stake or a double seaming machine.

Crimping machine. The crimping machine, shown in figure 3-11, is used to make one end of a pipe joint smaller than the other so that the two sections may be slipped together. Some of the crimping machines have combination beading rolls and crimping rolls. The bead serves to reinforce a formed cylinder and to prevent the crimped edge from slipping too far into the other cylinder.

The mechanism is similar to that of most rotary machines. For jobs with riveted or grooved seams, the crimp is started near one side of the seam and run around the cylinder to the other side of the seam. Never crimp a seam, because its thickness will damage the rolls and spring the shafts of the machine.

When you crimp a pipe or object, insert it between the rolls, and adjust the gage to the correct width of the crimp desired. Lower the top roll until it makes a slight depression in the cylinder as the operating handle is turned. Repeat this operation until the desired fit is obtained.

Beading machine. The beading machine, shown in figure 3-12, is used for making beads in sheet metal objects such as cans, buckets, and pipes. Beads act as stiffeners and serve as stops for connecting two or more lengths of metal pipe. The beading machine is easy to operate, and with practice, high-quality work can be turned out. It comes equipped with several pairs of rolls which can be removed and replaced in the same manner as the burring and wiring machine rolls. The beading machine rolls that are generally used are single rolls, double rolls, triple rolls, and ogee rolls.

To operate the beading machine, place the cylinder between the rolls so that the top roll is on the outside of the cylinder. Place the edge of the cylinder against the adjustable guide (gage), and keep it there at all times or the beads will not meet after the first revolution. The adjustable guide can be set at different locations so that one or more beads can be made at different distances from the edge. Next, lower the rolls with the crank screw until a slight depression is made in the metal. Turn the handcrank with the right hand as the work is guided with the left; as the work revolves around the rolls, an impression is completed. Do not run the rolls over a seam, because that will damage the machine and weaken the seam.

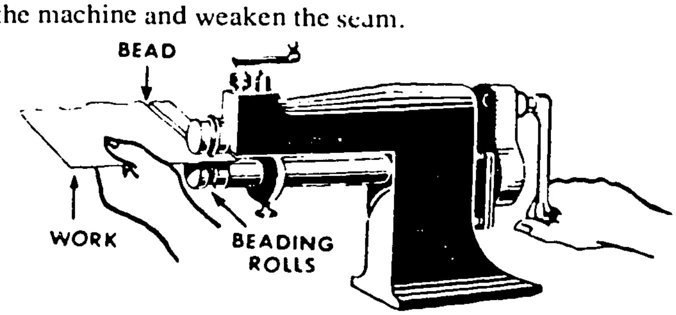


Figure 3-12. Beading machine.

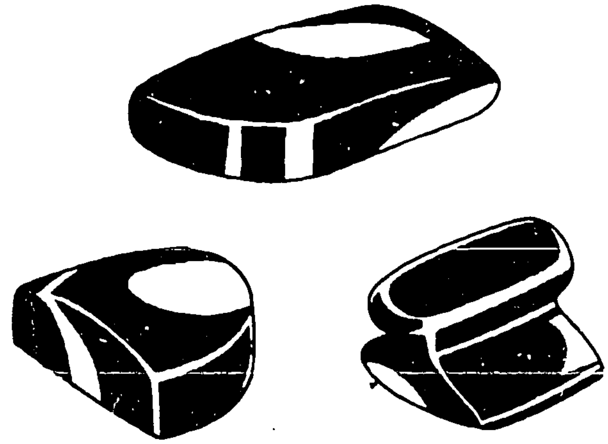


Figure 3–13. Hand dollies.

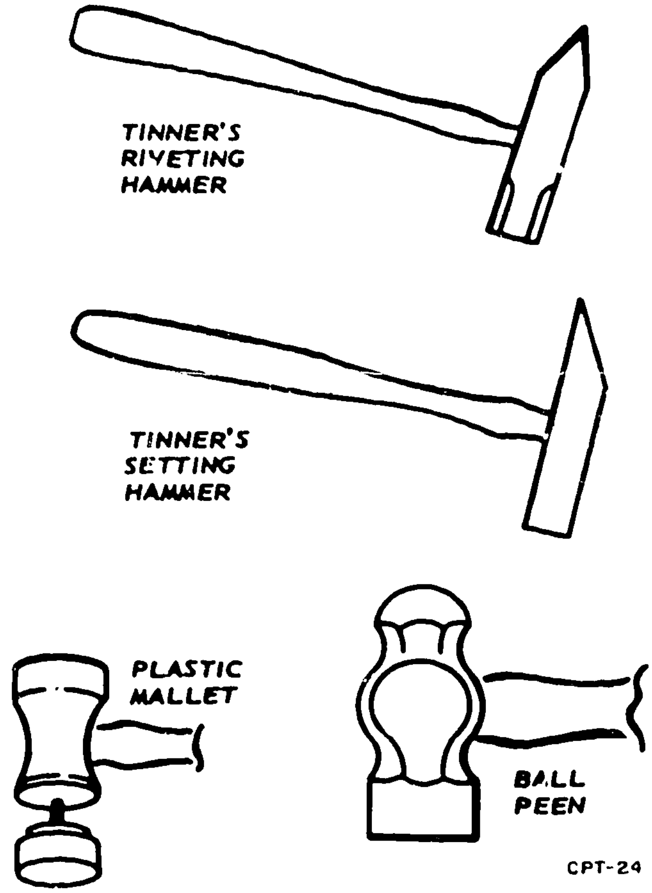


Figure 3–14. Hammers and soft-faced mallets.

Exercises (229):

1. What rotary machine is used to turn flanges and edges on circular discs and cylinder?

2. What rotary machine is used to form round flanges for wired edges?

3. What rotary machine is used when cylinders are to be connected together by interlocking grooves?

4. What rotary machine is used for tightening edges prior to double seaming?

5. Which machine would you use to make one end of a pipe joint smaller than the other?

230. State the purpose of hand forming tools and equipment.

Hand Forming Equipment. We have discussed several rotary machines which you use to form sheet metal parts. However, there will be times when you will not be able to perform some jobs on a machine. In the following paragraphs, we discuss hand dollies, hammers, mallets, and vises. With these tools you can do many jobs where a machine cannot be used or is not available.

Observe safety precautions at all times since most of the jobs you do will be with handtools that are small and hard to hold. Be cautious of metal burrs, and keep hands clear when forming with these tools.

Dollies. Hand dollies, which are commonly called bucking bars in sheet metal shops, may be shop made or purchased commercially. They are available in various sizes and shapes, as shown in figure 3-13. They may be used when forming metal. They may also be used when riveting in places where access to the job is difficult or at jobs away from the shop where stakes are not available.

Hammers and Mallets. Hammers and mallets, illustrated in figure 3-14, are used often in the sheet metal shop for such jobs as riveting, raising metal, setting seams, and driving punches and chisels. It is important to select the right hammer or mallet for the job.

The maintenance required to keep a hammer in good working condition consists of keeping the heads smooth and making sure the handle is good and properly secured to the head. As a safety precaution, make sure the wedge in the handle has not worked loose. If it has, the head could come off during use.

Tinner's riveting hammer. The tinner's riveting hammer has a square, slightly curved face with beveled edges to prevent the head of the hammer from marking the metal. The peen side is doubled tapered with a slightly rounded end. You will use this hammer often when riveting.

Tinner's setting hammer. The tinner's setting hammer has a square flat face for flattening seams without damaging the metal. The single tapered peen is used for setting down seams.

Ball peen hammer. The ball peen hammer has a variety of uses around a sheet metalshop. If you are working with punches, cold chisels, and other similar cutting tools, always use a ball peen hammer of the proper size. This hammer can be used also in riveting, peening, and raising metals.

Claw hammer. In many shops a common nail or claw hammer (not illustrated) is used to nail supports, to nail flat sheets of metal to wooden sheeting, to pull nails, and for other general utility purposes.

Mallets. Although they are not often mentioned as required tools, a wooden mallet, a plastic face mallet (or hammer), and, in some cases, a leather face mallet may be included in the sheet metalworker's toolkit or as a part of the sheet metal shop equipment. Remember that hammer faces are made of harder metal than the material being worked and may damage soft metals such as copper, aluminum, and light gage sheet metal. When you are doing the preliminary shaping of these metals on stakes, use a wooden or plastic mallet whenever possible, finishing up with the proper metal hammer. Some examples of when you would use mallets are the forming of grooved seams and wired edges which require a great deal of handwork in fabrication.

Vises. A bench vise, such as that illustrated in figure 3-15, is a very important piece of equipment in the sheet metal shop. Bench vises are manufactured in many sizes and designed for different jobs. A vise with a 4- or 5-inch jaw is commonly used in sheet metal shops to hold material for filing, forming, or sawing. The removable jaws are each secured with two screws and are usually grooved to keep the material from slipping. When working with soft metal, you should use jaws which are made of brass or aluminum and which are not so likely to mar the material being held. If jaws of soft metal are not available, use blocks of wood as a substitute.

Vises are usually secured to the workbench with screws or bolts; they have swivel bases to allow change of work positions for better access to the job. Avoid tightening the jaws too tight because the jaws and the slide work on a worm gear; if tightened excessively, the worm gear becomes worn and causes improper operation. The worm gear can be removed for cleaning, inspecting, and oiling by turning counterclockwise until it is disengaged from the vise.

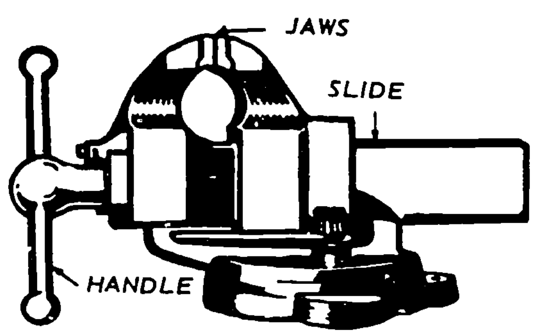


Figure 3–15. Bench vise.

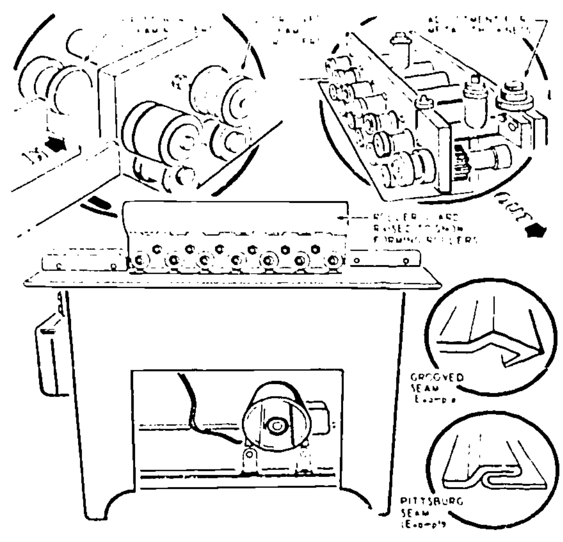


Figure 3–16. Pittsburg lock-forming machine.

Exercises (230):

1. What would you use as a bucking bar when riveting in close places?

2. What hammer is used to raise metal?

3. For what purpose are mallets used?

3-3. Seaming and Locking Equipment

There are several machines and handtools that may be used to make seams and locks. We have already discussed bar folders and brakes. In this section, we will discuss the Pittsburg lock forming machine, hand groovers, hand seamers, bench plates, and stakes for making seams and locks.

231. State the products of the Pittsburg machine, and tell how to use it.

Pittsburg Lock-Forming Machine. The Pittsburg lock-forming machine, shown in figure 3-16, is used to form Pittsburg lock seams for corners of rectangular or square ducts and to form grooved seams for round ducts. These two seams are shown in the illustration. By changing the rollers, the Pittsburg machine may be used to form other shapes of metal items. One such item is a drive slip used to connect sections of duct work. Check the manufacturer's handbook for other forming operations and the roller used

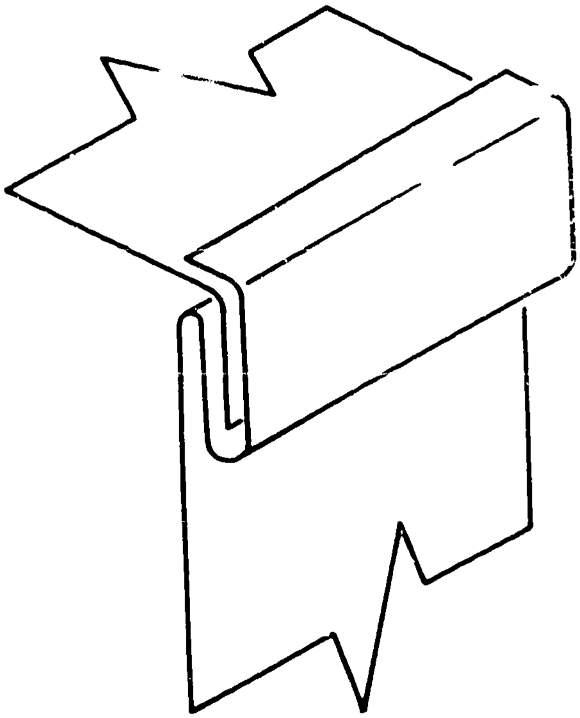


Figure 3–17. Pittsburg seam.

for each forming operation. The machine illustrated can form 26- to 18-gage sheet metal by adjusting for metal thickness. Be careful to set the thickness gage correctly to prevent damage to the rollers, and never overload the machine. The machine has guides to keep the material straight as it is fed into the rollers and has a protective cover over the rollers. Although figure 3-16 shows this roller guard in the raised position in order to view the rollers, the machine is never operated with the cover open. When the rollers are being cleaned or changed, electrical power to the machine should be removed so the on-off switch is inoperative.

Before using the Pittsburg lock-forming machine, you should make seam allowances on the pattern, and you should notch the material. Usually, for a Pittsburg seam the allowance is 1¼ inches (1 inch for the seam side and 1/4 inch for the flanged side). The 1-inch seam is formed by the machine as shown in the example of the Pittsburg seam in figure 3-16. The 1/4-inch flanged edge is bent 90° on a brake machine then fitted into the groove of the 1-inch seam as shown in figure 3-17. Then the metal which extends above the groove is flattened to hold the seam tight.

Allowance for a grooved seam, such as that shown in figure 3-18, will usually require 1/2 inch on each side to make the seam, plus an additional 1/2 inch because the seam will overlap. In figure 3-18, you can see how the grooved seam is secured by flattening the two parts.

After setting the thickness gage on the Pittsburg lock-forming machine to correspond with the material to be formed, turn the motor on and feed the material into the rollers. Hold the material flush against the guide as it passes through the rollers. It is important to start the material straight because once it has started through the rollers, the machine will complete the operation whether it is straight or not. Keep hands and fingers away from the rollers during the forming operation.

The Pittsburg lock-forming machine, like other machines in the sheet metal shop, should have a maintenance record folder, which has a list of items to be inspected and serviced, intervals of inspection, and a place to record and initial the maintenance completed. The manufacturer's handbook or the technical manual will specify exactly what parts are to be serviced, including lubrication of the rollers and drive gears. If the motor does not have sealed bearings, it also will require lubrication. Keep the rollers clean and wipe them with an oiled rag to prevent corrosion.

Exercises (231):

1. What are the products of the Pittsburg lock-forming machine?

2. What must you do to produce a drive slip on a Pittsburg lock-forming machine?

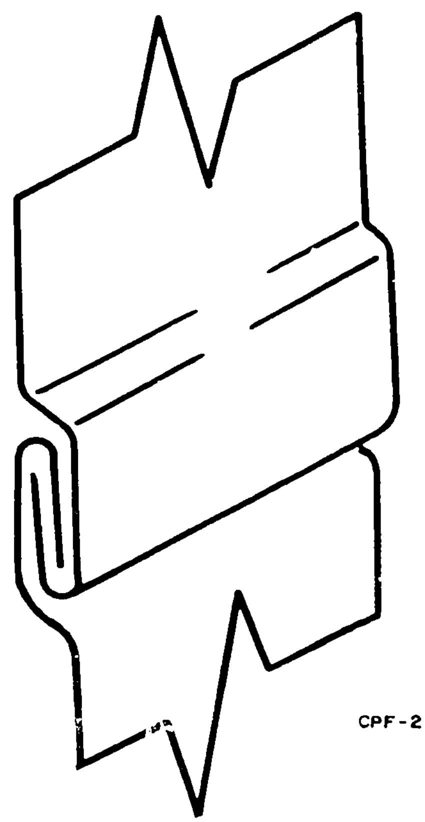


Figure 3–18. Grooved seam.

3. What allowances must be marked on the material before using the Pittsburg lock-forming machine?

232. State how to use bench plates and stakes.

Hand Seaming Equipment. The hand seaming equipment discussed in this section includes bench plates, stakes, hand seamers, and hand groovers.

Bench plate and stakes. Much of the work done in the sheet metal shop requires some handwork, such as shaping, seaming, and riveting. To do this work, small anvils, referred to as stakes, have been designed to perform many types of shaping and seaming which cannot be done by machines. These stakes, which consist of a horn, head, and shank, are fastened either in a vise or to a bench plate. Figure 3-19 shows a bench plate with a set of stakes designed to do almost any sheet metal forming that can be done by hand. The stakes described in the following paragraphs are the ones most often used. Other stakes include the beakhorn, common square, hatchet, conductor, coppersmith square, bottom, bevel edge square, and solid mandrel stakes.

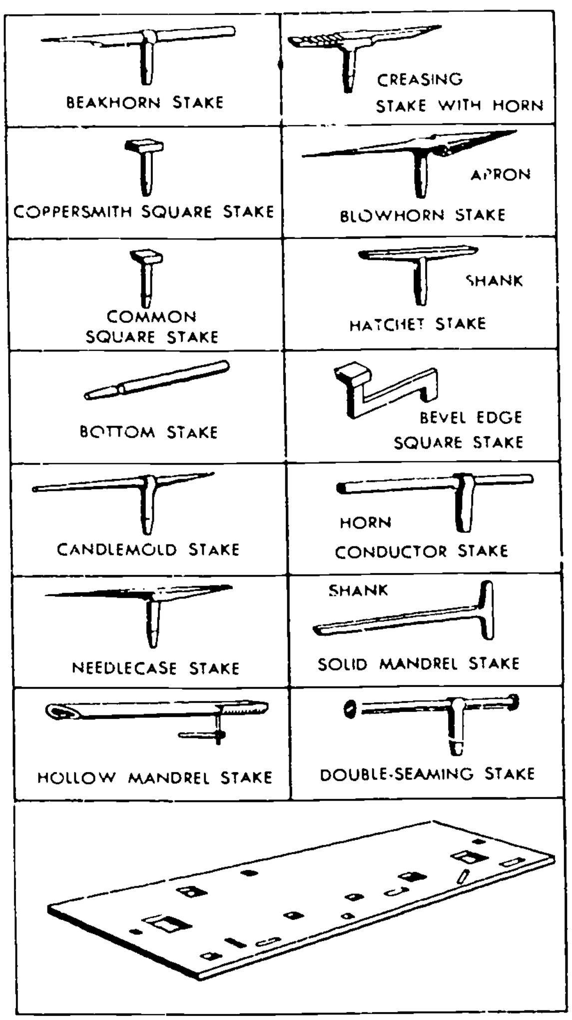


Figure 3–19. Bench plate and stakes.

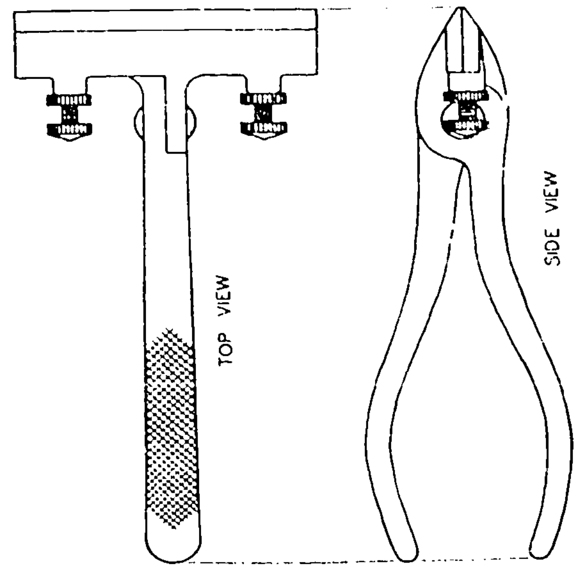


Figure 3–20. Hand seamer.

The *candlemold stake* has two horns of different tapers and is used in forming, riveting, or seaming long, flaring articles.

The *hollow mandrel stake* has a slot running through its length in which a bolt slides, permitting the stake to be fastened to the bench at any angle or length. The rounded end is used for riveting and seaming pipes. The rectangular shaped end is used for forming laps, riveting, and double seaming corners of pans, boxes, and similar sheet metal items.

The *creasing stake* has a round, tapered horn at one end and a rectangularly shaped horn with grooves on the other. It is used for forming, riveting, or seaming small, tapered articles; for creasing metal; and for bending wire.

The *needlecase stake* is used to do very fine handwork. It has a small, tapered horn at one end and a round beveled edge at the other.

The *blowhorn stake* has a short, tapered horn (apron) at one end and a long, tapered horn at the other. It is used in forming, riveting, or seaming tapered articles such as funnels and pitched covers.

The *double-seaming stake* is constructed with ball-shaped ends and is used for double seaming.

Hand seamers. Hand seamers are used to fold light gage metal and to form seams or joints. Figure 3-20 illustrates two views of a hand seamer you may use that has screws on either side of the head. These are adjustable for different width seams. Jamnuts prevent the screws from slipping, which might cause an uneven bend while folding the seams. This is also true for bends longer than the width of the hand seamer. The hand seamer is useful when turning edges for seams on small jobs and when the brake or bar folder is not available.

Hand groovers. The hand groover, illustrated in figure 3-21, is used to groove seams after they have been formed.

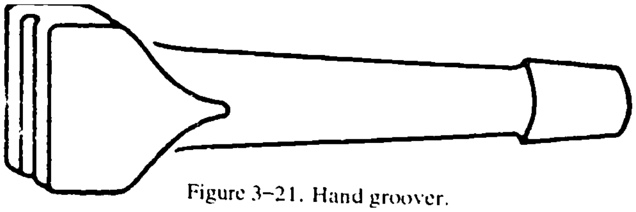


Figure 3–21. Hand groover.

It is useful for smaii jobs or when a Pittsburg machine is not available. Hand groovers are available in several sizes and are issued with your toolkit. The hand groover may be used to form a grooved seam such as that illustrated in figure 3-22. The two edges are turned back 160° with a bar folder, brake, or hand seamer. The two turned back edges are hooked together and placed over a backing surface; then the hand groover is placed over the lapped edges and struck with a hammer to set down the edges of the seam as shown in figure 3-22.

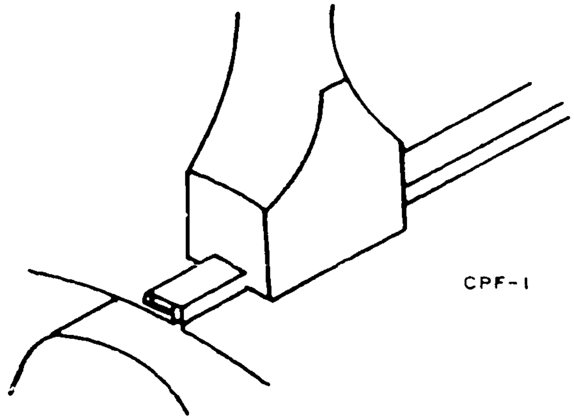


Figure 3–22. Locking a grooved seam with a hand groover.

Exercises (232):

1. How is the hollow mandrel stake secured to the bench plate?

2. \ ..ch stake shouid you use to install solid rivets in a pitched stack cover?

3. What is the candlemold stake used to form and rivet?

4. What must you adjust to maintain an even seam width with a hand seamer?

5. What tool is used with a hand groover?

Spot Welding, Lead Soldering, and Sealing

In this chapter, we discuss some very common operations in sheet metalwork. First we discuss spot welding, including equipment, technique, and safety. Then we cover lead soldering and sealing, which, like the other steps in the fabrication process, is important to do correctly to obtain a finished component of good quality.

4-1. Spot Welding

Spot welding, or resistance welding as it is sometimes called, is a pressure welding process in which heat is generated by resistance to the flow of electrical current. No flux or welding rod is required during the weld time because the surface of the sheets become fused while they are pressed together and electrical current is applied. However, the surfaces must be cleaned prior to welding. It is important to remove paint, grease, oxide, or any foreign matter that may interfere with the resistance of the surfaces being joined.

233. State procedures for using spot welding equipment.

Spot Welder. The spot welder, illustrated in figure 4-1 is the type found in many metal shops. The upper arm is actuated by air pressure and is lowered and raised in a vertical arc. The spot welder illustrated used 90 psi of air pressure and is used primarily to weld light gage metal. This spot welder must have a source of electricity, air pressure and water. The spot welding machine consists of an outside case, transformer, control box, foot switch, and electrode holders (arms).

The lower arm is adjustable but does not move during the welding operation. The upper arm is controlled by an air pressure cylinder. While operating a spot welder, keep close check on the oil and water separator mounted in the airline. If the oil and water separator were to overflow, it would damage the air control valves.

The principle of a spot welder is that when two pieces of metal are placed between the electrodes, and the transformer is energized, heat is produced between the electrodes and a weld is made as shown in figure 4-2. The key to this operation is to control the input electrical power, thereby controlling the amount of heat produced. When the heat between the electrodes reaches the melting point of the metal being welded, the electrical power is turned off and the molten metal cools into a spot weld holding the two pieces of metal together.

Portable Spot Welder. The portable spot welder, illustrated in figure 4-3, is manually operated. To operate this welder, place the item between the electrodes and squeeze the handle switch. The welder illustrated has an optional built-in timer that automatically turns the power off and prevents an overheated (HOT) weld. Welders without a built-in timer weld until the switch is released.

The portable spot welder can be handled by one person, and operated on 110-volt AC electricity. This welder is very handy for making repair welds on the job, in the shop, or about anywhere there is electrical power. Take care not to overheat the air cooled electrodes.

Exercises (233):

1. In addition to a source of electrical power what else is needed to properly operate a spot welder?

2. Which arm of a spot welder moves up and down vertically during each cycle?

3. True or False. The in-put electrical power produces the heat for the weld.

4. What is required to operate a portable spot welder?

234. State the procedures for troubleshooting the spot weld machine controls.

Controls. As stated in the last objective, the key to a good weld is the controls. There are seven items to be concerned with: (1) water for cooling the electrodes, (2) air pressure to actuate the upper arm, (3) current for welding heat, (4) cycle, (5) squeeze, (6) weld, and (7) hold.

Water Water may not be the most important item but it does keep the tips of the electrodes cool and extend their life. Some machines have a water-cooled transformer. It is essential to keep the transformer and electrodes cool, so always use water, even on short jobs.

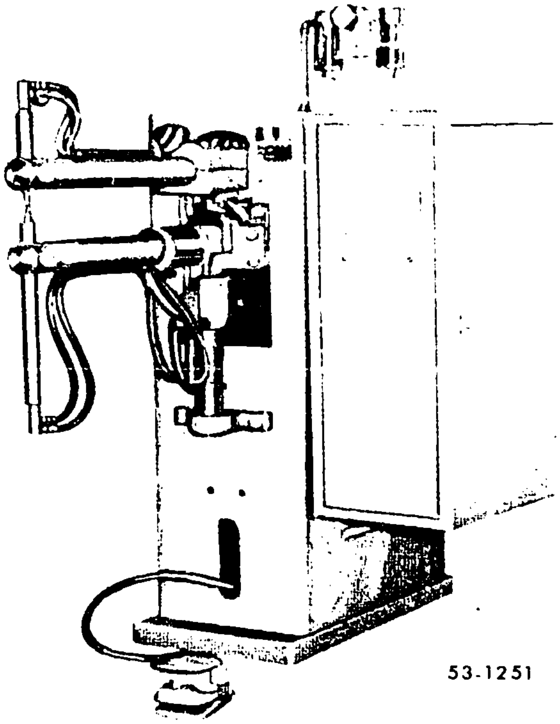


Figure 4–1. Spot welder.

Air pressure. Air pressure controls the upper arm on the welder and the amount of squeeze pressure put on the electrodes and the job. What might happen if the pressure is too low? This could affect other settings on the welder and the end product. When the pressure is set too low, the upper arm is slow to apply pressure and the machine may be into the next part of a cycle before the weld is completed. This results in a poor weld. Another problem of low pressure is, when the metal being welded is not held tightly together during the weld, the molten metal does not fuse together. If the pressure is too high, it squeezes the molten metal out and produces a poor weld. Select the pressure by adjusting the air pressure regulator to the desired setting on the gage. Drain the oil and water separator on the airline when necessary.

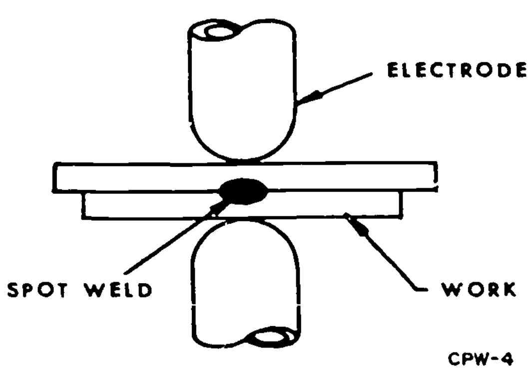


Figure 4–2. Spot weld.

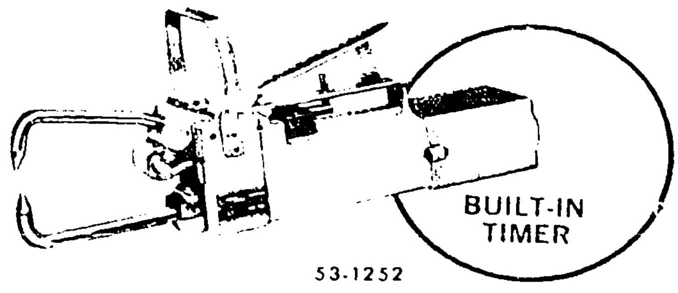


Figure 4–3. Portable spot welder.

Current. Select the amount of current (amperage) applied to the work with the control knob, which controls the heat used for making the weld. This control knob is turned clockwise to raise the amperage, and each step around the dial adds 10,000 amperes. Most spot welders have a maximum output of 80,000 to 100,000 amperes.

Cycle. The cycle of the welder is the time between the sequence of timed steps that start when you depress the foot switch. If a machine is equipped with a repeat cycle, it will continue to repeat all of the steps until the foot switch is released. This is very useful on jobs that require many welds in a small area. If there is no repeat cycle, or if it is turned off, the machine will complete one cycle each time the foot switch is depressed. The weld cycle is shown in figure 4-4. The off time is when the welder is open, ready for the next cycle to start. When the weld is off the tips usually stay open.

Squeeze. The squeeze time is the period in which the air pressure is applied to the cylinder to actuate the upper arm prior to the weld time starting. It is important that the electrodes make contact with the metal being welded before the weld time starts. Excessive squeeze time is better than insufficient squeeze time.

Weld. Weld time is the time that current actually flows through the electrodes and weld area. The weld time and the current are directly related in that, when the current is turned up one step, the weld time is turned down. This will result in better penetration without overheating the area around the weld.

Hold. Hold time is the next step after the weld time and is the time that the material (weld) is held under pressure while it cools. If the welds break apart as the electrodes separate, check the hold time. It should be about the same as the weld time for most jobs. Also check the weld time and the current settings. Refer to the manufacturer's recommendations for the proper settings for each job.

Exercises (234):

1. What adjustments should you make if the weld time starts before the electrodes make contact?

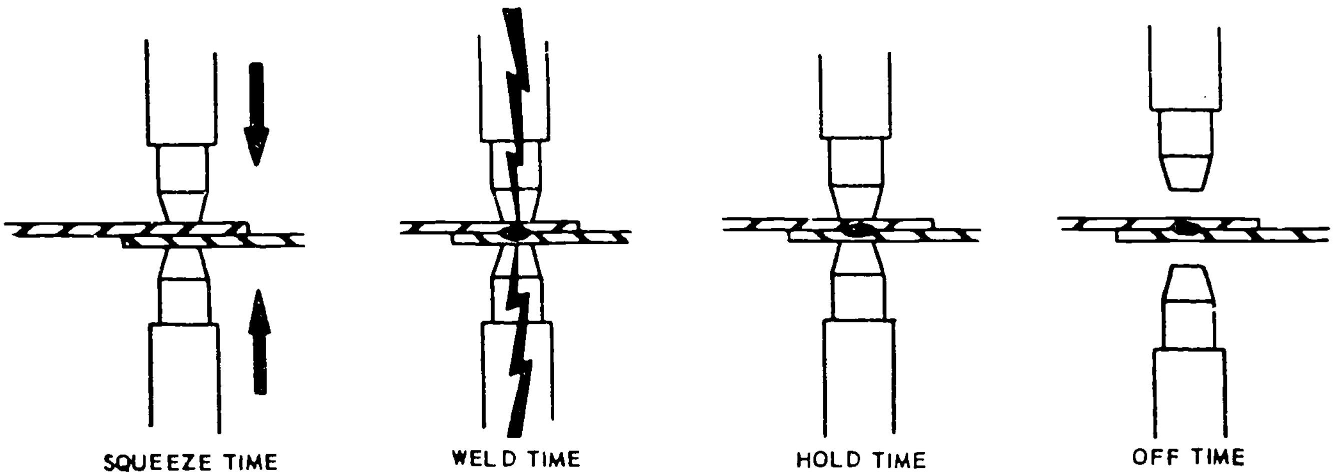


Figure 4-4. Weld cycle.

2. What should you check if the welds break apart as the electrodes separate?

3. If molten metal is forced out from under the electrode tips during the weld cycle, you should reduce the __________ __________.

235. State the uses of electrodes and how to care for them.

Electrodes. Electrodes are usually copper alloy cylindrical rods with various shaped tips. The electrical conductivity of the electrodes must be great enough to allow sufficient heating at the point of the weld without excessive heating at the tips of the electrodes.

The life of the electrodes is increased by water, which is why it is important to turn the water on before using the spot welder and also important to turn the water off after use. If the water is left on, it may cause harmful condensation on the transformer cooling pads.

The radius of the electrode tips determines the size of the spot weld. If the tips are too small, the weld may lack strength. If the tips are too large, the weld will have a poor surface appearance because the required additional heat will cause localized overheating.

The electrode tips must be cleaned and dressed frequently. Standard straight electrodes range in length from 1¼ inches to 4½ inches and are held in the place by a Morse taper. This allows quick and easy removal. The shape of the nose of the most commonly used electrode is domed. The dome should be even and gradual with a contact point of 1/8 to 1/4 inch in diameter. Remember, the shape of the tip will show on every weld, so dress them properly.

The double bend offset electrode is very useful in getting a weld into a corner or close to the bottom of an item. Take care not to turn the air pressure as high as with straight electrodes, because the electrode may collapse.

The success of your welds depends on the cleanliness of the tips of the electrodes. An electric wire is insulated with a coating to keep the electricity in the wire. This also occurs with a dirty (contaminated) point. As you weld, there is a certain amount of the material that will alloy with the tip. Since the conductivity of the metal being welded is lower than that of the electrode, it acts as an insulator and a poor quality weld results. So, you have to keep the tips dressed (smooth, clean, and domed).

Proper maintenance of spot welders is very important if good welding is to be done. Electrodes must be dressed (cleaned) because they become pitted through continued use. Dressing is done with the electrodes in correct alignment and with a mill file used on the points until the desired diameter is obtained. Use emery cloth to finish the points to a slight dome. Another maintenance item is cleaning the water lines inside the electrodes; clean and flush these every week to 10 days.

Exercises (235):

1. What electrode maintenance is required for good welds?

2. Where are offset electrodes used to weld?

3. How do electrode tips that are too small affect the weld?

193

4. How can water help extend the life of an electrode?

236. Specify types of materials that may be welded, and state characteristics of materials which affect their being welded.

Materials. Nearly all metals may be spot welded. Some have different characteristics and require different settings of the machine. When welding any metal, its surface must be free of oil or any foreign material. You should check the manufacturer's handbook or the technical manual for these settings.

Dissimilar materials are difficult to join and present problems not met in welding similar metals. For example, suppose you are welding stainless steel to a nickel alloy of steel. You will have to use a different electrode for each metal because the welding resistances are different. The metal with the greater resistance becomes hotter than the one with less resistance, and the desired fusion of one metal into the other does not occur properly. The selection of electrodes for a spot welder is just as much of a problem as finding the proper cement for bonding resins. Electrodes are chosen for their freedom from sticking to the metal that is being bonded.

Because of the inherent characteristics of aluminum alloys, it is necessary to use procedures that differ somewhat from conventional spot welding. The electrical conductivity of aluminum is much higher than most metals, and this factor requires higher welding currents.

Aluminum does not have a plastic range—a characteristic permitting a weld to be made without converting it to the liquid state. When welding aluminum, precise control is required of the energy input into the weld so that the material at the inner contact point will be brought to the melting point while surfaces in contact with the electrodes will remain relatively cool.

The oxide which forms on aluminum sheets must be removed before the welding process is started, since the oxide has a high and erratic electrical resistance. This resistance affects the amount of heat produced at the weld. Hydrofluoric acid in paste form is normally used to clean aluminum before spot welding, but after a few seconds it is washed off under running water.

The electrode tips must be cleaned and reshaped frequently when welding aluminum because aluminum has a tendency to alloy with the copper tips.

You will use the spot welder many times in the sheet metal shop. For instance, it may be used when making a lap seam, fastening corner seams, when making drip pans or similar jobs, or when making metal louvers to install between studding. The outside of a spot welded louver is smooth, so a close fit can be obtained.

When spot welding, always wear protective equipment prescribed by safety directives at your base. This includes protective clothing, goggles or safety glasses, and a face shield. The sparks spot welding generates are hazardous to eyes and skin and may travel several feet.

Exercises (236):

1. What metals may be spot welded?

2. What problem do dissimilar metals present?

3. Why is aluminum difficult to spot weld?

237. State how to prepare material for welding and why such preparation is necessary.

Preparation. Preparation of metals for spot welding is one of the most important steps for a strong, smooth and satisfactory appearing weld. As stated previously, foreign material in a weld joint acts as an insulator. Therefore, all foreign material must be removed from the weld area (seam).

What is foreign material? Anything that does not aid to the bonding of the two metals. A few of the most common foreign materials found on metal are rust, oil, paint, corrosion, and dirt. Any one of these or a combination of these materials can act as an insulator or insulate a portion of the weld area that results in a poor weld. Rust, paint, corrosion, and dirt can be removed with a scraper, file, grinder, or sandpaper. Oil can be removed with a clean rag and small amounts of solvent, if necessary.

After the metal is clean, cut and formed, and ready to be welded, check and insure that all areas to be welded form a proper fit.

Exercises (237):

1. Why must all of the paint be removed from the weld area of an item to be repaired?

2. What problem does foreign material in a spot weld create?

3. What should you use to remove a coating of oil from a weld area?

238. State procedures for testing spot welds.

Tests. Due to the many variables involved in spot welding, getting a proper weld can be a difficult task. Therefore, tests of spot welds are vital to get the proper setting on the machine. Some of these variables are

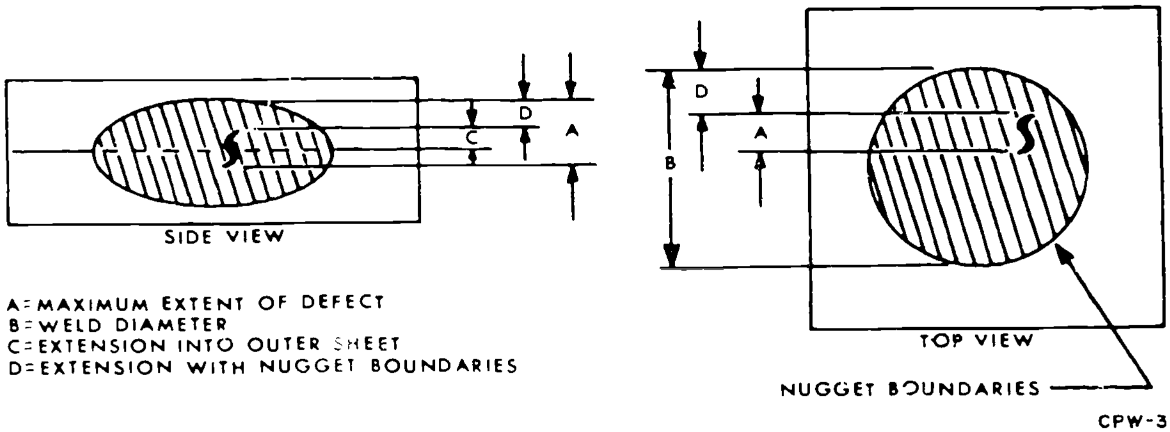


Figure 4–5. Internal defect-spot weld.

machine settings, conditions under which the welder is used, temperature of the metal, material condition, and electrode condition. Also, remember, welding two or three times in the same place causes the metal to crystallize. Thus, to get a machine adjusted just right, it is important to make several test welds. To start the test, select small strips, 2 x 8 inches or larger, of the same material as the job.

The tests we discuss are the peel test, visual test, and twist test. In the *peel test*, two strips are placed one above the other and a spot weld is made near one end. Then the two strips are separated by spreading (peeling) the two loose ends apart. The weld should not break, but peel or tear out of one of the test pieces leaving the test weld intact.

The *visual test* is to check the weld for proper size, shape, surface appearance, tip pickup, surface flashes, expulsion of weld between sheets, blow spots, surface indention, sheet separation, and edge distance. The electrode indentation should be slight and smooth. When a test weld is checked for internal defects it must be cut in half (fig. 4-5 shows two ways to cut a weld). If defects are too numerous or too large then a cure must be established to overcome the problem.

The *twist test* is made by placing one test piece on the other to form a "V" and making a spot weld where the two test pieces overlap. To test the weld, force the two loose ends together (as if closing a pair of shears). The weld should twist (tear) out of one test piece leaving the test weld spot intact. Figure 4-6 shows another way to do the twist test. The two ends are twisted around towards each other (pivot on the weld) to aid you in testing welds. Another simple test is to take two test pieces the same size, offset them 1/8 inch, as shown in figure 4-7, and weld. Then place the test piece in a vice and shear them apart by applying force to the offset sections. After the weld shears off you can see what it is like inside.

Exercises (238):

1. By what three methods may a spot weld be tested?

2. What must you do when a test weld is checked for intern l defects?

3. In the pell test, two p[illegible] placed one above the other and spot welded then __________ .

4. Where would evidence of surface flashes show up?

5. Another way of seeing the inside of a spot weld is the __________ test.

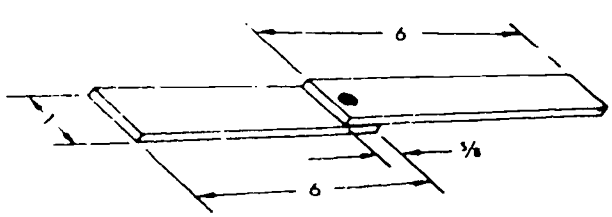


Figure 4–6. Tensile test coupons.

195

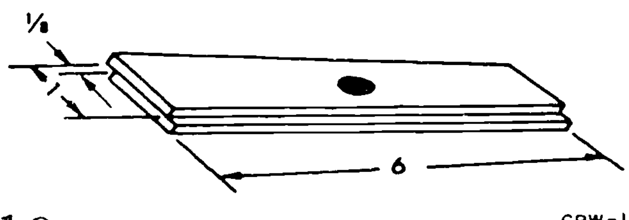


Figure 4–7. Lap-welded coupon.

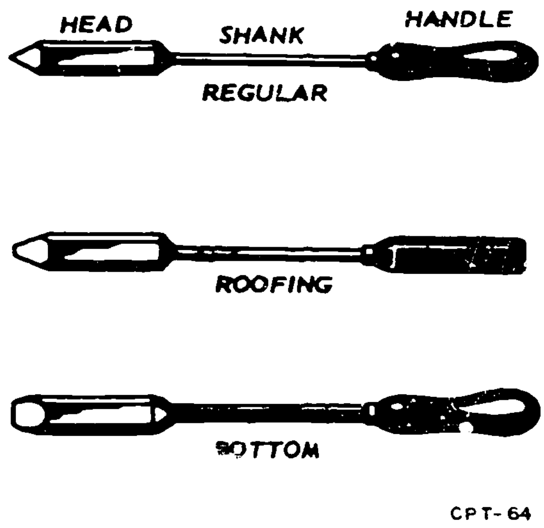


Figure 4-8. Soldering coppers.

4-2. Lead Soldering

Soldering is the process of joining two pieces of metal by a third metal or alloy that has a lower melting point than either of the metals to be joined. The solder is flowed (melted) between the surfaces and left to cool. As the solder cools, it hardens and cements the two pieces of metal together. Although the joint produced by soldering is weaker than a joint produced by other methods, soldering is especially useful for making airtight and liquidtight joints that do not have to withstand much pull or vibration. Iron, tin, galvanized iron, copper, stainless steel, and brass are metals that are commonly soldered.

Equipment for soldering includes soldering coppers, tinner's furnaces, fire p... blowtorches, hydrocarbon torches, solder, flux..., acid brushes, and tinning compounds. W... discuss the use and care of each of these.

239. Explain why fire-heated coppers are paired, and how to forge the tip on an electrically heated soldering iron.

Soldering Coppers. There are three shapes of fireheated coppers used in most sheet metal shops. Figure 4-8 illustrates the regular square point copper, bottom copper, and roofing copper.

The regular square point copper is used a great deal, since the point can be forged and shaped for different types of soldering tasks. Bottom coppers are used to solder pan bottoms, large tanks, and other flat bottomed objects. Roofing coppers are used to solder all types of metal roofing, flashing, and gravel guard.

Fire-heated soldering coppers are sized by weight per pair; for example, the 6-pound copper used for soldering seams consists of two coppers weighing 3 pounds each. The weight of a copper includes the head weight only; the shank and wooden handle are not included. It is important to select the proper size and shape. Normally, when you are soldering with a pair of coppers, you are heating one while using the other. This speeds the operation by keeping the surface hot.

Electrically heated soldering coppers (irons) (fig. 4-9) are sized by the wattage of the heating element and may be used for some soldering tasks. The copper tip can be removed and forged to the desired shape without damaging the electric heating element. Two sizes of electric soldering irons that you may have in the sheet metal shop are 200 watts and 550 watts. The 200-watt size can be used for light jobs, such as soldering screen wire to light-gage metal frames. The larger 550-watt size can be used for jobs such as soldering seams on metal up to 18 gage. Always check for the presence of heat by holding your hand above the copper or electric iron before using. The best rule is to handle all coppers or irons ... are hot.

Exercises (239):

1. Why are soldering coppers sized in pairs?

2. What steps should you take to forge the tip on an electrically heated soldering iron and why?

240. State the type of fuel used in a tinner's furnace, a blowtorch, and a firepot; and name the heating device recommended for small soldering jobs.

Heaters. To perform satisfactorily, soldering coppers must have well-formed, well-cleaned, and well-tinned points, and there must be a source of heat. A soldering copper must be hot enough to melt the solder being used. Some solder needs as much as 800° F. to melt and flow properly.

Tinner's furnace. A tinner's furnace, shown in figure 4-10, is used to heat soldering coopers fo... jobs being soldered in the shop. The furnace is mounted o... bench and may be a single or double burner model. It uses natural or artificial gas for fuel and is equipped with an adjustable control valve. Some furnaces have a pilot burner to ignite the main burner more quickly and easily. The single-burner tinner's furnace is recommended for coppers up to the 6-pound size, and the double-burner furnace is recommended for heavier coppers. Be sure to read and observe all safety rules when you are operating a tinner's furnace, since it can be hazardous if improperly used.

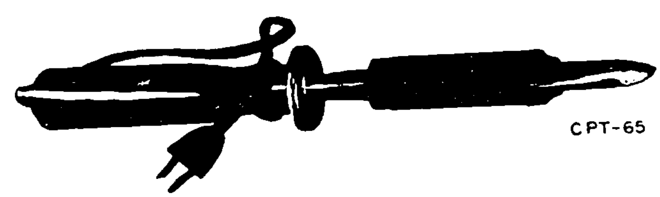


Figure 4-9. Electric soldering iron.

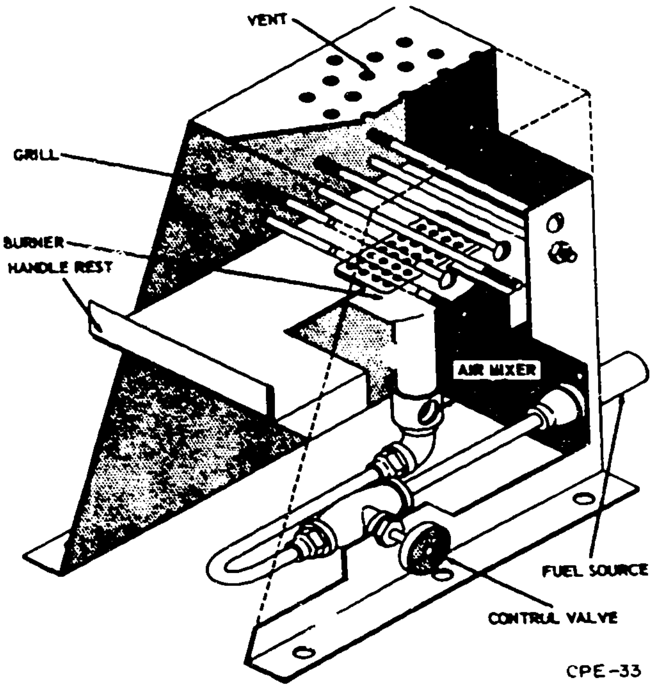


Figure 4-10. Tinner's furnace.

Propane tinner's furnace. A propane tinner's furnace, illustrated in figure 4-11, is used to heat soldering coppers for jobs outside of the shop This type of furnace is easy to use and does not present the hazards of the fire pot or blowtorch. The furnace is mounted on a stand or on top of the fuel bottle (not illustrated). These furnaces are fueled by propane gas. The fuel tanks have an excess pressure relief valve and a flow check valve that provide safety in its operation. The fuel tank usually operates for many hours without being refilled. A hose transfers fuel from the tank to the furnace. As we all know, a hose can become frayed, so check the hose often and keep it away from heat or hot coppers. Replace a frayed hose immediately. Don't wait or you may be too late.

Firepot. Firepots, like the one shown in figure 4-12, are available in many sizes and types and are used to heat soldering coppers in the shop or in the field. The firepot is equipped with a wind deflector and can be used to heat two coppers at a time. Unleaded (white) gasoline is used for fuel. Air pressure forces the fuel into the generating coil or chamber, which is kept hot enough to vaporize the fuel. Although operating procedures are similar to the operating procedures for a blowtorch, you should carefully follow the instructions for the particular firepot you are using. The firepot requires very little maintenance as long as you use only unleaded gasoline. In figure 4-12, you can see the principal parts of a typical firepot.

Blowtorch. The gasoline blowtorch, shown in figure 4-13, can also be used for heating soldering coppers in the shop or in the field, though the blowtorch is smaller than a firepot and not as efficient. Since the blowtorch is easier to carry, it is used mainly for small jobs or where portability is a factor. For heating, the head of a soldering copper is placed in the flame and the shank is placed on the two rest points.

To operate the blowtorch, fill it about two-thirds full of clean, unleaded gasoline, and pump sufficient air pressure into the tank to cause the gasoline to flow when the valve is opened. Don't pump too much, however, because excessive pressure may rupture the washers and seals. When the valve is opened, liquid gasoline flows from the jet of the torch and drips into the priming tank (pan). Close the valve when the pan is about three-fourths full; then ignite the gasoline with a match. The flame from the burning gasoline in the priming pan heats the perforated nozzle (heating tube). When the nozzle is sufficiently hot, open the valve slowly, allowing the gasoline vapor that has been formed to flow from the nozzle where it will ignite and burn with considerable force. Adjust the flame to the desired intensity by turning the valve counterclockwise. For best results, adjust the valve so that a clean, pale blue flame is produced. If the pressure in the torch decreases, it is permissible to pump in more air while the torch is in operation. When you are through using the torch, close the valve, and tighten it sufficiently to prevent gas from escaping. Remember that the hot metal contracts when it cools and causes the valve to stick.

The gasoline blowtorch requires very little maintenance as long as you use only unleaded gasoline. If leaded gasoline is used, a compound forms that stops up the gasoline passage, and the torch becomes a source of trouble from that time on, since it is almost impossible to clean the passages thoroughly. Insufficient heating from the priming pan is the cause of most difficulties in lighting a blowtorch.

For heating soldering coppers, we have discussed four types of heaters. All four use an open flame. The flame may be inside the heating chamber but it is exposed to the air in the room or job site. Check for the presence of flammable vapors and make sure that there is adequate ventilation before lighting the heater.

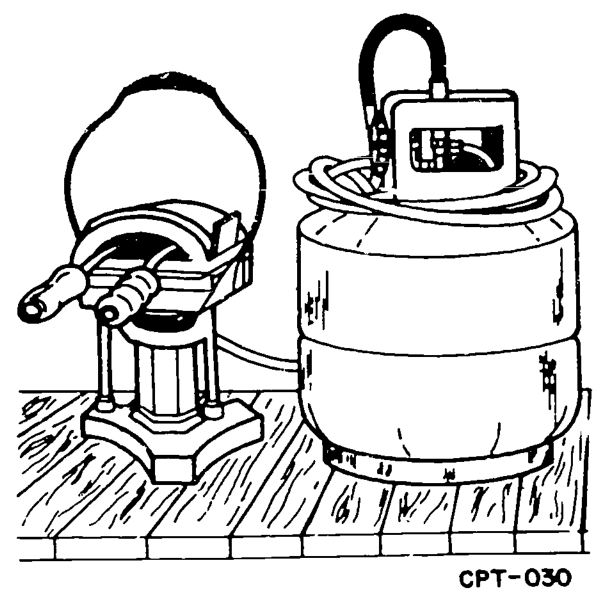


Figure 4-11. Propane tinner's furnace.

Exercises (240):

1. What type of fuel is used in a tinner's furnace?

2. What heating device is recommended for use on small soldering jobs?

3. What type of fuel is used in the blowtorch and fire pot?

241. Cite some of the processes used to clean and care for soldering equipment.

Cleaning Soldering Coppers. The tip of the copper must be clean. Clean it before you use it, and clean it while you are using it. Soldering coppers may be cleaned in three ways: (1) Rub the hot copper on a cake of sal ammoniac and wipe it off with a clean cotton cloth. (2) Dip the hot copper into a container of powdered sal ammoniac and wipe it clean. (3) Dip the hot copper into a solution of sal ammoniac (1/2 ounce of powdered sal ammoniac to 1 quart of clean water) and wipe it clean. To wipe the heated copper with a rag (do not use rags made of materials other than cotton), place the rag on the bench (do not hold the rag in your hand) and quickly drag the copper across it. Clean all of the tinned surface of the copper.

Shaping Soldering Coppers. Soldering coppers and the copper from an electrical soldering iron can be shaped to fit the requirements of the job by filing or forging. Always remove the copper point from an electric iron before forging. If the copper needs excessive reshaping, it is best to forge it rather than file it. To shape a copper by forging:

(1) File the copper to remove all the scale and smooth the surfaces.

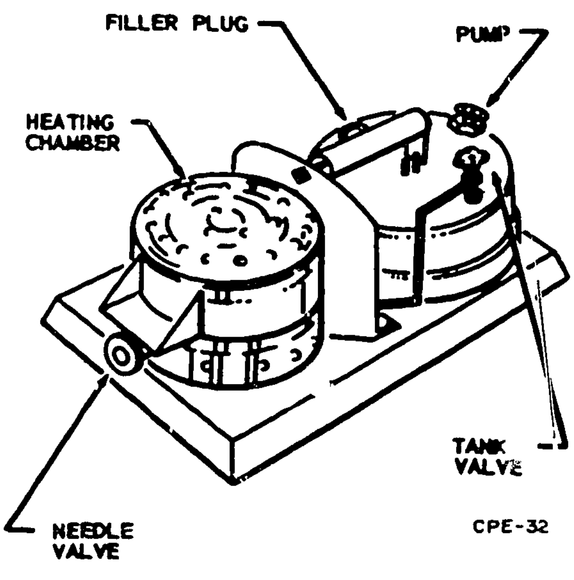


Figure 4–12. Firepot.

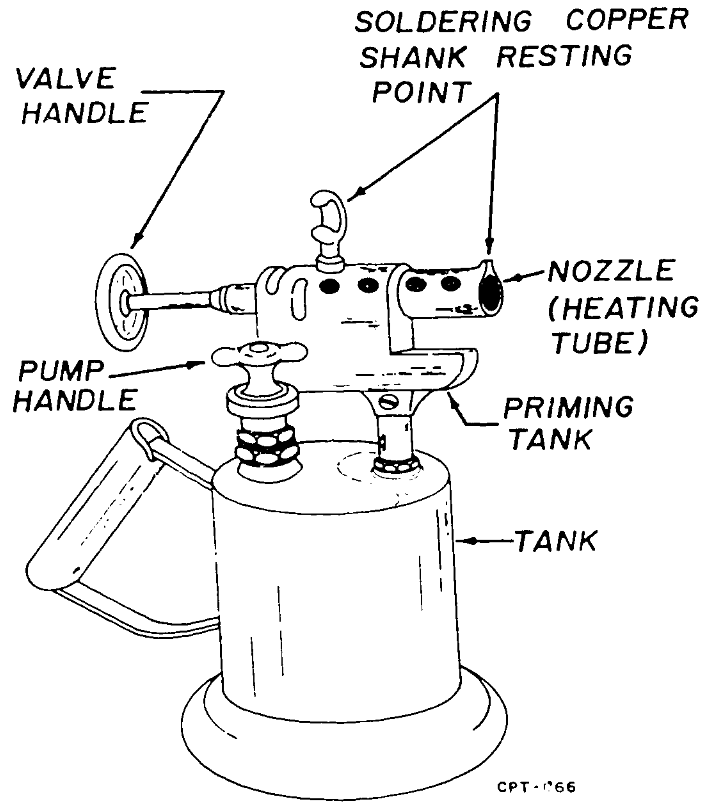


Figure 4–13. Gasoline blowtorch.

(2) Heat the copper to a bright red.

(3) Hold the copper on an anvil and change it to the required shape by striking it with a hammer. Turn the copper often to produce the necessary squared-off sides. Keep a blunt point on the copper by hammering the point back. This keeps the point from cooling off too rapidly. Reheat the copper as often as necessary to make it easy to work. As you work the copper into shape, keep the sides of the point smooth.

(4) Reheat the copper to a bright red and file it to a smooth finish. Then tin the copper.

Tinning Compound. A tinning compound is used to coat the copper with solder. Sal ammoniac is an example of a tinning compound normally used in the metal shop. As the sal ammoniac is heated by the hot copper, it gives off hydrochloric acid, which dissolves the oxides from the surface of the copper. With the surfaces of the copper clean, smooth, and free of oxides, the solder will adhere to it.

Tinning Soldering Coppers. To tin a copper, there are three basic steps:

(1) Heat the copper so that it melts the solder.

(2) Rub each filed side of the copper back and forth across the cake of sal ammoniac. Don't hold it still because the concentrated heat causes the sal ammoniac to crack. Don't breath the fumes given off from hot sal ammoniac.

(3) After all sides of the copper have been applied to the sal ammoniac, apply solder to the copper and continue to rub it back and forth on the sal ammoniac. Repeat this for each side of the copper to be tinned.

Exercises (241):

1. Why should you keep a blunt point on a copper that is being forged?

2. What two items are used to clean a soldering copper?

3. How should you use the rag to clean a copper?

2. Specify how to clean and tin joints and seams

Joints and Seams. To tin joints, there are four basic steps:

(1) Clean the metal to be tinned. This means removing dirt, grease, foreign matter, and oxide so that the flux and solder can make contact with the surface of the metal itself.

(2) Deburr (file or remove anything that will prevent the metal (joint) from mating properly. This can be done with a file at the same time the oxide is removed.

(3) Apply flux to the area to be tinned. The flux is used to clean the joint area to remove the oxide film (that is normally present on the metal and has been missed by the file) and to prevent further oxidation. Fluxes also decrease the surface tension of the solder and thus, make the solder a better wetting agent and help the solder to adhere to the metal.

(4) The last step is to apply solder to the areas to be joined. This is done by heating the area with a copper and applying solder to the metal (not the copper). Work the copper back and forth on the metal until a thin layer of solder covers the area of the joint. Remember, don't pile the solder up in thick puddles. With a thin coating of solder adhered to the metal, it is said to be tinned. Tin both parts of a joint.

Exercises (242):

1. What action is necessary to tin a joint or seam?

remove o des from items to

243. State soldering techniques and the composition of common solder mixtures.

Soldering Techniques. As a sheet metalworker, you must be able to solder galvanized iron, stainless steel, copper, lead, brass, and bronze. However, most of your soldering will involve galvanized iron with the solder used as a sealer for joints and seams to make them liquidtight. Solder flows toward heat, so heat the part you want joined. Apply the solder to the metal, and when it begins to flow into the seam or joint, move the copper slowly and smoothly along the seam. Notice how the solder flows in between the two parts as they reach the melting temperature of the solder. Don't move too fast or you may leave voids in the solder. A point to remember: once over the seam produces the best solder job.

Soldering riveted seams. When you solder a riveted seam, the rivets as well as the seam must be soldered to insure a well-sealed seam. After applying flux with an acid brush, move the heated copper slowly along the seam, sweating the joint and adding solder to the seam and rivets, as needed. Remember to apply the solder to the surface, not to the copper. If the surface is heated properly, the solder will flow evenly into the seam and around the rivet heads.

Soldering grooved seams. The method for soldering grooved seams is similar to soldering riveted seams, except that there are no rivets to be soldered. Installing metal roofs is an example of grooved-seam soldering.

Resoldering. In some cases, you will be required to resolder joints or seams that are dirty from use, such as drip pan seams that have grease or oil in the pores of the old solder and metal. In this case, you need to melt and remove the old solder by wiping with a clean, damp cotton rag. After this wiping, apply the flux, heat the surface again, and apply enough solder so that it can be wiped several times with a clean, damp, cotton rag. This procedure removes any remaining grease from the pores and, at the same time, tins the surface. After this cleaning and tinning has been done, you can solder the metal as you would a new seam or joint.

Sweating. To make a properly sealed seam or joint, it is often necessary to sweat the solder. Sweating is the process of flowing solder into heated joints or seams. To sweat a tinned joint, you apply heat until the solder in the joint melts and flows evenly and the excess solder is forced out of the joint. Remove the heat and hold the joint firmly until it cools.

Cooling and cleaning a soldered surface. After soldering has been completed, hold the pieces firmly in place and allow the surface to cool slowly until the solder is solid. When heated and cooled properly, the solder has a bright, shiny appearance. If you have used corrosive flux, you can use warm soapy water mixed with washing soda to prevent streaking. [illegible] cleaning the excess flux, rinse the surface; then dr[illegible] ith a clean rag to prevent streaking and [illegible]ning.

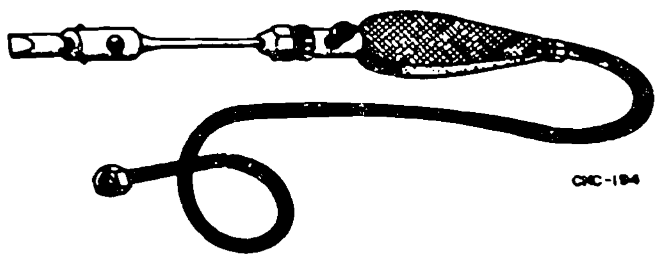
Solder Composition. Solder is a mixture of tin and lead. Three commonly used blends of solder are 40/60, 50/50, and 60/40. In the first example—(40/60)—the 40 represents the percent of tin, and the 60 represents the percent of lead. When pure tin (which melts at 450° F. and lead (which melts at 620° F.) are mixed they become a fusible alloy that melts according to the mixture. You will find a good all-around solder to be the 40/60 mixture, which melts at 464° F. The 50/50 mixture melts at 428° F. and the 60/40 mixture at 374° F. These blends of solder are avilable in wire form and in bars, weighing from 1/2 to 1½ pounds.

Exercises (243):

1. What technique is used to sweat a joint?

2. After the heat is removed, what must you do to produce a good strong solder joint?

3. Explain the mixture in 40/60 solder.



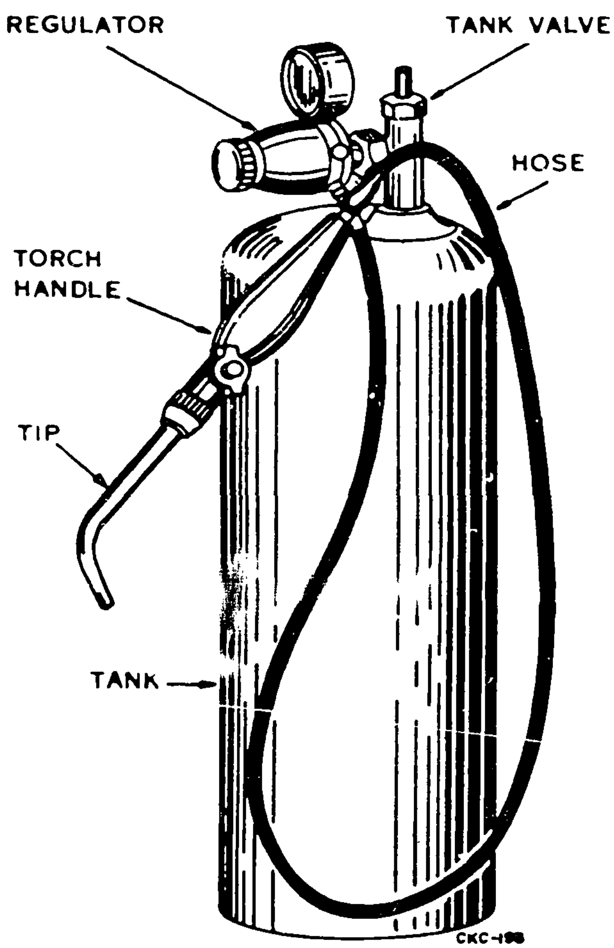


Figure 4-14. Hydrocarbon torch.

4. Why should you not move too fast when soldering?

5. How do you remove old solder?

6. What is sweating?

7. What is the appearance of solder when it has been properly heated and cooled?

244. Name the parts of the hydrocarbon torch, and cite the methods used for soft solder with the hydrocarbon torch.

Hydrocarbon Torch. The hydrocarbon torch shown in figure 4-14 is used for soft soldering by the direct flame method, or by using a flame-heated (indirect method) soldering iron as shown in figure 4-14. The hydrocarbon torch consists of a tank, tank valve, pressure regulator, hose, handle, and tips. The tank contains the acetylene (fuel). When the tank valve is opened, the acetylene is admitted to the regulator and to the tank pressure gage which is shown in figure 4-14. The regulator regulates the amount of pressure to the torch. This can be done by adjusting the regulator knob.

CAUTION: Do not use acetylene at pressures above 15 psi; to do so may cause an explosion.

Change the tips to compensate for various applications where you require more or less heat.

Soft Soldering Procedures. Before soldering, you must clean the pieces that are to be joined together; then clean and tin [illegible]e solder[illegible] i[illegible] if you pl[illegible] use it. If using the [illegible] select the proper tip for the job. [illegible]ing, apply a thin layer of flux to both pieces, fit the p[illegible] together, and rotate them to distribute the flux evenly.

To prevent damage to the regulator, turn it counterclockwise before opening the tank valve. Open the tank valve and adjust the acetylene to the correct pressure with the regulator knob and use a friction lighter to light the fuel and air mixture. (CAUTION: To keep from burning your hand, do not use a cigarette lighter or matches to light the torch.)

After lighting the torch, apply the flame evenly to the joint until solder appears at the joint. The joint is complete except for the cleaning process. Clean the joint with a wire brush, scraper, or emery cloth to remove the flux residue and for inspection purposes.

Exercises (244):

1. Name the parts of the hydrocarbon torch.

2. Cite the two n[illegible]ed to soft solder with the hydrocarbon torch.

245. Specify techniques for using, and characteristics of materials used in soldering aluminum alloys.

Soldering Aluminum Alloys. Soldering aluminum alloys is more difficult than soldering many other metals. The difficulty arises largely from the fact that aluminum alloys are always covered with a layer of oxide, the thickness of the layer depends upon the type of alloy and the conditions to which it has been exposed.

Many aluminum alloys can be successfully soldered, however, if the proper techniques are used. Wrought aluminum alloys are usually—although not always—easier to solder than cast aluminum alloys. Heat-treated aluminum alloys are extremely difficult to solder, as are aluminum alloys containing more than 1-percent magnesium.

The solders used for soldering aluminum alloys are generally tin-zinc or tin-cadmium alloys, and are usually referred to as *aluminum solders*. Most of these solders have higher melting points than the tin-lead solders used for ordinary soldering. Both corrosive and noncorrosive fluxes are used in soldering aluminum.

The first step in soldering aluminum is to clean the surfaces completely and remove the layer of oxide. If a thick layer of oxide is present, remove the main part of it by mechanically filing, scraping, sanding, or wire-brushing. A thin layer of oxide [illegible] can [illegible] rem[illegible] [illegible] using corrosive [illegible] [illegible]e, must be completely [illegible] [illegible] the joint after the soldering is finished.

A[illegible]g and fluxing the surfaces, tin the surfaces with aluminum solder. Apply flux to the work surfaces and to the solder. You can tin the surfaces with a soldering copper or with a torch. If you use a torch, do not apply heat directly to the work surfaces, to the solder, or to the flux. Instead, play the torch on a nearby part of the work and let the heat be conducted through the metal, to the work area. Do not use any more heat than is needed to melt the solder and tin the surfaces. Work the aluminum solder well into the surfaces. After the surfaces have been tinned, the parts may be sweated together.

A procedure that is sometimes used for soldering aluminum alloys is to tin the surfaces with an aluminum solder and then to use a regular tin-lead solder to actually joint the tinned surfaces. This procedure may be used when the shape of the parts prevents the use of the sweating method or when a large amount of solder is required to joint the parts. When you are using tin-lead solder with aluminum solder, it is not necessary to use a flux.

Exercises (245):

1. What types of aluminum alloys are the most difficult to solder?

2. What is your first step in soldering aluminum?

3. What types of flux are used to solder aluminum?

4. What tinning material should you use?

246. Cite the uses of flux and explain the precautions you should take while working with fluxes and soldering equipment.

Flux. Before soldering, treat the surface of the metal with a flux to remove the oxide, to prevent oxidation during heating, and to lower the surface tension of the solder so that it will flow properly. The corrosive fluxes that you will use include zinc chloride and muriatic acid. Following the use of a corrosive flux, rinse the surface of the metal with water to prevent the flux from acting on the metal that has been soldered. Corrosive fluxes are usually applied with an "acid brush." Dip the brush into the liquid flux and spread it on the metal to be soldered. After each use, rinse the acid brush in running water to prevent the corrosive action of the flux from ruining the bristles. Be very careful because most fluxes are harmful to your skin and clothing. [illegible] [illegible]ing water immediately to rinse off any flu[illegible] [illegible] you. Protect your tools from corrosive flu[illegible] [illegible] store liquid fluxes with the containers closed.

Rosin is a noncorrosive fl[illegible] used in soldering bright copper, such as roofing [illegible]d electrical wiring. Rosin prevents oxidation during heating, although it does not remove oxidation as do the corrosive fluxes. Rosin is available as a powder or a paste. Either can be melted on the surface with a hot iron. Like other acids in the metal shop, when there is a spill, clean it up. If it spills on people or clothing, wash it away with an abundance of water.

During the soldering process, keep the tip of the copper clean by dripping it into a sal ammoniac solution (1/2 ounce of powdered sal ammoniac to 1 quart of clean water). If a dipping solution is not available, you may use a cotton rag. Wipe the heated tip lightly and quickly across the rag. (Do not use rags made of material other than cotton.) Remember that tinning the coppers and keeping them clean is important in order to perform good solder[illegible]obs.

Safety Precautions. When you are using soldering equipment, safety precautions are very important. For example, do not use the blowtorch and firepot in unventilated areas. Check this equipment for safe operation in accordance with the manufacturer's handbook or the technical manual.

When you fill a blowtorch or firepot with unleaded gasoline, it is best to do it out of doors. If the filling must be done indoors, make certain that there are no nearby sources of ignition, such as a pilot burner, open flame, or sparking equipment. Keep the gasoline for the firepot or blowtorch in outside storage areas for safety purposes, and mark the storage tank to designate its contents. Never smoke when you are filling the tank or going to the storage area.

Place the firepot or blowtorch on a firm foundation away from walls and other combustable materials and do not ignite it if gasoline has spilled. Do not move blowtorches and firepots until all of the gasoline in the priming tank has burned away.

The propane tinner's furnace is a dangerous piece of equipment because it is mounted on, or attached to, a tank (bottle) of liquid propane under pressure. Like the firepot or blowtorch, it has an open flame. Apply the above safety rules to the propane tinner's furnace.

Always treat soldering coppers as if they were hot. A hot copper can cause a serious burn. Check them before use to make sure that the shank is firm in the handle. Do not hold the dry, cotton cleaning rag in your hand when you are wiping a copper, but place it where the heated copper can be pulled over the rag.

Do not inhale the harmful fumes from the flux and acid. You should also avoid using too much solder. It can drip and burn you or someone else.

Disconnect electric soldering irons when they are not in use, and before dipping into a sal ammoniac solution. Be careful to dip only the tip. Check the cords and connections often for breaks in the wire, insulation, and prongs.

Exercises (246):

1. What action should you take if you spill flux on yourself?

2. Why is a propane tinner's furnace dangerous?

3. What should you do with an electric soldering iron when it is not in use?

4. What is the purpose of treating the surface with flux before applying solder?

5. When should you use a noncorrosive flux?

6. How should you keep the tips of the copper clean when soldering?

7. What is the purpose of zinc chloride?

4-3. Sealants Used in Sheet Metalwork

In this section, we discuss such sealants as sealing tapes, asphalt roof cement, contact cement, and calking compounds. Sealants make joints and seams airtight or watertight. They should not be used for holding strength. For instance, if you are setting a roof jack, nail it to the roof and then seal around its edges. Other uses of sealants include sealing the doors and window facings of metal buildings and sealing the joints and seams of ducts. Follow the manufacturer's instructions when using sealants.

247. Name three types of sealer and give a use of each.

Tape. Tape is used more and more in the sheet metal industry. Pressure sensitive duct tape is used to cover small openings, to hold items together, to make sheet metal items airtight, and to connect parts of air systems. On a duct system, duct tape can be used to cover seams and joints to make them airtight, also to make connections or slip joint fittings, and to stop vibration noise by holding the parts together.

Cement and Adhesive. In this great day and age of advancement in technology, there are many improvements in ways of attaching items together. Look at some of the old duct systems on your base. How was the insulation held on? Today, there are several brands of cements or adhesives on the market. In many applications, they have replaced screws, nails, and rivets.

Sealants. Sealants are available in many forms, such as can, tube, and roll, and can save many hours in installing and maintaining equipment. Sealants are used in areas subjected to weather, heat, and movement caused by expansion and contraction.

Exercises (247):

1. Name three types of sealer and give a use of each.

248. Distinguish among the types of sealing compound and cement.

Sealing Compounds. Calking compound is a thick paste-like substance used to seal around windows, ducts, and any number of items that must fit closely together. Calking compound is available in cans and the more popular tube. Silicon sealants are available in tubes that fit into a standard calking gun. They are made in almost any color and can be applied directly to any clean, dry surface. When you are using silicon sealants, be sure there is adequate ventilation. This sealant gives off toxic fumes as it cures into a rubbery form that never sets up hard. When silicon sealant is first removed from the container, it is a thin paste and can be worked into cracks and joints easily.

Applied with a calking gun, silicon sealants produce a good seal with acceptable appearance.

Roofing cement. We will discuss two types of roofing cement: (1) Asphalt-impregnanted roofing cement that is a heavy, elastic, liquid, waterproofing adhesive, usually black in color but available in aluminum. (2) Plastic roofing cement that is a strong elastic adhesive, black or aluminum in color. It is used widely to seal around roof jacks and like items subjected to the weather. Roofing cement is usually applied with a brush or paddle.

Cements. Most of the cements used in the metal shop are contact cements and rubber-to-metal cements. Use contact cement with care. It is a liquid that is usually amber in color and dries very quickly, holding items together without the use of screws or rivets. Apply it with a brush or roller to both surfaces; then let it dry and join the surfaces together. Be sure to get them correct the first time as they are very hard to move after they make contact. Rubber-to-metal cement is used to attach insulation to duct work. It is a rubber-base cement, usually amber in color, and is applied with a brush, roller, or spray, with a longer open time (drying time) than contact cement. Most sealants and cements used in the sheet metal shop are harmful if they remain in contact with the skin for long periods of time.

Exercises (248):

1. What type of sealant is recommended for use around windows and similar items?

2. What sealant is available in any color and is a thin paste when applied?

3. What is the black or aluminum cement used to seal ventilators, jacks, and other items exposed to weather called?

4. What is the amber liquid used to hold items together without screws or nails called?

203

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

200 − 1. They may become damaged.
200 − 2. Some oils have corrosive properties that can cause damage to the tool finish.

201 − 1. True.
201 − 2. False. If you are not going to use the drill in a few minutes, put it up where it belongs.
201 − 3. True.
201 − 4. False. A clean shop usually means an efficient shop.
201 − 5. True.
201 − 6. False. Always pick up your tools and place them in the toolbox. Loose tools, those not properly stored or secured, can be a safety hazard for personnel.
201 − 7. True.
201 − 8. (1) d.
(2) c.
(3) a.
(4) b.

202 − 1. Double-cutting shears.
202 − 2. Aviation snips.
202 − 3. Straight snips.
202 − 4. Aviation snips.

203 − 1. The metal was inserted into the shear before the shear was turned on.
203 − 2. Wheel and belt guards and blade guards.
203 − 3. Turn off the shear and remove cut material.
203 − 4. To raise the blade when the cut is complete.
203 − 5. The treadle.
203 − 6. False. The holddown is operated by handles.
203 − 7. Back gage.

204 − 1. Size of the machine.
204 − 2. It can make more types of cuts than a squaring shear.

205 − 1. Throatless shears.
205 − 2. Circle shears.
205 − 3. Ring and circle shears.
205 − 4. Ring and circle shears.

206 − 1. Upper blade positioning lever.
206 − 2. On the stationary unishear the lower blade moves to make the cut, and on the portable unishear the upper blade moves to make the cut.

207 − 1. Install the blade so the teeth are pointed forward.
207 − 2. Hold the saw at an angle that allows at least two teeth to contact the cutting surface. Use long strokes and apply just enough pressure on the forward stroke to cause each tooth to cut.
207 − 3. Position the item to be cut so that it touches both the blade and the work rest, then lift the saw just enough to raise the blade off the work and depress the switch trigger. Then, let the weight of the saw do the cutting. Keep the work rest against the work.
207 − 4. 14 teeth per inch.
207 − 5. 24 teeth per inch.
207 − 6. One with 32 teeth per inch.

208 − 1. Clamp the material in the vise jaws.
208 − 2. Use the blade lubricating device.
208 − 3. By adjusting the feed pressure control.
208 − 4. Adjust the position of the vise jaws.

209 − 1. Metals and nonmetallic materials.
209 − 2. The skill and knowledge of the operator.

210 − 1. Keeper block.
210 − 2. Left insert, right insert, and thrust roller.
210 − 3. Install the proper inserts.
210 − 4. There is no hard-and-fast rule.
210 − 5. The center of the pulley.

211 − 1. Line voltage regulator.
211 − 2. The tension control.
211 − 3. Loosen the stationary jaw thumb screw.
211 − 4. Grinding and annealing.

212 − 1. Hole saws are used to cut holes up to 4 inches in diameter in light gage sheet metal and wood.
212 − 2. First, use the setscrew wrench to adjust the adjustable arm for the size circle and to adjust the cutting point to the correct depth. Then, while cutting the hole, hold the cutter firmly and perpendicular to the material being cut.

213 − 1. Square file, double cut.
213 − 2. Single cut mill file.

214 − 1. Width of the blade.
214 − 2. You would draw the temper out of it.
214 − 3. You grind the mushroom (spreadout) off.
214 − 4. Firmly against the tool rest and moved in a steady motion back and forth across the face of the wheel.

CHAPTER 2

215 − 1. Carbon or high-speed steel.
215 − 2. On the shank.
215 − 3. Inch.
215 − 4. Failed to use a center punch to sink a mark at the desired drill spot.
215 − 5. The instant the twist drill breaks through the material.
215 − 6. Either clockwise or counterclockwise, depending on the individual.
215 − 7. The heel and the web.

216 − 1. Concrete, brick, or cinder block.
216 − 2. To bevel the edges of a hole so that countersunk head bolts and rivets can be inserted properly.

217 − 1. Where electric power is not available.
217 − 2. At a right angle.
217 − 3. To test for trueness and vibration.

218 − 1. Goggles, safety glasses, or a face shield.
218 − 2. Chuck key.
218 − 3. Manufacturer's handbook or technical manual.
218 − 4. Use a cutting oil to cool and prevent breaking the twist drill.
218 − 5. 1/2 inch.

219 − 1. Starter punch.
219 − 2. Prick punch.
219 − 3. Whitney punch.

220 − 1. To remove burrs from holes.
220 − 2. In hand drills; electric drills and drill presses.
220 − 3. Stiff paper.
220 − 4. No. The upper and lower turrets are synchronized.
220 − 5. To ream or enlarge holes.

221 − 1. 2000 rivets.
221 − 2. 11/32 inch.
221 − 3. Monel.
221 − 4. Stagger.
221 − 5. Access with a bucking bar to the back side of the material being riveted is not necessary.
221 − 6. General rule is that the rivet diameter is three times the thickness of the metal.
221 − 7. Slightly larger than 1/8 inch or a No. 30.
221 − 8. It is a holding device used to hold metal sheets in place during drilling or riveting.
221 − 9. Setting, upsetting, and heading.
221 − 10. The jaws are loaded.

222 − 1. Set, upset, and head.
222 − 2. File a flat spot on the manufactured head, center punch, drill the depth of the head with a drill bit the same diameter as the rivet shank, drive the rivet out with a pin punch.
222 − 3. Place a solid rivet, head down, on a bench plate, place the metal to be joined over the rivet and tap lightly with a mallet. Use a rivet set and tinners hammer to drive the rivet through the metal.

223 – 1. In metal parts that may later be disasse[illegible]led
223 – 2. Type A.
223 – 3. Vibration
223 – 4. Tapped holes or nuts.
223 – 5. Square, hexagon, wing, self-locking, and sheet spring
223 – 6. Screw nail. Because of its greater holding power.

224 – [illegible] On the corners of sheet metal assemblies.
224 – 2. To dress and strengthen corners.
224 [illegible] [illegible] of the cleat is bent over the head of the nail.
224 – 4. When large ducts need additional [illegible]pport and strengt[illegible]
224 – 5. To sup[illegible] [illegible]nd [illegible] duct systems.

225 – 1. They are [illegible]ded and numbered to indicate power levels.
225 – 2. [illegible]
225 – 3. [illegible] level.
225 – 4. Cracks or spalling.

CHAPTER 3

226 – 1. The wing pressure screws.
226 – 2. The adjustable collar stop.
226 – 3. The wedge.

227 – 1. Adjusting screws P and O.
227 – 2. The bending leaf adjusting bolt.
227 – 3. Molds or formers.
227 – 4. It has removable, interchangeable fingers.

228 – 1. The lower rear roll.
228 – 2. Reversing switch.
228 – 3. To keep the rear roll parallel with the upper roll.
228 – 4. Be adjusted to compensate for different diameters.
228 – 5. The two lower rolls.

229 – 1. Burring machine.
229 – 2. Turning machine.
229 – 3. Elbow edging machine.
229 – 4. Setting down machine.
229 – 5. Crimping machine.

230 – 1. Hand dollies.
230 – 2. Ball peen hammer.
230 – 3. To work soft material without damaging it.

231 – 1. It forms grooved seams on round ducts and forms lock seams for corners of rectangular ducts.
231 – 2. Change rollers.
231 – 3. You must mark the seam allowances.

232 – 1. With a bolt.
232 – 2. The blowhorn.
232 – 3. Long flaring articles.
232 – 4. Screws with locknuts.
232 – 5. Hammer.

CHAPTER 4

233 – 1. Water; air pressure.
233 – 2. The upper.
233 – 3. False. The transformer circuit produces the heat.
233 – 4. 100-volt electrical current.

234 – 1. Increase the squeeze.
234 – 2. The hold.
234 – 3. Air pressure.

235 – 1. Keep the electrodes dressed.
235 – 2. In corners and near bottoms of containers.
235 – 3. The weld will lack strength.
235 – 4. It keeps it cool and that helps keep it clean.

236 – 1. Nearly all metals.
236 – 2. They are difficult to weld.
236 – 3. It does not have a plastic range.

237 – 1. To remove the chance of poor weld (insulator).
237 – 2. It interferes with the bonding of the metals being welded.
237 – 3. A clean rag and solvent if necessary.

238 – 1. Peel, twist, or visual.
238 – 2. Cut it in half.
238 – 3. Separated.
238 – 4. In the visual test.
238 – 5. Shear.

239 – 1. So one can be heating while the other one is in use.
239 – 2. Remove the tip so that the heating element is not damaged.

240 – 1. Natural or artificial gas.
240 – 2. The blowtorch.
240 – 3. Unleaded gasoline only.

241 – 1. To keep the tip from cooling off too rapidly.
241 – 2. Sal ammoniac and a cotton rag.
241 – 3. Place the rag on the bench and drag the copper across it

242 – 1. Smooth and clean the area to be tinned; then apply flux, heat, and solder.
242 – 2. Oxides are removed with flux.

243 – 1. Move the heated copper slowly and make sure that the solder flows into the seam or joint.
243 – 2. Hold it firm until it has cooled.
243 – 3. 40 percent tin and 60 percent lead.
243 – 4. You may leave voids.
243 – 5. Melt solder and remove with clean, damp cotton rags.
243 – 6. The process of flowing solder into heated joints or seams.
243 – 7. Bright and shiny.

244 – 1. Tank, tank valve, pressure regulator, hose, torch handle, and tips.
244 – 2. Direct or indirect methods.

245 – 1. Heat-treated alloys and alloys containing more than 1-percent of magnesium.
245 – 2. To remove the layer of oxide.
245 – 3. Corrosive and noncorrosive.
245 – 4. Aluminum solder.

246 – 1. Wash it off with water.
246 – 2. It has an open flame and is attached to a supply of liquid propane under pressure.
246 – 3. Disconnect it from the electrical supply.
246 – 4. To remove oxide, to prevent oxidation during heating, and to lower surface tension of the solder.
246 – 5. On bright copper.
246 – 6. Dip into sal ammoniac or use a clean cotton rag.
246 – 7. Corrosive flux.

247 – 1. a. Tape—to make sheet metal items airtight.
b. Cement and adhesive—to attach insulation.
c. Sealant—to protect from weather, heat, expansion, and contraction.

248 – 1. Calking compound.
248 – 2. Silicon sealant.
248 – 3. Roofing cement.
248 – 4. Contact cement.

205

AU GAFS, AL. (853092)600

S T O P - 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

55252 02 22
SHEET METAL TOOLS AND EQUIPMENT

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet .
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover your answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you have to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If mandatorily enrolled student, process questions or comments through your unit trainer or OJT supervisor. If voluntarily enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the Learning Objective Number where the answer to that item can be located. When answering the items on the VRE, refer to the Learning Objectives indicated by these Numbers. The VRE results will be sent to you on a postcard which will list the actual VRE items you missed. Go to the VRE booklet and locate the Learning Objective Numbers for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the best answer to each question.

1. (200) If tools are left on beams, rafters, or ducting systems,

   a. they may become lost.
   b. someone could be injured.
   c. they may fall off and be damaged.
   d. any of the above may occur.

2. (201) Which of the following materials would create a class C fire?

   a. Electrical motors and transformers.
   b. Sodium and magnesium.
   c. Gasoline and paint.
   d. Wood and trash.

3. (201) Which of the following materials would cause a class D fire?

   a. Wood and trash.
   b. Gasoline and paint.
   c. Sodium and magnesium.
   d. Electrical motors and transformers.

4. (202) Which one of the following shears is designed to cut 16 gage sheet metal?

   a. Bench.
   b. Circle.
   c. Aviation.
   d. Double cutting.

5. (203) When operating a squaring shear, the operator can keep his or her hands out of the way during a cutting operation by using the

   a. treadle.
   b. holddowns.
   c. back gage.
   d. safety guards.

6. (203) When cutting several pieces of metal to the same dimensions, you should use

   a. holddowns.
   b. a back gage.
   c. a side gage.
   d. extension arms.

7. (203) The proper sequence when making a cut with a manually operated squaring shear is to set the

   a. back gage, insert the metal, set the holddown, and depress the treadle.
   b. holddown, depress the treadle, set the back gage, and insert the metal.
   c. holddown, insert the metal, set the back gage, and depress the treadle.
   d. back gage, insert the metal, depress the treadle, and set the holddown.

8. (204) When comparing a gap squaring shear with a squaring shear of the same capacity, the gap squaring shear is

   a. more compact.
   b. less versatile.
   c. heavier and larger.
   d. lighter and smaller.

9. (204) The advantage of the gap squaring shear over the squaring shear is

   a. that any cut made with a squaring shear can be made with a gap squaring shear.
   b. that more types of cuts can be made by the gap squaring shear.
   c. that a cut can be made that is longer than the length of the blade.
   d. that all of the above are true.

10. (205) The lower blade of a throatless shear is adjusted with

   a. setscrews.
   b. bolts and shims.
   c. large Allen head bolts.
   d. any of the above.

11. (205) Which one of the following shears is <u>best</u> suited to cut out a flange for a ceiling thimble?

   a. Circle.
   b. Utility.
   c. Throatless.
   d. Ring and circle.

12. (206) To make an irregular cut in an 18 gage metal duct installed in a building, you should use

   a. straight cut aviation shears.
   b. a throatless design portable unishear.
   c. a stationary unishear which has an upper blade positioning lever.
   d. any of the above.

13. (206) What engineering feature allows the portable unishear to cut irregular shapes?

a. Throatless design.
b. A flexible electrical cord.
c. It is designed for right or left hand operation.
d. The upper blade moves up and down during cutting.

14. (207) What saw blade pitch on a cutoff saw is used for cutting cast iron?

a. 14.
b. 18.
c. 24.
d. 28.

15. (207) If a portable power saw jerks forward during a cut, the

a. blade pitch is too fine.
b. blade pitch is too coarse.
c. work rest is not in contact with the material being cut.
d. speed of the power saw is too slow and the blade is installed incorrectly.

16. (208) Cutting oil is used on power hacksaws and power cutoff saws to provide

a. longer blade life.
b. improved performance.
c. longer life of the saw.
d. all of the above.

17. (209) When cutting metal or nonmetalic material on an upright bandsaw, the quality and precision of the work is controlled by the

a. knowledge and skill of the operator.
b. pitch of the blade and blade velocity.
c. feed pressure and thickness of the blade.
d. tension of the blade and shape of the inserts.

18. (209) To repair an upright bandsaw that has a broken saw band, you

a. must replace the saw band.
b. use a resistance type spot welder.
c. use the upright band saw butt welder.
d. weld the saw band at the base welding shop.

19. (210) The guide blocks on an upright bandsaw are used to

a. keep the blade in track.
b. control the variable speed unit.
c. hold the inserts and thrust roller.
d. hold the material being cut straight.

20. (210) The steps required in "setting up" an upright bandsaw to cut with a different width blade are

a. to rotate the wheels by hand until the blade tracks and adjust the tension.
b. to install correctly the proper inserts and open the upper and lower access doors.
c. to remove the filler plate and place the sawband over the upper and lower wheels.
d. to do all of the above.

21. (210) Before shifting an upright bandsaw transmission from "low" to "high", you must

a. turn the machine "off."
b. slow the speed to 50 FPM.
c. slow the speed to 100 FPM.
d. do all of the above.

22. (211) When welding saw bands of different widths using a butt welder, it is necessary

a. to increase line voltage.
b. to decrease line voltage.
c. to adjust the tension control.
d. to trim the wider band to fit.

23. (211) The next step after welding a saw band is

a. cooling.
b. clamping.
c. grinding.
d. annealing.

24. (212) What size electric drill is recommended for drilling with a 1 5/8-inch hole saw?

a. 1/4-inch.
b. 3/8-inch.
c. 1/2-inch.
d. 1 1/2-inch.

25. (213) In an area where other type files will <u>not</u> fit, the type of file that should be used to remove burrs and sharp edges from a dining hall hood is a

a. flat, single cut.
b. mill, single cut.
c. half round, double cut.
d. triangular, double cut.

26. (213) What type file should be used where a rough finish is permissible and a fast cut is desirable?

a. Double cut.
b. Second cut.
c. Single cut.
d. Deep cut.

27. (214) The proper angle to grind a cold chisel is

a. 57° to 58°.
b. 58° to 60°.
c. 60° to 70°.
d. 70° to 79°.

28. (214) On a grinder, the maximum distance the tool rest can be from the wheel is

a. 1/16-inch.
b. 1/8-inch.
c. 1/4-inch.
d. 1/2-inch.

29. (215) Which one of the following reflects the largest size twist drill?

a. A.
b. 1.
c. 15/64".
d. Z.

30. (215) What lip angle should be used when drilling brass or bronze?

a. 30° to 40°.
b. 40° to 50°.
c. 50° to 60°.
d. 60° to 70°.

31. (215) If a twist drill bit breaks when you are drilling a hole through cold rolled steel, you should

a. stop drilling.
b. decrease the pressure and stop the drill.
c. increase the pressure and continue to drill.
d. decrease the pressure and continue to drill.

32. (216) Masonry drills are used when drilling holes in

a. brick and metal.
b. concrete and hardwood.
c. concrete, brick, and metal.
d. cinder block, concrete, and brick.

33. (217) Hand drills are used

a. where there is no electric power.
b. when there are only two or three holes to be drilled.
c. when it would require more time to get electric power to the site than to drill the holes with a hand drill.
d. in any of the above instances.

34. (217) Using a slightly bent twist drill will result in

a. wobbling.
b. scratching.
c. enlarged holes.
d. damaged threads.

35. (218) Before drilling a hole with a drill press, you should

a. adjust the work table.
b. secure the item to be drilled.
c. center punch the item where the hole is to be drilled.
d. do all of the above.

36. (218) Which one of the following should never be left in its working position on a drill press?

a. Chuck key.
b. Belt guard.
c. Feed handle.
d. Working table.

37. (218) To adjust the spindle speed on a drill press, shift the

a. V-belt on the motor.
b. V-belt on the spindle.
c. transmission to a lower gear.
d. V-belt on the motor and spindle.

38. (219) To locate the vertex of a radial line layout, use a

a. pin punch.
b. drift punch.
c. prick punch.
d. center punch.

39. (219) To remove a 5/32-inch pin from a shaft, you should use a

a. pin punch.
b. drift punch.
c. Whitney punch.
d. starting punch.

40. (219) What two punches have interchangeable dies?

a. The rotary punch and the drift punch.
b. The rotary punch and the Whitney punch.
c. The hand lever punch and the hollow punch.
d. The hand lever punch and the Whitney punch.

41. (220) The diameter of each rotary punch is indicated on the

a. lower turret body.
b. upper turret body.
c. front of the dieholder.
d. right side of each punch.

42. (220) During preventive maintenance inspections, the punches in a rotary punch are raised and lowered in their respective dies

a. to ensure that the punches move freely.
b. to check for proper alignment.
c. to inspect for cleanliness.
d. to do all of the above.

43. (220) The shank diameter of a 5/8-inch conical rotary file is

a. 1/4-inch.
b. 3/16-inch.
c. 3/8-inch.
d. 5/8-inch.

44. (221) When compared with most other rivets, the head on a tinner's rivet is

a. larger.
b. thicker.
c. smaller.
d. thinner.

45. (221) What size of tinner's rivet should you use when making a double row riveted lap joint on 16 gage sheet metal?

a. 2 lb.
b. 2.5 lb.
c. 3 lb.
d. 4 lb.

46. (221) What type of a rivet is most suited to areas where the use of a bucking bar is difficult or impossible?

a. Blind rivet.
b. Monel rivet.
c. Aluminum rivet.
d. Tinner's rivet.

47. (221) The rivet that has a long, slim stem protruding upward from the rivet head is a

a. Monel rivet.
b. blind rivet.
c. tubular rivet.
d. tinner's rivet.

48. (222) Which of the following is the first step taken to install a tinner's rivet after the rivet is placed in the hole?

a. Bucking the rivet.
b. Heading the rivet.
c. Setting the rivet.
d. Upsetting the rivet.

49. (222) What tools are needed to properly install a solid rivet?

a. Hammer, rivet set, and a backing surface.
b. Hammer, a backing surface, and drift punch.
c. Rivet set, backing surface, and cleco.
d. Hammer, rivet set, and cleco.

50. (222) When solid rivets are installed in light gage sheet metal without first drilling or punching holes, it is called

a. driving rivets.
b. drawing rivets.
c upsetting rivets.
d. transverse riveting.

51. (222) When removing a rivet (solid or blind), you should drill on the

a. driven head.
b. shop-made head.
c. manufactured head.
d. head that is easiest to reach.

52. (223) What type of fastener is recommended for use on sheet metal items which may later be dissassembled?

a. Stove bolts.
b. Blind rivets.
c. Machine screws.
d. Sheet metal screws.

53. (223) Square nuts can be tightened with open end or adjustable wrenches. To get a tighter fit and reduce the chance of rounding the corners of the nut, what tools does the text recommend be used to tighten a hex head nut?

a. Open or box end wrench.
b. Box end or socket wrench.
c. Open end or adjustable wrench.
d. Socket or adjustable wrench.

54. (224) To dress and strengthen corners on sheet metal assemblies that have been notched or damaged, the item to use is a

a. clip.
b. cleat.
c. brace.
d. fascia.

55. (224) Which items are used to support level heating and air conditioning ducts?

a. Clips.
b. Cleats.
c. Hangers.
d. Brackets.

56. (224) When used to fasten sheet metal components and assemblies, the purpose of braces is

a. to level small duct systems.
b. to level large duct systems.
c. to support and strengthen large ducts.
d. to hold rain gutters and leaders in place.

57. (225) What is the difference between direct and indirect acting powder actuated tools?

a. The direct acting is designed for light duty work.
b. The indirect acting is designed for heavy duty work.
c. The direct acting uses a piston driven by the powder charge to set the fastener.
d. The indirect acting uses a piston driven by the powder charge to set the fastener.

58. (225) Who is authorized to use a powder actuated tool?

a. Only shop supervisors.
b. Only 5 and 7 level airmen.
c. Only trained qualified operators.
d. Only those personnel assigned to the specific job order.

59. (225) How should a test fastening be made with a powder actuated tool?

a. Use a powder load one-half the fastener weight.
b. Use a powder load equal to the fastener weight.
b. Use the highest powder load recommended for the tool.
d. Use the lowest powder load recommended for the tool.

60. (226) The bar folder is adjusted for different thicknesses of material by adjusting the

a. wing pressure screws.
b. stop collar.
c. wedge knob.
d. gage screw.

61. (226) To make numerous bends of 60° on a bar folder, you should set the

a. gage screw.
b. wedge knob.
c. collar stop.
d. wing pressure screws.

62. (227) See text figure 3-2. When more tension is put on adjusting bolt number 7 on a cornice brake, the center of the

a. bed will drop.
b. bed will raise.
c. bending leaf will drop.
d. bending leaf will raise.

63. (227) See text figure 3-2. On a cornice brake, if the clamping handle is pushed back and the leaf fails to raise, which of the adjusting screws should you tighten?

a. BB.
b. EE.
c. EE and FF.
d. P and M.

64. (227) The "fingers" of a box and pan brake can be removed

a. to allow bends on four sides of an item.
b. to allow bends of 90 degrees or more.
c. to make it possible to form off-sets.
d. to do all of the above.

65. (228) The front roller on a slip roll forming machine is adjusted

a. to obtain the desired radius.
b. to remove the formed cylinder.
c. to fit the thickness of the metal being formed.
d. to do all of the above.

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66. (229) Which one of the following machines is used to tighten edges prior to double seaming?

a. Turning.
b. Crimping.
c. Setting down.
d. Rotary burring.

67. (229) Which of the following rotary machines is used to make one end of a pipe joint smaller than the other end?

a. Burring.
b. Turning.
c. Crimping.
d. Setting down.

68. (230) What hammer should be used to drive rivets, punches, and chisels?

a. Raising.
b. Ball peen.
c. Planishing.
d. Tinner's setting.

69. (230) A vise is normally used in a sheet metal shop to

a. hold material.
b. bend material.
c. form material.
d. do all of the above.

70. (230) Mallets are used to form

a. wire edges.
b. grooved seams.
c. copper or aluminum.
d. all of the above.

71. (231) What is the normal seam allowance for a Pittsburg seam?

a. 1 inch.
b. 1 1/8 inches.
c. 1 1/4 inches.
d. 1 5/16 inches.

72. (232) Bench plate and stakes are used to

a. shape metal parts.
b. install solid rivets.
c. seam metal components.
d. do all of the above.

73. (232) To shape a funnel spout or wire for the top of a rectangle pan, you should use a

a. creasing stake.
b. blowhorn stake.
c. needlecase stake.
d. hollow mandrel stake.

74. (232) To seam the bottom of a metal cup, use a

a. bench plate and bottom stake.
b. hollow mandrel stake and hand dolly.
c. bench plate and double-seaming stake.
d. double-seaming stake and hollow mandrel.

75. (233) To make a spot weld, you must

a. place the material in between the electrodes.
b. apply pressure to the electrodes.
c. energize the transformer.
d. do all of the above.

76. (233) The heat between the electrodes of a spot welder is produced by the

a. 110-volt current.
b. energized transformer.
c. in-put electrical power.
d. pressure between electrodes.

77. (234) How many machine controls are involved in setting up a spot welder?

a. 4.
b. 5.
c. 6.
d. 7.

78. (234) During a spot weld operation, molten metal is forced out from under the electrode tips. To correct this, reduce the

a. hold time.
b. weld time.
c. air pressure.
d. electric current.

79. (235) The electrode on a spot welder must have

a. greater strength to resist over heating.
b. lower conductivity to avoid over heating.
c. higher conductivity than the metal being welded.
d. alloys of the same base metal as the metal being welded.

80. (235) Spot weld electrodes are dressed with a

a. mill file and sandpaper.
b. mill file and emery cloth.
c. second cut file and sandpaper.
d. second cut file and emery cloth.

81. (236) To choose the correct electrodes for a welding job of dissimilar metals, a key factor is the

a. size and alloy of the electrode.
b. alloy of the metal being welded.
c. size of the electrode.
d. thickness of the job.

82. (237) What constitutes foreign material in a spot weld joint?

a. Compatible metals.
b. Dissimilar metals.
c. Material that aids the weld.
d. Material that hinders the weld.

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83. (237) To remove rust, paint, corrosion, or dirt from metal prior to spot welding, you should use

a. a scraper, file, or grinder.
b. a piece of scrap metal.
c. solvent or thinner.
d. a sand blaster.

84. (238) To test a spot weld by the peel method, the test pieces are

a. separated from the loose ends first.
b. forced together from the loose ends.
c. forced together like metal shears.
d. separated like metal shears.

85. (239) The size of electric soldering coppers (irons) is determined by

a. amps. c. pounds.
b. watts. d. diameter.

86. (240) Which of the following soldering copper heaters uses unleaded gasoline?

a. Tinner's furnace. c. Firepot and blowtorch.
b. Propane tinner's furnace. d. Firepot and tinner's furnace.

87 (241) To care for and shape a soldering copper by forging, the first step is

a. to tin the copper with solder.
b. to remove the scale and smooth the surfaces.
c. to rub a hot copper on a block of sal ammoniac.
d. to hold the copper on a forge and hit with a hammer.

88. (241) What is used to remove the oxide while tinning a soldering copper?

a. File. c. Wire brush.
b. Clean rag. d. Sal ammoniac.

89. (242) What is used to remove burrs and some oxides from a joint or seam to be tinner?

a. Flux. c. A copper.
b. A file. d. A grinder.

90. (242) The tinning step of a soldered joint is performed with

a. solder.
b. soldering flux.
c. a heated copper.
d. all of the above.

91. (243) A good technique used in soldering is to take advantage of the characteristic that solder flows

a. toward flux.
b. toward heat.
c. away from heat.
d. away from flux.

92. (243) To sweat a solder joint, you heat the

a. joint and then apply solder.
b. joint only enough to melt the solder.
c. joint until the solder flows evenly.
d. solder and then apply it to the joint.

93. (243) A 60/40 solder blend consists of

a. 60% tin and 40% lead.
b. 60% lead and 40% tin.
c. 60% zinc and 40% lead.
d. 60% lead and 40% zinc.

94. (244) How can you prevent damage to a hydrocarbon torch regulator?

a. Turn it clockwise before opening the tank valve.
b. Turn it counterclockwise before opening the tank valve.
c. Turn it counterclockwise after opening the tank valve.
d. Turn it clockwise after opening the tank valve.

95. (245) The main difficulty in soldering aluminum alloys is the

a. heat.
b. flux.
c. oxide.
d. magnesium content.

96. (245) Which of the following alloys is recommended to solder aluminum?

a. Tin and zinc.
b. Zinc and lead.
c. Cadmium and lead.
d. Tin and lead 60/40 solder.

97. (246) If you spill corrosive flux on yourself or someone else, you should

a. wipe it up with a clean rag.
b. wash it off if it begins to burn.
c. wash it off with an abundance of water.
d. cover it with baking soda to neutralize it.

98. (246) After a blowtorch has been filled with unleaded gasoline, it should be ignited only if

a. the coils are hot.
b. the area is unventilated.
c. there is adequate ventilation.
d. there is gasoline in the priming tank.

99. (247) What is used to hold insulation on a metal duct?

a. Cement.
b. Adhesive.
c. Pressure sensitive tape.
d. All of the above.

100. (247) Three types of sealers used in metal buildings, doors, window facings, joints and seams of ducts are

a. tape, cement, and sealants.
b. tape, cement, and adhesive.
c. tape, adhesive, and insulators.
d. cement, adhesive, and insulators.

101. (248) To attach such things as insulation to a duct, you should use

a. contact cement.
b. roofing cement.
c. silicone sealant.
d. rubber-to-metal cement.

102. (248) A paste-like item that is used to seal just about any clean dry surface and dispensed in convenient tube form is

a. a calking compound.
b. a silicone sealant.
c. a plastic roofing cement.
d. an asphalt roofing cement.

END OF EXERCISE

MAIL TO: ECI, GUNTER AFS AL 36118-5643

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: [illegible] PRINCIPAL PURPOSE: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package and used by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's inquiry. Failure to provide all information would result in slower action or inability to provide assistance to the student.

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15	Other (Explain fully in "Remarks")

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I certify that the information on this form is accurate and that this request cannot be answered at this station.

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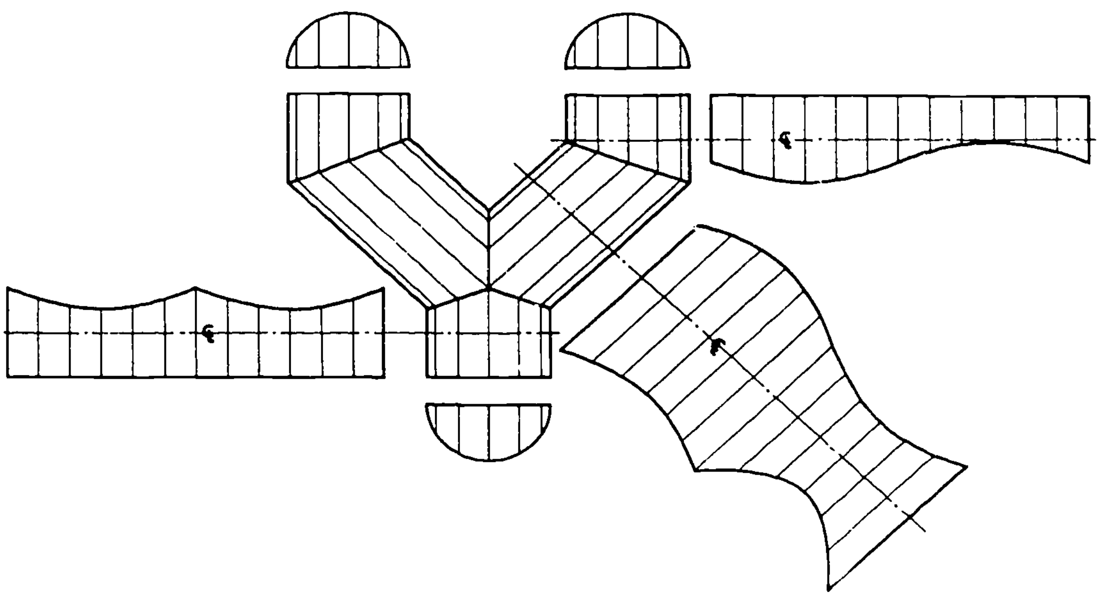
METAL FABRICATING SPECIALIST

(AFSC 55252)

Volume 3

Layout and Duct Systems



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Preface

THIS VOLUME covers duct systems all the way from layout to installation. Chapter 1 covers blueprints, drawings, and layout methods. There also is a short section on structural steel layout. Chapters 2 and 3 deal with seams, joint connections, and airflow control devices. Chapter 4 covers planning, layout, fabrication, and installation of duct system components. Chapter 5 explains stacks and ventilators.

Foldouts 1 and 2 are printed and bound in the back of the volume.

Code numbers appearing on figures are for preparing agency identification only and should be of no concern to the student.

Direct your comments relating to the accuracy or currency of this volume to the course author: 3770 TCHTG/TTGIC, ATTN: MSgt Ringstad, Sheppard AFB TX 76311. If you need an immediate response, call the author, AUTOVON 736–2879, between 0700 and 1600 (CST), Monday through Friday. *(NOTE:Do not use the suggestion program to submit changes or corrections for this course.)*

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This volume is valued at 33 hours (11 points).

Material in this volume is technically accurate, adequate and current as of July 1982.

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NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see whether your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Drawings and Layout

IN THIS SECTION you will learn the types of drawings and what they tell you. Blueprints are special instructions to you, the worker. But if you cannot read them, they might as well be in a foreign language. Let's take the first step and then the jump.

1-1. Types of Drawings

Working drawings, sometimes called plans or blueprints, are used by workers in all crafts and trades, such as carpenters, electricians, and metal fabrication specialists. The lines and symbols used on working drawings may be compared with the lines and symbols used on roadmaps, where different kinds of lines indicate the types of roads and where symbols identify the roads as Federal, State, or county. Other symbols identify state capitols, county seats, airports, ferries, etc. Maps also show the distances between towns and cities and their size.

The working drawings that you will be using can be compared with roadmaps, too, since they also contain solid and dashed lines that outline objects and show routings, symbols that abbreviate and identify components, and dimensions that show the distance between components and how large they are.

The symbols and instructions contained on working drawings must be followed carefully if a component is to be properly fabricated and installed. For example, suppose you have made the duct work for a heating system but another person has failed to adhere to specified dimensions for the opening in the wall through which the ducts must run. Because of his failure to follow instructions in the working drawings, the ducts cannot be installed without additional expense and delay. Remember, then, that careful adherence to the plans is very important.

In this section, we discuss the use and interpretation of lines, symbols, dimensions, specifications, and notes used in working drawings. These subjects are according to your specialty training standard that states that you interpret drawings and sketches of sheet metal assemblies. The knowledge you gain from this section can be used every time you develop patterns, fabricate components, or install components.

400. Specify requested drawings and views, and identify each by its characteristics.

Drawings that you use will convey ideas concerning the fabrication, assembly, and installation of sheet metal components. From a working drawing, you can learn what the architect or engineer intends for you to build. The drawings will be duplicates made by photographic reproduction processes, such as blueprints or ammonia-developed oxalid prints. These prints will be approximately 30" x 40" in size. In the following paragraphs, we explain some of the types of views and drawings the draftsman uses to graphically describe the jobs you are to perform.

Pictorial and Orthographic Projection Drawings. In figure 1-1, you can see the relations of pictorial and orthographic projection drawings. A pictorial drawing is so called because it is similar to a picture.

The three rectangles marked "top," "side," and "front" are called orthographic projections and show the true size of each side of the rectangular prism. Two or more views of orthographic projections are usually at right angles to each other and perpendicular to the plane of projection. Notice how the top, front, and side have been projected so that each resembles a rectangular plane. In the pictorial view, it appears that the angles at the four corners are not equal, whereas in the projection views we can see that all of the angles are equal. Pictorial drawings always show the features of an object in a somewhat distorted way and are used only to a limited extent in working drawings, but they are used extensively in the shop and are easy to interpret with little training. Keep in mind when using pictorial drawings that care must be taken in using the measurements that are listed and not go by their appearance. Orthographic projection drawings, on the other hand, have the advantage of showing all the features in their true shapes.

In orthographic projection drawings, such as that illustrated in figure 1-1, three views of the object are shown. This is done to show you the three main dimensions—length, width, and thickness. The orthographic projection showing the top is called the top or plan view. It shows the part that would be seen if you were standing directly over the object and looking down at it. The orthographic projection showing the front is called the front or elevation view. It shows the part of the object that

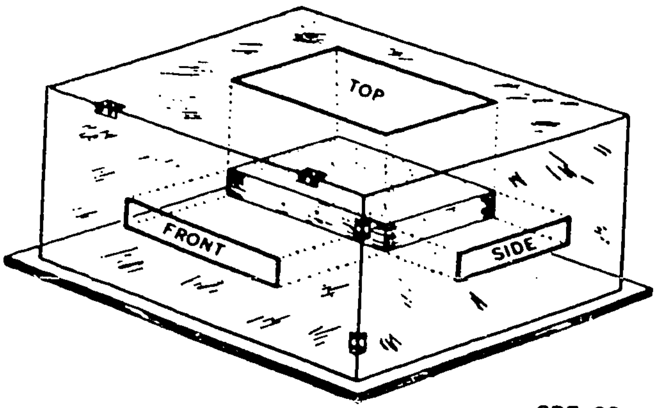

Figure 1-1. Pictorial and orthographic projection drawing.

would be seen if you were standing directly in front of the object and looking squarely at it. The orthographic projection of the end is used to show the distance from the front to the back. It is also an elevation view and shows the part of the object seen if you were standing at the end and looking squarely at the object. As you can see, in simple orthographic projections of regular shapes like this, the end view is not important because al: .s are obtainable from the top and front view.

Curved surfaces do not alway. look curved in an orthographic projection because you are looking at the top, bottom, or side of an object 90° to the surface. In a pictorial drawing, you can see that the edges are curved; but in an orthographic projection, you see the surface broadside, and it appears flat. The example shown in figure 1-2 is a top-view orthographic drawing of a cone. Although you know that the side of a cone is curved, you cannot see the curvature in the drawing. However, from the accompanying plan view, you can see that the base of the elevation view is circular. It is a good idea to keep in mind that lines in orthographic projections are not curved but may indicate a curved surface, and it is up to you to determine the curvature from one of the other views.

Types of Views. Working drawings will provide you with sufficient information to develop patterns and fabricate, assemble, and install the components represented. This includes such information as size and shape of the components and how they are installed. Working drawings usually are divided into three general classes—detail drawings, assembly drawings, and installation drawings; however, in sheet metal drawings, these classes are combined into plan views, elevation views, and detail views.

Plan views. In this section, we already have mentioned plan views and have used two figures to illustrate them. In the orthographic projections shown in figures 1-1 and 1-2, the plan views show the objects as they would be seen if you were standing directly over them and looking down. This also is true of an architectural drawing, where the plan view is an overhead view of the floor plan, as shown in figure 1-3. In this plan view, you can see how a heating system is installed.

A plan view such as that illustrated in figure 1-3 includes much of the information necessary for installation of components or assemblies in a building. It shows the dimensions necessary for locating the parts with relation to other parts, and it shows room dimensions that are helpful in the various layout and installation problems. Notice, in the illustration, such information as the overall appearance of the installed duct system, the size and shape of the duct pieces, the room dimensions, the grill locations, the direction of airflow, and the location of underfloor return ducts. Now that you have looked over the drawing of the duct system, you probably are wondering about the symbols and different kinds of lines used. Later in this section, we will discuss lines and symbols; however, at this point it is more important that you learn about plan, elevation, and detail views.

Elevation views. In figures 1-1 and 1-2, two simple elevation views are illustrated. Now, in figure 1-4, you can see the elevation view of a furnace and supply trunk. Notice that this side view contains information that cannot be shown in a plan view. From elevation views of this type,

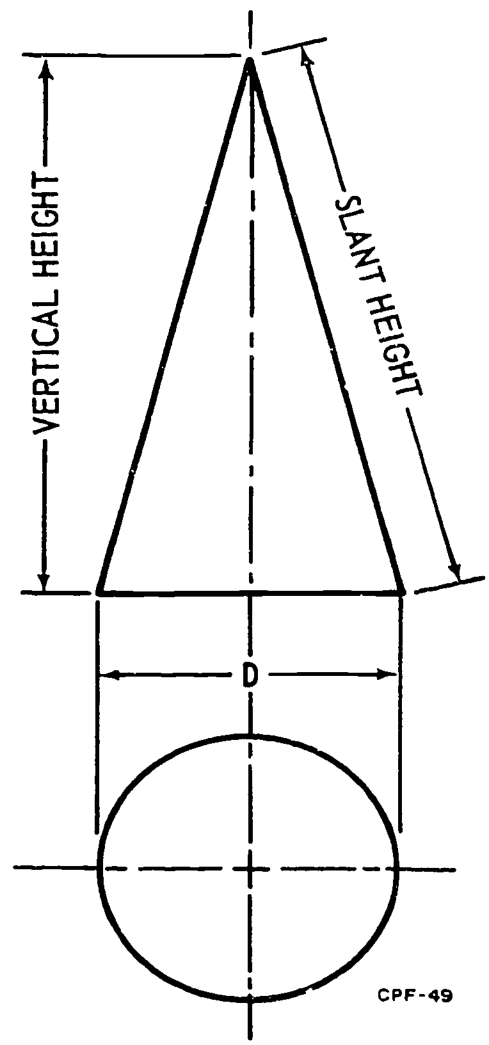

Figure 1-2. Orthographic projections of a cone.

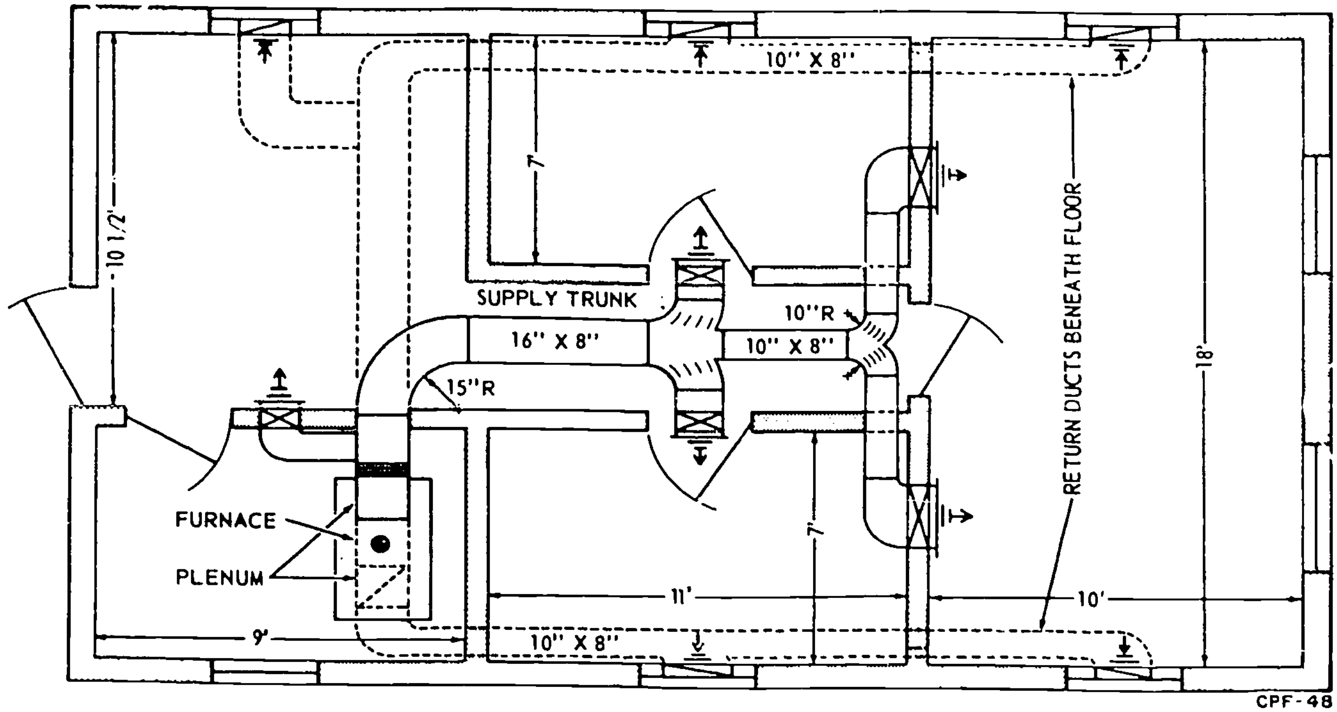

Figure 1-3. Plan view of a duct installation.

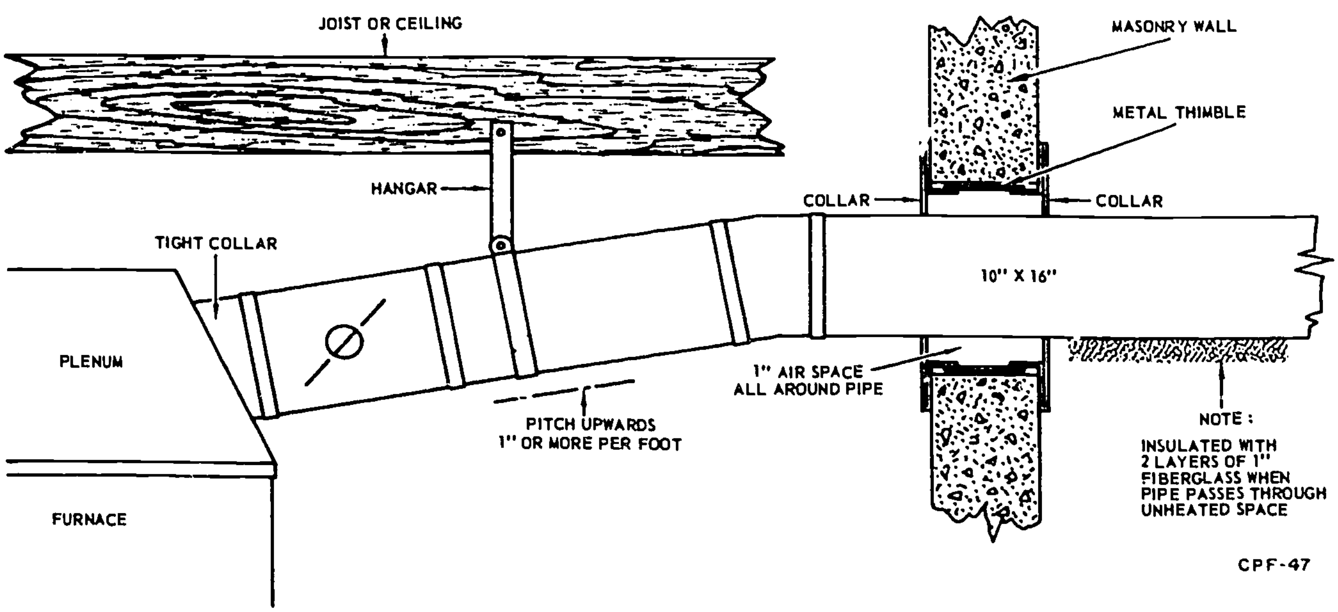

Figure 1-4. Elevation view.

you also can determine vertical dimensions and distances needed for pattern layout, fabrication, and installation. In sheet metal work, elevation views similar to this often are contained on the same working drawings as the plan views.

Detail views. Detail views often show small parts that cannot be seen clearly in the plan and elevation views. For example, the detail view shown in figure 1-5 illustrates the use of a cloth connector and methods of making the connection. This cloth connector is used to prevent furnace noise from being transmitted through the duct system. You will find detail views similar to these included with most plan and elevation drawings that include descriptions such as size, specifications, shape, materials, and methods of fabrication.

Exercises (400):

1. List two types of drawings and three types of views.

2. The true size of all sides of an item are shown in which drawing?

3. What view contains vertical dimensions?

4. What is the advantage of pictorial drawings.

5. What view is an overhead view?

6. What view shows small items greatly enlarged?

7. Why do orthographic projection drawings show three views of an object?

8. What are the three classes of sheet metal working drawings?

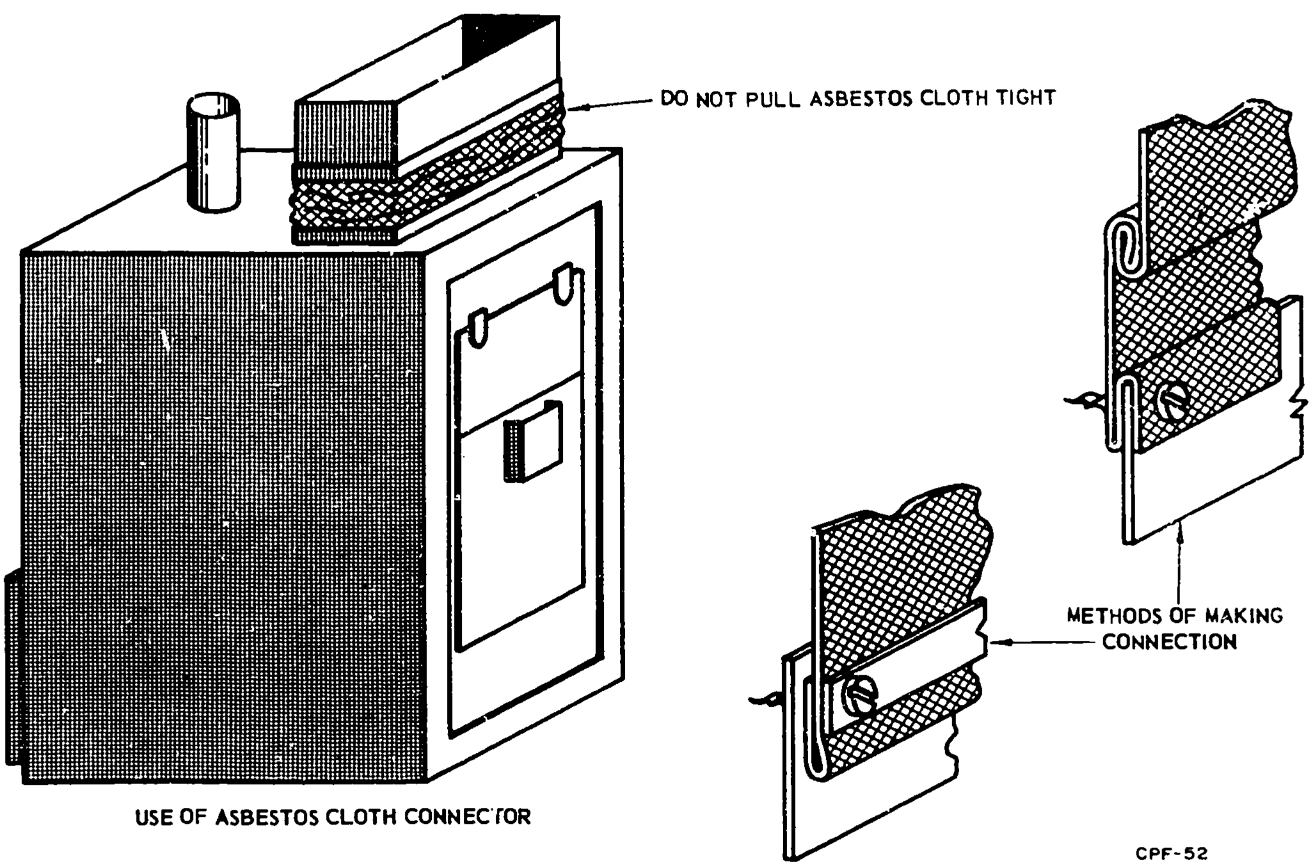

Figure 1–5. Detail view of a duct.

401. List dimensioning terms used on working drawings, and state the procedures for indicating dimensions on drawings.

Descriptive Terms and Dimensions. In this section, we discuss dimensioning terms, use of lines, dimensions, and scale measurements that are applicable to working drawings of sheet metal components.

Dimensioning Terms. Later in this text, we will review how to measure with graduated scales using whole numbers, fractions, and decimals. First, let's see how measurements, or dimensions as we will call them, are used on working drawings. To accurately understand the dimensions of an object, it is necessary that you and the person making the draft follow the same definition of terms—length, width, height, etc.

Length. This term usually refers to the greatest dimension of an object or the greatest dimension of any part of the object being described. For example, figure 1-6 shows a board to which a cleat has been attached. We speak of the board as being 24 inches in length and, at the same time, of the cleat as being 18 inches in length. In both cases, the length is the greatest dimension of the object.

Width. The term "width" usually refers to the dimension of an object from side to side or in a direction at right angles to the length. For figure 1-6, the board is 18 inches in width and the cleat is 3 inches in width.

Thickness. This term usually refers to the smallest dimension of any part of the object being described. Thickness can apply either to the main part of the object or to some separate part attached to the object being described. It also can apply to a part projecting from the object; however, it does not apply to a groove that is cut in an object. Figure 1-6 shows us that the board is 3/4 inch in thickness and that the cleat also is 3/4 inch in thickness.

Height. This term is used to indicate a dimension of an object, or a part of it, that rises above either the surface of the object being described or the one on which it stands. For example, if you place a block on a table in a position so that its greatest dimension is upright (standing on end), you would refer to the dimensions as height instead of length. In figure 1-6, the center block is 3 inches high.

Depth. Depth is a perpendicular measurement downward from the top surface or backward from the front. Note in figure 1-6, the drawing of a block with a groove in the top surface. We would say this groove is 1/2 inch below the top surface of the block.

Lines and Their Use. Your ability to read this printed page depends on your skill in recognizing the letters of the alphabet. In addition to recognizing these letters, you must know how they are used in the construction of words and sentences. Likewise, being able to read working drawings depends on your ability to recognize the character of the lines used and to understand how they fit into the description of objects, as represented.

Visible outlines. In describing an object with a drawing, the outline of all faces is represented by lines. The surfaces visible to the eye always are outlined in solid lines. Being bold, solid lines, they become the basis for comparison of the weights of all other lines. Notice the weight of these lines in figure 1-7.

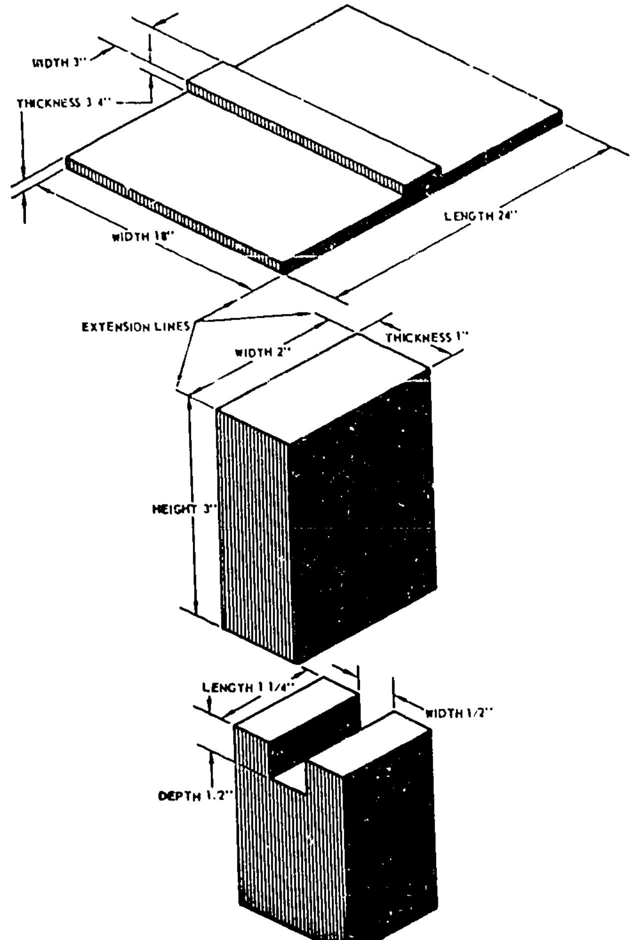

Figure 1-6. Dimensioning terms.

Hidden lines. Surfaces that are invisible (or hidden) are outlined with dashed lines. A hidden line actually is a series of short dashes of medium weight, about half as heavy as the lines used to indicate visible surfaces. When reading working drawings, it is important for you to remember that a series of short, uniform dashes always represent surfaces that are hidden. Examine figure 1-7 and locate the lines that indicate hidden surfaces. Also, examine the invisible (dashed) lines used in figure 1-5 to see if you understand what they represent.

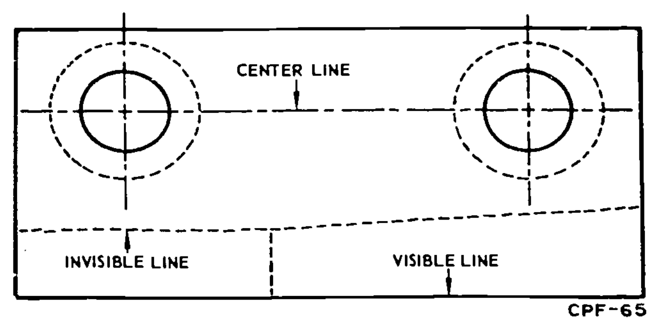

Figure 1-7. Visible and invisible outlines.

Centerlines. For the sake of accuracy in the construction of many objects, it is essential to lay off the dimension from a centerline rather than from the edge or side. This is true particularly of circular objects or objects made up of curved parts. This centerline in a working drawing also is known as the central axis and is illustrated in figure 1-7, where it is used to locate holes that are to be drilled along a straight line. Note that, in this case, the centerline is not the center of the object but is drawn through the centers of the holes. A centerline is made up of a series of long and short dashes.

Dimension Lines. If a working drawing is to be satisfactory, it must have not only the correct shape but also the size of the object and all of its features. The size is indicated by dimension lines that are recognized easily by the arrowheads at each end. Examine the use of dimension lines in figures 1-5 and 1-6. Notice that the dimension lines are not continuous because of a space near the center where the dimension is written.

Extension Lines. Usually, the draftsman tries to place all dimensions of an object outside it outline. This is done primarily for neatness and clarity. In figure 1-6, you can see how extension lines are used so that the dimension lines will be understood clearly. The solid lines extend the limits of a dimension out and away from the object and are lighter in weight than the visible outlines.

Use of Dimensions. Now that you have learned some of the dimensioning terms used on working drawings and how lines are used, let's consider how dimensions are used on working drawings. Although draftsmen do not always follow it, there is a standard procedure for placing dimensions on drawings. Learning this standard procedure will enable you to read working drawings quickly and accurately. Dimensions of rectangular ducts often are written on the working drawings, as shown in figure 1-3. Notice the section of 16" x 8" duct which is 16-inches wide and 8-inches high. If this same section of duct is shown on an elevation view, it would be marked 8" x 16".

Angles. Dimensions of angles are shown in figure 1-8. Notice how the dimension lines are used and how the sizes of the angles are to be read from a horizontal position, regardless of the position of the angle. If the angle is too acute to be read, as shown by the 15° angle, the dimension may be placed outside the angle.

Circles. Figure 1-9 shows how dimensions are drawn for circles on working drawings. Centerlines should not be used as dimension lines; therefore, when you show diameters inside the circles, do it as shown in the upper left circle of the illustration. Notice the preferred way of showing the diameter. The two circles shown in the lower right illustrate the way holes (small circles) are dimensioned.

Arcs. Figure 1-10 shows how dimension lines are used to indicate the radii of arcs. Notice that an X is placed at the center point, with a dimension line going to the appropriate arc. In this illustration, the radius is shown for each arc, although in actual practice the drawing of a rectangular elbow like this will have only the throat radius marked. (The throat radius is the smaller of the two arcs. The radius of the larger arc is called the heel radius.)

Holes. For distances between holes in an object, dimensions usually are indicated from center to center rather than from outside to outside of holes. Figure 1-11 shows a piece of sheet metal with three equally spaced 9/16-inch diameter holes not on a centerline. Dimension and extension lines have been used to indicate various dimensions. The diameters of the three holes have been shown. The hole diameters also could have been dimensioned, as shown in figure 1-9.

Geometric solids. On working drawings, the diameter for a sphere usually is given on the view that is most convenient. The two necessary dimensions for a cylinder—length and diameter—can be shown on one view. Often, one view of a cone is used to indicate the diameter and height, although it is better to have two views, as shown in figure 1-2. Two views also are desirable for working drawings, showing the dimensions of a pyramid. These dimensions—vertical, height, slant height, width,

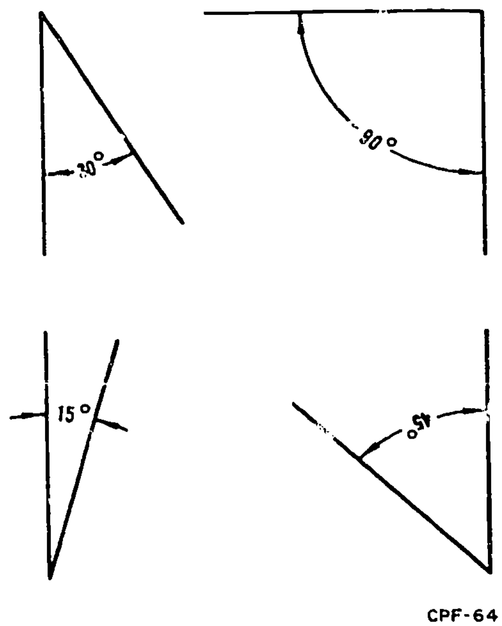

Figure 1-8. Dimensions of angles.

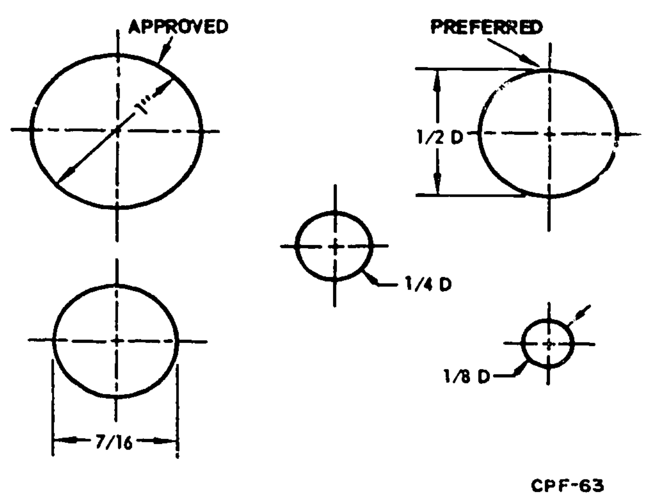

Figure 1-9. Dimensions of circles and holes.

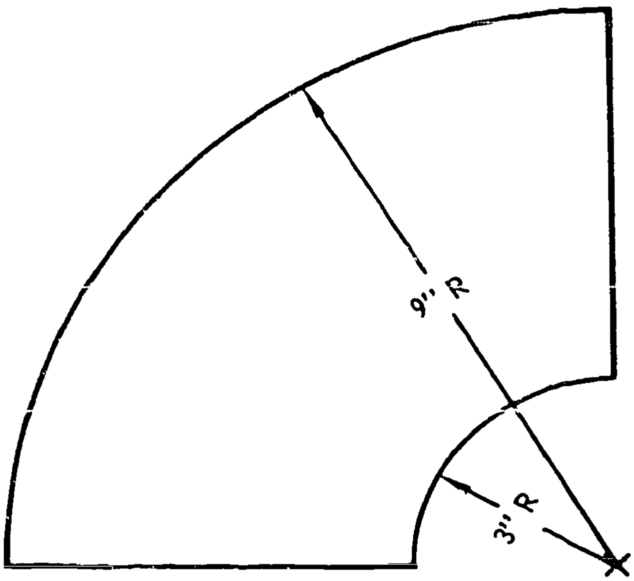

Figure 1-10. Dimensions of arcs.

diameter, etc.—are shown on the working drawings in the plan, elevation, and detail views.

Scale Dimensions. Previously, you learned how to use the architect's scale to reduce the dimensions of objects too large to be drawn full scale. Now, let's learn how to use the architect's scale to measure objects that are drawn to scale on a working drawing. For example, a working drawing such as that shown in figure 1-3 probably will be drawn 1/4" = 1' scale. By using the 1/4-inch scale, you easily can determine dimensions such as the length of the duct sections and distances from the wall. If you have a working drawing of a very large building, the scale may possibly be 1/8" = 1' so that the entire structure can be shown on one drawing. However, in most architectural working drawings you use, the scale will be 1/4" = 1'. But, when written dimensions are included on the working drawing, as shown in figure 1-3, they should be followed in preference to using the architect's scale.

If you have a working drawing of a small object, the size most likely will be full scale, since there is no advantage in reducing the size of the object if it conveniently can be drawn full size on the sheet of drawing cloth or paper.

Exercises (401):

1. List five terms that deal with the dimensions of an object.

2. Dimensions of holes usually are laid off from where?

3. Dimension lines of angles are located where?

4. Lines of surfaces that are not visible on a geometric solid are shown by ________________.

5. When would you use extension lines?

6. What do solid lines on a drawing represent?

7. What do dashed lines on a drawing represent?

8. How are the dimensions of an angle indicated?

9. What is the preferred method of indicating dimensions of a circle?

10. In using dimension lines on arcs, how is the center point located?

11. How do you indicate the dimension between two holes in an object?

12. How many views are shown in an orthographic projection of a cone?

13. How many dimensions are required for a drawing of a cone?

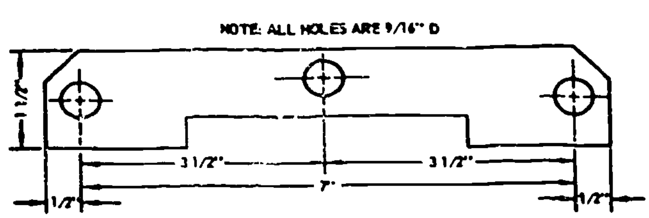

Figure 1-11. Dimensions for holes.

402. State the uses of given symbols used on drawings.

Symbols Used on Heating and Ventilating System Drawings. With a good working drawing and the knowledge of how to read and interpret it, you can develop patterns, fabricate components, and install entire heating and ventilating systems. Already in this chapter, you have learned how to read and interpret lines, views, and dimensions used on working drawings; and in figure 1-3, you noticed symbols used on the drawings. Now, let us examine the various symbols used for ducts, dampers, registers, grilles, and louvers.

Symbols for Rectangular Ducts. Duct symbols are used on working drawings for such purposes as distinguishing one duct from another; determining if a duct is round or rectangular; or determining if the duct is a supply, return, or exhaust line. Also, the direction of airflow, inlets and outlets, flexible connections, and turn vanes can be identified with symbols. In figure 1-12, you can see some of the symbols used for rectangular ducts.

Duct size. The height and width of a duct are determined by dimensions written on a section of the duct. Remember that the first number will indicate the dimension of the visible side of the duct, regardless of whether it is a plan or elevation view. For example, if drawing a in figure 1-12 is an elevation view, the duct is 12-inches high and 20-inches wide.

Duct direction of flow. This symbol, (fig. 1-12,b) indicates the direction of flow through the duct. The symbol is not always used, since many duct systems are simple and the inlet and outlet openings will have direction of flow indicated with letters or arrows.

Duct, exhaust section. This symbol, shown in c of (fig. 1-12,c) is used to identify an exhaust opening in a duct, with the direction of flow indicated by a single diagonal and the letter E (exhaust). The arrow in this symbol does not indicate direction of flow but points out the size of the opening, which, in this case, is 12" x 20". Notice also in figure 1-12 that several other duct symbols are similar to this one except for letters and diagonal lines. The single diagonal line always indicates that flow is into the duct.

Duct weather-air section. This symbol (fig. 1-12,d) indicates a duct opening where inside air A and outside air W are flowing into the duct. These symbols may be found on a drawing of a duct which is the return air system to a furnace and which mixes outside air and inside air.

Duct, recirculation system. This symbol (fig. 1-12,e) is similar to the weather-air symbol except that only return air (designated by the letter "R") is involved. This symbol will be found on most drawings that have a return air duct system to the furnace.

Duct, other section. This symbol (fig. 1-12,f) has a single diagonal to represent direction of flow, and a letter or letters to indicate function. In this case, we use the E to represent exhaust, and K to represent kitchen.

Duct, supply section. This symbol (fig. 1-12,g) has two diagonals that indicate the direction of flow is from the duct. The letter S, which may or may not be used, simply means supply. The arrow does not indicate direction of flow but points out the size of the duct, which in this case, is 12" x 20". Remember that two diagonal lines represent a supply duct.

Fan with flexible connections. This symbol (fig. 1-12,h) is used to indicate the location of a fan or blower in a duct system. The arrows indicate the direction of airflow. Not enough of the system is shown in the illustration to indicate whether the fan is being used for exhaust purposes or for supply purposes; however, when this symbol is used on a working drawing, you can determine its purpose by its location in the duct system.

The connector symbol (four parallel lines shown in fig. 1-12,h) also is important to you, as a sheet metal specialist, because you are responsible for installation and maintenance of connectors. This symbol represents a flexible connector between the furnace outlet and the supply duct. The same four-line symbol may be used to represent a flexible connector on the return air or intake side of the furnace.

Symbols for Round Ducts. Most of the round ducts you will encounter are in kitchen exhaust systems and the heating and cooling ducts of family housing units.

Round duct, exhaust system, nonwatertight. The duct symbols, shown in a figure 1-13, are used on working drawings to indicate a round nonwatertight exhaust duct such as that used with a hood to exhaust smoke and heat

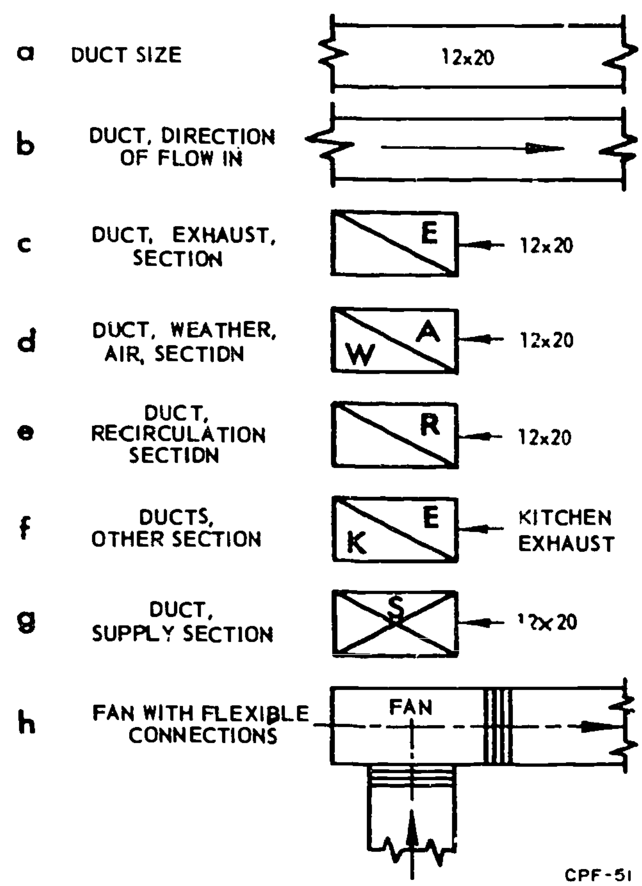

Figure 1–12. Symbols used with rectangular ducts.

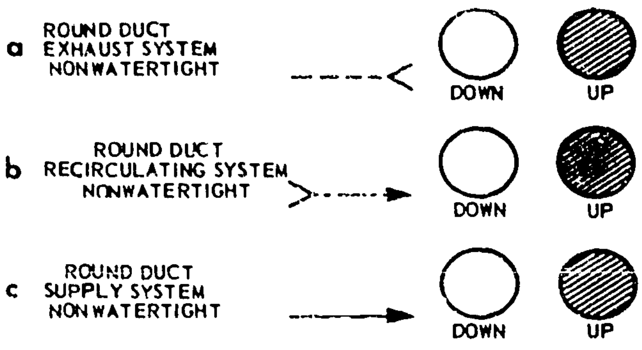

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Figure 1–13. Symbols used for round ducts.

from a kitchen range. The broken line with the flared end (tail end of the broken arrow) is used on the plan views with the appropriate down or up symbol.

Round duct, recirculating system, nonwatertight. This symbol (fig. 1-13,b), is used on the plan views of working drawings for round return ducts such as the return air duct to furnaces. This symbol is a slight variation from that of a rectangular duct.

The appropriate up or down symbol should be identified with a broken line arrow as shown in the illustration.

Round duct, supply system, nonwatertight. This symbol (fig. 1-13,c) is used on the plan views of working drawings to indicate round supply ducts to components such as furnaces.

Symbols for Turn Vanes. The turn vane symbols, shown in figure 1-14, are used on working drawings to indicate the location of turn vanes inside of ducts. Vanes reduce the air resistance at elbows to permit the air to change direction with less turbulence; they are installed at the shop during fabrication of the elbows.

Damper Symbols. Dampers are deflecting or shutoff devices installed inside ducts to regulate the flow of air. Many dampers are operated manually and have handles that are accessible from outside the duct; however, some are motor-operated for remote control and others operate automatically. Figure 1-15 shows six kinds of symbols that are used on working drawings for various dampers.

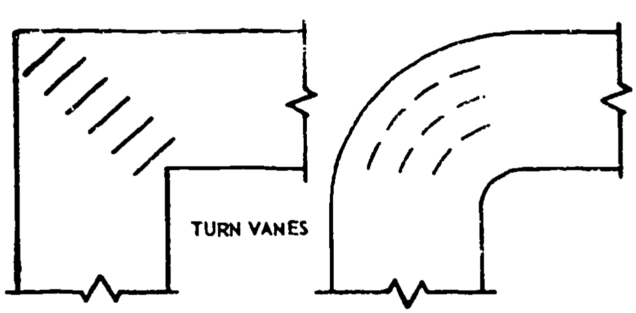

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Figure 1–14. Symbols used for turn vanes.

Damper off, adjustable. The symbol used for a damper off, adjustable (blankoff or shutoff) is shown in figure 1-15,a. This device may be of the butterfly type, similar to f of figure 1-15, or it may be a sliding gate.

Dampers, automatic. This symbol is used for multiple blade dampers which are operated automatically. The symbol shown in figure 1-15,b, is for a motor-operated damper; when the damper is not motor-operated, the symbol will not have the letter M. An example of a nonmotor-operated damper is a fire damper installed in a duct system; in case of fire, a fusible link will melt, and the spring-loaded damper blades will close off the airflow through the duct.

Damper, deflecting. The deflecting damper symbols shown in c, d, and e of figure 1-15 represent similar dampers used to deflect airflow. The purpose of these dampers is to balance the airflow at a takeoff or branch in a duct.

Damper, volume. This symbol, shown in the two views in f of figure 1-15, is frequently used in drawings to show the location of volume dampers in air ducts such as those used in heating or cooling systems. Notice the similarity of the plan and elevation views.

Symbols for Registers. Symbols used to indicate locations of registers on working drawings are shown in figure 1-16. In sheet metal work, a register is a supply outlet for heating and cooling systems. The register is the portion of the duct system that covers the duct outlet. Registers usually are finished to match the room and often have turn blades to control the direction of airflow.

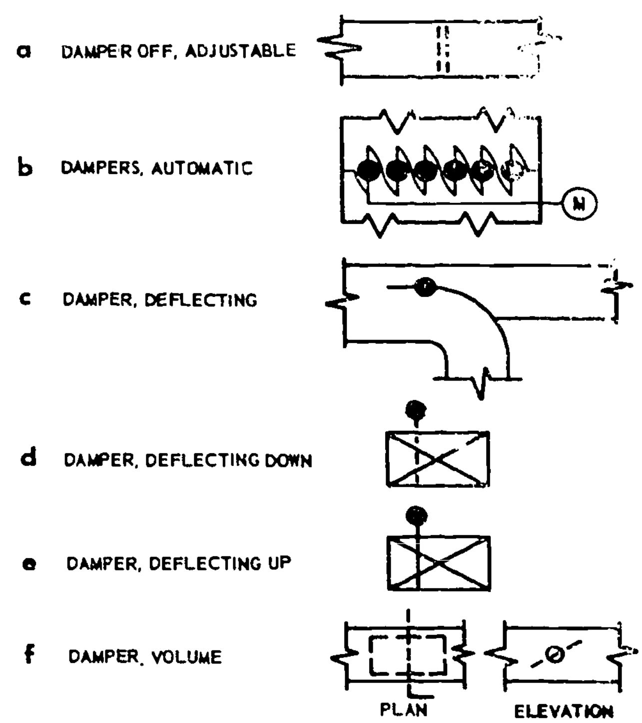

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Figure 1–15. Symbols used for dampers.

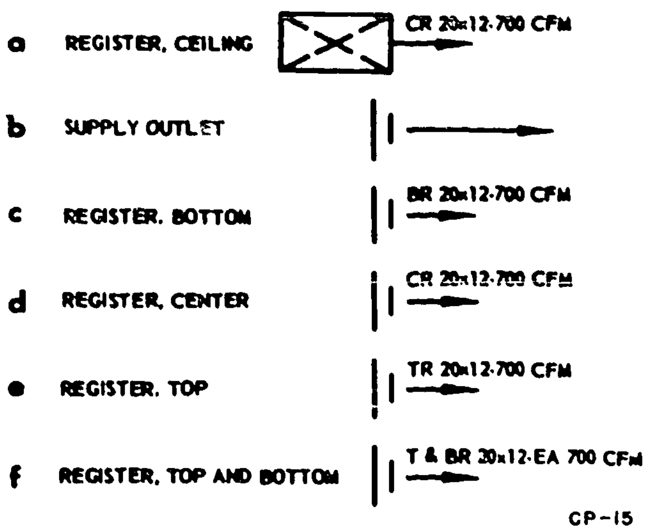

Figure 1–16. Symbols for registers.

Register, ceiling. This symbol, shown in a of figure 1-16, is used on plan views to indicate the location of ceiling registers. The arrow and the two diagonals indicate a supply outlet. The other information shown indicates that the outlet is a ceiling register of the given dimension of airflow. The 700 cfm indicates a supply of 700 cubic feet of air per minute.

Register, wall. The symbols, shown in b through f of figure 1-16, are similar except for specific uses. The basic symbol for a supply register is shown in b; the other symbols are variations identified by letters such as BR for the bottom register used near floor level, CR for a center register used about halfway between floor and ceiling level, and TR for a register used near ceiling level.

Symbols for Grilles. The symbols for grilles are the same as symbols for registers except for the identifying letters. For example, the letters BR identifying a bottom register would be changed to BG for a bottom grille. A grille consists of a plain or fancy framework of metal bars, wires, or louvers used to cover an opening such as the inlet of a return duct. Whether used at an inlet or outlet, a grille does not include deflectors or a regulating device.

Symbols for Louvers. In figure 1-17, you can see two symbols used to identify louvers on working drawings. A louver is a series of sloping slats set in a frame or other opening to allow passage of air. In sheet metal work, louvers are used as ventilating slits to cover inlet and outlet openings in duct systems or exhaust fans. Louvers can be stationary, manual, or automatic type.

Louver opening location symbol. Location of a louver on a working drawing is identified by the symbols shown in a of figure 1-17. This symbol identifies the location only and does not designate the type of louver. The arrow indicates the direction of airflow. Notice that the louver symbol has two vertical lines, the same as for registers.

Louver and screen. The symbol, shown in b of figure 1-17, designates a weather or air intake louver screen. An example of the use of this symbol would be in a plan view of a duct system such as the weather-air intake of the return ducts to a furnace. This symbol represents the type of louver used at the intake shown in part d of figure 1-12.

Exercises (402):

1. On a duct drawing, the dimensions of the visible side of the duct always appear where (first or last)?

2. What is the symbol for a circle with a solid arrow pointed towards?

3. The damper symbol which has one solid dot at an outlet is the symbol for a __________ damper.

4. The symbol for registers and grills are the same except for identifying letters. Which other duct symbol also is similar except for the lettering?

5. What letters are in a duct symbol for a duct that mixes return air and fresh air?

6. A wall register identified by the letters BR is to be located at what vertical height?

7. TG on the working drawing indicates and shows location of what item?

403. Specify the purpose of special instructions for working drawings.

Notes and Specifications. Specifications for sheet metal work and other construction projects are used to supplement

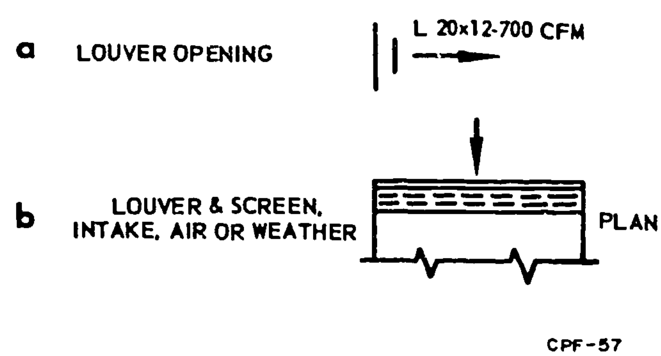

Figure 1–17. Symbols for louver and opening.

the information on working drawings. They are written descriptions of the standards to be maintained and they state specifically all the factors not shown on the drawings. Notes and specifications have a similar purpose, but notes are the condensed versions that are written on the working drawings.

Notes. The notes shown on drawings are similar to portions of the specifications and are used to explain the drawing. Examples of notes are contained in figures 1-18 and 1-19. Figure 1-18 shows a pictorial view of the gravel stop and fascia used around the edges of a flat roof. Figure 1-19 is a detail view of expansion joints used with the gravel guard and fascia. Notice that the drawing serves as a fabrication guide for either aluminum or copper construction, that the notes indicate that bronze flathead wood screws are to be used if the gravel guard is made of copper sheet, and that aluminum flathead screws are to be used with aluminum sheets.

Specifications. The specifications for sheet metal work, should indicate clearly the quality and quantity of materials, the methods of construction, the nature of the workmanship, the manner of conducting the work, and the general conditions and agreements. Specifications consist of two types—general and specific—and much time and thought are given to their preparation to make sure that every detail is covered. The specific types concern individual projects, such as a contract job for construction of a new building where the specifications are definite rather than general. Specific specifications cover such items as the quality of the material, details of construction, working drawings, and other special features.

General specifications are, as the name implies, general in nature and are applicable to more than one construction job. The Corps of Engineers prepares general specifications for all types of military construction. These general specifications cover all kinds of sheet metals, fastening methods, soldering, welding, seaming, and fabrications for different sheet metal components.

Gravel stops and fasciae are formed of sheets of standard stock lengths not less than 8 feet long; they are shop

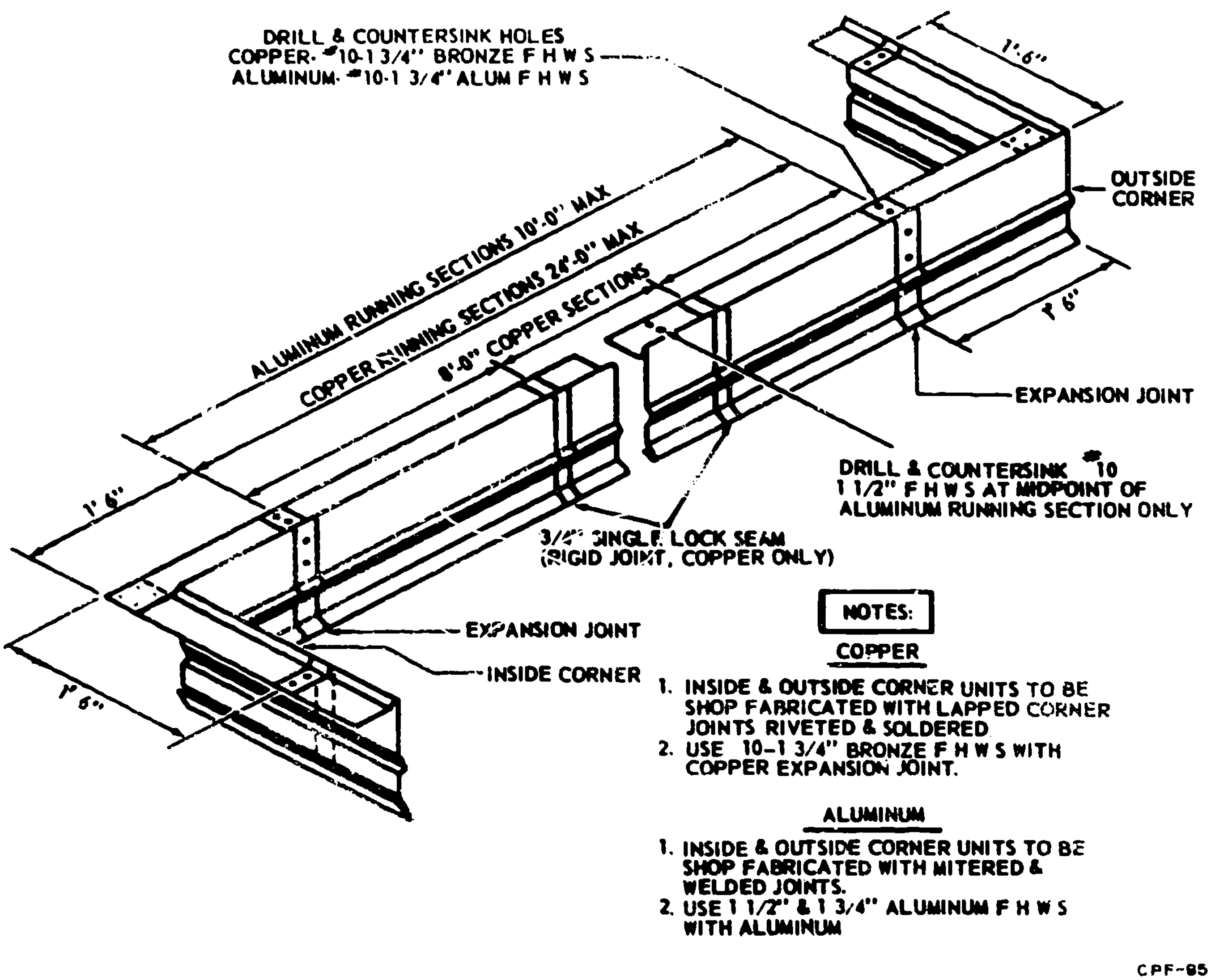

Figure 1–18. Gravel stop and fascia.

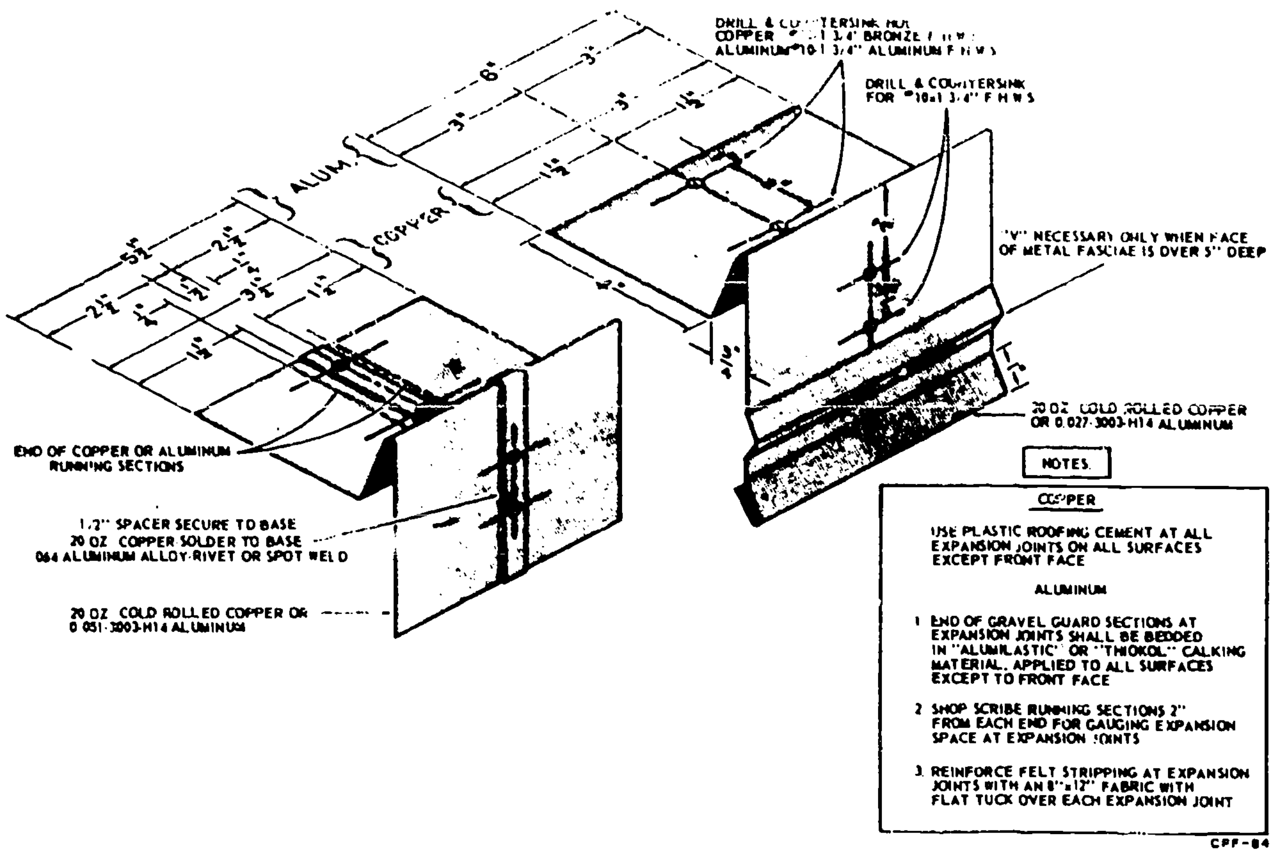

Figure 1–19. Detail of expansion joint.

fabricated from one piece of material of suitable width. Note in figure 1-20 that the gravel stop and fascia extend above the roof line. Gravel stops and fasciae must be provided with concealed splice plate or other suitable slip-joining member designed to allow for expansion at specified intervals. Expansion and contraction joints must be one-piece assemblies around internal and external corners, and the allowance for expansion cannot be less than 1/4 inch at each joint. Splice plates or other concealed items for securing the joints must lap the gravel stops and fasciae not less than 4 inches. The inner flange of the gravel stops and fasciae must extend not less than 4 inches onto the roof over the felt roofing plies and must be fastened to the edge nailing strips with nails spaced not over 3 inches on centers. Where the fascia part of the gravel stop is 5 inches or more in width, the lower edge must be hooked at least 3/4 inch over the edge drip strips and bent outward at an angle of 45° to form a drip.

Working Drawings. Figures 1-18, 1-19, and 1-20 are working drawings for fabrication and installation of gravel stops and fasciae for building with flat roofs. With these drawings and dimensions of the buildings, your shop can fabricate exact replacements. These working drawings are considered a part of the specific specifications and must be closely followed closely for fabrication and installation procedures.

As you examine the pictorial view shown in figure 1-18, you quickly can see the overall shape of the gravel stop and fascia (sometimes called a gravel guard and fascia). Further examination will indicate additional information such as dimensions of the running sections and how the corners are fabricated.

From the detail views of the expansion joint shown in figure 1-19, you can see fabrication information that was not included in figure 1-18. The detail views show the construction of the expansion joint, which is made of three pieces of metal—the base, the spacer, and the face that matches the fascia. Other information shown includes such details as the gage of metal to use, dimensions, and special notes.

Figure 1-20 is a cross section detail view of the gravel guard and tar stop. In this view you can see, in detail, how the installation is made, including such items as the gravel guard, tar stop, lower support strip, and felt strips. This detail view also illustrates the method of nailing the tar stop and lower bent strip support. The abbreviation "OC" in the notes means on center.

Exercises (403):

1. What is a "note"? Where is it found?

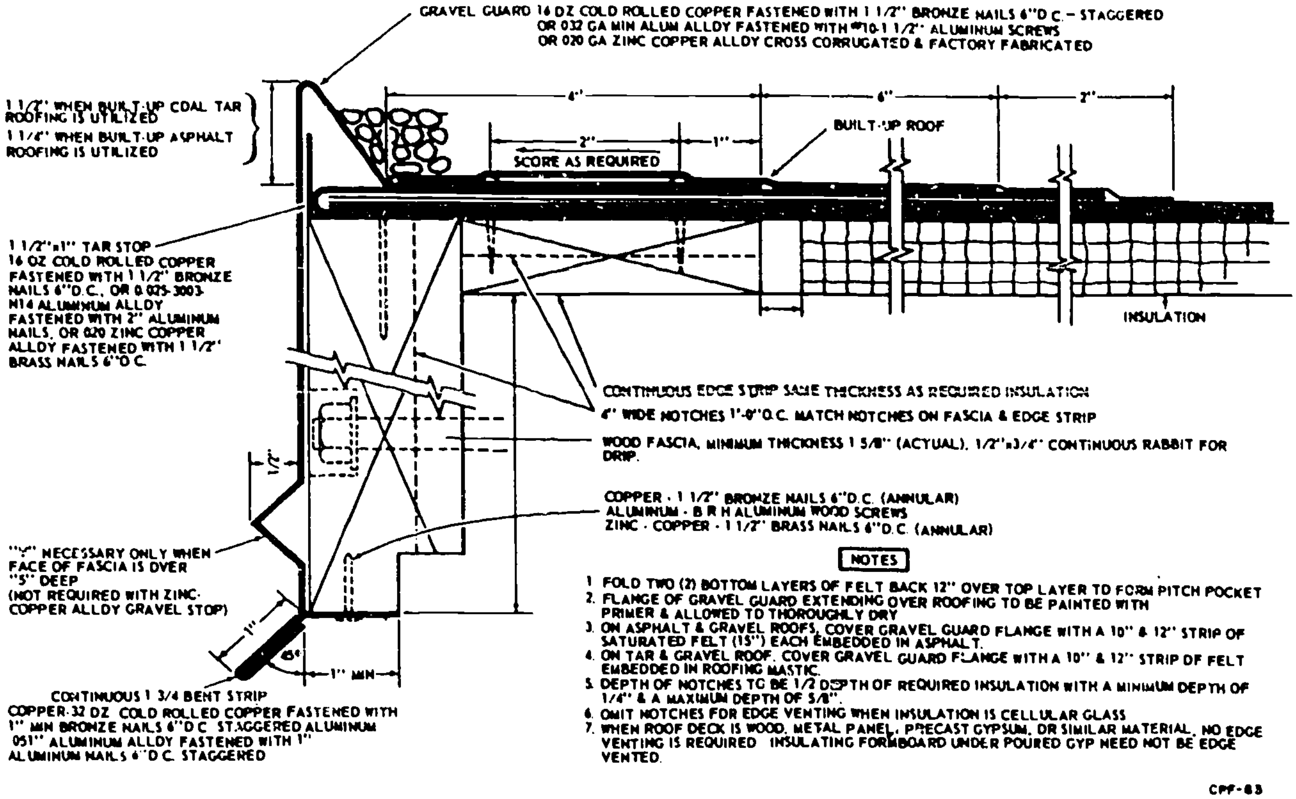

Figure 1–20. Detail of gravel and tar stop.

2. What are general specifications for general sheet metal work?

3. What guide is used by the sheet metal worker to fabricate exact replacement items?

4. What is covered in specific specifications?

5. Why must gravel stops and fascia be assembled with slip joints?

1-2. Measurement and Layout Tools

All metal fabrication work requires accurate measurement and layout techniques, and this section has been prepared to help you learn about the tools used in measurement and layout operations. Your specialty description states that, as a metal specialist, you will take measurements from drawings and lay out working details for fabrication of sheet metal items. Your specialty training standard contains a list of the tools you must learn to use.

In this section, you will learn how to use measuring tools, such as rules, tapes, combination sets, squares, and calipers. And you will learn how better to use layout tools, such as levels, architect's scales, compasses, dividers, T-squares, triangles, protractors, templates, irregular curves, trammel points, plumblines, and chalklines.

Each measurement and layout tool has special uses in sheet metal work. For example, rules and tapes are used for measuring sheet metal which is to be cut or folded, or for the measuring of parts to be duplicated. Another example is the compass, which can be used to draw a polygon inside a circle or to perform graphic solutions to problems. Still another example is the scriber that can be used to scribe or mark a line to indicate where a sheet of metal is to be cut. From these examples, you can see that each measurement and layout tool has specific uses; we discuss separately how each applies to your job. Let's begin with measuring tools.

The portions of the chapter which discuss geometric figures are accompanied by formulas for determining dimensions, area, and volume.

404. Specify types and identify parts of a graduated scale.

Reading Graduated Scales. As a metal fabrication specialist, you will use graduated scales such as measuring

rules, tapes, squares, protractors, twist drill size gages, adjustment gages on metal cutting machines, and thickness gages. These measuring devices used in most metal work are graduated in inches and feet. It is very important for you to understand fractions so that you can measure fractional distances. For example, you frequently will measure distances or thicknesses in fractional parts of the inch, such as eighths, sixteenths, thirty-seconds, and sixty-fourths.

In figure 1-21, you can see the fractional parts of an inch that commonly are used. As you study the rule shown in the upper part of this figure, notice that one side of the rule is graduated in eighths of an inch and the other side in sixteenths. The rule illustrated in the lower part of the figure is graduated in thirty-seconds and sixty-fourths. You must learn to correctly read figures like these because correct measurement is essential for most jobs involving layout, fabrication, repair, and installation of metal articles and components.

As a brief review of your ability to read graduated scales, use the upper rule in figure 1-21 to locate the marks representing 1 inches and $1\frac{7}{8}$ inches. In the lower rule, locate the marks representing 17/32 inch and 35/64 inch.

To further improve your skill in reading graduated scales, refer to the 6-inch rule illustrated in figure 1-22 and verify each of the following:

- Position 9 is 6 inches.
- Position 7 is 4 inches.
- Position e is $3\frac{1}{8}$ inches.
- Position c is $1\frac{13}{16}$ inches.
- Position 2 is 25/32 inches.

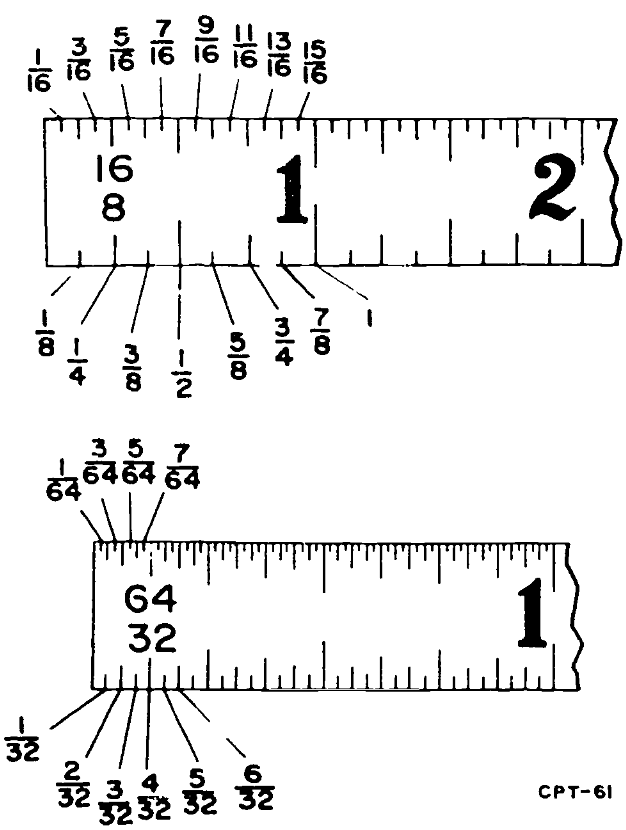

Figure 1-21. Graduated scales.

Now that you have achieved the ability to read fractions of an inch, let's go to the next step y comparing the inch (sixty-fourths, thirty-seconds, sixteenths, fourths, and halves) with the inch in tenths and the meter shown in figure 1-23. If you check closely, you will find most framing square's have one scale in tenths. Some steel rules (inch based) are graduated in 10ths, 20ths, 50ths, and 100ths. You will need to practice to accurately and quickly read these scales.

Since the meter is over 39 inches, we will concentrate on smaller parts of the meter. In the lower part of figure 1-24, the centimeter is divided into 10 parts (millimeters); and, on the bottom edge, the mm is divided in half. Now, just for practice, take a close look at the two scales in figure 1-24 and see if you can find any two readings that represent the same distance.

Exercises (404):

1. List five types of measuring devices (graduated scales) used in sheet metal work.

2. What term identifies the graduation on a ruler that is less than an inch?

3. Identify the graduations on the rule in figure 1-22.

405. Given measurements containing mixed numbers, abbreviate them correctly.

Although the importance of correctly reading fractional parts of inches has been emphasized, you also must use care in correctly reading measuring tapes that are graduated in feet and inches. For example, the measurement of a panel to be cut may be 2 feet wide and 7 feet $3\frac{1}{2}$ inches long. (These measurements may be abbreviated as 2 ft. by 7 ft. $3\frac{1}{2}$ in. or as 2′ X 7′ $3\frac{1}{2}$″. The measurements may be made with a steel tape, folding rule, or the measuring gage on squaring shears. Using any of these requires the measurement to be made from the exact edge of the metal to the right mark on the graduated scale.

Exercises (405):

1. Abbreviate the following:
   a. 6 feet wide by 22 feet $9\frac{7}{8}$ inches long.

   b. 1 foot wide by 3 feet 3 inches long by 1 foot 8 inches high.

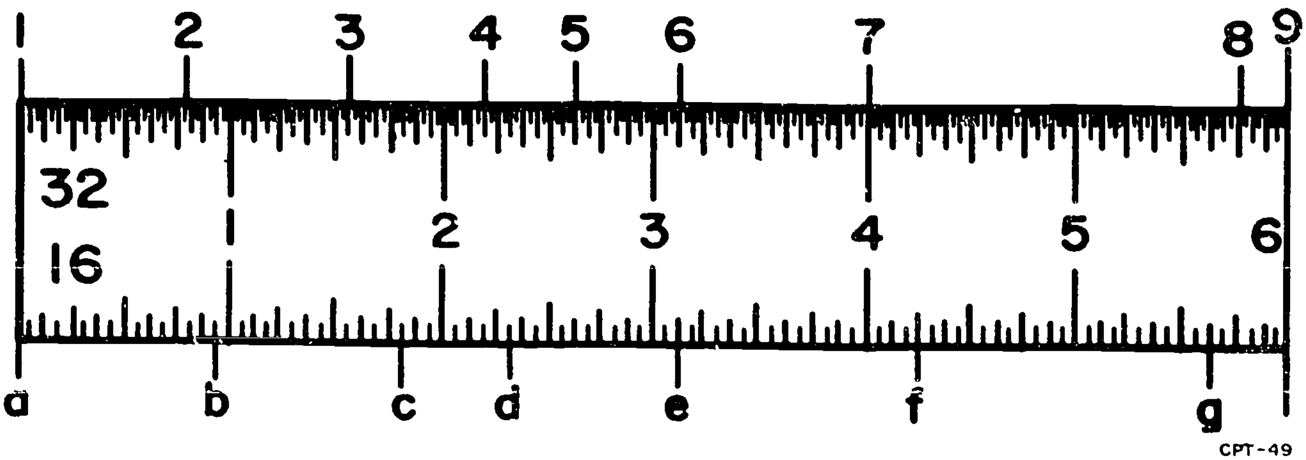

Figure 1–22. 6-inch rule.

406. Specify type of measuring tools most commonly used in the metal shop and state characteristics and rules concerning each.

Measuring Tools. In this section, we discuss the measuring tools used in the fabrication, repair, and installation of sheet metal parts.

Rules. The term "rule" is accepted as a general term used to describe a great number of measuring devices. More specifically, a rule is a strip of wood, metal, or other suitable material made in standard lengths and is marked along one or more edges into specified parts, divisions, or units of measure. The English system of linear measure, of which inches and feet are units of length, is used most commonly for measuring sheet metal. The inch may be divided into smaller parts by means of either common or decimal fractional divisions. The fractional divisions for an inch are found by dividing the inch into equal parts—the more common ones are halves, quarters, eighths, sixteenths, thirty-seconds, and sixty-fourths. Fractions of an inch also are expressed in decimals; for example, 1/8′ – 0.125′, 1/4′ = 0.250′, 1/2′ = 0.500′, etc.

At home and at school you have learned to use common wood or plastic rulers that were 6, 12, or 15 inches long, with subdivisions down to sixty-fourths of an inch. Probably, you also are familiar with the common yardstick, which is 3 feet long and has subdivisions down to eighths of an inch.

Steel rules. Steel rules are available in lengths of 6, 12, and 15 inches and may be rigid or flexible. They may have information on the back side, such as a decimal equivalent scale. To measure with a steel rule, use it as shown in figure 1-25. You will be using several layout and measuring devices that incorporate a rigid steel rule, such as the combination set, framing square, and circumference rule. These are discussed later in this section.

Folding rule. The folding rule shown in figure 1-26 is typical of this kind of rule, which unfolds to 6 feet and is

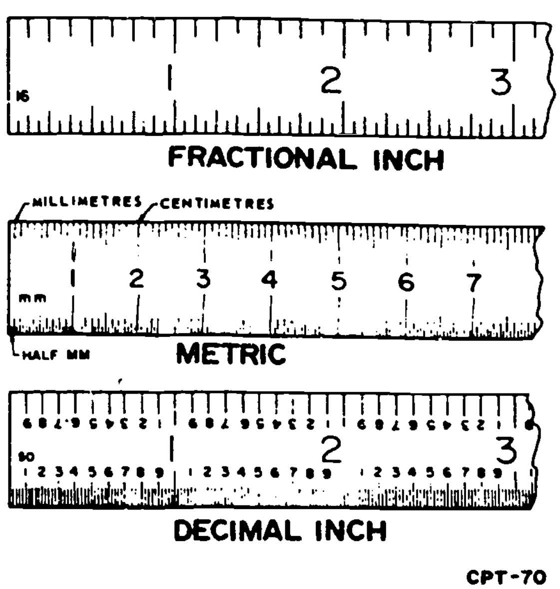

Figure 1–23. A comparison with metrics.

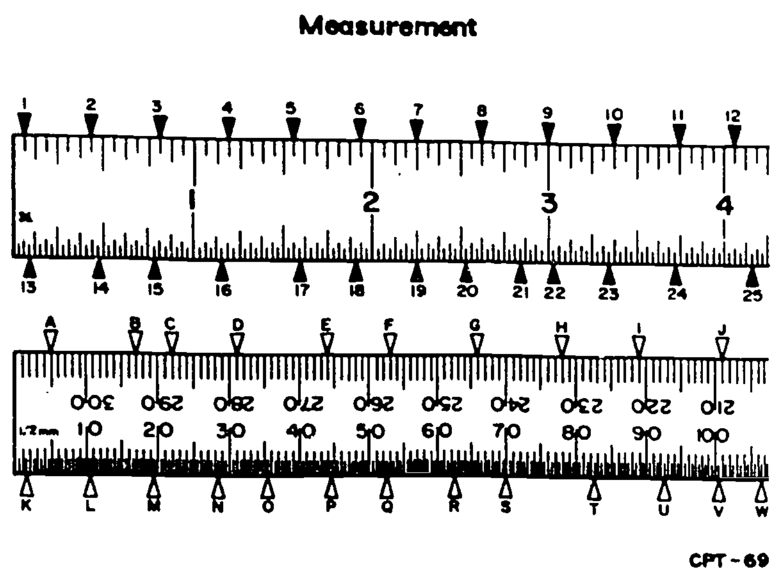

Figure 1–24. Varied measurements scales.

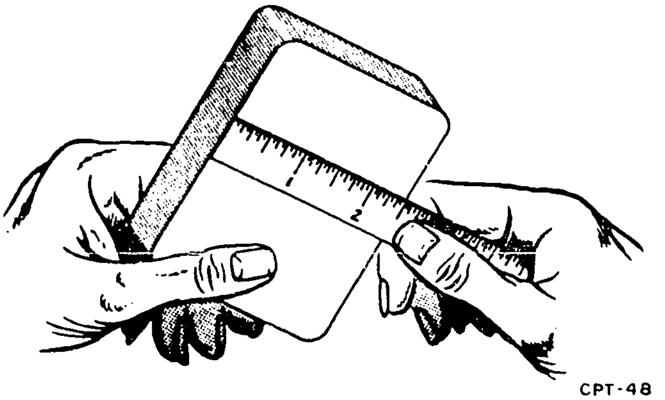

Figure 1–25. Using a 6-inch rule.

graduated in sixteenths of an inch. Folding rules are usually made of wood, have brass tips called striking plates, and have positive locking joints also made of brass. Although these rules are principally used by carpenters, sheet metal specialists also find them handy and easy to use.

Circumference rule. The circumference rule shown in figure 1-27 provides a "shortcut" method for computing the circumference of a circle. This rule is available in 36- and 48-inch lengths. The upper edge is graduated in inches in the same manner as a regular steel rule, but the lower edge is graduated quite differently. The lower edge will give you the approximate circumference of any circle within the range of the rule. The circumference scale is equivalent to the diameter times 3.1416. You should remember the formula for finding the circumference of a circle ($C = \pi d$). Notice in figure 1-27 that the reading on the lower edge directly below the 3-inch mark is a little less than 9½ inches. This reading is the approximate circumference of a circle with a diameter of 3 inches.

Steel tapes. Steel measuring tapes are available in lengths from 6 to 100 feet and are contained in various shapes of handheld cases. These easy-to-wind tapes are flexible and are wound around a reel with a small handcrank or by a spring inside the reel case. Two kinds of measurements are made with steel tapes, inside measurements, and outside measurements. For a simple explanation, think of a wooden box with no top. An inside measurement is made by putting the tape down inside the box and measuring the distance from one side to the opposite side. An outside measurement is made by measuring the external dimensions of the box,

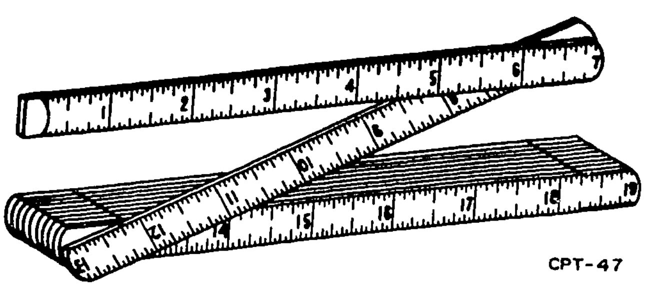

Figure 1–26. Folding rule.

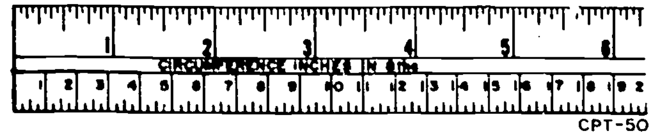

Figure 1–27. Circumference rule.

such as the height or width. Some steel tapes are designed to make both inside and outside measurements.

The 25-foot steel measuring tape shown in figure 1-28 is graduated in eighths of an inch and is wound into the case by the hinged handcrank. This type of case is used also for 50-, 75-, and 100-foot tapes. In sheet metal work, these longer tapes are useful to measure such items as long ducts, gutters, gravel guards, and metal roofs. The 25-foot and longer tapes are best suited for making outside measurements; however, inside measurements are possible. When using one of these longer tapes for outside measurements, be sure to examine the hook or ring on the end of the tape for the actual point of beginning. Since measuring tapes are available with a variety of ends—such as hooks, rings, or a combination of both—it is possible to make a measurement error of approximately 1/16 inch. The inch and foot graduations printed on the tape are measured from the outside of the ring, which is the actual end of the tape. When measuring from a point not at the actual end of the tape, such as with the ring hooked on a nail, a correction equal to the thickness of the ring must be figured into the readout measurement.

The steel tape you most frequently will use is the pocket-sized power-return tape shown in figures 1-29 and 1-30. The tape case contains an internal spring that returns the tape when measuring is completed. This flexible tape has a slight curvature that causes it to be stiffened when extended; this is a good feature, because it allows the tape to be extended straight out of the case. Power-return steel tapes are available in 6-, 8-, 10-, and 12-foot length. These tapes are graduated in sixteenths and thirty-seconds of an inch and are designed for both inside and outside measuring. Each tape has a self-adjusting hook that

Figure 1–28. 25-foot steel measuring tape.

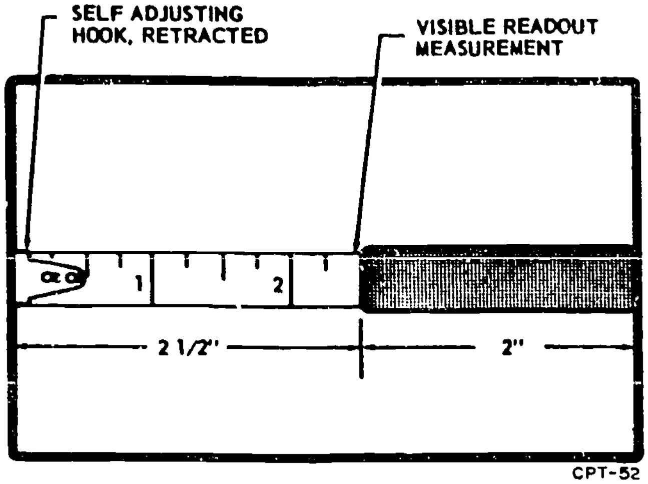

Figure 1–29. Making inside measurement with a power-return steel tape.

automatically compensates for the thickness of itself. Thus, you do not have to figure in a correction when making measurements. The case specially is designed for making inside measurements. Since it is 2 inches long, when making inside measurements, the 2 inches simply are added to the visible readout, as shown in figure 1-29. The visible readout when making inside measurements is the end of the tape to the index point at the case. For example, an inside measurement of a box might show a readout of 2½ inches, which added to the 2 inches for the tape case would be a total inside measurement of 4½ inches. An example of an outside measurement is illustrated in figure 1-20. Notice that the self-adjusting hook is extended, and the readout measurement is the inches or feet at the exact edge of the surface.

Calipers. Calipers are used for measuring diameters and distances and for comparing distances and sizes. The three common types include outside calipers, inside calipers, and hermaphrodite calipers. None of these are recommended for precision measurements that involve measurements of less than 1/64 inch.

Outside calipers. Outside calipers are used for measuring outside dimensions, as shown in figure 1-31. The illustration shows how the outside caliper can be used to measure diameters such as the diameter of a round stock; it also shows how the caliper can be set to a desired measurement and the stock checked for conformance with specifications. In order to prevent errors in measurement, hold the legs of the caliper at right angles to the object being measured.

Inside calipers. The inside calipers, shown in figure 1-32, have curved legs for measuring inside diameters of holes, the distances between two surfaces, the width of slots, and other similar jobs. Notice how the legs of the inside calipers differ from the legs of outside calipers. The illustration shows how inside calipers should be held at right angles to the cylinder being measured. If they are held in a position labeled "wrong," the measurement will be incorrect. Inside calipers may be used to measure distances or to check an opening for a specified size.

Exercises (406):

1. List four types of rules used in metal work.

2. The circumference rule is flexible so that it can be bent around curved objects in order to determine the distance around them. (true or false?)

3. List the measuring device most frequently used in the metal shop.

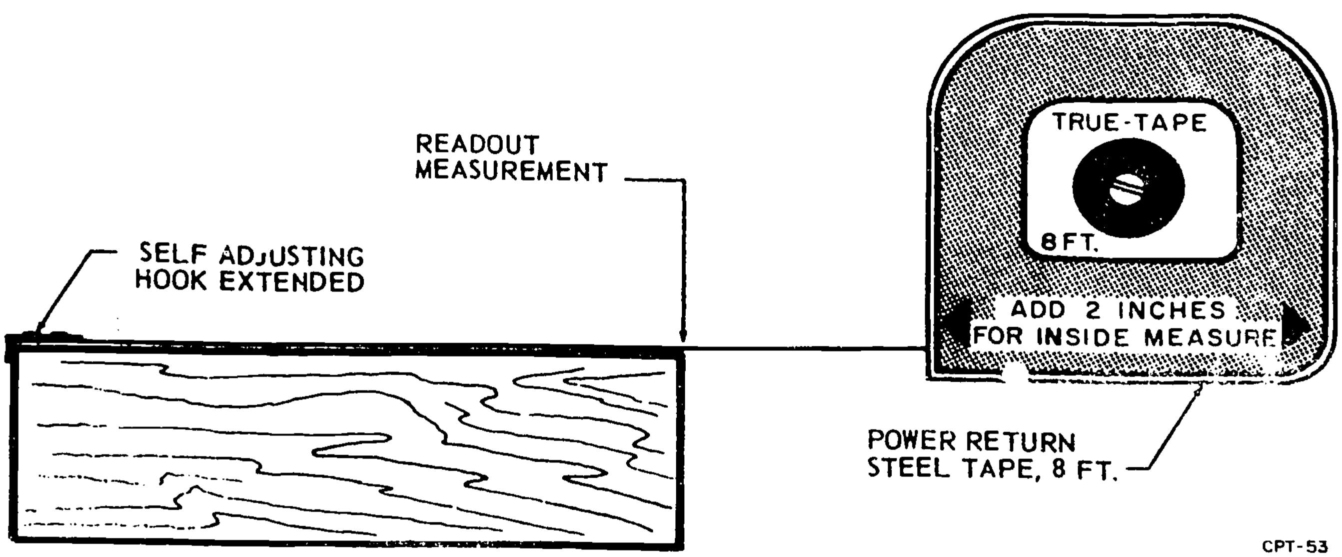

Figure 1–30. Making outside measurement with a power-return steel tape.

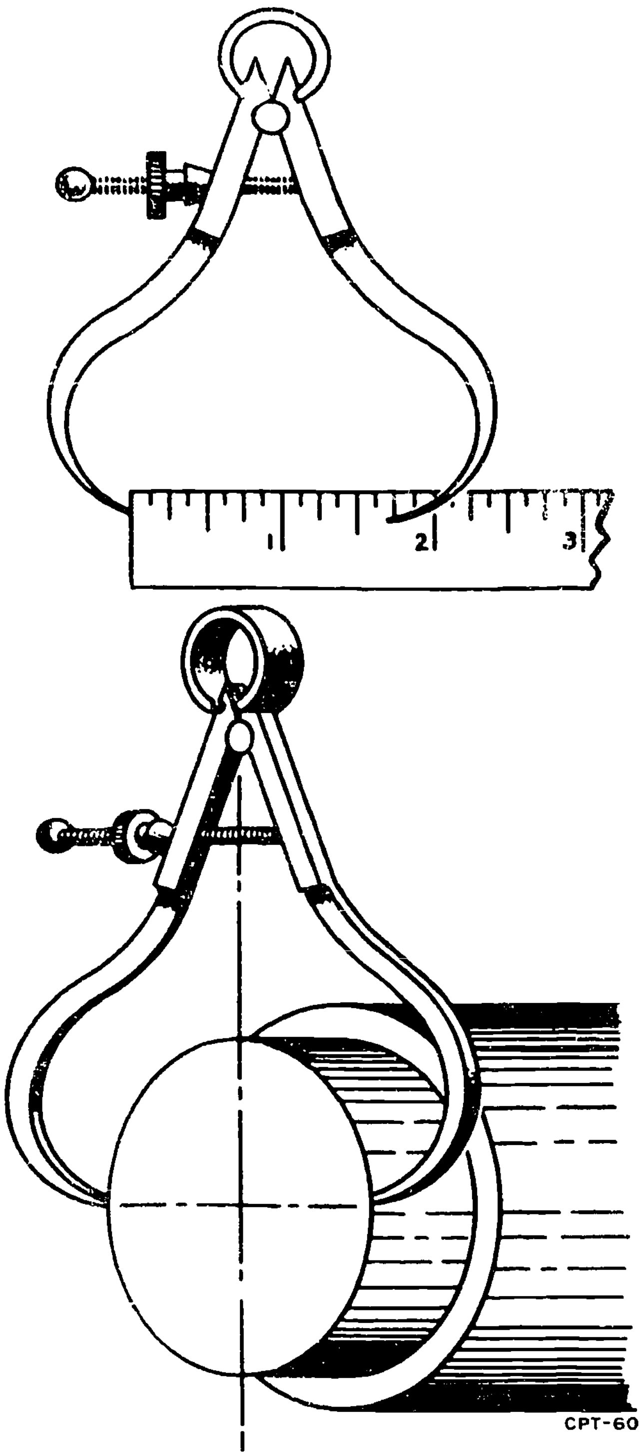

Figure 1–31. Using an outside caliper.

4. Why must a correction be made on the readout of a 25-, 50-, or 75-foot steel rule?

5. Calipers are used to measure distances of ________ inch and greater.

6. List 3 types of calipers.

7. What information can be obtained from the lower edge of a circumference rule?

8. Why does the blade of a flexible steel tape have a slight curvature?

407. Specify the parts and uses of a combination set and a framing square.

Combination Set. The combination set shown in figure 1-33 is, as its name indicates, a tool that has several uses. It consists of a rigid steel rule, called the blade, and three attachments—the square and miter head, the turret protractor head, and the center head. Although the illustration shows all three attachments installed on the blade, they are used individually. During use, only one attachment will be on the blade.

The blade has a central groove to permit the attachments to be moved to any desired setting and locked in that

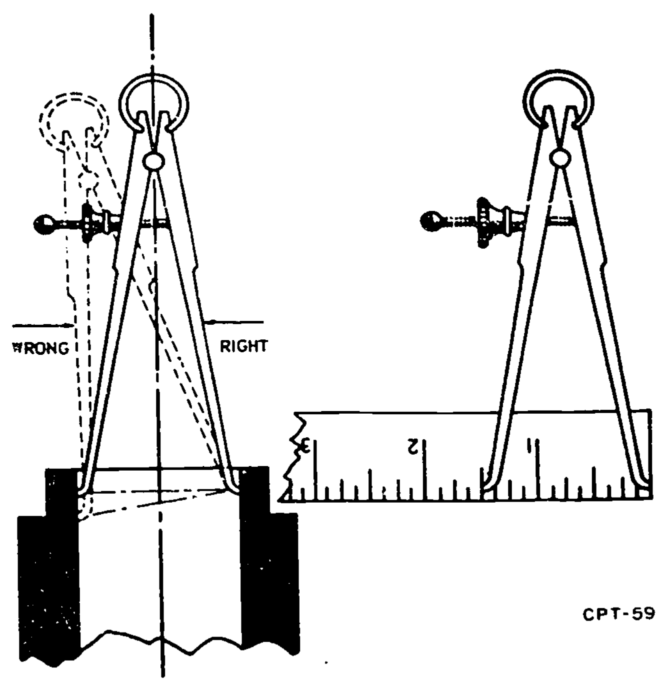

Figure 1–32. Using an inside caliper.

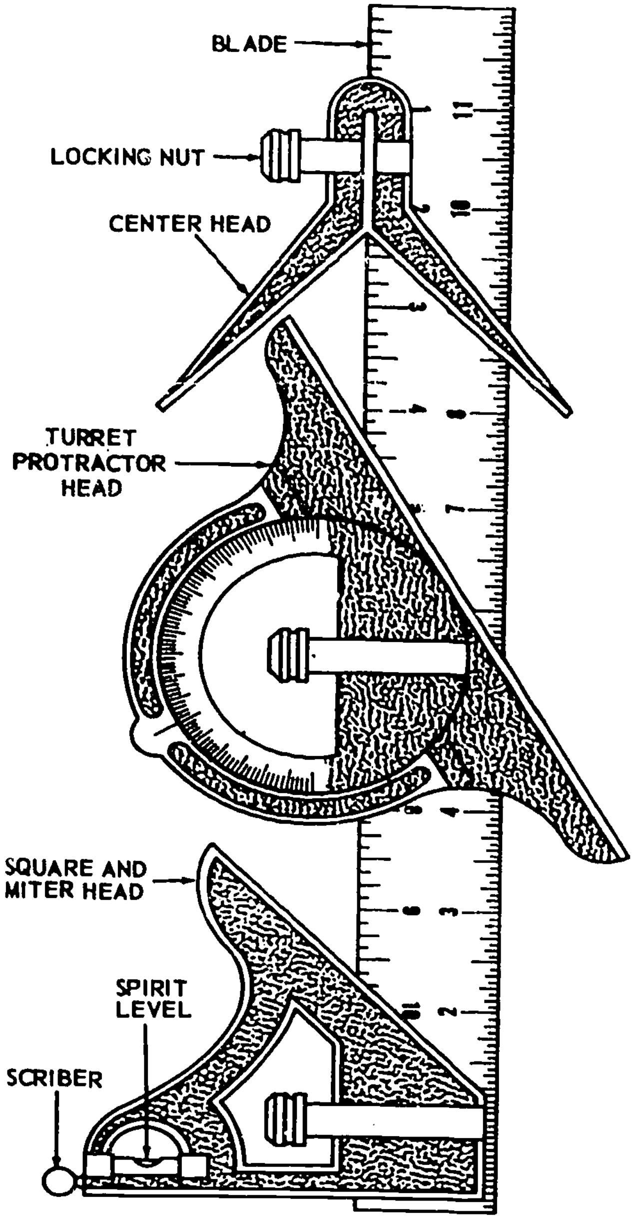

Figure 1-33. A combination set.

position. The central groove is not visible in figure 1-33 because it is located on the reverse side of the blade illustrated. However, in figure 1-34, the central groove is shown in each view of the blade. The steel blade usually is graduated in eighths, sixteenths, thirty-seconds, and sixty-fourths of an inch; it may be pulled out of the attachments and used as a measuring rule, if desired.

When only the square and miter head is installed on a blade, it is called a combination square, since the head has 90° and 45° angles. Figure 1-34 shows several uses of the combination square. In each of these, the square and miter head has been moved to the desired position on the blade and locked at that position with the locking nut. Another convenient feature of the square and miter head is the spirit level, since it often is necessary to square one piece with another and at the same time tell whether one or the other is level or plumb. Or, if desired, the square and miter head can be used as a simple level. As a further convenience, a small scriber is contained in the square and miter head. It is removed easily for use in marking (scribing) lines on metal.

The center head, shown in figures 1-33 and 1-34, can be used to scribe a line through the center of a circular object or to measure the diameter. Notice how one edge of the blade bisects the angle of the center head. To locate the center of a circular object, you need to scribe two lines as shown in figure 1-35. The center is the place where the two scribe lines intersect. Hold the heads of a combination set snugly against the object being marked.

The turret protractor head, shown in figure 1-33, is graduated in 360° and can be used to determine the number of degrees in an unknown angle, to construct angles of known degrees, or to transfer and lay out identical angles. In the terminology of sheet metal working terminology, the words "angle" and "bevel" often are used interchangeably. For example, a long section of gravel guard, for the edge of a flat roof, will have a V-shaped groove for a stiffener. When making the angles of groove on a cornice brake, you may hear them referred to as angles or bevels. The turret protractor can be used to duplicate bevels such as these V-shaped grooves of gravel guards.

Framing Square. The steel framing square, shown in figure 1-36, often is used in sheet metal work. It also is known as a rafter square and a carpenter's square; however, in your shop it most likely will be called a square. Although it has many specialized uses and is available with various graduations, its principal value to you is in making layouts, for checking the squareness of corners, for measuring distances under 24 inches, and for determining the pitch of roofs. In figure 1-36, you can see the parts of the framing square—the body, which usually is 24 inches long and 2 inches wide; the tongue, which usually is 16 inches long and 1½ inches wide; and the 90° heel. One side of the square is called the face and the other side is called the back. It is common for the face to be graduated in eighths and sixteenths of an inch and the back to be graduated in tenths and twelfths of an inch.

One of the jobs of a sheet metal specialist is to fabricate and replace roof jacks. A roof jack, as shown in figure 1-37, is a sheet metal component which seals a chimney, stovepipe, or stack to a roof. The lower end of the roof jack is cut to the same angle as the slope (pitch) of the roof. This lower end is fastened to a square sheet of metal called the base. Now, cutting the roof jack to the same pitch as the roof is important, if it is to stand erect without leaning. Thus, your problem is to determine the pitch of the roof, which will also be the angle to make the roof jack. One of the ways to determine the pitch of the roof is to use a framing square and a level, as shown in figure 1-37. The body of the square is leveled and the 12-inch mark placed on the roof line. The reading on the tongue will be the drop in 12 inches. In the illustration, the roof drops 5 inches every 12 inches. These two calculations are significant because in this example the pitch of the roof is 5-12. (This also can be expressed as a 5-foot drop in 12 feet.) For the purposes of making the roof jack, the square also can be used to make the pattern with the corresponding 5-12 pitch.

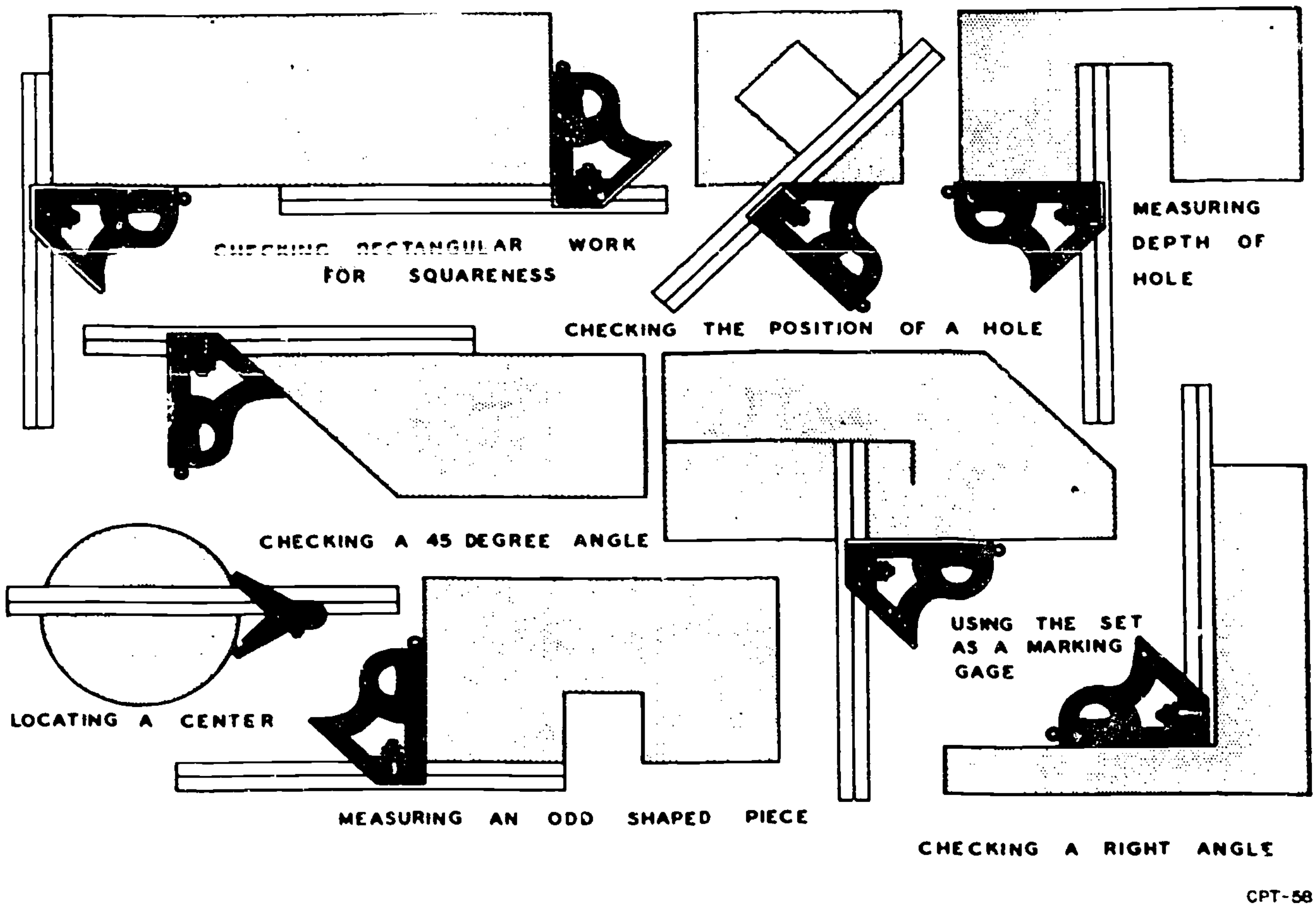

Figure 1–34. Several uses of the combination set.

After the roof jack has been fabricated, the framing square can be used to verify that the pitch is correct.

Another use of the square is for finding the opposite point on the circumference of a circle. This method is useful when locating holes for round duct dampers, placing ears on pails, etc. In figure 1-38, assume that we want to find a point opposite of point A. With the tongue of a square located on point A and the heel placed at any other point on the circumference, such as point C, the body will cross the circle at point B, which is directly opposite point A. A second example, illustrated by the dashed lines, shows that the heel of the square can be located at any convenient point on the circumference of the circle.

Figure 1–35. Use of center head.

Exercises (407):

1. List the four parts of the combination set.

2. Of what parts does the combination square consist?

3. List the parts of a framing square.

4. What tool is used to locate points on a circle that are opposite each other?

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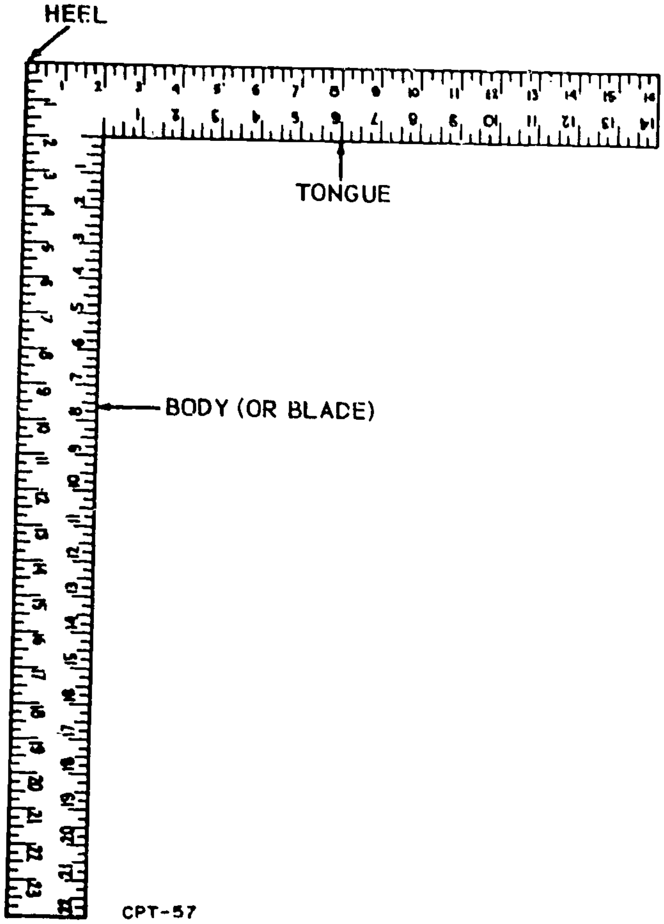

Figure 1–36. Framing square.

5. What are the principle uses of a framing square?

6. How do the measurements on the face and the back of a framing square differ?

7. Which head of tne combination set can be used to determine the number of degrees in an unknown angle?

408. Identify layout tools by matching descriptive statements with the tool.

Layout Tools. You have just studied the measuring tools used in sheet metal work; now let's consider related items called layout tools. Some layout tools are used for both measuring and layout operations. One example is the framing square, which is used for laying out right angles as well as for measuring. In the following paragraphs, we will discuss layout tools found primarily in the shop, such as the level, T-square, triangles, dividers, pencil compass, and architect's scale, to name a few. Let's begin with the level, since you already have learned that it is used with a framing square to determine the pitch of a roof.

Level. The level shown in figure 1-39 is typical of most levels, although others may be longer or shorter or may be made of wood. All levels have one or more glass vials that are tubular in shape and bent in a slight arc. The vial with closed ends contains fluid (usually alcohol) and a bubble of

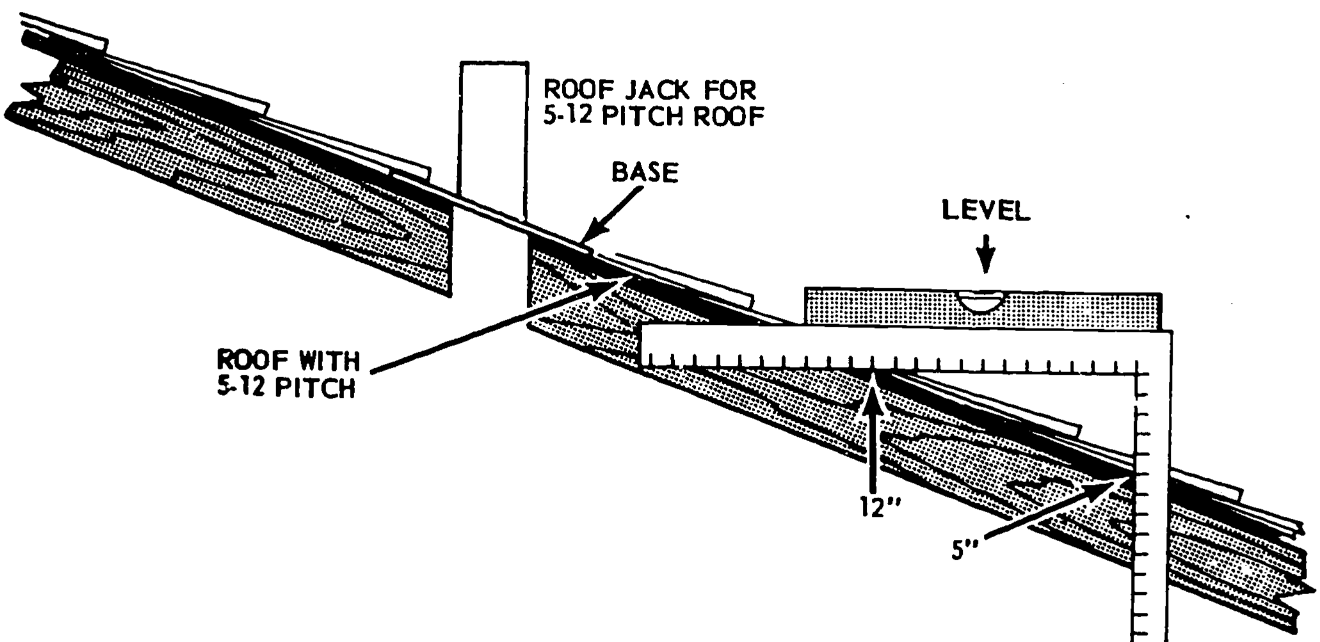

Figure 1–37. Measuring pitch of a roof with framing square and level.

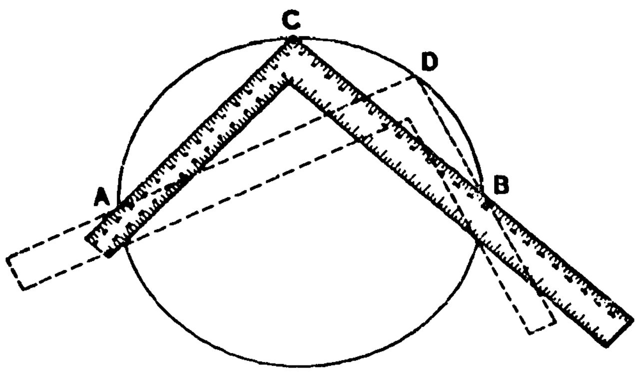

Figure 1–38. Locating the opposite side of a circle with a square.

air; and when the level is held horizontally, the bubble of air will move to the highest point of the arc. The glass is etched (marked) at this highest point, as shown in the illustration. The vial is then accurately installed in a frame so that when the frame is level, the bubble will center itself between the two etched marks.

The level, illustrated in figure 1-39, has six vials—two for horizontal leveling and four for vertical plumb. (Level means parallel with the horizon, and plumb means perpendicular to the horizon.) The enlarged detail in the illustration shows how the vials are mounted in pairs so that leveling can be made with either side or either end of the level.

In sheet metal work, you will frequently use the level for determining the level or plumb condition of components being installed or for checking the condition of components already installed. For example, you may be checking a duct to see if it is level, or you may have to make a level installation of a duct.

Architect's scale. When referring to a drawing made to scale, you use the architect's scale to indicate the ratio of the size of the view as drawn to the true dimensions of the object. When full-size drawings are not practicable, drawings will be made to either reduced or enlarged scales. Enlarged scales may be used when the actual size of the object is so small that full-size representation would not clearly represent the features of the object.

An architect's scale is used for almost all drawings. The triangular scale, shown in figure 1-40, is standard and contains 11 scales. Six scales read from the left end and five scales read from the right end. The various scales are arranged so that inches and fractions of inches represent 1 foot. Thus, drawings can be made to proportion, such as 1/4 size (3″ = 1′ − 0″) and 1/48 size (1/4 = 1′ − 0″). On all scales except the full scale, the end unit is divided to represent inches and fractions of inches. Scales arranged this way are called open divided.

If an object is too large to be drawn full size, it can be drawn in reduced proportion. This frequently is done on blueprints and working drawings of the sheet metal components that you will be fabricating and installing.

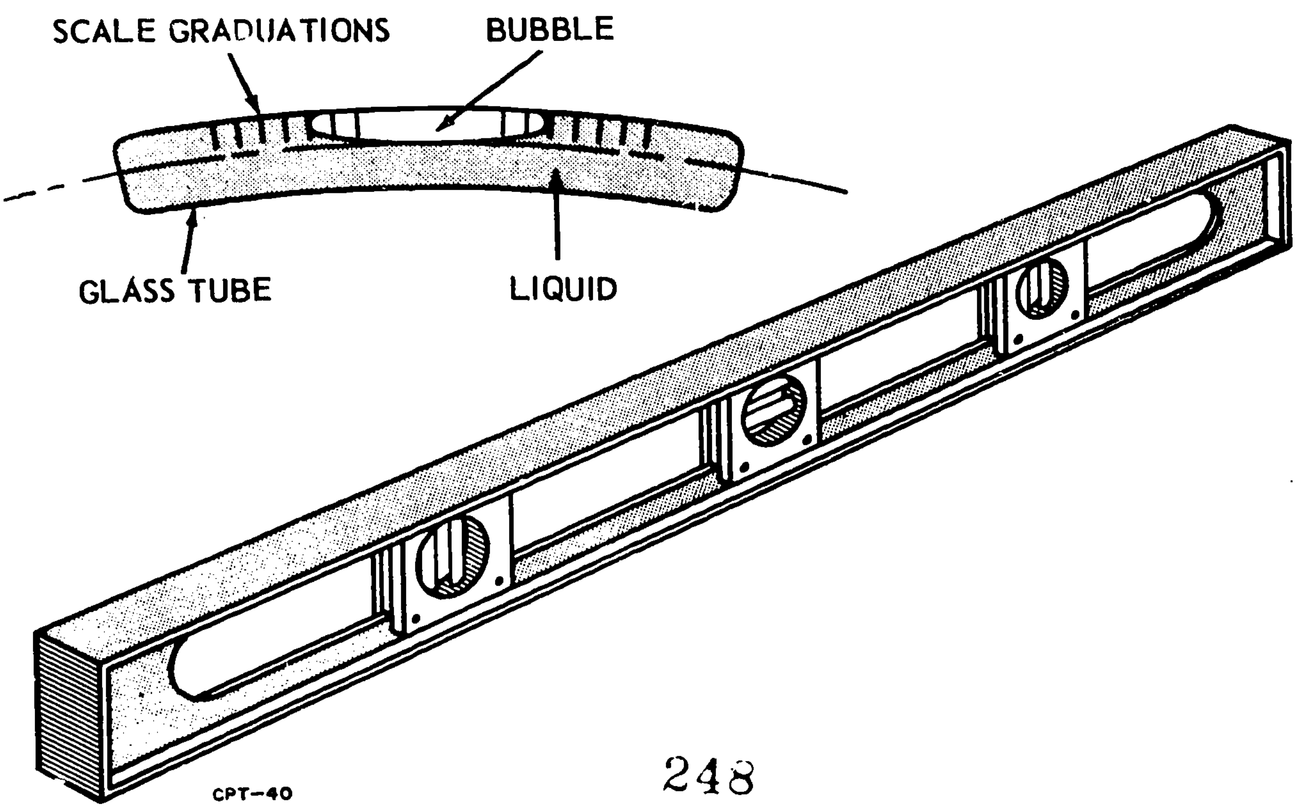

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Figure 1–39. Level.

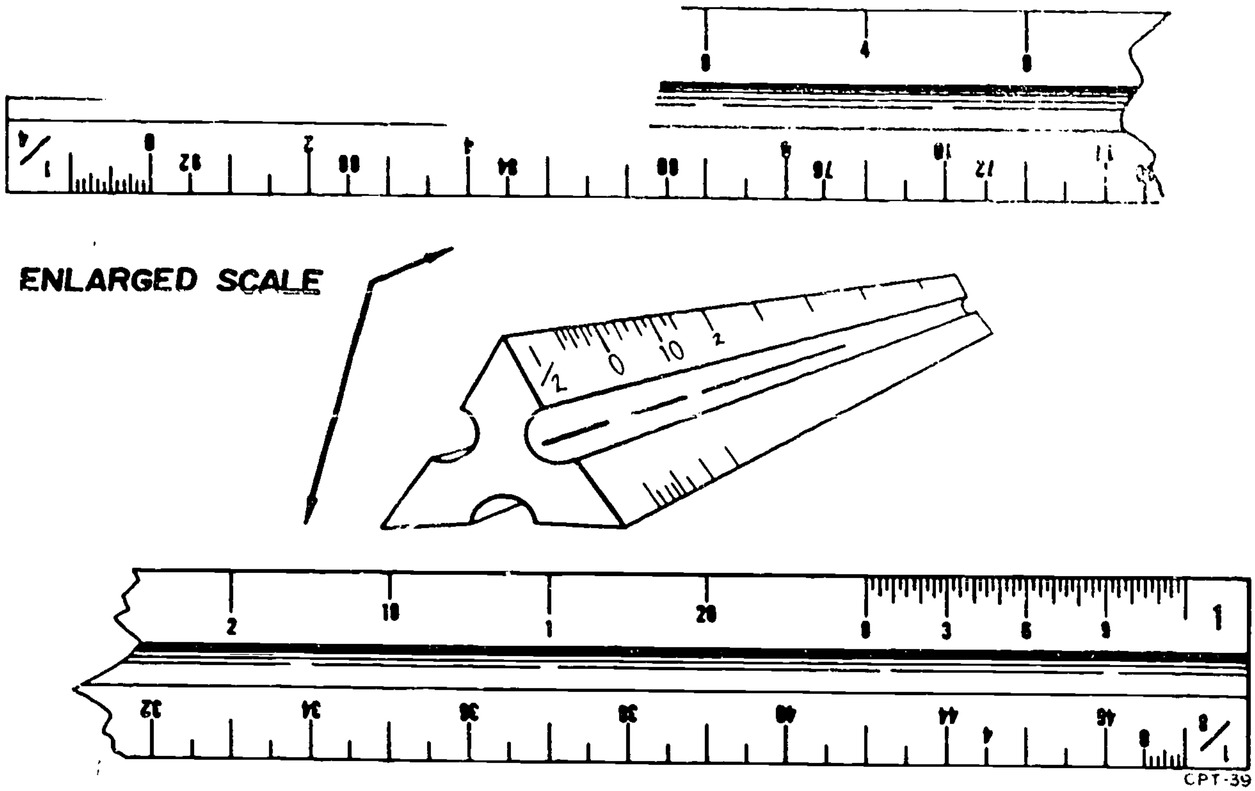


Figure 1–40. Architect's scale.

When using an architect's scale, you should form the habit of reading across (on the far side of) the scale, so as you read the numbers they are not upside down, and read the scale dimensions as real dimensions. Notice in figure 1-40 that only the ends are shown. One scale starts on the left and one on the right. Each scale has a 0 (zero) as the starting point. From the 0 toward the end of the scale, the markings represent fractions of a foot (inches). From 0 toward the center of the scale, the marks represent feet. Look at the 1/2 scale in figure 1-40. Locate marks representing 4'8". Check your work with a rule or tape. The distance (in this example only) should be 3¼". Did you get it right? Remember, when reading open-divided scales, feet are read from 0 toward the inside of the scale and inches are read form zero toward the outside (end) of the scale. When laying off a measurement from a given point, place the proper foot graduation on the given point and place a pencil mark opposite the graduation, representing the required number of inches.

Accuracy in measuring requires sighting the scale perpendicularly by placing the eye directly over the graduation being marked, and holding the pencil perpendicular to the paper directly in front of the graduation. Remember that cumulative errors can make measurements grow into something that will not fit.

Figure 1-41 shows an enlarged portion of the quarter scale (1/4"–1'). Notice that the inch scale to the right of the zero mark is marked off in 12 increments, each representing on inch. For example, the scales on an architect's scale include 3/32", 3/16", 1/8", 1/4", 3/8", 1/4". 3/8", 2/4", 1/2", 1", 1½", 3", and 12". Each of these scales equals one foot (3/16" = 1'). When measuring with an architect's scale, remember to think full size and read the larger graduations from zero as feet and the small increments on the other side of zero (toward the end) as inches.

Pencil compass and dividers. The two dividers shown in figure 1-42 are the wing type and the spring type. Each consists of two pointed branches or legs, joined at the top by a pivot. The two straight legs are tapered to a needle point. Dividers are used to transfer dimensions from working drawings to metal surfaces, to scribe circles and arcs, to perform graphic solutions to problems, and to transfer measurements from the steel rule to the job. However, more accuracy is obtained in transfers of measurements with dividers than with a compass.

To draw an arc or circle with either dividers or a compass, hold the thumb attachment on top with the thumb and forefinger. With pressure exerted on both legs, swing in a clockwise direction and draw the desired arc or circle, as shown in figure 1-43. The tendency to slip is avoided by inclining the compass or dividers in the direction in which they are being rotated. On aluminum or stainless steel, the divider is used only to scribe arcs or circles that will later be

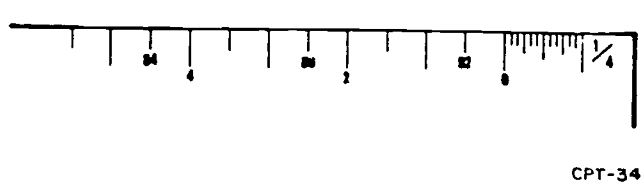


Figure 1–41. Architect's quarter scale.

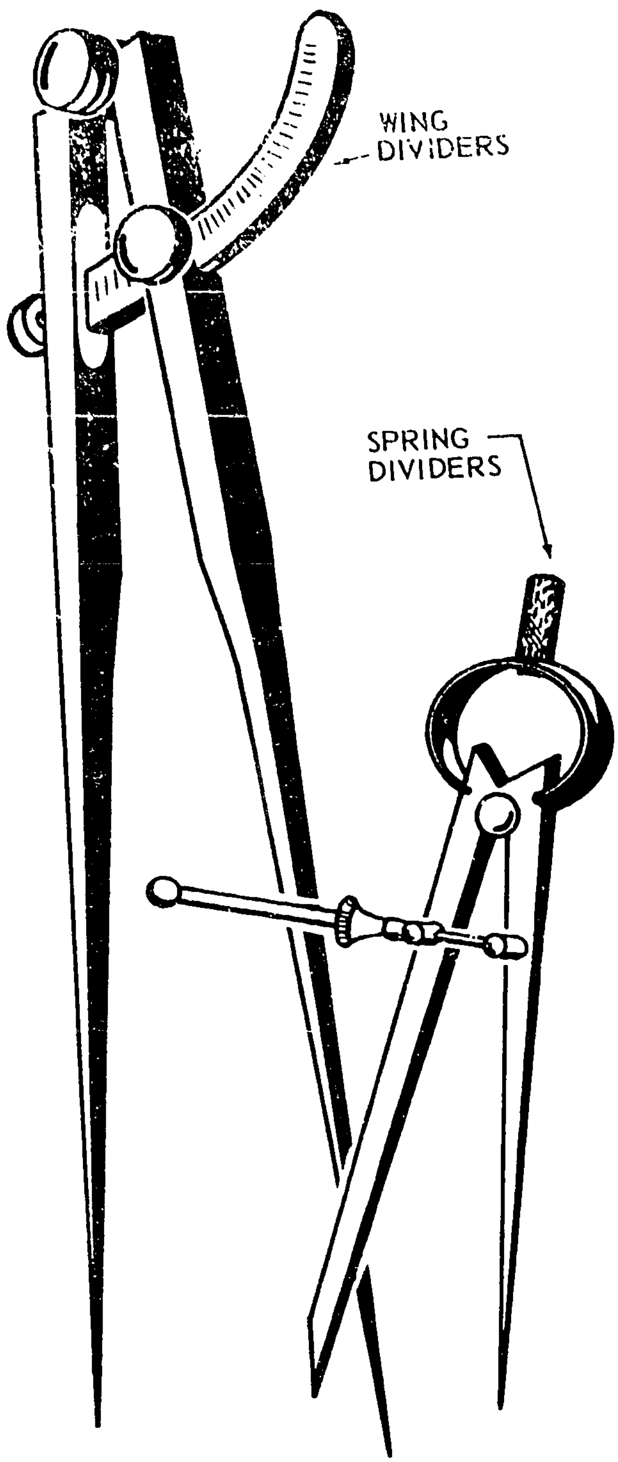


Figure 1–42. Dividers.

removed by cutting; all other arcs or circles should be drawn with a pencil compass to avoid scratching the material.

The following procedure is suggested for using dividers and compasses to transfer measurements from a steel rule. To set either one, hold it in one hand, place the point of one leg in the graduations on the steel rule (as shown in fig. 1-44), and adjust the other leg until the point rests on the desired graduation of the steel rule. This spread represents the required measurements which may be transfered to patterns or metal. In the following paragraphs, you will learn how the compass and dividers are used to perform graphic solutions that will be useful in laying out patterns for sheet metal objects.

In addition to scribing arcs and transferring measurements, compasses and dividers can be used for such opei ns as stepping off the circumference of a circle into equal parts, as you did when constructing polygons. But now let's think about ways these handy layout tools can be used, such as in graphic solutions which do not require arithmetic figuring. In sheet metal work, you frequently will need to lay out circles, diameters, radii, perpendicular lines, various polygons, etc.

In figure 1-45, you can see how a line can be bisected (divided into two equal parts). Of course, the line could be measured with a rule and mathematically divided into two parts, but it also can be bisected with a compass or a divider. To divide line AB into two equal parts, use the compass to form a radius greater than one half of line AB, and draw two arcs with A and B as the centers. Then, draw a straight line through the two intersections of the arcs to

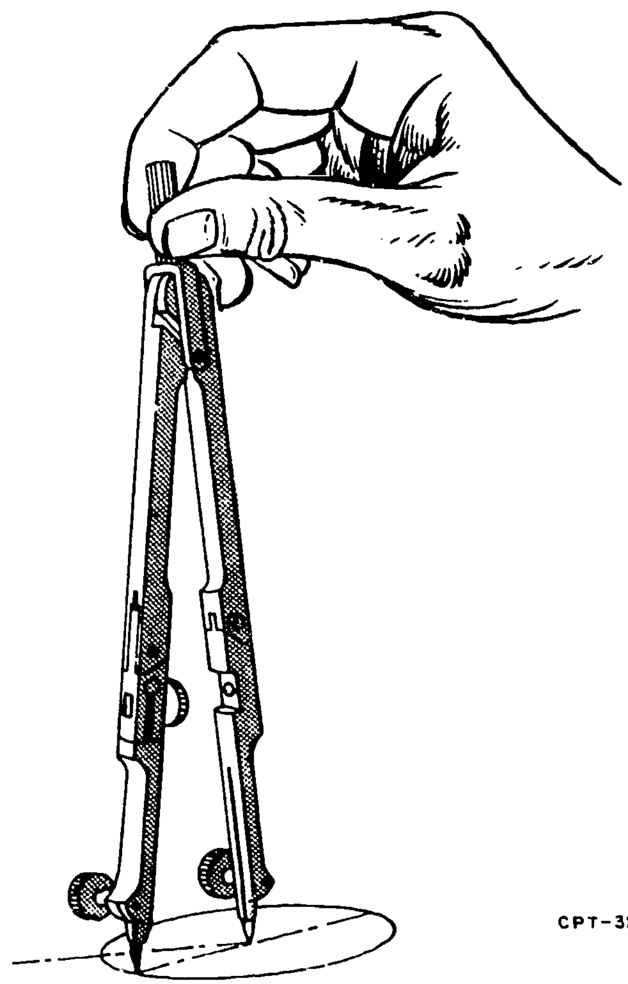


Figure 1–43. Pencil compass.

divide line AB into two equal parts. This line also is perpendicular to line AB.

In figure 1-46, you can see how a perpendicular can be drawn from a given point on a line. With a point C as a center, draw two arcs crossing the horizontal line at A and B; then, draw two arcs with points A and B as centers. The line drawn from C and D will be perpendicular to the horizontal line at point C.

Figure 1-47 shows how to draw a line parallel to a given line. First, draw two perpendiculars from points A and B; then, with points A and B as centers and any given radius (the distance between the parallel lines), draw two arcs CD and EF. A line drawn from points G through H will be parallel to line AB.

Figure 1-48 shows how any angle can be bisected. With O as a center and using any radius, draw the arc AB. Then, using points A and B as centers, draw two arcs that meet at point C. Now, a line drawn between points O and C will bisect the angle AOB.

Figure 1-49 shows how to find the center of a circle. This is done by drawing two chords such as AB and CD, then bisecting each with perpendicular lines. The two perpendiculars will cross at the center of the circle.

Figure 1-50 shows how two parallel lines are connected with an ogee (S) curve. This is done by first connecting B and C with a straight line, then selecting a point such as E through which the curve is to pass. Lines BE and CE are each bisected and two arcs constructed: arc BE from center point F and arc CE from center point G. These two arcs connect the parallel lines AB and CD. In sheet metal work, you will use ogee bands in rain gutters, the side pieces for duct offsets, and anywhere sheet metal is formed into a reverse or S curve.

Figure 1-51 shows how a pentagon may be constructed inside a circle. First, draw a diameter line AB with radius

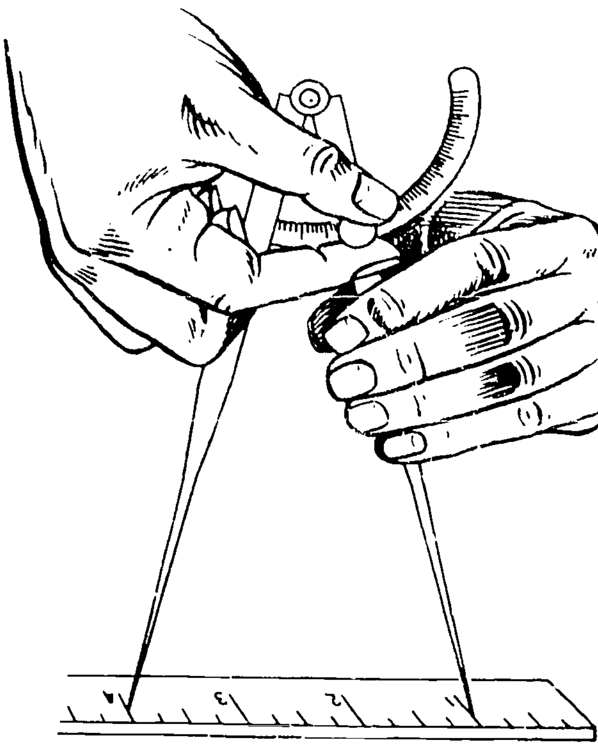
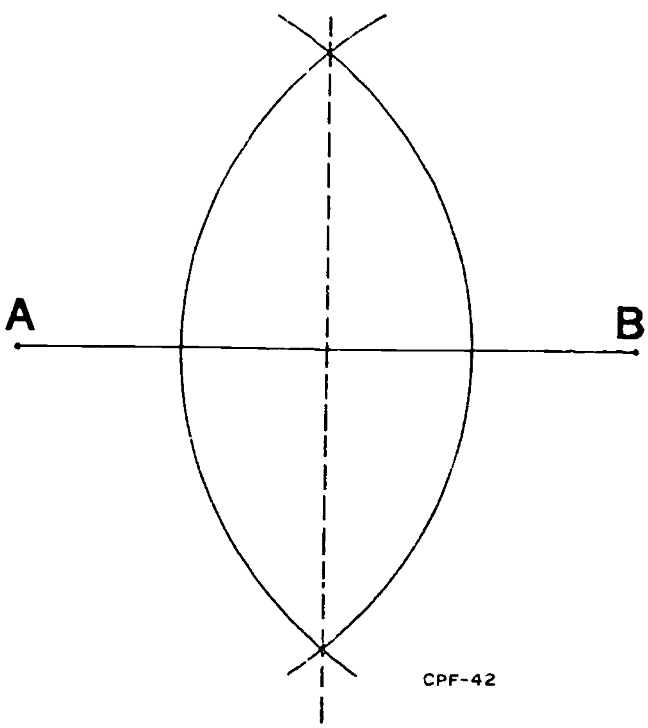
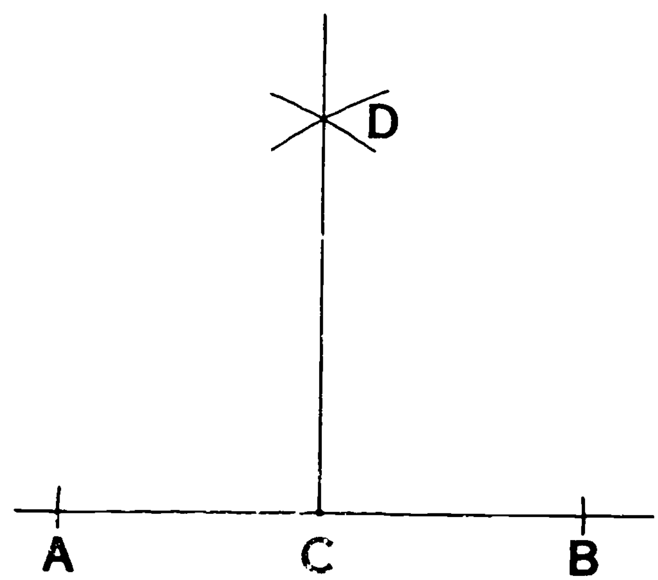

CPT-31

Figure 1-44. Transferring measurements with dividers.



CPF-42

Figure 1-45. Bisecting a line and drawing a perpendicular.



CPF-41

Figure 1-46. Drawing a perpendicular to a straight line at a given point.

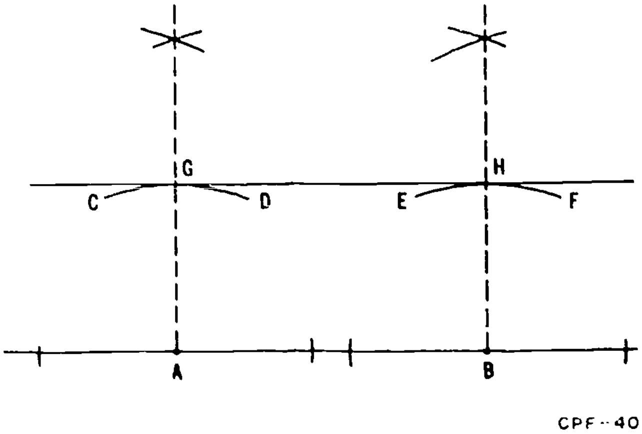


Figure 1–47. Drawing a line parallel to a given line.

line OC perpendicular to it. Line OB is bisected with point D at the center. Draw arc CE from center D. Then, draw arc EF from center C. The radius CF is the length of each of the five sides, which may be stepped off and connected with chords.

To inscribe any regular polygon in a circle, scribe the diameter AB and divide it into as many equal parts as there are sides to the polygon. (In fig. 1-52 there are seven sides to the polygon.) Starting at B, identify point No. 1 (the second point on the diameter).

With A and B as centers and a radius equal to AB, scribe intersecting arcs at C. Draw a line from C through point 1 on the diameter, extending to the circumference of the circle at 2.

A line drawn from 2 to B is one side of the polygon. Follow this same procedure for a polygon of any number of sides.

Knowing the length of one side, you can construct a regular polygon of any number of sides, by following these six simple steps and following the steps in figure 1-53.

(1) With the sides AB as radius and A as center, draw a semicircle, and divide it into the number of equal parts as to the number of side's, in this case seven.

(2) Through the second division from the left, draw radial line A–2.

(3) Through points 3,4,5, and 6, extend radial lines as shown.

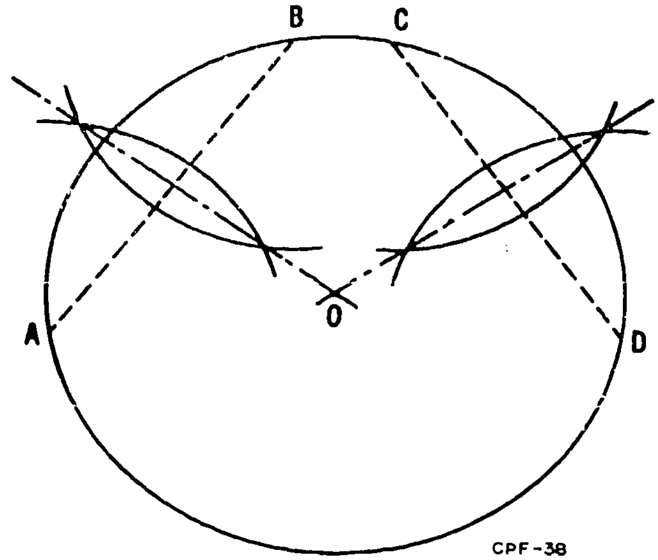


Figure 1–49. Locating the center of a circle.

(4) With AB as radius and B as center, cut line A–6 at C.

(5) With C as center of the same radius, cut A–5, at D, and so on, at E and F.

(6) Connect the points obtained.

Figure 1-54 shows how a hexagon may be constructed inside a circle. With points A and B as centers, draw two arcs equal to the radius. The points where these arcs cross the circle will be the corners of the hexagon when chords are drawn between AC, CD, BD, BF, EF, and AE.

Figure 1-55 shows how a square can be drawn inside a circle by dividing the circle into quarters with two diameters at right angles to each other. When points A, B, C, and D are connected with chords, a square is formed.

Figure 1-56 shows how an octagon can be drawn inside a circle by dividing the circle into quarters and bisecting an angle such as AOC. The length of chord AE will be the same as each of the eight sides stepped off with the compass. Each point is then connected with chord lines.

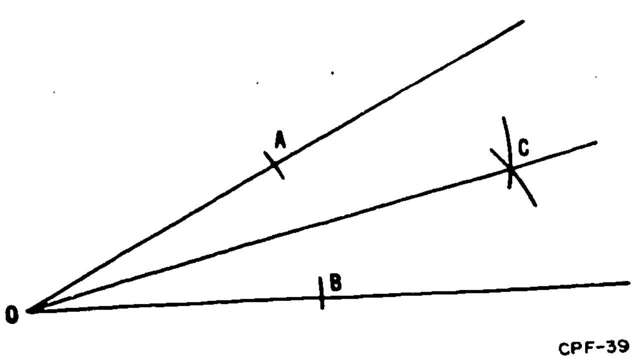


Figure 1–48. Bisecting an angle.

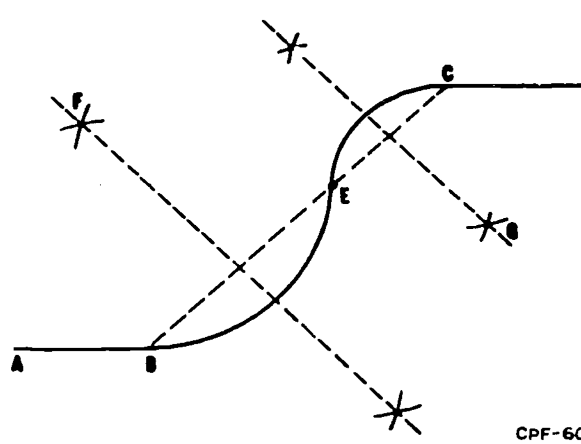


Figure 1–50. Drawing ogee curves.

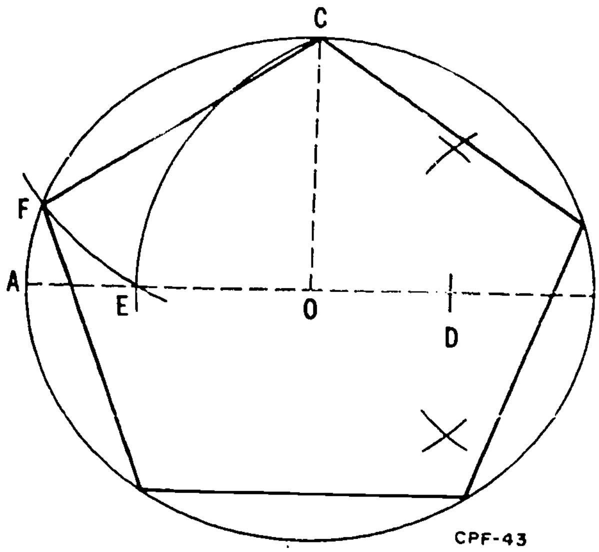


Figure 1–51. Drawing a pentagon inside a circle.

Many other graphic solutions are possible with the use of a compass or dividers; however, the 10 examples discussed in the preceding paragraphs will be used most often. Your knowledge of these basic uses will lead to various other combinations that may arise in laying out patterns for sheet metal objects. Later, you will find additional use for the compass and dividers for graphic solutions in the development and layout of sheet metal patterns.

T-square and triangles. Figure 1-57 shows two triangles and a T-square on a drawing board. The T-square shown has a head made of wood and a blade made of wood with transparent plastic edges. These edges are used as a straight edge for marking horizontal lines and as a base line for the triangles. With the T-square held firmly, it is easy to draw 30°, 45°, 60°, and 90° angles from the base line. These layout tools will be very useful when you are making patterns and layouts, since many sheet metal components are drawn with straight lines. Triangles usually are made of plastic and are available in various sizes. The 8- to 12-inch sizes are suitable for most sheet metal pattern development.

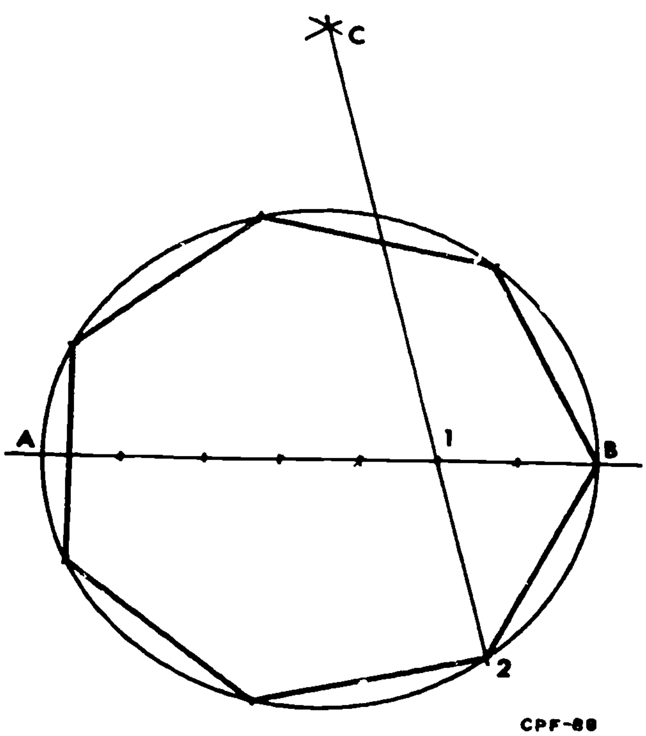


Figure 1–52. Inscribe any regular polygon in a circle.

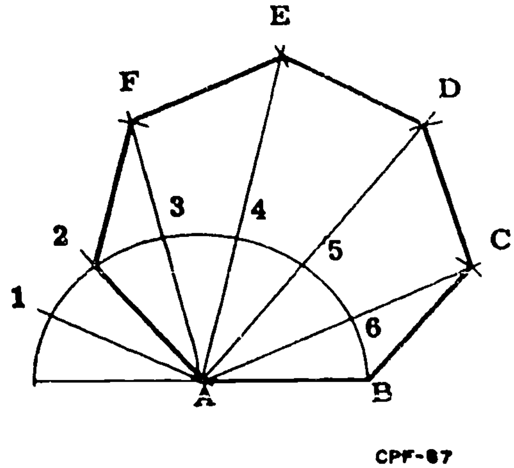


Figure 1–53. To construct any regular polygon from a given side.

Protractor. It is sometimes necessary to measure or draw angles other than the common 30°, 45°, 60°, or 90° variety. When this need arises, a protractor like the one shown in figure 1-58 can be used. The protractor is a semicircular scale divided into 180 equal parts (180°). It usually is made of plastic, and it is used for drawing and measuring angles. Its function is similar to that of the turret protractor head of the combination set that you studied earlier in this chapter, except that a protractor lies flat and is used on the drawing

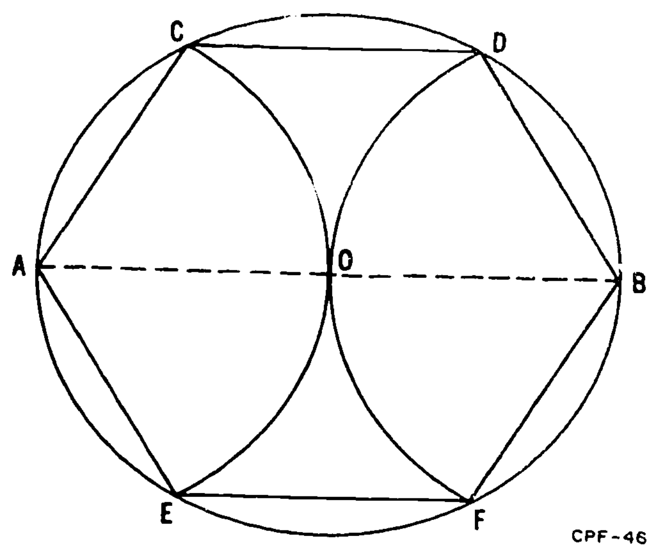


Figure 1–54. Drawing a hexagon inside a circle.

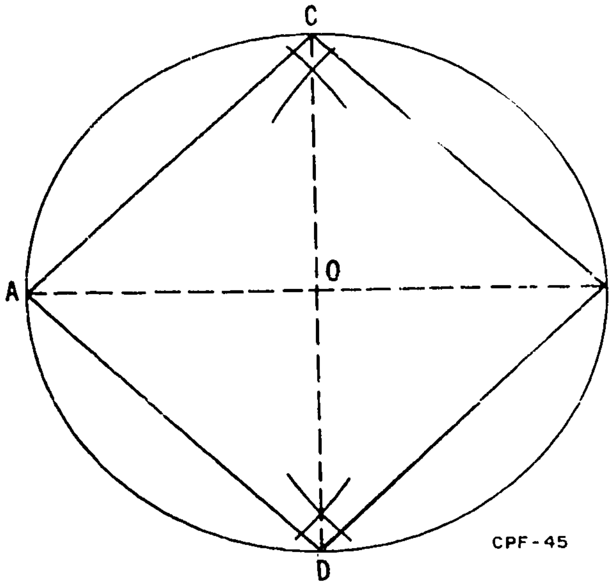


Figure 1–55. Drawing a square inside a circle.

board or pattern layout table with a T-square. Notice in the illustration that the protractor has two scales; and at a point near the pencil, you can see a calibration where 100° and 80° are at the same location. If you examine all such numbered calibrations, you will find that the two at each location can be added together for a sum of 180°. Two scales are the equivalent of a left and a right protractor combined. To measure or draw an angle with a protractor, the index point located on the base line (near the left-hand index finger in the illustration) is used at the vertex of the angle. For example, if the base line of the protractor is placed on a straight line and another line is drawn from the

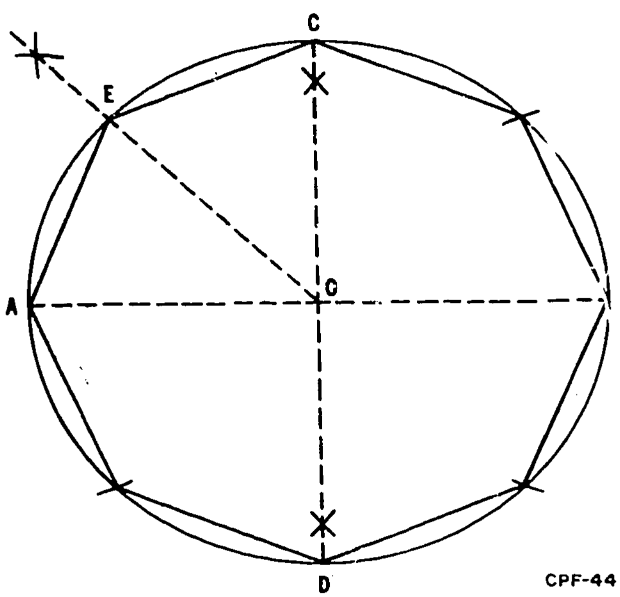


Figure 1–56. Drawing an octagon inside a circle.

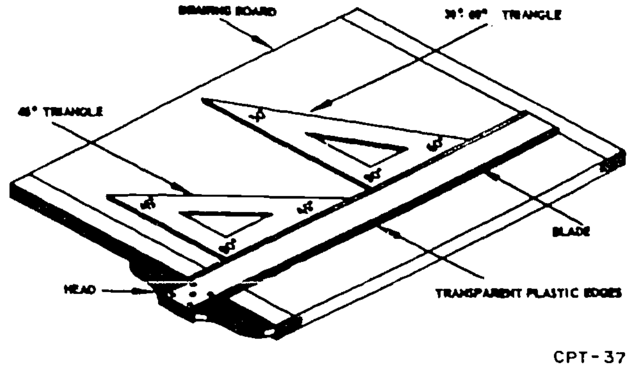


Figure 1–57. T-square and triangles.

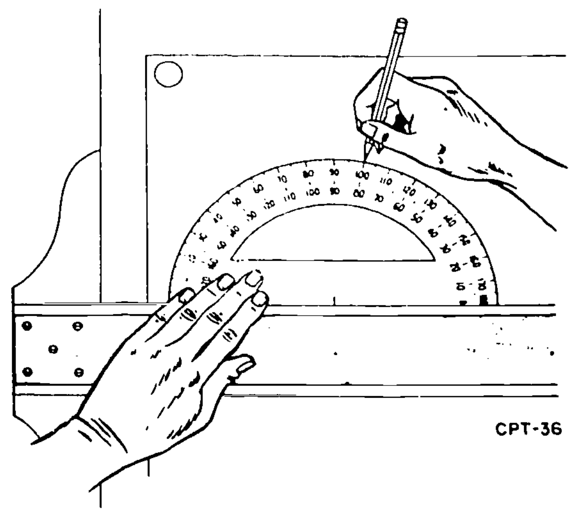


Figure 1–58. Protractors.

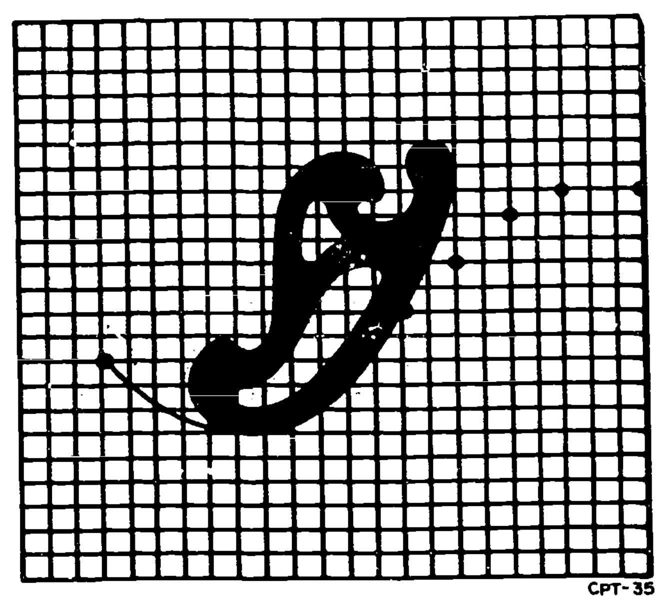


Figure 1–59. Using an irregular or French curve.

index point to the 100° and 80° point, the smaller angle on the right will be 80°, and the larger angle on the left will be 100°.

Irregular curves are plastic devices sometimes called French curves; they are used to draw lines with irregular curvature. The devices are available in various shapes and sizes, but all are used in a similar manner. In figure 1-59, the irregular curve is being used to connect points on the grid. Notice that the curvature needed to connect the last two points will not be the same as the curvature that connected the other points.

Trammel points. Sometimes ordinary dividers are not large enough for a particular application. In this case, you use a set of trammel points such as the one shown in figure 1-60. Trammel points sometimes are called beam compasses and are used to lay out large circles and arcs or to transfer dimensions from one location to another. The trammel points shown in figure 1-60 are typical, although others may have a different shaped adjustment screw and a round, flat, square, or triangular-shaped bar which may or may not be calibrated in feet and inches. The information you have just learned concerning transferring measurements and graphic solutions with compasses and dividers also will apply to the use of trammel points.

Plumb line. A plumb line like that shown in figure 1-61 consists of a weight hung at the end of a line to determine whether a wall downspout, etc., is vertical. The word "plumb" also means vertical; therefore, a plumb line is a vertical line. One of the uses you will find for plumb lines is to establish a vertical reference line when installing rain or gutter downspouts on the sides of the buildings. Plumb lines normally are used when installing long vertical objects, and a carpenter's level is used for determining vertical plumb of shorter objects. The pointed weight of a plumb line is called the plumb bob and usually is made of brass or coated steel. Plumb bobs have various means for attaching to the line; however, the plumb bob illustrated in figure 1-61 simply has a hole through which the line is passed and tied. When an object is not vertical, it may be called out of plumb or off plumb.

Chalk line. A chalk line as used in the building trades is a length of heavy cotton cord stretched between two points to provide a straight reference line for installation of such

DESCRIPTION OF LAYOUT TOOLS

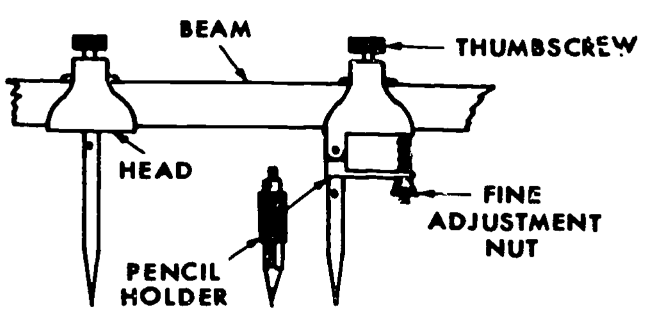


Figure 1-60. Trammel points.

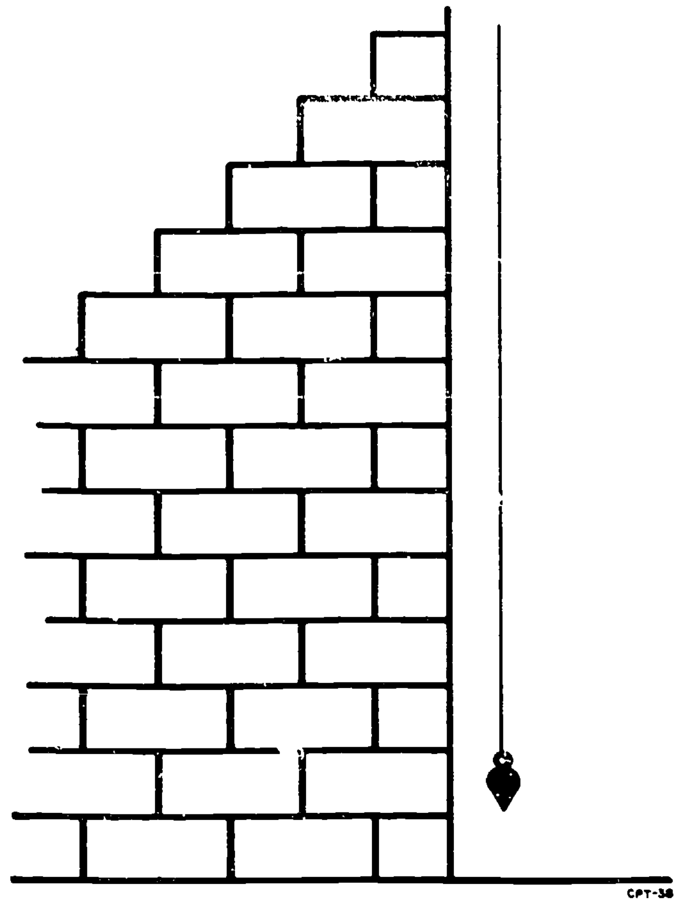


Figure 1-61. Plumb line.

items as roofing, sliding, gutters, ducts, etc. Chalk lines are available in various lengths and are contained in a reel that also holds chalking powder. The reel has a crank used to wind in the line on the reel and a cap for checking and filling with chalk. Don't mix colors of chalk. Be sure to maintain the reel one-half full or more for adequate rechalking. Chalk is available in several colors and comes in powder form. Changing colors is not recommended but may be necessary for a specific job. To use a chalk line, tightly stretch it between two points and snap the string (at or near center, lift the line 8–10 inches and let it snap back to the surface being marked). A chalk line can be used as a reference line that is level, vertical, or with a drop, such as for a gutter that is designed to make water drain toward a downspout.

Exercises (408):

1. Match the layout tools in column B with the identifying phrases in column A.

Column A	Column B
____ (1) Has two pointed branches joined at the top by a pivot.	a. Chalk line.
	b. Plumb line.
____ (2) Used when ordinary dividers are too small.	c. Trammel points.
	d. Irregular curves.

Column A		Column B
____ (3)	Used to draw 30°, 45°, 60°, 90° angles.	e. Templates.
____ (4)	Stretched between two points to provide a reference line.	f. Protractor.
____ (5)	Used to measure or draw angles other than 30°, 45°, and 60°.	g. Pencil compass and divider.
____ (6)	Used to check horizontal or vertical alignment of installed components.	h. Architects' scale.
____ (7)	Have scales for measuring reduced proportions.	i. Level.
____ (8)	Patterns that are used repeatedly.	j. T-square and triangles.
____ (9)	Used to determine if a downspout is vertical.	
____ (10)	Used to connect points not in a straight line.	

1-3. Sheet Metal Layout

As a sheet metal specialist, you will be using the different methods of layout to make flat patterns from working drawings and blueprints. Flat patterns are developed, using one or more of three layout methods—parallel line method, radial line method, and triangulation method.

These different layout methods are needed to develop flat patterns for different shapes of sheet metal components. For example, to select a layout method, you need to know why true lengths are different from tapered lengths; why parallel lines are used to lay out square and rectangular ducts; why triangles are important when laying out transitions; and why radial lines are used when laying out cone-shaped or pyramid-shaped components. These layout methods are important to you, since they will be used to develop patterns when you fabricate new or replacement components.

The layout methods learned in this section will be used later in this course when you study the fabrication, installation, and repair of sheet metal components. In the fabrication and repair of different components, you will be developing patterns for such items as round ducts, square ducts, rectangular ducts, elbows, offsets, ventilators, and transitions. First, let us consider how to make flat patterns from working drawings

409. State the basic requirement for making a flat pattern, and list the three layout methods.

Making Patterns for Sheet Metal Components. Working drawings, in most cases, are drawings that you, your supervisor, or a draftsman have made from prints, from sketches, or from a component that is to be replaced. Good drawings include correct and accurate measurements, which are essential if you are to make an accurate layout.

When you are laying out a pattern for a component, regardless of the source of its description, you will need to determine the layout method to be used. A drawing or print will show the dimensions of the component; however, if a drawing is not available and a duplicate or like item is to be made, you will have to take measurements and make a sketch of the component on a piece of paper. The sketch should include all needed descriptive information.

When using a blueprint or working drawing, you can get a description of the item from the plan view and/or elevation view. If the component is shown only in the plan view or the elevation view, the measurement will give a good description. However, if detail views are shown on a drawing or print, they will illustrate the component much better.

Obtaining measurements and a description of the component is the first step in making a flat pattern. This is where the blueprint or drawing is important, since it is the guide for developing patterns for the components to be made. In this chapter, you will learn how other plan views and elevation views are used to develop flat patterns for sheet metal components.

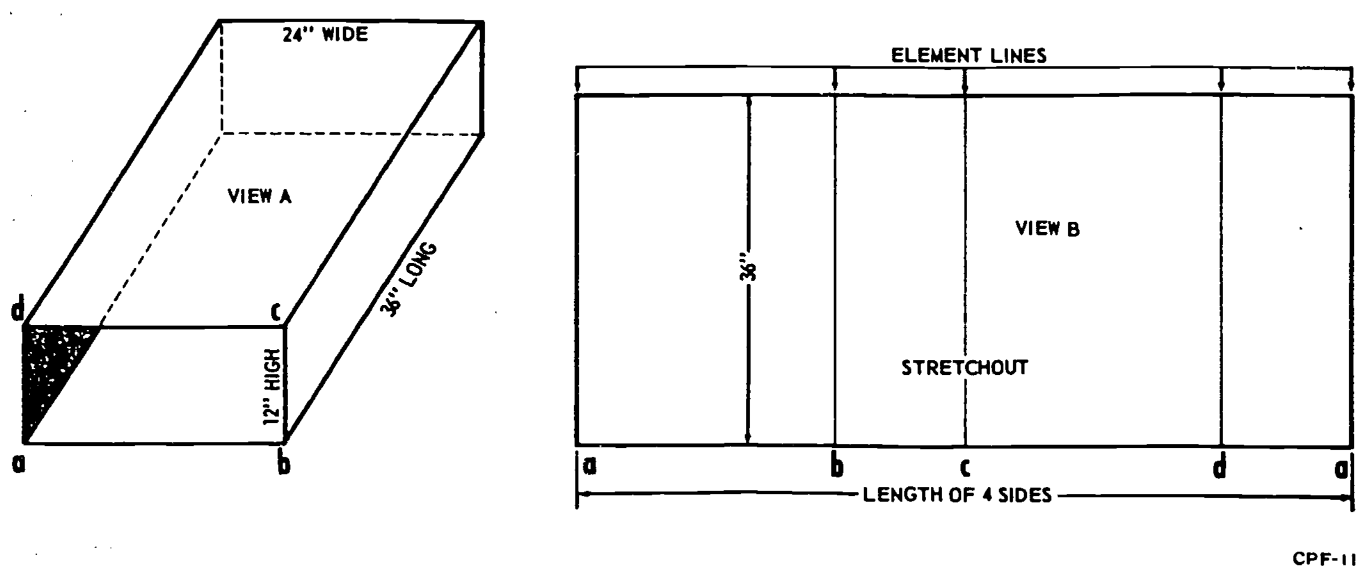


Figure 1–62. Parallel line pattern development for a rectangular duct.

Flat Pattern Layouts. Flat pattern layouts are drawings that show the shape of components in the flat or stretched out position. You studied many kinds of figures such as triangles, squares, rectangles, prisms, cones, and pyramids. Now in figure 1-62, view A, you can see a section of a rectanglular sheet metal duct. View B shows a flat pattern or stretchout of the same duct. Note that the stretchout is a series of rectangles. In figure 1-63, you can see the stretchout of a square duct. In figure 1-64, view A, you can see the half plan and elevation views of a round duct, and in view B the stretchout of a round duct (cylinder).

Patterns for rectangular, round, and square ducts are developed through use of the parallel line method. Cone- and pyramid-shaped components are developed through use of the radial line method. Transitions such as square to round and rectangular to round are developed through use of the triangulation layout method.

When laying out patterns of objects (such as straight ducts that are round, square, or rectangular), a parallel line stretchout (figs. 1-62, 1-63, and 1-64) can be used to show the shape of the part. However, this simple type of stretchout cannot be used to lay out round, square, or rectangular objects that are larger on one end than the other. These more complex flat pattern layouts involve additional layout methods such as the radial line method and triangulation method. The three methods are discussed in more detail in the following paragraphs.

When developing patterns using the three layout methods, you will be using layout tools you learned about earlier, such as T-square, triangle divider, compass, and drawing board.

Exercises (409):

1. What is the first step in making a flat pattern?

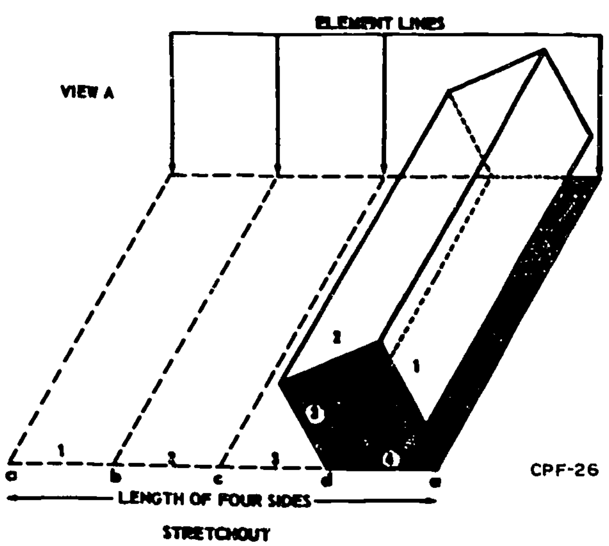


Figure 1–63. Parallel line pattern development for a square duct.

2. List the three layout methods.

3. When making a sketch of a component, what information should you include?

410. State some of the key points and rules of parallel line layout.

Parallel Line Layout Method. The parallel line method of layout is used to develop patterns for components that have parallel sides. True lengths of elements play an important part in parallel line development. Element lines, as shown in figures 1-63 and 1-64, are equally spaced lines used to layout the pattern. In parallel line development, all element lines are parallel or perpendicular to each other. The length of the duct section (or true length) is indicated by the length of the element lines. True length does not include the seam allowances.

Now, let's develop patterns for the square, round, and rectangular ducts, starting with view A in figure 1-62. As you see, sides ab and cd are the same width, and bc and da are the same width. To lay out a pattern for view A, the length, height, and width of the four sides are needed. Suppose the duct measurements are 24 inches wide, 12 inches high, and 36 inches long (24" x 12" x 36" long). The flat pattern is laid out by drawing a straight line (stretchout) equal to the perimeter of the four sides. Element line a on the left, which is 36 inches long, is drawn perpendicular to the stretchout line. Element line b is drawn 24 inches from element line a and parallel to element line a. Element line c is drawn 12 inches from element line d and parallel to element line d. All the element lines are 36 inches long (the true length of the duct). The element lines should be joined across the top to complete the pattern. It is a good practice to check the pattern for correct dimensions and squareness after it has been developed. This pattern can be formed into a rectangular-shaped duct by breaking 90° (bending the metal) at element lines b, c, and d.

Figure 1-63 shows the stretchout of a square duct. The parallel line layout method is used to develop square duct patterns the same as those for rectangular ducts. The stretchout length is the perimeter or the sum of the four sides: 1, 2, 3, and 4. The length of the element lines is determined by the true length of the duct. To form the stretchout into a square duct, the element lines b, c, and d are broken at 90° Angles.

View A in figure 1-64 includes both the plan view and elevation views for a round duct (cylinder). The half plan shows part of the cylinder as you would see it looking down from the top. The half plan arc is divided into 12 equal parts, resulting in 13 element lines. Notice how the half-plan view is used to represent a whole-plan view and is divided into half the spaces of the plan view. In view B of figure 1-64, which is the pattern for view A, notice that the stretchout is divided into 12 equal parts, and the element lines are parallel to each other. Remember that the element

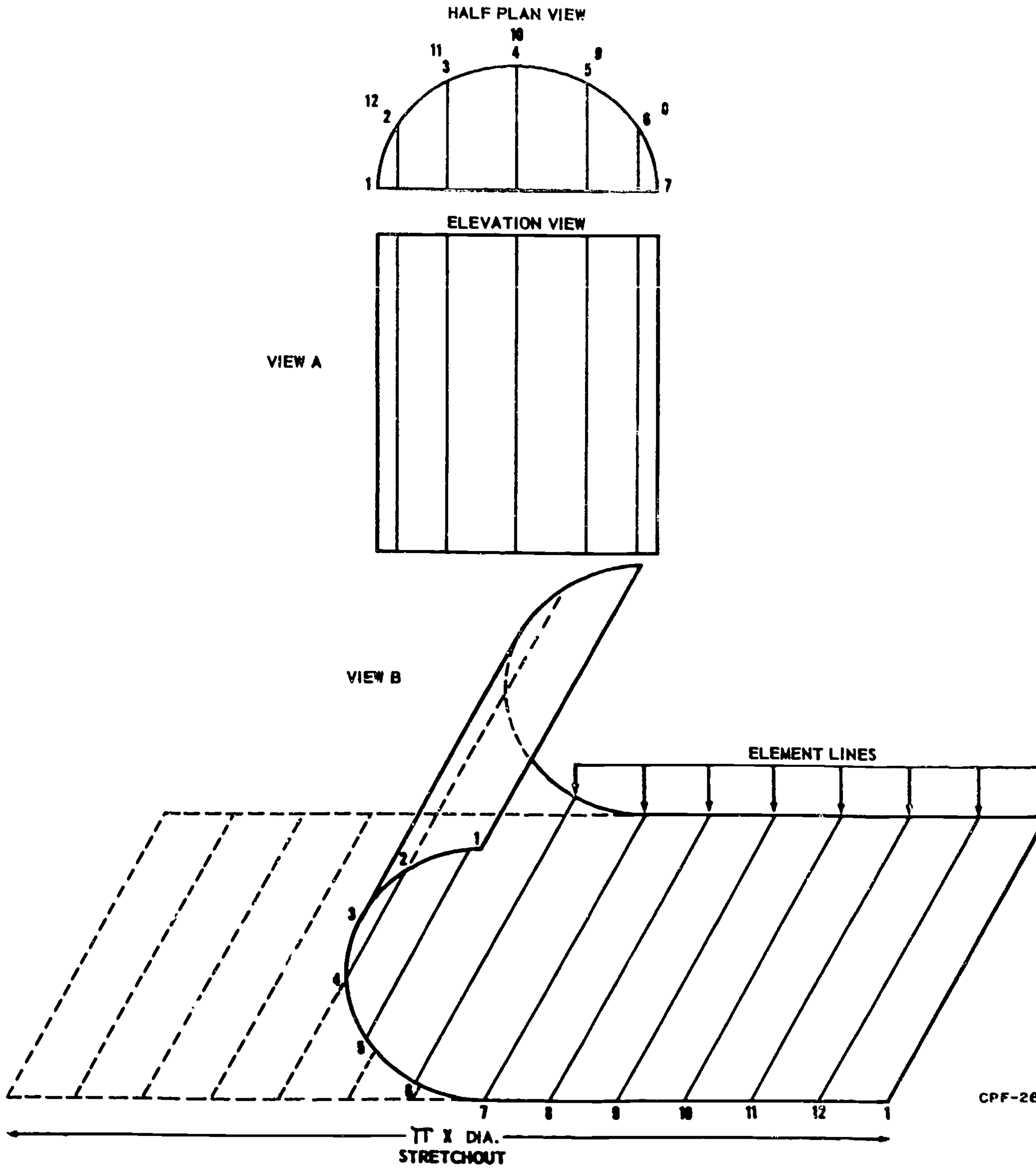


Figure 1–64. Parallel line pattern development for a cylinder.

lines are the true length of the duct you are laying out. View B also represents view A as it would look stretched out in a flat pattern. To determine the length of the stretchout line for view B, use the circumference formula you learned in behavioral objective 206 ($\pi \times d$): multiply the diameter of the duct by 3.1416. The stretchout line is divided into equal parts; in this case, we will use 12 parts. This pattern is formed by rolling, as shown in view B of figure 1-64.

Now that you have developed simple patterns using parallel lines, let's proceed to the development of parallel line patterns that require more accuracy and thought; for example, a pattern for a round pipe that has a 30° miter line. As you recall, a plan view and an elevation view are needed to determine the length of the element lines. Line CD in view A of figure 1-65 is a miter line that will require element lines of different lengths. Where element lines are not the same length, a more accurate pattern can be made if additional element lines are drawn—the more the better. Using a T-square on the edge of the drawing board, draw line AB, as shown in view A. Using a T-square and a triangle, elevate lines AC and BD (drawn 90° to line AB). To draw line CD, draw it with a 30°- 60° triangle. The center of line AAB in view A can be found with a rule or by bisecting line AB with dividers or a compass. Draw the arc of the half-plan view, using the midpoint of line AB as the center. Draw a centerline perpendicular to line AB through the midpoint. Draw this perpendicular up to the miter line and down to the half plan arc. This centerline is identified as element line 4–10. The arc of the half plan is divided into three equal parts on both sides of element line 4–10. After this, element lines 2–12, 3–11, 5–9, and 6–8 are elevated through line AB to meter line CD.

The next step is to lay out the flat pattern, as shown in view B of figure 1-65. The T-square is used to draw line ABA, which is the stretchout line of the cylinder. If line ABA in view B is drawn straight across from line AB in view A, the length of the element lines can be transferred easily by use of a T-square. Next, divide line ABA in the stretchout into 12 equal parts by element lines, and transfer the length of the elevation view element lines to the corresponding number in the stretchout. The length of the element lines can be transferred by using dividers, compass, or T-square. After the length of each element line in the stretchout is established, the points are connected by using an irregular (French) curve. Now, we have a pattern of a cylinder with a meter line. Notice that element points 1 through 7 represent one-half of the stretchout; element points 7 through 12 back to 1 represent the other half of the pattern. Point 1 is the seam line, since it is the starting of the point numbering. All seam allowances are made at point 1, which is line AC on either side of the stretchout. It is a good practice to cut patterns out and tape them together to see the finished product.

Elbows. Another important article used extensively in sheet metal work is the multiple round elbow—multiple meaning more than one, and elbow meaning turned or bent at an angle. The elbows that you will make are constructed from a number of pieces of metal called gores, which are fastened together. It is important to remember that, when gores are used in the construction of an elbow, the resistance to airflow will be less. The elbow with five gores will have less air resistance than the three-gore elbow. Elbows are used to connect straight lengths of pipe that run in different directions. For example, suppose you have two

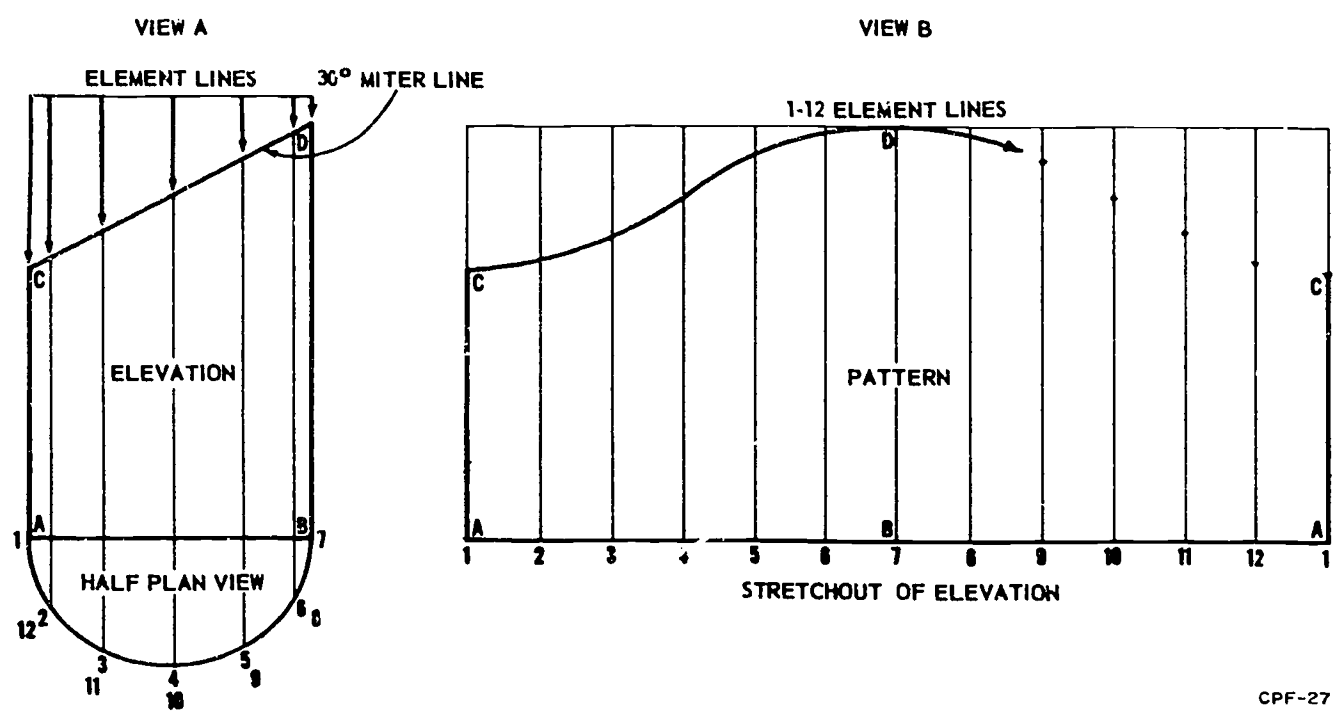


Figure 1–65. 30° miter pattern development.

lengths of round air duct with one running vertically between the wall studs and the other running horizontally between the floor joists. An elbow is needed to connect these two ducts so that the flow of air will pass from one section to the other.

The elevation view of a three-piece 90° elbow is shown in figure 1-66. Study the illustration and learn the names of the parts and the meaning of the symbols. Such terms as throat, heel, cheek, angle, diameter, and radius will be used when elbows are discussed in this text and when you are fabricating elbows in the shop. Notice that upper case R is the radius of the heel and lower case r is the radius of the throat. The diameter is represented by upper case D. The diameter, number of sections, throat radii, and shape of elbows will have no effect on the principle involved in the drawing of patterns. An important step necessary before pattern development can begin is the construction of the true miter lines. In figure 1-66, you can see these miter lines and the various parts of an elbow.

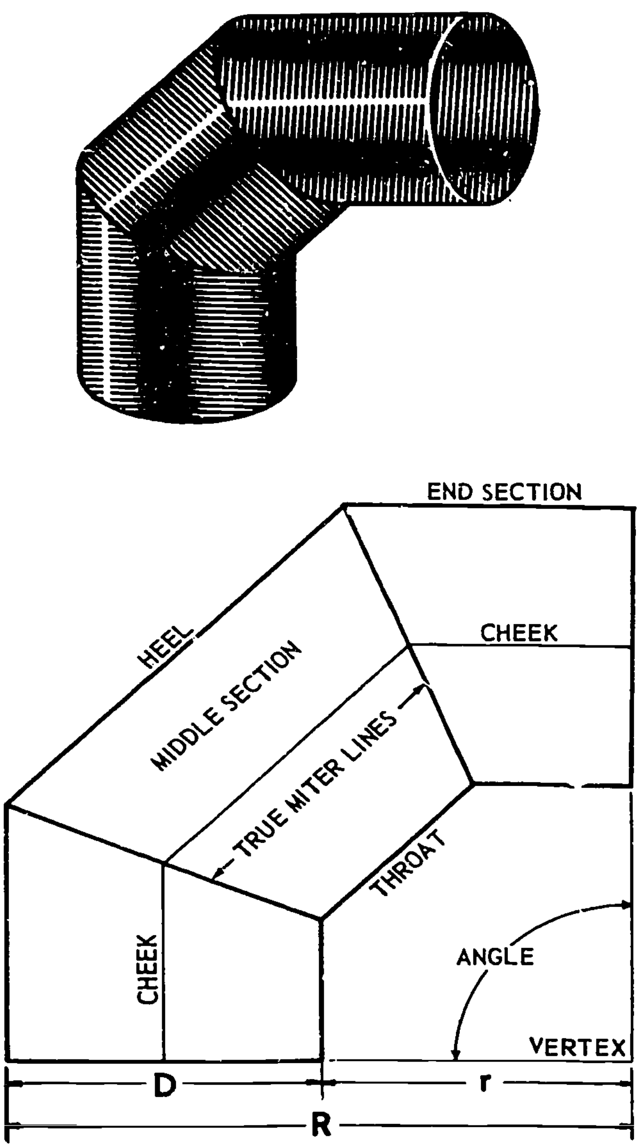


Figure 1–66. Parts of an elbow.

In figure 1-67, you can see the various steps necessary in developing true miter lines for 90° elbows. As you observe each, notice that regardless of the number of parts (gores) in the elbow, the miter lines are constructed by dividing the 90° arc into the desired number of equal parts. Also, notice that there is one less miter line than the numbered sections. For example, in view D, the five-piece elbow has only four miter lines. (The dark lines are the miter lines.)

To construct the miter lines in view A of figure 1-67, you must bisect the arc, then draw a line from the point of bisection to the vertex of the angle. You can use a compass or dividers to divide the angle. When you are drawing miter lines for elbows (views B, C, and D), a simple formula is used. Multiply the number of pieces (gores) in the elbow by 2 and subtract 2. For example, in view B, a three-piece elbow is desired. So 3 × 2 = 6 and 6 − 2 = 4. Therefore, the elevation view will be divided into four equal segments, with two segments on each side of the 45° bisecting line. As you can see, this formula provides more segments than pieces required. The general practice is to allow one segment for each end piece and two segments each for the remaining pieces. Thus, in view B there will be two miter lines. Using the formula for view D, which has five pieces (5 × 2 = 10 and 10 − 2 = 8), the elevation view will be divided into eight equal segments, with four segments on each side of the 45° bisecting line. Thus, view D will have four miter lines when you allow one segment for each end piece and two segments each for the remaining pieces.

Now, let's use miter lines to develop a pattern. Suppose the drawing or blueprint requires a 90° elbow with a 6-inch diameter and a 3-inch throat radius. To develop the pattern as shown in figure 1-68, first draw the elevation view so as to construct a right angle, and then draw heel and throat arcs from the vertex. The heel radius for any size elbow is the sum of the diameter of the elbow and the throat radius.

The miter lines are drawn by connecting the vertex to points stepped off on the heel arc, which divides arc AC into eight equal segments or spaces. Now, draw the dark miter lines to make pieces I and V each equal to one segment on the heel arc, and pieces II, III, and IV equal to two segments. Drawing these miter lines completes the elevation view.

Using AB in the elevation view of figure 1-67 as the base line, construct the half-plan view in a similar manner, as shown in figure 1-65. The greater the number of element lines and spaces you use, the more accurate the pattern will be.

To draw the stretchout shown in figure 1-68, first draw the working line, then divide into the same number of element lines and spaces as contained in the half-plan view, which in this case is 12 spaces and 13 element lines. From the 13 points on the working line, draw element lines on both sides of the working line and number, as shown. The beginning and ending numbers in the half plan and stretchout designate the location of the seam in the finished elbow. Generally, the best location for a seam on an elbow is on the cheek. However, for appearance, you may want the seam on the throat or heel.

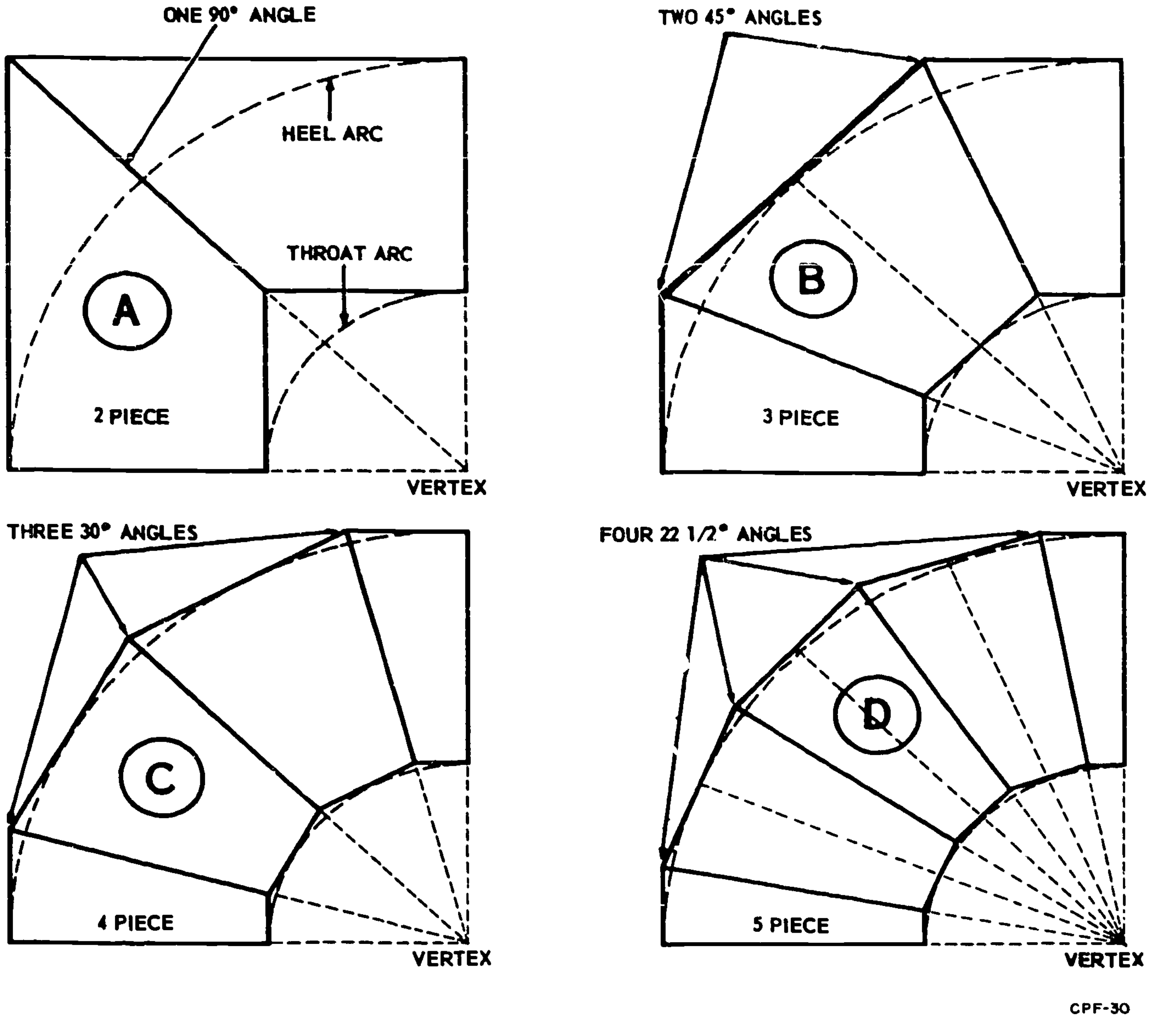


Figure 1–67. True miter lines.

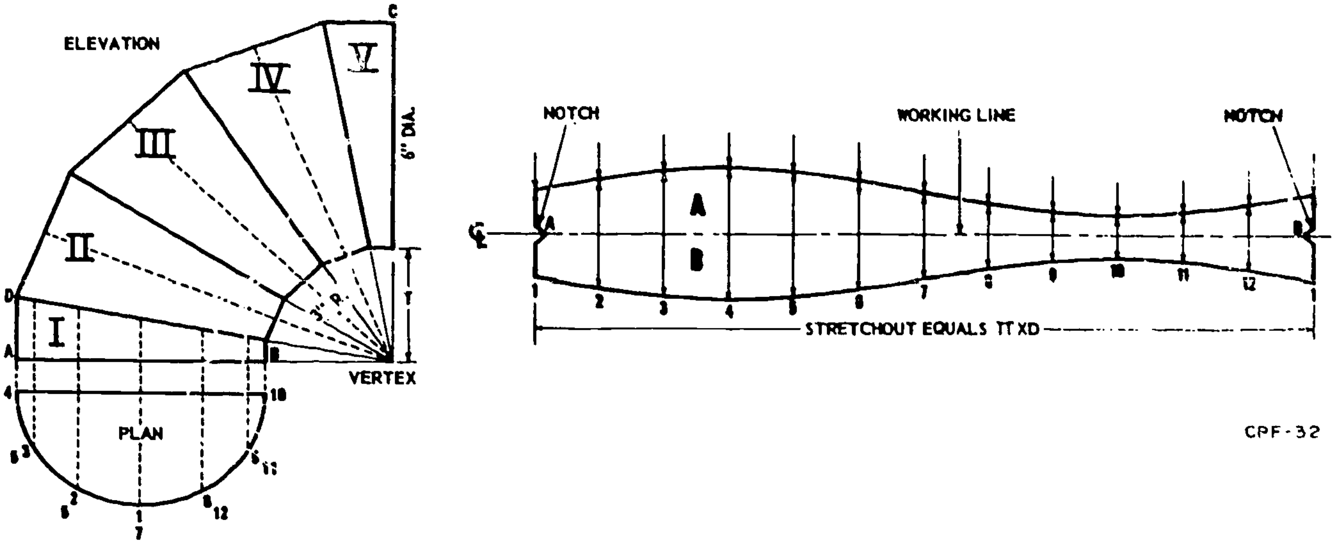


Figure 1–68. A five-piece elbow pattern development.

To determine the length of the element lines on each side of the working line, use a compass to transfer the length of each element line located between line AB and true miter line D in the elevation view. Transfer this distance to the stretchout by placing the sharp point of the compass on the working line, making two arcs (one above and one below) to indicate the total length of the element line. Make sure the element line numbers correspond. An irregular (French) curve is used to connect these arcs with smooth curved lines.

The stretchout shown in figure 1-68 is the pattern for one whole piece or gore of the elbow shown in the elevation view. The stretchout is used to make pieces II, III, and IV. Side A or one-half of the pattern is used to make piece I, and side B is used to make piece V; however, since they are identical, they can be used for either end of the elbow. If the pattern is notched on both ends of the working line, alignment will be much easier when you transfer the pattern to metal. Elbows of different angles can be made by using various combinations of the pattern.

Y-branch. The Y-branch shown in figure 1-69 is made in five individual pieces, numbered I, II, III, IV, and V. When these five pieces are fastened together, the single duct is divided into two ducts of the same diameter. Y-branches also can be designed to connect different sizes of ducts. The miter lines and the angles at which these pieces meet may vary from job to job. Because of this, you may have to make as many as five different patterns, one for each piece shown in the elevation view.

In Y-branch pattern development, you will repeat some of the steps used to lay out elbows. From the elevation view of a Y-branch, you can obtain the true length of the element lines. First, draw the elevation view so that you can determine the shape of the five pieces or gores; then draw the half-plan view and divide into an equal number of spaces. From the 13-numbered point, the numbered element lines are projected through each section of the elevation view. This gives you the true lengths of the element lines for each piece (gore). Stretchouts for each piece are drawn as shown in the illustration, and the pattern is developed in the same manner as in figure 1-68.

T-joint. You have seen that to develop a stretchout pattern by the parallel line method, elevation and plan views must be drawn. These two views, when constructed, will give you the true lengths of all miter and element lines. In figure 1-70, you can see the two main parts of a T-joint collar, or branch, and main pipe. The lines where the main pipe and collar meet are called lines of intersection. These lines also are called miter lines.

Figure 1-70 illustrates the method of constructing miter lines in the elevation view and the projecting lines from the plan views. Both pipes shown have a diameter of 3 inches to simplify the layout explanation. Draw elevation view A by using a T-square and a rule. Draw line AB 3 inches long. Draw lines AC and BD perpendicular to line AB. Draw line DC parallel to line AB. Draw the half-plan view B directly below the elevation view, and divide half of the arc into three equal spaces. Number and project the dividing points to elevation view A by using the T-square and the triangle to form lines 1 through 7. In this example, the intersecting point for the collar is at the center of the elevation view. At the center of line AC in the elevation view, draw the dotted line 1–7–1 so that it will extend 2 inches beyond line BD. Line ER is 3 inches long; set the compass for 1½ inches and strike an arc from the 2-inch mark on line 1–7–1. To both sides, draw solid lines 4–E and 10–F, using a T-square. Draw line ER 2 inches to the right of line BD, using the T-square and triangle.

Draw half-plan view C and divide the arc into six equal parts and number as shown in figure 1-70. Project the points on the arc with a T-square until each point intersects a line. Notice where the horizontal element lines intersect the vertical element lines in the elevation view. Draw the V-shape miter lines by joining intersecting points 1, 2, 3, 4, 5, 6, and 7. Miter line 1–4 is 45° to line AB. Miter line 4–7 also is 45° to line AB.

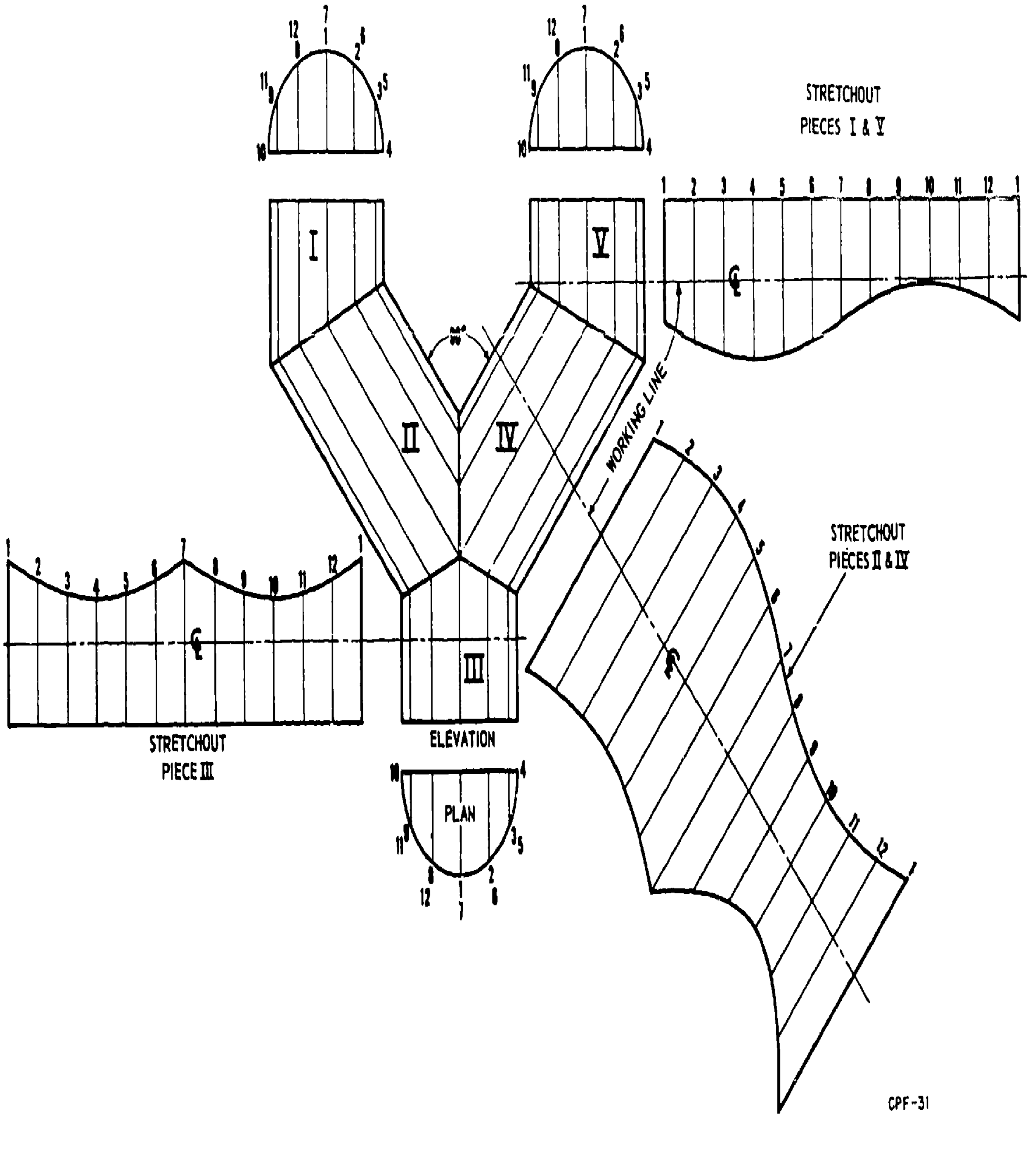


Figure 1-69. Y-branch development.

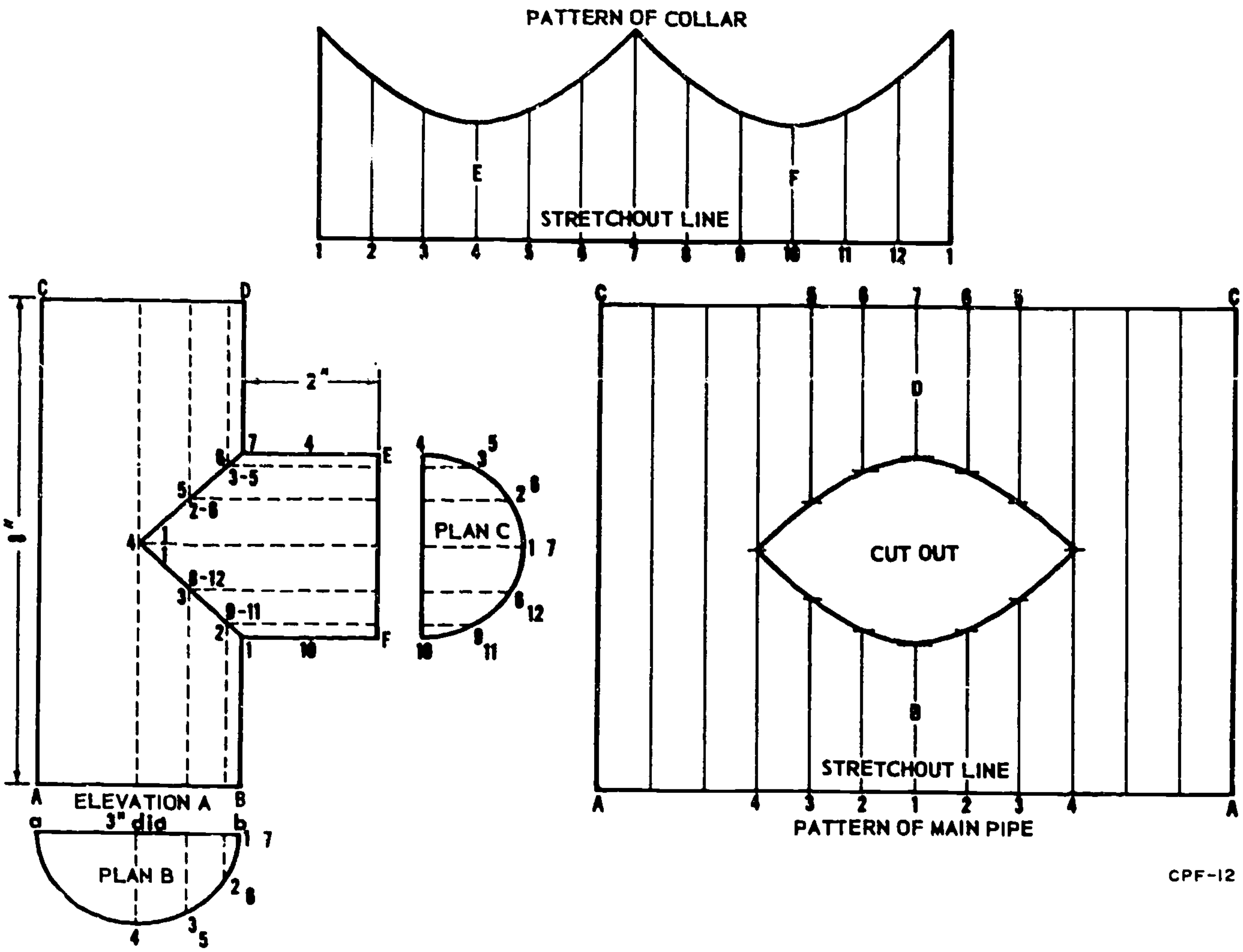


Figure 1-70. Developing patterns for T-joints.

To develop a pattern for a collar, shown in figure 1-70, draw a stretchout line equal in length to the circumference of the pipe. Divide the stretchout line into 12 equal spaces, and elevate the element lines. Transfer the element lengths to the stretchout, and join the intersecting points as before. Notice that the collar will be joined at the cheek.

To develop a stretchout pattern for the main pipe, the length of the stretchout line will be equal to the circumference of the main pipe (9.4248 inches), and the height will be 8 inches. Divide the stretchout into 12 equal parts, and elevate the element lines. Notice that the numbering is somewhat different in this stretchout. In this case, it is easier to start numbering at the center, since the joining point is line AC and the center is line BD. The cutout is on both sides of center. The length of the cutout lines can be projected easily with a T-square from the elevation view; however, these projection lines are not shown in figure 1-70. Points 1 through 7 in the elevation view are projected to form the cutout. When the intersecting points in the stretchout are connected, you have a pattern for the main pipe. Compare the numbering of the element lines in the stretchout with the numbering of the element lines in the elevation view.

This completes our discussion of the parallel line method of pattern development. We have shown you how patterns are developed for elbows, Y-branches, and T-joints. You should have noticed that each round, square, or rectangular duct developed by the parallel line method has not changed in diameter or cross section; therefore, the sides and element lines in each pattern have remained parallel. In the following paragraphs, we will show you how to use the radial line layout method to develop patterns for components, such as cones and pyramids that do not have parallel sides.

Exercises (410):

1. In parallel line development, element lines are __________ or __________ to each other.

2. What type of views are required to determine the length of element lines in developing a pattern for a round pipe?

3. How does the number of gores in a round elbow affect air resistance?

4. The stretchout pattern for a round duct is equal to the __________ of the duct.

5. What is the first rule of parallel line layout?

6. The length of the stretchout line is equal to the __________ of the item to be laid out.

7. A miter line is used in parallel line layout to develop gores for what type of an item?

8. What is the stretchout line equal to on a pattern for a square duct?

9. What two measurements are added together to give you the heel radius of an elbow?

10. How are the cross sections of all components developed by the parallel line method alike?

411. State the procedures and rules to follow when developing a radial line layout.

Radial Line Layout Method. The radial line method of layout is used to develop patterns for sheet metal components that are cone or pyramid shaped. However, each cone or pyramid must have a centerline (vertical height) that is perpendicular to the base; in other words, a right cone or a right pyramid. While the characteristics of the radial line method of pattern development differ somewhat from those of parallel line development, you will notice that certain steps, such as drawing the elevation and plan views, are similar. Figures 1-71 and 1-72 will show you these basic similarities. For example, in each illustration the elevation view shows the height of the

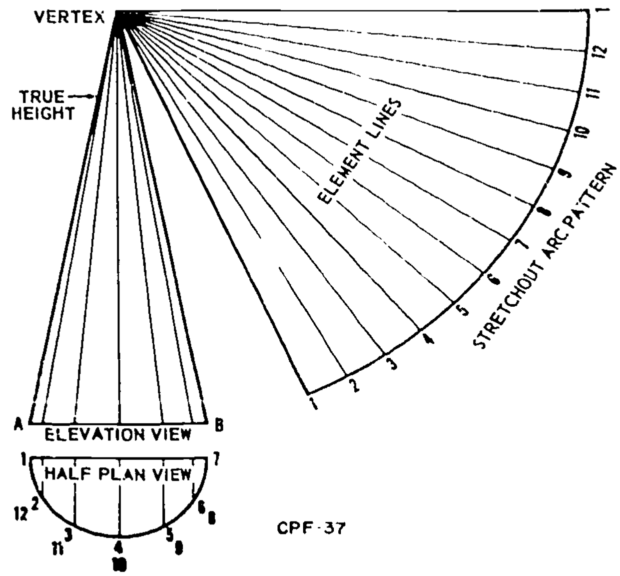


Figure 1-71. Radial line development for a cone.

object, and the plan view determines the length of the stretchout line. These two views are drawn first. Draw the stretchout arc with a radius equal to the true height. Draw this arc long enough to allow each space in the plan view to be stepped off and lettered or numbered. Get the element lines from the elevation view and draw the stretchout to complete the pattern. You studied these operations in parallel line development.

All cone- and pyramid-shaped objects that are to be developed by the radial line method have certain characteristics: a circle for their base or a base that can be

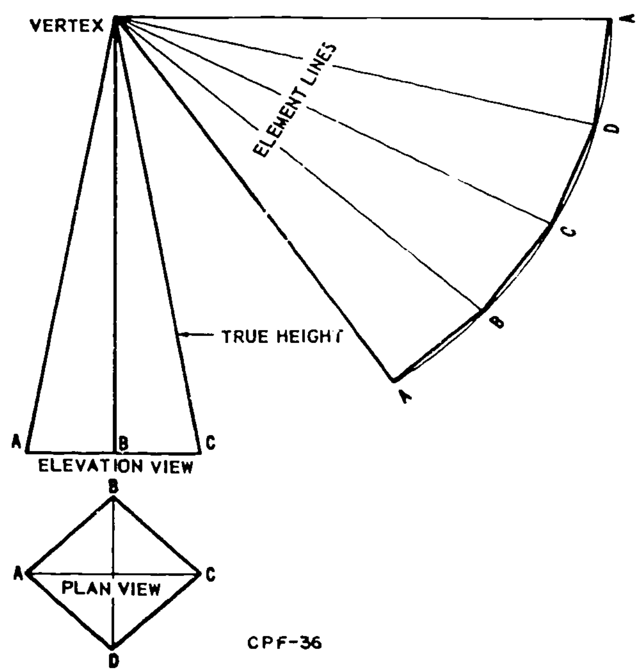


Figure 1-72. Radial line for a pyramid.

inscribed in a circle, and sides that slant to a common vertex located directly over the center of the base. Figure 1-73 shows several examples of bases that can be inscribed in a circle.

To obtain the true height for a pattern, first study the illustration shown in figure 1-74 and notice the vertical height, BO, shown in the elevation view (ABC), then examine the plan view which shows the shape of the pyramid base. Observe that the plan view is inscribed within a circle. To get the true height, set the compass equal to the distance O'Y', using O as a center, and make an arc on the extended line AC at point Y. Then, draw the slanting line BY, which is the true height of the pyramid and will be the true length of the radius in the stretchout.

Figure 1-75 shows (view B) an example in which the position of the base in the plan view is arranged so that the slant height (AC) in the true elevation view also will be the true radius for the stretchout arc. Do not make the mistake of using the slant height (AB), as shown in the front elevation view (view A), for the true radius of the stretchout arc. When the pattern is cut and formed, the height of the pyramid will be considerably less than desired.

In view B of figure 1-75, the elevation view appears larger because the slant line AC will be the true length for the radius in developing the pattern. The ultimate shape of the object depends greatly on the arrangement of the elevation and plan views. This clearly shows that, to construct the true height, you must draw the base of the elevation parallel to a diagonal line which is the widest part of the plan view.

Although there are similarities between radial line development and parallel line development, you have just learned one of the differences. To determine the true height of a pyramid, it is necessary to draw the plan view before drawing the elevation view.

Right pyramid. The shape of the pattern for a right pyramid having six sides can be illustrated by holding its vertex at a definite point and rolling the pyramid, as shown in view 1 of figure 1-76. This shows the outline of each face of the pyramid as imprinted on the surface over which it is rolled; view 2 shows the stretchout of the same pattern.

To develop a pattern for a six-sided pyramid, first draw the plan view, which in this case is a hexagon. The dimensions of this hexagon are the same as those of the base of the pyramid. Each edge is numbered as shown in the illustration. From these numbered points, project vertical lines downward to intersect the base line of the elevation view. This establishes points 1 through 6. Point C is the vertex, which is determined by the vertical height of the given pyramid. From the points of intersection on the base line, element lines are drawn to the vertex. All lines from the vertex C represent edges of the pyramid that are equal in length; however, they do not appear so in the elevation view because of the inclined surfaces. Therefore, only the outside lines give the true lengths for uses as the radius of the arc in the stretchout. Next, draw the arc for the stretchout and step off points 1 through 5 with spaces equal to the length of any side shown in the plan view. Number these points as shown in view 2. The points located along arc AB are each connected with straight lines and element lines drawn from each point to the vertex. This completes the pattern. Although the element lines you have just drawn are not absolutely necessary when forming the pyramid, they do clearly show where the folds will be made when the object is formed.

Truncated pyramid. A pyramid with the top cut off (truncated) parallel to the base is called a regular frustum of a pyramid. A pyramid with the top cut off at an angle to the base is called an irregular frustum, as shown in the elevation view of figure 1-77. The pattern for an irregular frustum of a pyramid is developed in a manner similar to that for an entire pyramid—with the exception of the element lines, which are no longer the same length. To construct this pattern, draw the plan view and elevation view as described previously; this provides the shape and dimensions of the pyramid. Observe in the elevation view that lines have been constructed to locate the vertex of the pyramid; this is an essential part of the pattern. The plan view shows the base outline of the pyramid from which the side widths may be obtained. Draw the stretchout the same as for an entire pyramid, except for the length of the element lines. You are now at the step where the method of obtaining the true length of the element line is different because of the truncation.

Suppose the pattern begins with the shortest element (line O'−1). This element line, as seen in the elevation view of figure 1-77, is of true length and can be transferred to the stretchout. Element lines 2, 6, 3, and 5 do not show their

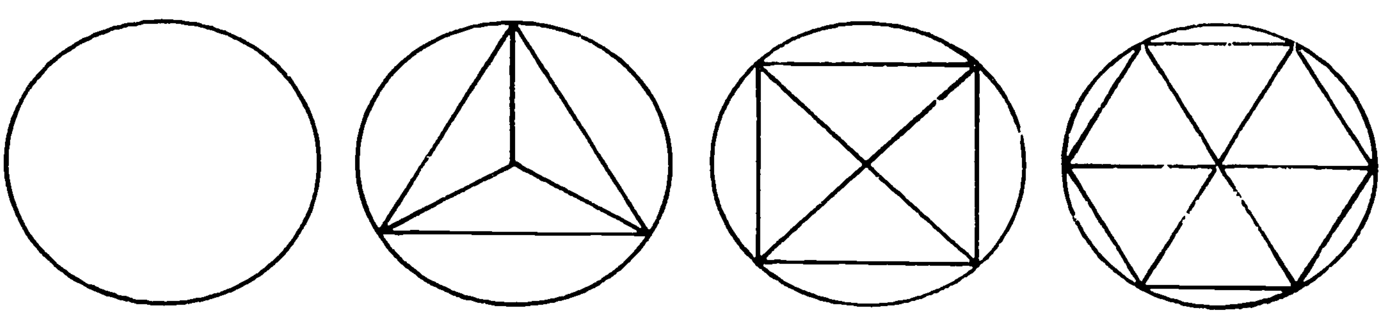


Figure 1–73. Bases that can be inscribed in a circle.

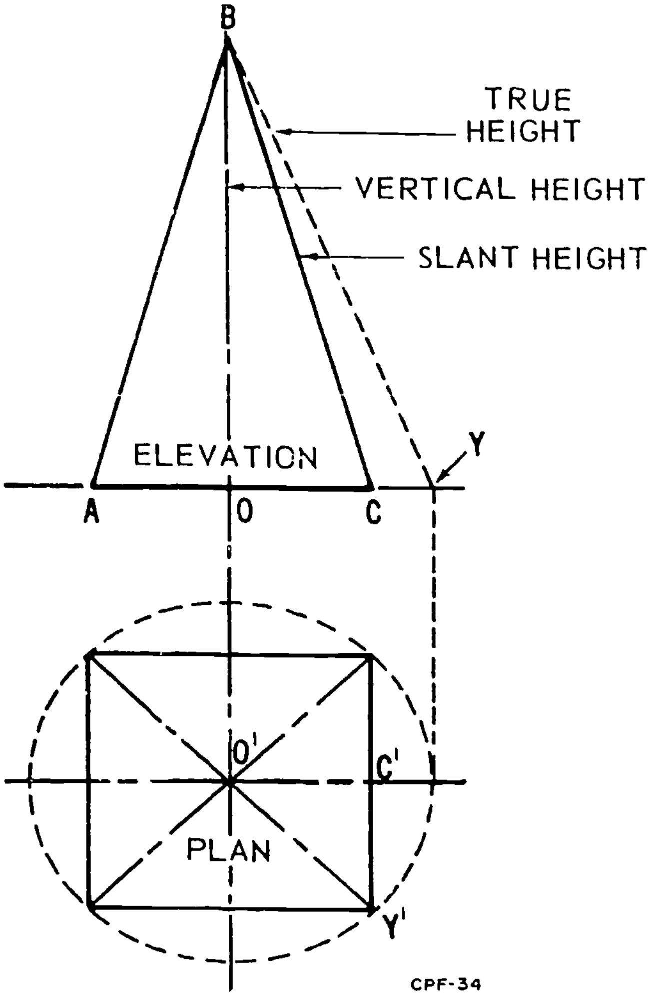


Figure 1–74. Height of a pyramid.

true lengths because they are inclined to the plane of projection. This means that, to find their true lengths, you must imagine the pyramid's being rotated until the edges concerned come into the position of element line 1, where the true lengths can be seen. To accomplish this on the elevation drawing, draw a horizontal projection from the upper end of element lines 2 and 6 until it crosses the extension of element line 1. The true length of element lines 2 and 6 is the distance from this point of intersection to the base line of the elevation view. Find the true length of element lines 3 and 5 in the same manner. Element line 4 is shown in its true length and need not be projected. These true lengths along line O–1 are transferred to the stretchout to form the pattern. The points of intersection are connected with a straight line, resulting in a completed pattern for a truncated pyramid.

Right cone. Developing a pattern for a cone is somewhat simpler than for a pyramid because the true height and slant height are the same. The radial line method of pattern development is used also for whole cones or truncated cones with the tops cut off, as shown in figure 1-78. A cone

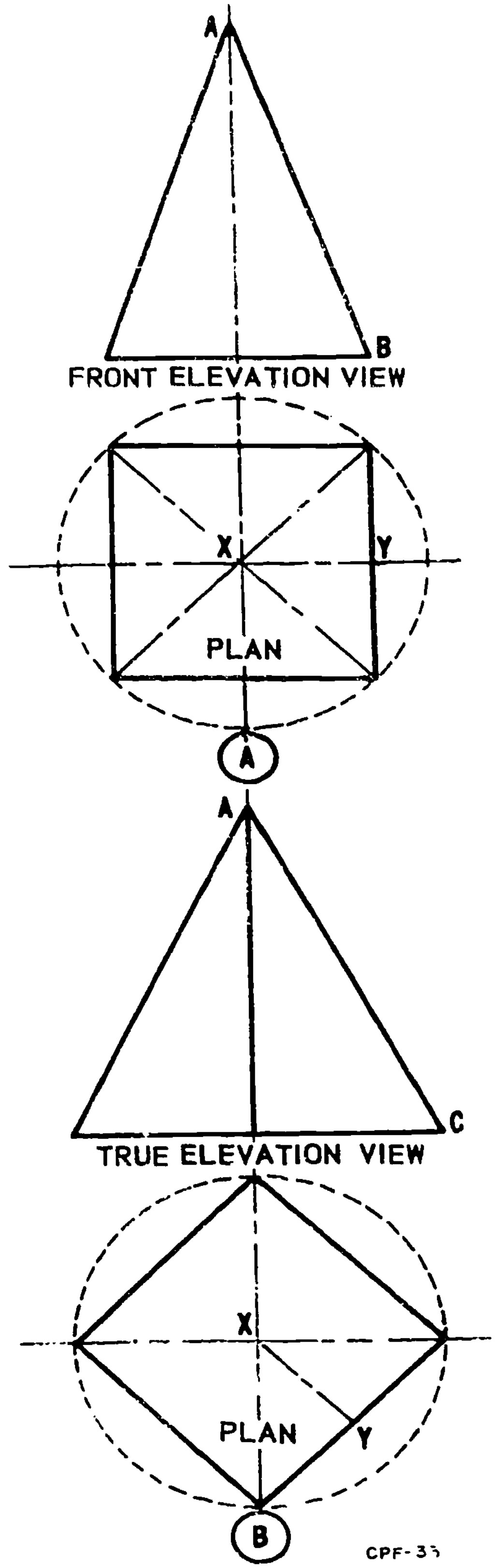


Figure 1–75. Arranging a plan view of a pyramid.

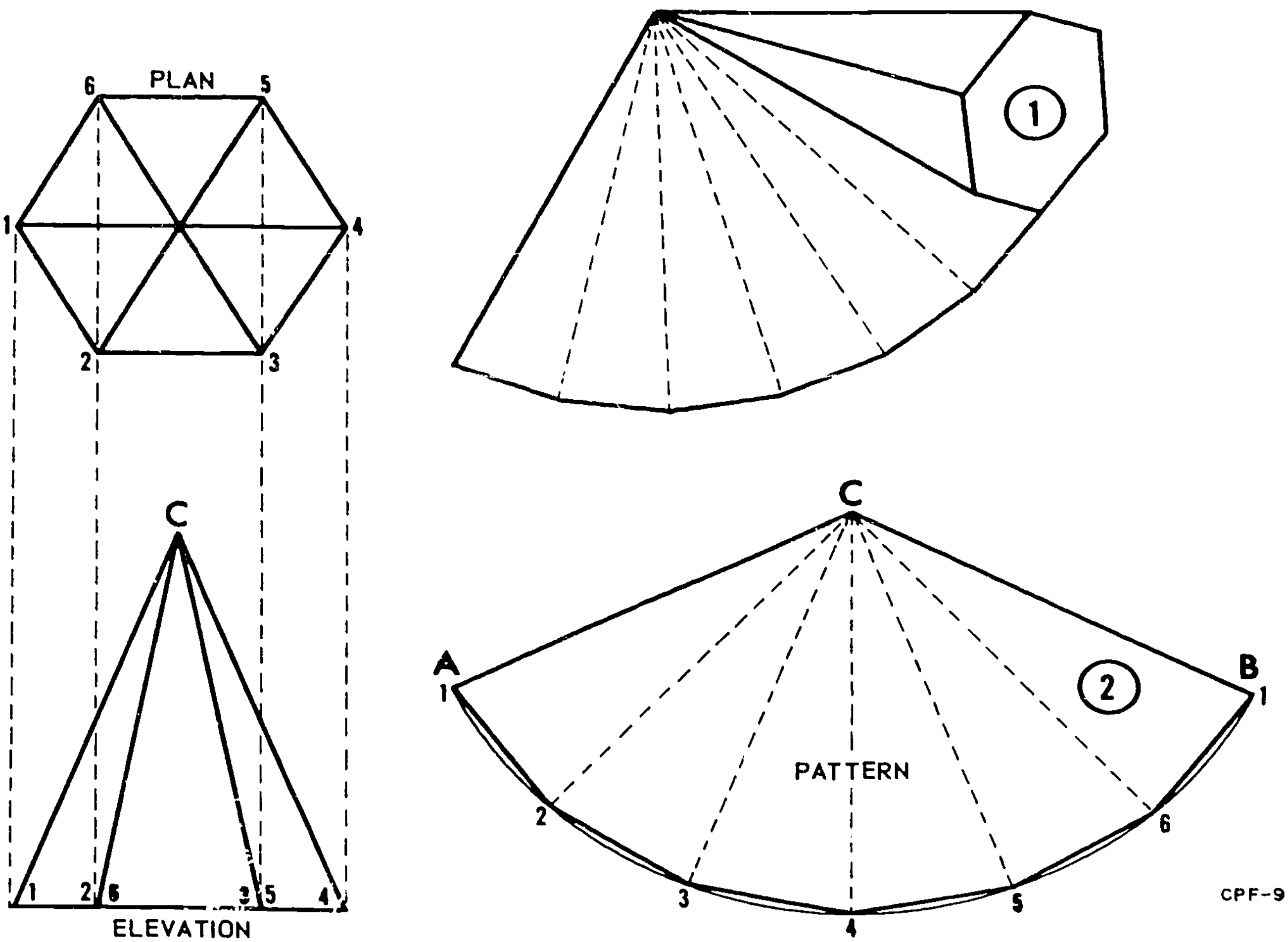


Figure 1-76. A right pyramid.

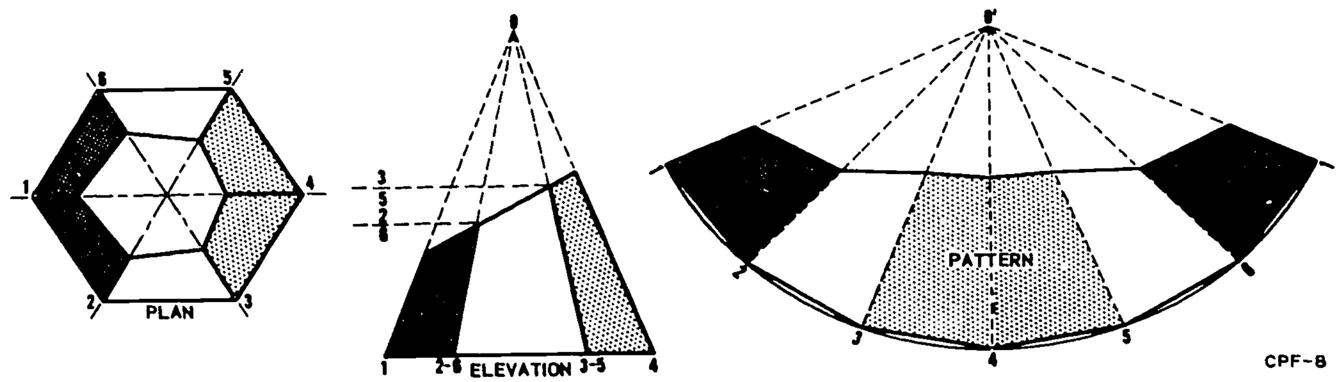


Figure 1-77. Truncated pyʳamid pattern development.

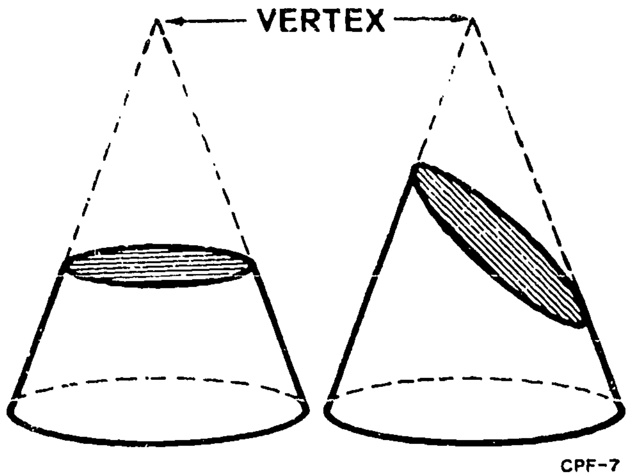


Figure 1–78. Truncated cone.

with the top cut off (truncated) parallel with the base is called a regular frustum. One with the top cut off on any angle with the base is called an irregular frustum. Generally, the pattern for a cone is fan shaped, as shown in figure 1-79; when the object is unrolled, the stretchout pivots (radiates) around the vertex.

To develop a pattern for a regular frustum of a cone, you must draw the elevation and half-plan views. In figure 1-79, the vertex is lettered A and the base line BC. At any point on the cone, and parallel to line BC, construct a line that cuts off the top portion of the cone and letter line DE. Draw the half-plan view beneath the base of the frustum and divide into equal sections, as previously done in parallel line development. From the numbered points on the half-plan view, erect perpendicular lines to the base of line BC. From the points at which these lines intersect BC, draw lines to the vertex A. These element lines that you have just drawn are not absolutely necessary for the construction of the stretchout pattern; however, they do show that the element lines in the elevation view converge at the vertex. Since line BC represents the widest part of the plan view, lines AC and AB are of true length (true height). Draw the stretchout arc with vertex A as the center and the radius equal to the length of line AC. From the same center, draw another arc with a radius equal to line AE. Element lines need not be drawn, since there are no folds or edges as with pyramids. The area inclosed between the arcs and both No. 1 lines is the pattern for the frustum of a cone. After you add allowances for seaming and edging, the stretchout will be completed.

If an irregular frustum of a cone such as that shown in figure 1-80 is to be developed, the truncation line DE is drawn in the elevation view. This line represents the top edge of the object. Divide the circumference of the half-plan view into equal sections as previously done in parallel line development; in this case, it will be from 1 to 12 to 1. From each of these points, erect a perpendicular line to the base of the frustum. Then, from each point of intersection with the base, draw radial lines to the vertex. From each point where the radial lines intersect the truncation line on the elevation, project horizontal lines to line AC and numbers 1 through 12, as shown. The distance from the vertex along line AC to any of these points will give you the true length of the corresponding radial line.

To construct the pattern, draw the stretchout arc with a radius equal to the distance from A to C, as shown in figure 1-80. Now, divide the stretchout into 12 equal spaces and number to correspond with those in the half-plan view. From the points of intersection with the stretchout arc, draw element lines to vertex A. It is necessary to construct these lines because they are essential in developing the pattern. Next, with a compass and using the vertex as a center, measure the distance between points A and 1 along line AC. Transfer this measurement to the stretchout arc; again using the vertex as center, swing an arc to intersect the corresponding element line (1) in the stretchout arc. Repeat the procedure for each of the numbered horizontal lines in the elevation view. Then, with an irregular (French) curve, connect these points. This curved line determines the top edge of the pattern, and the stretchout arc determines the lower edge.

We are going to describe a job situation that you may encounter. Suppose you are to replace a piece of half-round

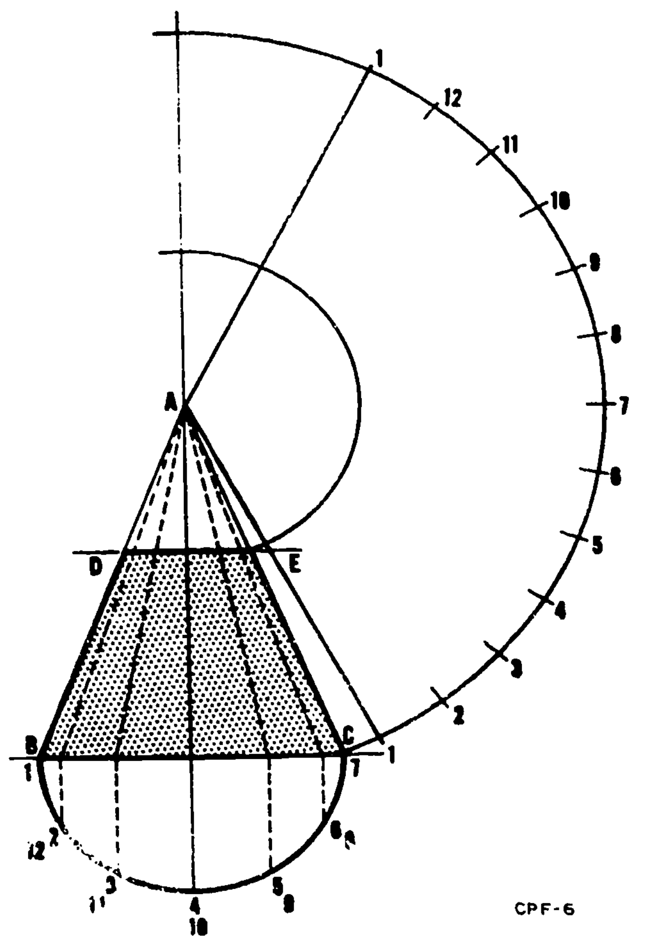


Figure 1–79. Regular frustum pattern development.

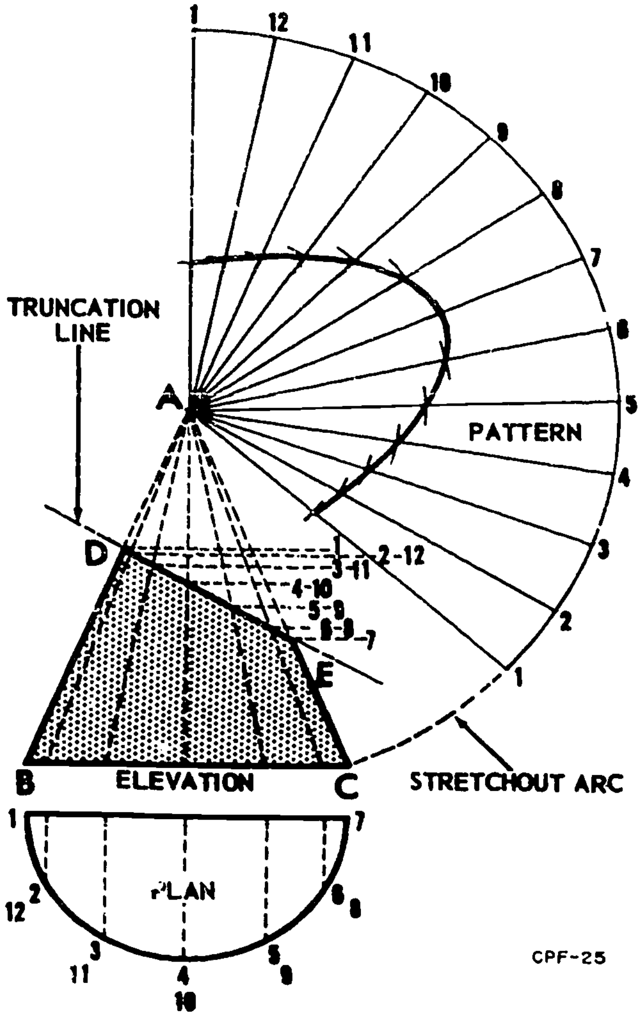


Figure 1–80. Irregular frustum pattern development.

gutter with a 4-inch downspout outlet that is tapered to 2 inches. In the pictorial view of figure 1-81, you can see that a miter is needed so that the downspout connector will fit the contour of the gutter. To lay out the downspout connection, you will have to determine which layout method to use. (Since the downspout connector is tapered, the radial line method will be used.) Begin the pattern by drawing an end view of the gutter 6 inches in diameter, as shown in the illustration. Next, draw the elevation view and half-plan view. After determining and numbering the dividing points on the half-plan view and drawing the element lines in the elevation view, project and number the horizontal lines. After the stretchout arcs are drawn and divided into 12 equal spaces, extend the element lines to the vertex. Determine the length of the element lines and transfer them to the pattern. Notice how this pattern, if rolled up so that both No. 2 element lines meet, will fit the contour of the gutter.

To develop a pattern for a tapering roof collar, draw the half plan and elevation views as if for a regular frustum; and at the desired height, draw a line that cuts off the top of the cone parallel to the base and perpendicular to the centerline. This line must equal the diameter of the vent. Divide the half-plan view into equal sections as done previously in parallel line development. From the numbered points on the half-plan view, erect perpendicular lines to the base line of the elevation view. From the point at which these lines intersect the base, draw lines to the vertex. Now, draw a line from the point where the base and one side intersect to the other side, at an angle equal to the pitch of the roof. Notice that you now have two lines that cut across the elevation view; both are needed.

From each point where the radial lines intersect the lower truncate line, project horizontal lines to the side of the cone. You now have the true length lines for each radial line.

Now, to construct the pattern, draw the stretchout arc. Divide the stretchout into equal spaces to correspond with the spaces in the plan view. Remember, you need to reach around the complete circumference of the base. From these points, draw radial lines to the vertex.

With the vertex as center and a radii equal to the true length, swing arcs to intersect the corresponding radial lines in the stretchout. Connect these points with a curved line that will form the bottom edge of the collar so that the single arc near the top will form the top edge.

This completes our discussion of the radial line method of pattern development. We have shown you how patterns are developed for tapered components such as pyramids and cones.

Exercises (411):

1. In radial line layout, all element lines meet at the ________.

2. In radial line layout for a pyramid-shaped object, why must you draw the plan view before drawing the elevation view?

3. To find the true length of the element lines on a truncated cone, all element lines must be projected ________ to the side element line.

4. How many truncate lines are there in the layout of a tapering roof collar?

5. In radial line layout, where is the center for arcs that intersect the element lines?

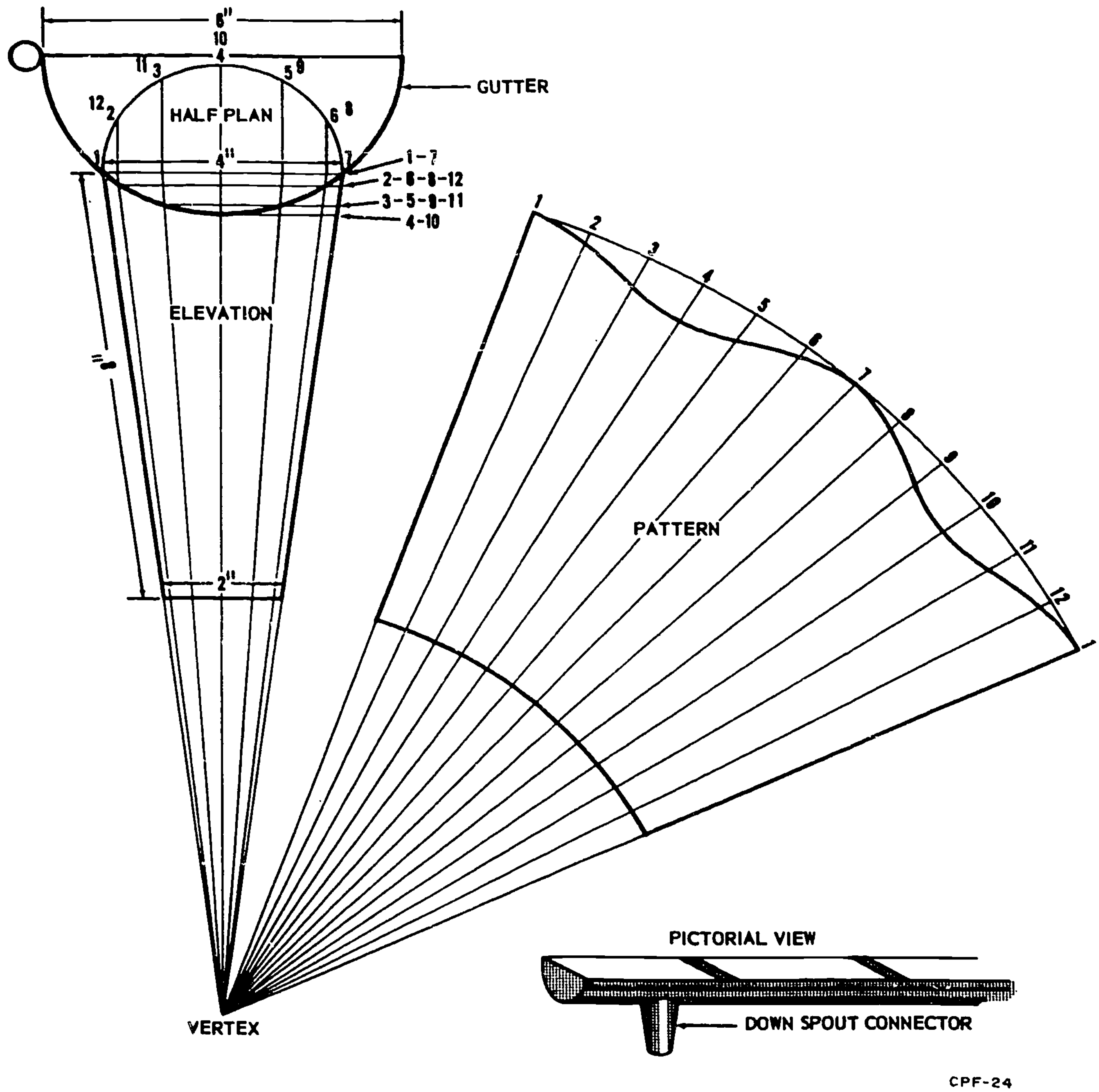


Figure 1–81. Making a pattern for a gutter downspout.

6. The true height and the slant height are the same in which radial line development?

412. Tell ways to check pattern layout and specify layout procedures.

In the following paragraphs, we discuss the triangulation method of pattern development for components that do not have a common center or parallel sides.

Triangulation Layout Method. You are probably beginning to realize that, regardless of how complicated the component may be, you can develop a pattern for it by applying the principles in this section (parallel line, radial line, or triangulation methods). There are many irregular shapes, such as transitions and offsets, in sheet metal work that have patterns that cannot be developed by the methods already explained. Examples of transitions are shown in figure 1-82. Notice that lines drawn on these irregular shapes do not run parallel with each other or meet at a common point. Instead, the surface is divided into a series of triangles that slope in many directions. Finding the true lengths of these sloping triangles makes it possible to develop the patterns.

In triangulation, the surfaces of the elevation and plan views are divided into a convenient number of triangles, the sides of which form the element lines. When you look at these element lines from the plan view and elevation view, they appear shortened. To make this a little clearer, suppose you take a pencil about 6 inches long and hold it at arm's length, perpendicular to the line of sight, as shown in figure 1-83. Now, as you tilt the top end of the pencil away from you, notice how its length appears to shorten. If you measure the pencil in this position, it will still be 6 inches long, although it appears shorter.

Before the sloping lines of transitions can be transferred to a pattern, their true lengths must be found by making a true length chart. In some cases, it is necessary to show the element lines in two views as a basis for finding these true lengths. The elevation view shows the vertical height of the element lines, and the plan view shows the horizontal distance covered by the same lines. You can see in figure 1-84 how these two distances are laid off as the sides of a right triangle the hypotenuse of which shows the true length of the element line.

Square-to-square-twisted. Now let's apply the triangulation principles in the development of an object which has relatively few element lines and will demonstrate true length. The first step is to construct the plan view and label the points as shown in figure 1-85,a. Notice that the smaller opening is twisted 45° from the larger. Draw the element lines from all corner points, 1 to A, 1 to B, 2 to B, 2 to C, etc. Next draw the elevation view to show the side and the height of the component (see fig. 1-85,b). These two views give you all the information you need to construct the pattern. None of the element lines in either the plan or the elevation views are true length. To determine the true length of each line, you must construct a true length chart as shown in 1-85,c. The distance marked on the vertical leg of the chart is taken from the elevation view (fig. 1-85,b) and is equal to the vertical height of the component. The distance marked on the horizontal leg of the chart is taken from the plan view and is equal to the horizontal distance each element line travels. In this pattern, all the element lines are equal because the small opening is centered on the larger; thus, line 4C–4D = 3B = 3C = 2B = 2A, etc. Now we are ready to actually develop the pattern. To avoid confusion, start with line 1–2, and draw it equal to the length shown in the plan view (fig. 1-85A). (Note that this line is shown in its true length on the plan view and does not have to be charted on the true length chart, fig. 1-85,d). Now, using the true length of line 1–A (from the true length chart) and 2–A (also from the true length chart), complete triangle 1–A–2. To do this, set a compass to the true length of these lines, and using points 1 and 2 as centers, draw intersecting arcs to find point A. Now we will construct the rest of the triangles in the same sequence as they appear in the plan view. The next triangle is 2–A–B. First set your compass to distance A–B on the plan view; then, using point A on the pattern as center,

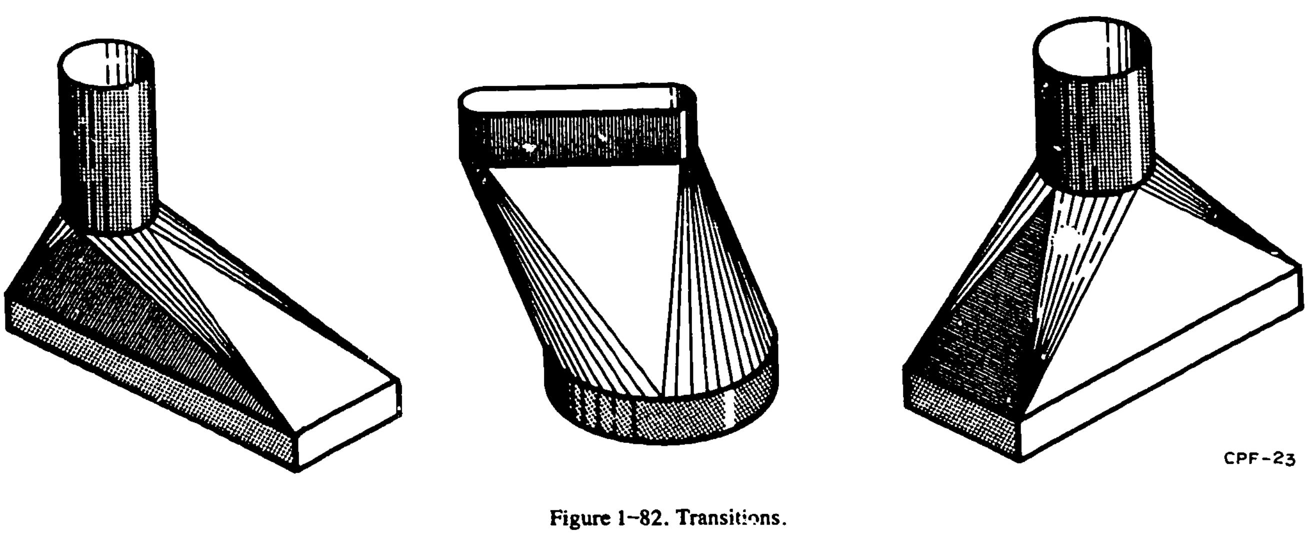


Figure 1–82. Transitions.

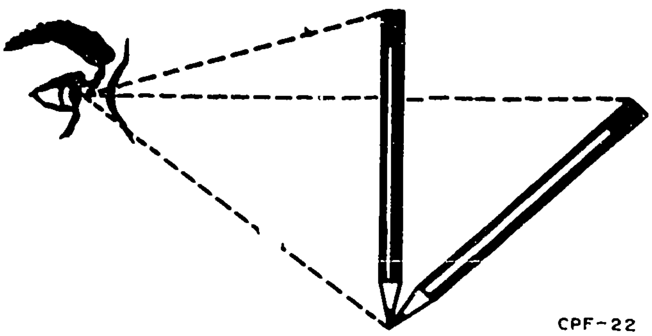


Figure 1–83. Line of sight.

draw an arc as shown in figure 1-85,d. Now set the compass to the true length of line 2–B (from the true length chart). Use point 2 on the pattern as center and draw an arc to intersect the first one—this locates point B and you can now complete triangle 2–A–B. Continue this procedure for triangles 2–B–3, 3–B–C, 3–C–4, 4–C–D, 4–D–1, and 1–D–A, as shown in figure 1-85,d. Note that you have two lines 4–C, this will be the seam when the component is formed and these lines *are* the same. Now let's apply this same procedure to a component with more element lines.

Square-to-round symmetrical transition. A transition is a sheet metal component designed to connect pipes or ducts of different shapes. Figure 1-86 is a pictorial view of a rectangular-to-round transition piece, and figure 1-87 shows the development of a square-to-round pattern. Both polygons are symmetrical; the pattern development procedures are the same for both. In figure 1-86, the transition is made up of one isosceles triangle where the sections join. In addition, eight parts with curved surfaces form one-fourth of the round opening and their vertexes meet in corners A, C, E, and F (F is not shown).

Only a half pattern of the stretchout shown in figure 1-87 is needed because the transition piece is symmetrical in shape. You will have to cut two pieces to this pattern in order to complete the transition. Figure 1-87 shows the various steps necessary in the development of this pattern. First, draw the plan view as shown, keeping the exact diameter and diagonal of the round and square connectors. In other words, ABCD represents the square end, and the circle represents the round end. Divide the circle into equal parts and number 1 to 7 to 12. From the numbered points on the circle, draw straight lines to vertexes A, B, C, and D to form right triangles. Next, draw the elevation view to determine the distance between sections being joined.

From the numbered points on the plan view, project lines parallel to the centerline so that they intersect the top of the elevation view. Number these points of intersection to correspond to the numbers in the plan view. When element lines are drawn from the numbered points to the corners of the base, triangles are formed. These are not true length element lines. To determine the true lengths of these element lines, you must set up a true length chart, as shown in figure 1-87, by drawing a right angle with a vertical height equal to H. Beginning with element line A–1 in the plan view and using a compass, transfer lines A–1, A–12, A–11, A–10, and G–10 to the base line of the true length chart and number respectively. From the center of the plan view, you can see that the transition has four identical parts with several element lines of the same length. This is why the true length chart shows multiple numbers for each true length line. From the numbered points on the base line, draw straight lines to form a vertex. These straight lines are the true lengths of the element lines.

To start the half-pattern stretchout for the transition shown in figure 1–87, draw a horizontal line which is equal in length to AD in the plan view. Set the compass to the true length of element line A–1, and using A and D in the half pattern as centers, swing two arcs so that they intersect. Number the point of intersection 1-7. Next, set a compass equal to the distance between points 1 and 2 in the plan view and transfer to each side of point 1–7 in the half pattern. For simplicity, this compass should be left adjusted to this setting since it will be repeated and another compass used to transfer the lengths of the remaining element lines of various lengths from the true length chart. (For greater accuracy, this measurement often is made by drawing a stretchout or straight line of the round end of the transition.) The round end shown in the plan view has 12 spaces; therefore, a straight line for this example would be divided into 12 equal spaces. This method is more accurate because the straight-line distance between two points on an arc is actually the length of a chord between the points rather than the length of the arc between the two points.

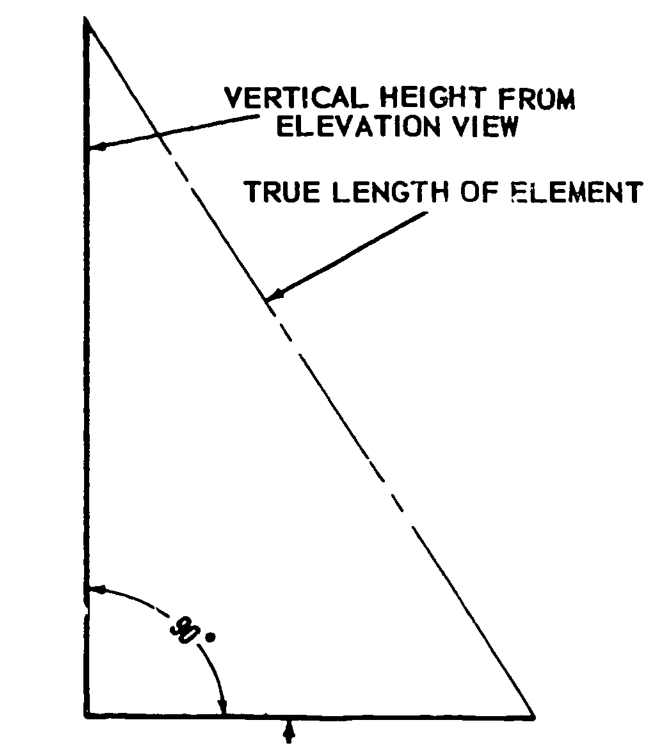


Figure 1–84. True length line.

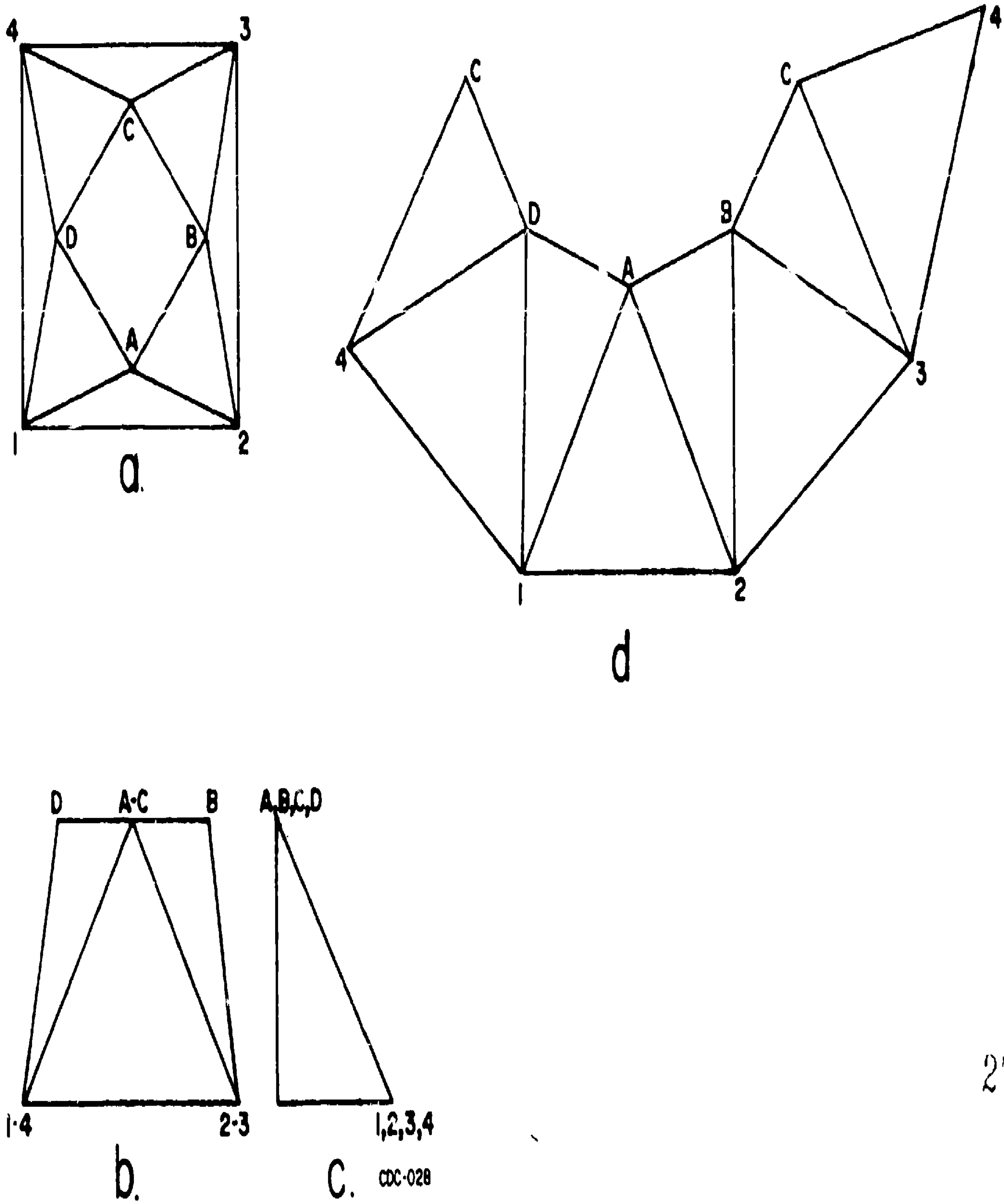


Figure 1-85. Square-to-square-twisted.

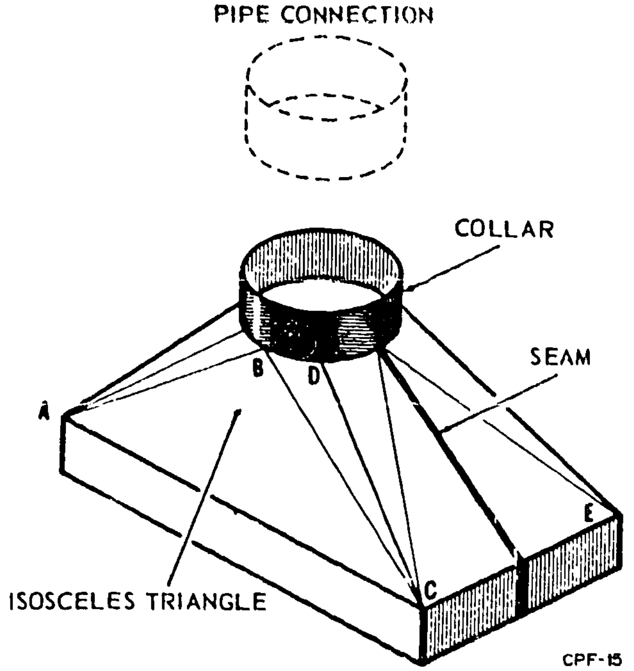


Figure 1-86. Transition.

The compass which is set to the distance between points 1 and 2 in the plan view is used repeatedly to establish the distance between the remaining points to the left and right of point 1–7 on the half pattern. The arcs that have been drawn to each side of point 1–7 (half pattern) are now to be intersected by arcs swung from points A and D. The radii of these arcs are taken from the true length chart, line A–12 (D–2). Establish the remaining points to the left and right of the vertex by repeating these steps, using the appropriate true length lines. After your number each point and drawing the element lines, the final steps are to locate points G and H.

To locate G and H, set the compass to the true length 10–4; and with 10 and 4 as center, scribe arcs at G and H on the half pattern. Then, set the compass to DH; and with D and A as centers scribe intersecting arcs at H and H and draw lines A–G, G–10, D–H and H–4. By connecting all points of intersection with straight or curved lines, you complete the pattern. This final step forms the two right triangles at the extreme ends of the half pattern.

You have seen why a transition that is symmetrical requires only a half pattern. However, a transition with a double offset will require separate half patterns, since all four sides are different.

Offset rectangle-to-round transition. A pattern for an offset rectangle-to-round transition is developed in much the same way as a square-to-round transition, and a half pattern will be sufficient if the offset is only to one side of the center. The rectangle-to-round transition with the round section off-center has two equal sides on either side of the centerline, as illustrated by line EF in the plan view of figure 1-88.

Draw the plan view and the elevation view with the round section off center. Draw the elevation view to the desired height (8 inches, in this case). The two true length charts represent the element lines for each quarter part of the half pattern and are lettered A and B. The true lengths of the element lines are found by using the same methods that are used for square-to-round transitions. The half pattern is developed, using the measurements of the rectangular base, circumference spacing, and the true length element lines.

Offset cone. The offset cone is developed in the same way as the components we have already discussed; however, there are a few additional steps. Notice in figure 1-89 that there are two circumferences for the frustum that do not share the same center. Connecting the points of each circumference forms the base of triangles, such as triangle 2–3–4, which is necessary for pattern construction. Two true length charts (one with solid lines and one with broken lines) are used to avoid confusion when transferring true lengths to the pattern. Other than this, the method of developing the pattern for an offset cone is similar to that for developing a pattern for an oblique cone.

Since this particular frustum is symmetrical in shape (two equal halves), only half of the required element lines need to be drawn in the plan view. After you draw the plan and elevation views, divide the circumference in the half-plan view into the same number of equal parts. Number these points so that the even numbers are all on one perimeter and the odd numbers on the other. From the numbered points in the plan view (starting from point 1), draw a solid line from 1 to 2, then a broken line from 2 to the odd No. 3. Continue this process until the plan view resembles the one shown in figure 1-89.

To determine the true length of the element lines, it is necessary to draw two true length charts, as shown in figure 1-90.

To construct the pattern for an offset cone, as shown in figure 1-91, the half-pattern stretchout is begun by drawing line 1–2 (its true length), which is obtained from view A of the true length chart. This is the reference line for the pattern, and all future points or lines must be built around it. The distances between the odd-numbered points (1 through 13) on the base line of the pattern are equal and identical to the distances between the same numbers in the plan view. The distances between the even-numbered points (2 through 14) of the pattern are equal and identical to the distances between the same numbers in the plan view. The element lines of the pattern are not equal in length, but are identical to the lengths of the corresponding numbered lines in the true length charts. To complete the pattern, except for seam allowances, connect all points of intersection with smooth curved lines.

Remember that, in pattern development, the numbering of element lines begins where the component is to be joined. For patterns made by the triangulation method, the numbering starts at the center of the pattern.

Many items are developed by triangulation. As you look around the base, each sheet metal item you see was developed through one or a combination of the layout methods we have discussed. This completes our discussion of layout methods. You have studied how the parallel line method, radial line method, and triangulation method are used to develop patterns for sheet metal components.

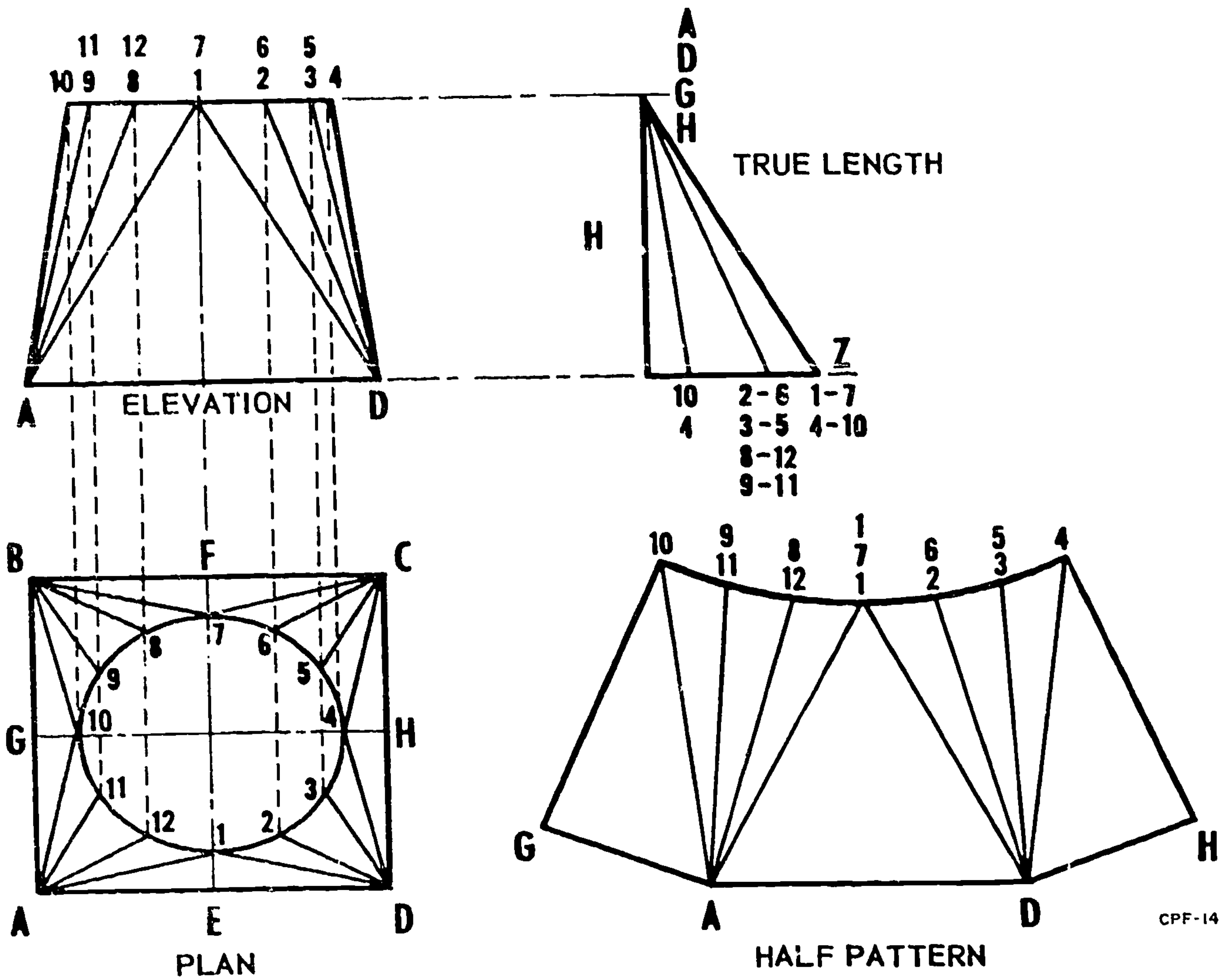


Figure 1-87. Developing a square-to-round transition pattern.

Exercises (412):

1. If an element line travels 5 inches on the plan view, and the elevation view shows the object to be 5-inches high, what is the true length of the element line?

2. Why are two true length charts helpful when laying out an offset cone?

3. Why are two compasses helpful when using the triangulation method?

4. Mark the components requiring triangulation development.
   ____ a. Round elbow.
   ____ b. Square-to-Round transition.
   ____ c. Cone.
   ____ d. Offset cone.

5. How many views of an element line are needed to determine the true length of an element line?

6. Why is only a half pattern necessary for symmetrical transition?

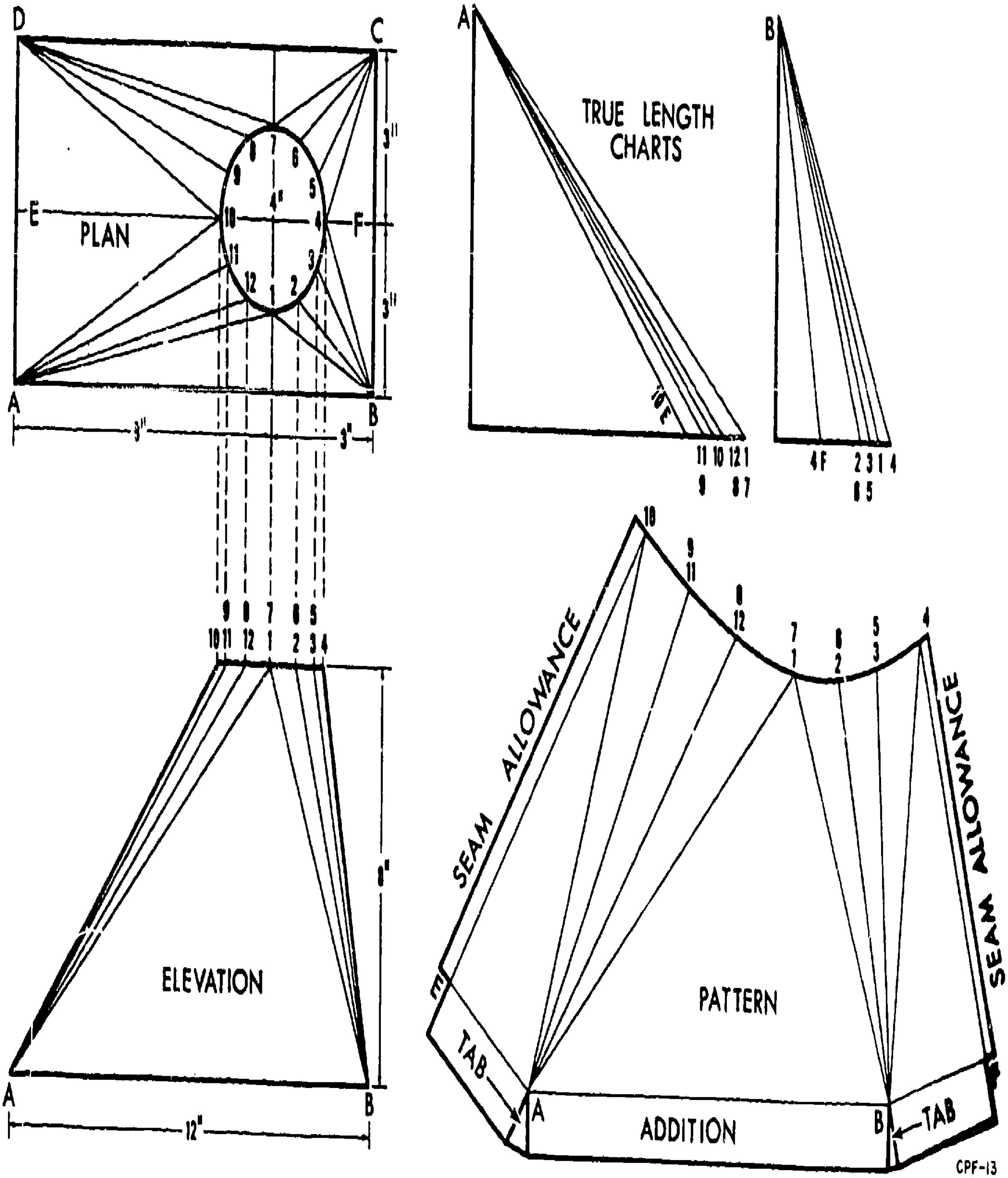


Figure 1-88. Developing a rectangular-to-round transition pattern.

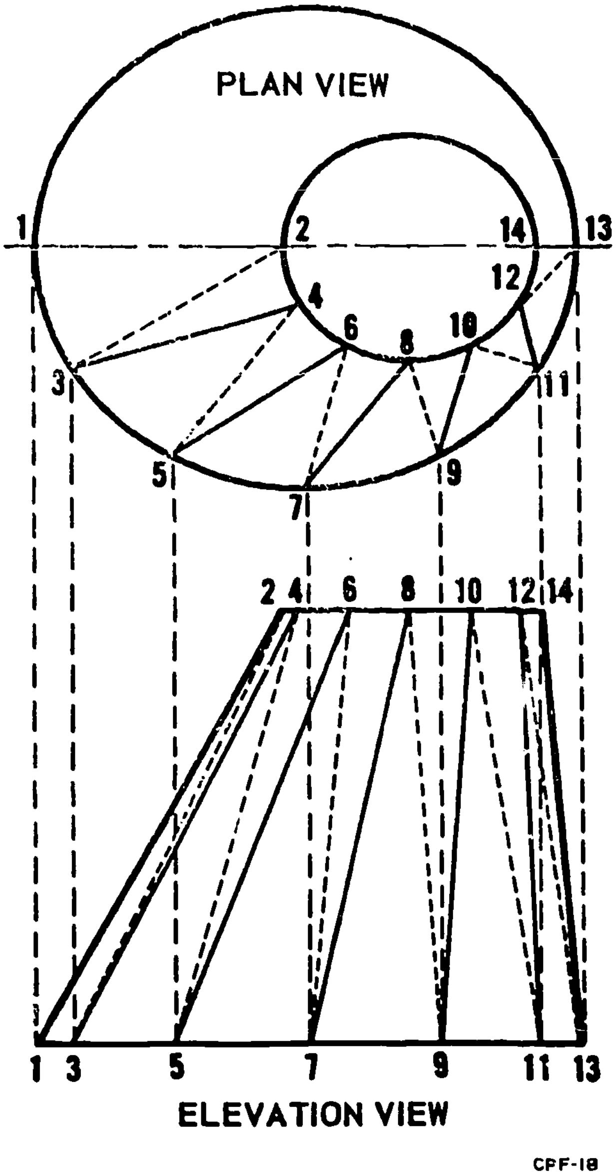


Figure 1-89. Offset cone.

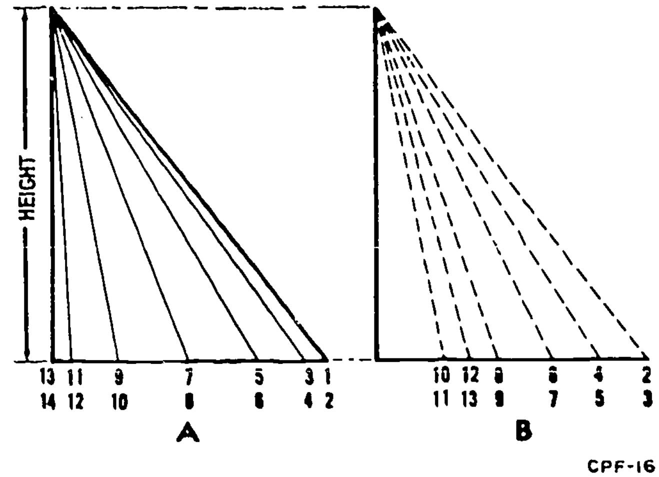


Figure 1-90. True length chart.

413. State the location of and the effect on the size of material by seam allowance and additions.

To simplify these discussions, we have not considered seam allowances and additions, although in actual practice they are included in the pattern development. In the following paragraphs, we discuss seam allowances and additions which are made and described on the pattern.

Seam Allowances. In figure 1-88, you can see an example of seam allowances and additions to a pattern for a transition. Sheet metal patterns such as the two halves of the transition are assembled with seams. (Later in this course, you will learn to make and use several types of seams, such as lap seams and various types of lock seams.) Any one of these requires additional length or width to a pattern. Patterns developed by the parallel line, radial line, or triangulation method do not include allowances for seams; therefore, you must determine how much length or width is to be added. For example, if the transition shown in figure 1-88 is to be assembled with 1/4-inch grooved seams, the pattern must allow for a 3/8-inch extension along line F–4 and 3/8-inch extension along line E–10. These seam allowances must be determined and added to the paper and metal patterns before they are cut out.

Additions. Figure 1-88 also shows *additions* to a pattern. This additional length may be needed for several reasons. For example, if the pattern is for a transition such as that shown in figure 1-86, the additions to each end are probably 2 or 3 inches. However, they can be more or less, depending on how the transition is to be used. The rectangle-to-round transition has additions at both ends which permit the duct to continue in the same direction, although the shape has changed from rectangular to round. Another reason for an addition is illustrated in figure 1-86, where the round addition is necessary to fit into the pipe connection. Still another use for additions is to extend the length of a component a few inches to fill a gap in a duct. If the rectangular end is to be connected to a rectangular-shaped duct, a seam allowance also must be added to the addition.

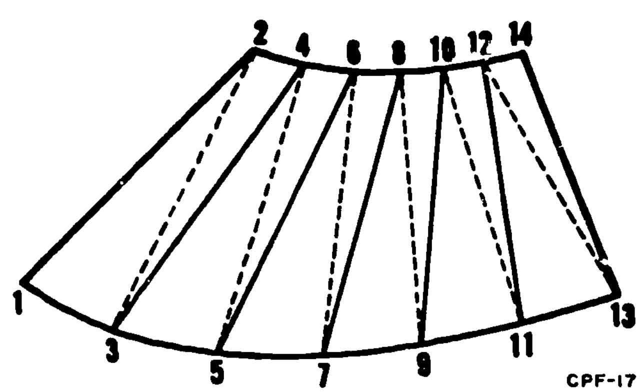


Figure 1-91. Offset cone pattern.

Suppose that you need to add 2 inches to the pattern shown in figure 1-88 at lines AB, AE, and BF. Begin by squaring down from line AB 2 inches at points A and D and striking a mark, repeating the same at points E and F. The marks are joined with straight parallel lines.

Notice that the additions have tabs at A and B. The two tab lines at points A and B are perpendicular to the base lines of the triangles shown in the pattern. Only one of the tab lines at points A and B is cut, so the corners can be joined when the transition is assembled. The tabs are secured by spot welding or riveting when the pattern is assembled.

In figure 1-92, the rectangular duct pattern will need an allowance for connecting ends (a). If the cut is joined without making an allowance for seams, it will have two short sides. Suppose this duct is to be joined with a Pittsburgh lock seam. The seam allowance is determined by the type of seam to be used. To make the Pittsburgh lock seam, allowances are made on each side of the duct. On one side, 15/16 inch or 1 inch is needed, whichever the machine in your shop requires. On the opposite side of the pattern, 1/4 inch is needed to complete the lock seam allowance. The length of the duct also will need allowances, since it will be joined to another duct on one end or both ends. Again, the allowance will be determined by the connection. If you are using an S-shaped hook to join the duct on both ends, you must allow 1/2 inch on either end of the length, since it requires a 1/2-inch allowance. All element lines to be folded should be notched, as shown in figure 1-92, so that the connection can be made more easily.

Layout tools useful for drawing seam allowances and additions on paper patterns include the compass, T-square, irregular (French) curve, steel rule, and triangle. The layout tools used to make seam allowances and additions on metal patterns include the framing square, combination set, dividers, and scribe. The procedures involved in making seam allowances and additions to patterns include using these tools to measure and make parallel lines.

Exercises (413):

1. Do additions for seams on a layout pattern increase the size of the item?

2. Explain where the seam allowance is placed.

3. For a 1/4-inch grooved seam, how much extension must be made on a pattern?

4. Why are additions made to both ends of a rectangular-to-round transition?

5. What layout tools are used to make seam allowances and additions to metal patterns?

414. State ways to eliminate mistakes and insure correct pattern transfer.

Transferring Patterns to Metal. In the previous discussions about layout, you probably wondered why it was suggested to first draw the pattern on paper. Two reasons for using paper are: (1) development lines can be seen much more easily on paper during the layout process and (2) materials can be saved when several different patterns are arranged on the sheet metal close to each other. In a previous section, we referred to making templates

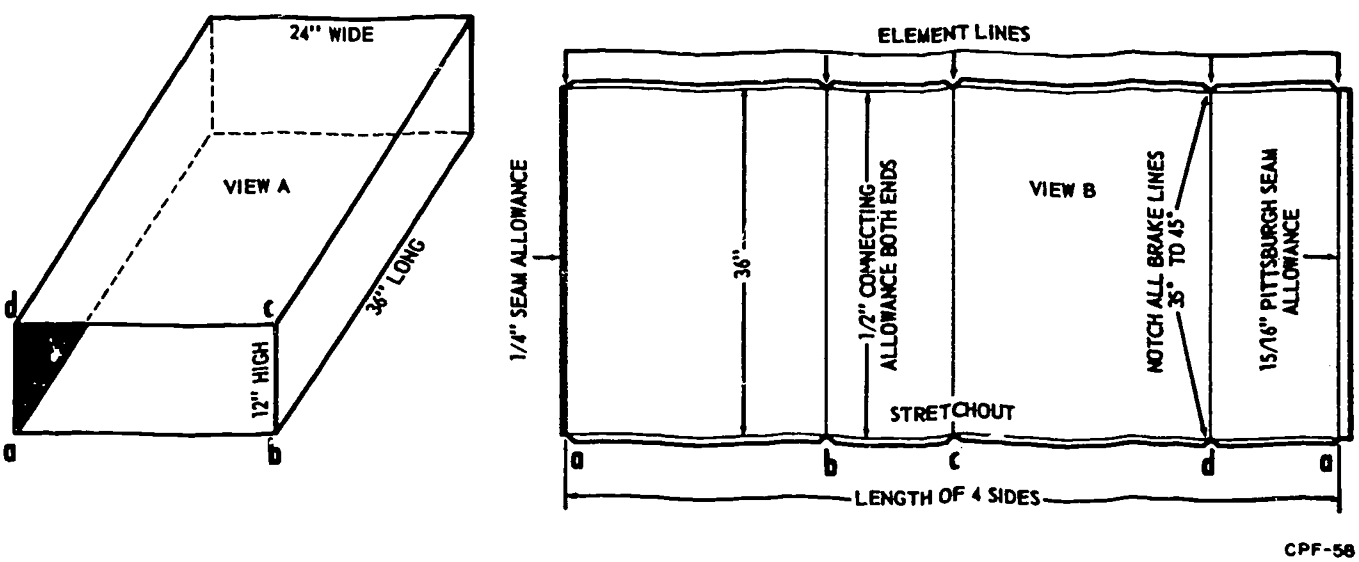


Figure 1–92. Seam allowance for a rectangular duct.

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(metal patterns) of components that are frequently made in the shop. When several of the same components are being made, metal patterns or templates are used, since paper patterns become grayed and worn, causing defects when marking lines and points. When transferring a pattern to metal, you are simply using the outside lines and points to mark the metal so that it can be formed into the shape of the component. All points and lines should be marked to eliminate mistakes when you are forming the component.

Transferring paper patterns to metal is done by duplicating the points at the ends of element lines on the metal. A pencil with a sharp point should be used to carefully mark the outside lines. Weights can be placed on the pattern to prevent slipping during the transfer. The points and li·· are then prick-punched on the metal for clarification. (A prick punch is a sharp-pointed punch.)

Patterns that are used repeatedly are made of metal and are called templates or master patterns. If paper patterns are used repeatedly, they soon become worn and inaccurate. When several identical items are to be made, you will save time by preparing a template. Figure 1-93 shows a metal template of a cylindrical pipe cut at an angle, and a scriber is being used to mark the lines to be cut. Templates larger than the one illustrated usually are held in place with clamps while the scriber is used.

Transferring metal patterns is just like transferring paper patterns, except that different tools are used. A scribe is used to mark the edges and the lines. The prick punch is used to mark points at the end of element lines, just as is done for pattern transfer. The metal pattern to template can be held in place with weights, as in figure 1-94, or by a clamping device.

Transferring a pattern for a rectangular duct is fairly easy. For example, the pattern in figure 1-92 is transferred to metal by duplicating its shape and using a prick punch to locate the ends of the element lines. Lines b, c, and d are the break lines when forming the duct.

Transferring the pattern for a cone-shaped component with a miter, such as shown in figure 1-65, is done by simply duplicating the shape of the mitered pattern on the sheet metal.

Transferring elbow patterns, such as those shown in figure 1-68, requires a little different method. This is a single pattern that is sufficient to make five pieces for the elbow. The working line on this pattern is very important when you are transferring the pattern to metal. During the following explanation of the transfer, you will see why marking the pattern for identification is necessary. A five-piece elbow requires five gores. Marking gores I and V requires half the pattern (A or B), which is divided at the working line. Gores II, III, and IV are made by using the whole pattern (A and B). Thus, you can see that transferring other elbow patterns to metal is similar to transferring other patterns, except that you must remember to use half patterns for the end gores.

If you need to make a 45° elbow, the same elbow pattern can be used, transferring only 2 half gores and 1 full gore. Notice in the plan view of figure 1-68 that each of the whole gores is divided by broken lines to show whole and half gores.

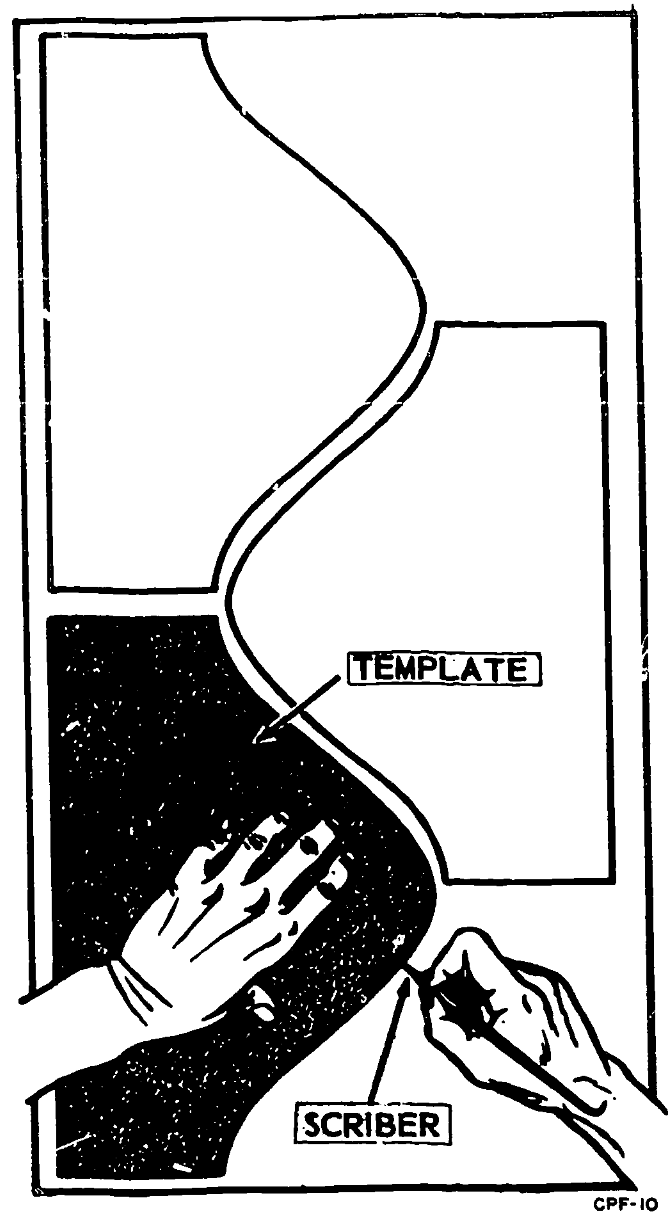


Figure 1–94. Transferring metal patterns.

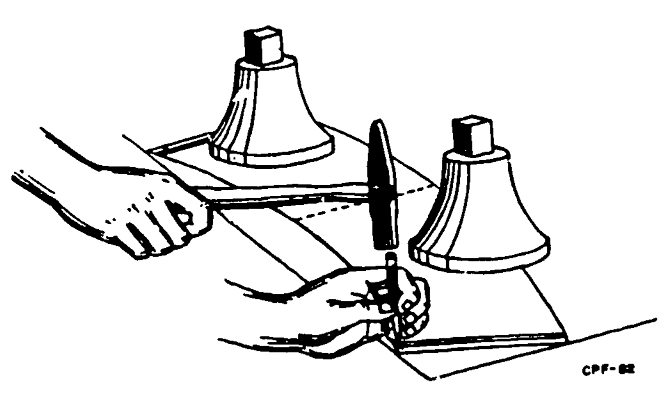


Figure 1–93. Using a template.

Transferring patterns for a round Y-branch, as shown in figure 1-69, is similar to the process for other patterns. This layout has only three patterns. The pattern for piece III is transposed only one time, but patterns for pieces II and IV and I and V are transposed twice.

Transferring patterns for a T-joint, such as that shown in figure 1-70, is done by marking on the outside edges, except for the cutout in the pattern of the main pipe. The cutout is marked on the inside so that the line can be cut out before forming.

When transferring a pattern for a pyramid, such as that shown in figure 1-76, the lines are made on the outside edge and at the intersecting points. The intersecting points are the break lines for forming the pattern into shape.

When transferring the pattern for a round offset, such as that shown in figure 1-91, you will need two half patterns, since it was laid out in a half pattern. If you want to make only one seam instead of two with this half pattern, it is necessary to make one half of the pattern, roll it end-to-end, aligning lines 1–2, and continue marking the other half.

The procedures for transferring patterns for square-to-round components, such as those shown in figure 1-87, are much the same as for other patterns. The outside of the pattern is marked, and the ends of the element lines are prick punched so that they may be seen when you are forming the component.

You have learned how patterns are developed from working drawings. This included the parallel line, radial line, and triangulation methods of pattern development. You have studied about seam allowances, additions, and how patterns are transferred to metal.

Exercises (414):

1. To eliminate mistakes while forming a component, what should you do?

2. A one-time pattern usually is made from what type of material?

3. Break lines on a metal pattern are transferred by what tool?

4. To eliminate pattern shifting during the transfer of break lines, what action should you take?

5. How do you use the elbow patterns to make end gores?

6. When transferring the patterns for a round offset, you will need how many patterns?

7. How is the pattern transferred for a T joint?

1-4. Structural Steel Layout

When working with thin sheet, you can estimate (or sometimes even disregard) the thickness of the material. When working with plate iron or structural steel, neglecting the thickness of the material would cause serious deviations from specified dimensions or perhaps a complete lack of fit between component parts.

When bending metal to exact dimensions, you must know the amount of material used in forming the bend. The amount of material which actually is used is known as the bend allowance.

415. Match bend allowance terms with the correct definitions.

Bend Allowance Terms. Bending compresses the metal on the inside of the bend, and stretches the metal on the outside of the bend. Halfway between these two surfaces or extremes, lies a space that neither shrinks or stretches, but retains the same length. This is the neutral axis. Figure 1-95 (top) illustrates the neutral axis of a bend. It is along the neutral axis that the bend allowance is computed.

In order for you to more thoroughly understand the calculation and discussion of bend allowance, you should understand thoroughly the following definitions. Figure 1-95 of (bottom) illustrates each of these component parts.

Leg. The longer part of a formed angle.

Flange. The shorter part of a formed angle. If both parts are the same length, each is known as a leg.

Mold line (ML). The line formed by extending the outside surfaces of the leg and flange so that they intersect.

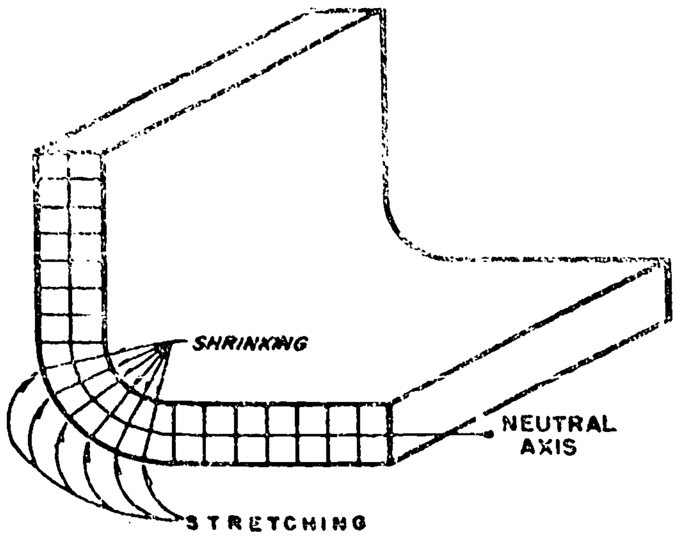
Bend tangent line (BL). The line at which the metal starts to bend.

Bend allowance (BA). The amount of material consumed in making the bend.

Radius (R). The radius of the bend it is always measured from the inside of the bend unless otherwise stated.

Setback (SB). The amount that the two mold line dimensions overlap when they are bent around the formed part. In a 90° bend, SB = R + t (radius of the bend plus the thickness of the metal).

Bend line (also called brake line or sight line). The layout line on the metal being formed which is set even with the nose of the brake and serves as a guide in bending the work. (Before bending it must be decided which end of the material can be most conveniently inserted in the brake.) The bend line is then measured and marked with a soft pencil, from the bend tangent line closest to the end which is placed under the brake. This measurement should be



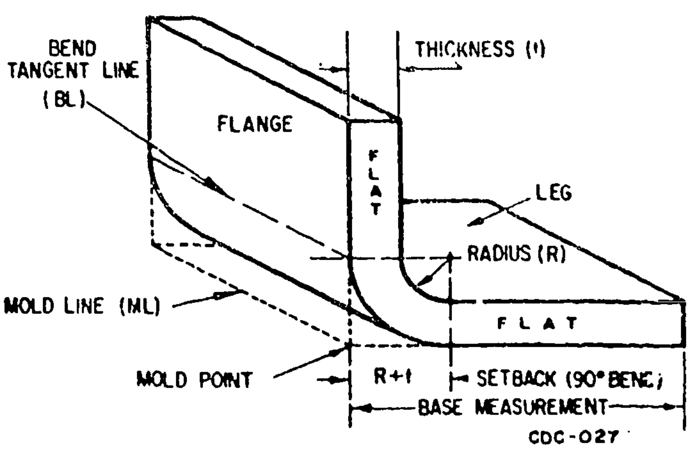


Figure 1-95. Bend allowance terms.

equal to the radius of the bend. The metal is then inserted in the brake so that the nose of the brake will fall directly over the bend line.

flat portion or Flat. The flat portion or flat of a plate is that portion not included in the bend. It is equal to the base measurement minus the setback.

Base measurement (or mold line measurement). The base measurement is the outside dimensions of a formed plate. Base measurement will be given on a blueprint or drawing or may be obtained from the original part.

Closed angle. An angle that is less than 90° when measured between legs, or more than 90° when the amount of bend is measured.

Open Angle. An angle that is more than 90° when measured between legs, or less than 90° when the amount of bend is measured.

Exercises (415):

Select the term in column B which best matches the definitions in column A.

Column A	Column B
_____ 1. The amount of material consumed in making the bend.	a. Leg.
_____ 2. Line which serves as a guide when bending the work.	b. Flange.
_____ 3. Base measurement minus the setback.	c. Mold line.
_____ 4. Angle less than 90° between legs.	d. Bend tangent line.
_____ 5. The longer part of a formed angle.	e. Bend allowance.
_____ 6. The shorter part of a formed angle.	f. Setback.
_____ 7. Mold line overlap when formed around part.	g. Bend line.
	h. Flat.
	i. Base measurement.
	j. Closed angle.
	k. Open angle.

416. Compute the bend allowance required for given ban radii and plate thickness.

Computing Bend Allowance. In order to compute bend allowance, two primary facts must be known; the radius of the bend, and the degree of angle in the bend. Usually, each of these factors can be determined from the blueprints or drawings from which you are working.

As you study the following examples, refer to figure 1-95 (bottom) to help you understand where and how the mathematical figures are obtained. Remember, bend allowance is measured from the inside of the bend; but bend allowance is computed along the neutral axis of the material being used. Therefore, when calculating bend allowance, add the bend radius to one-half of the thickness of the metal to determine the radius of the neutral axis.

Bend allowance is the product of the radius of the neutral axis of the bend multiplied by the size of the bend in radians. The radian relates the length of the arc generated to the size of the angle. For the purpose of computing bend allowance, the number of radians per degree of bend is 0.017453. Thus, the formula for bend allowance is:

$$ba = r \times \theta$$

Where

ba = bend allowance

r = radius of the neutral axis of the bend

θ = of the angle of the bend in radians

Example 1 (fig. 1-96). What is the bend allowance for a 90° bend which is to be made in plate that is 1/2-inch thick?

$$r = 0.50 + 0.250 = 0.750 \text{ inches}$$

$$\theta = 0.017453 \times 90 = 1.57 \text{ radians}$$

Therefore

$$ba = 0.750 \times 1.57 = 1.178 \text{ or } 1.18 \text{ inches}$$

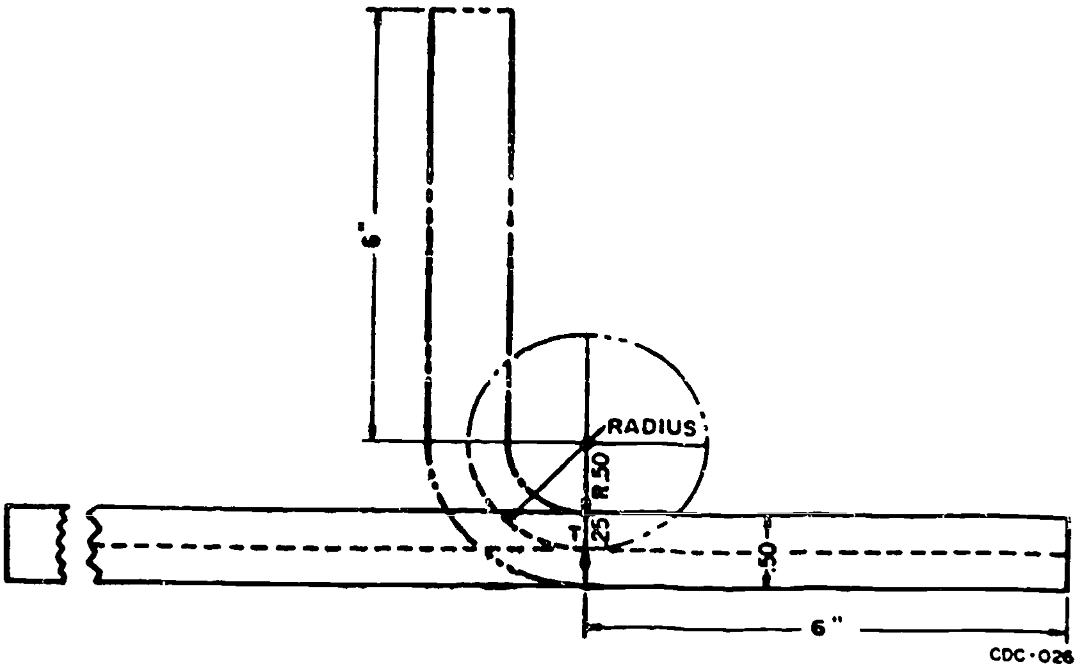


Figure 1–96. Bend allowance and length computation for a 90° L-shaped bracket.

Example 2 (fig. 1-97). What is the bend allowance for a 180° be‵‵d which is to be made in a length of 1/2-inch stock?

$r = 1.0 + 0.250 = 1.25$ inches

$\theta = 0.017453 \times 180 = 3.14$ radians

Therefore

ba $= 1.25 \times 3.14 = 3.925$ inches

Exercises (416):

1. Compute the bend allowance for a 1/2-inch thick plate to be bent at a 45° angle with a 1-inch bend radius.

2. What number is used to compute the number of radians per degree of bend?

3. What is the formula used to determine bend allowance? What does each symbol of the formula mean?

4. What information must be obtained from a print or drawing before a bend allowance can be computed?

5. Compute the bend allowance for a 1/4-inch thick plate to be bent 180° with a 2-inch bend radius.

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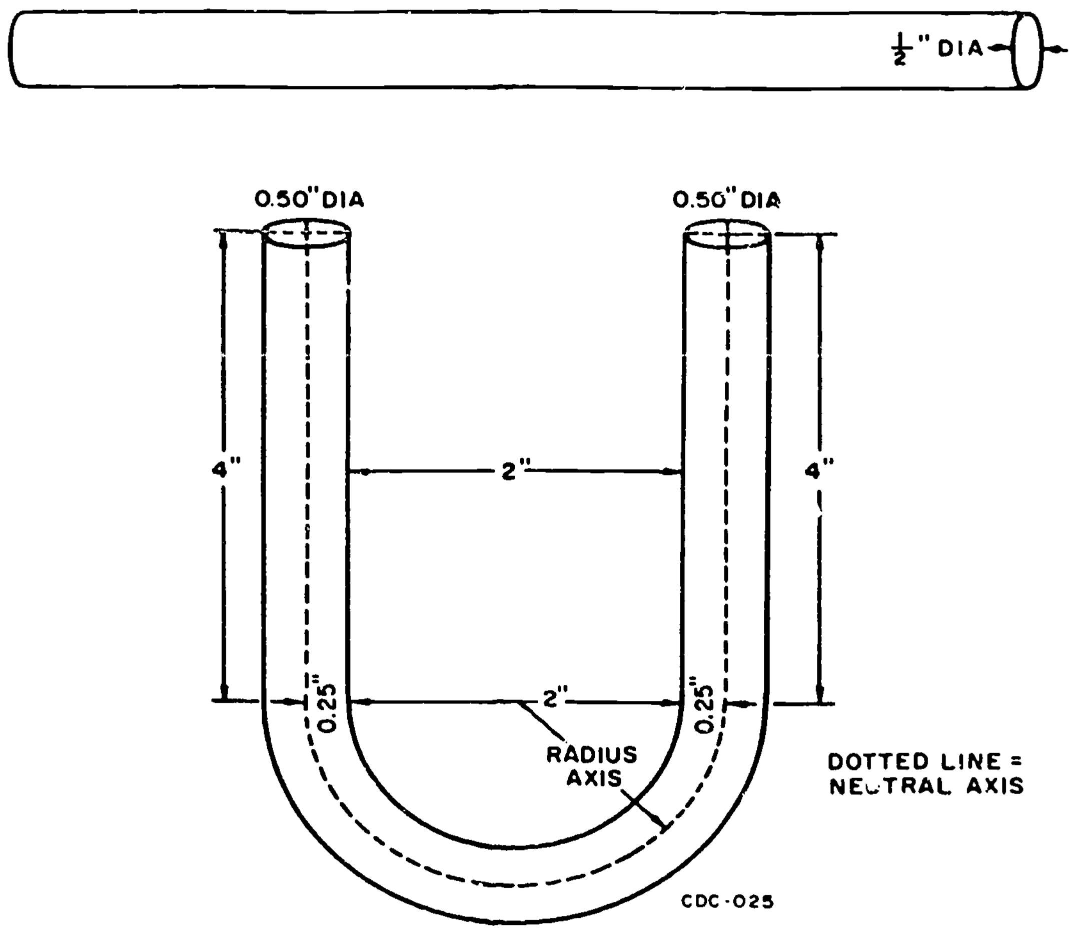

Figure 1–97. Computing overall length of a U-bolt.

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Seams and Joint Connections

IN THIS CHAPTER we will discuss several types of seams that are used to assemble sheet metal components. Some of these have been previously mentioned in other volumes of this CDC, and you are not a stranger to their purpose and use. Now you should be ready to learn how to make these seams and joint connections.

We will discuss lap seams, such as flat lap, offset lap, and corner lap; lock seams, such as grooved, double, Pittsburg, and dovetail; and joint connectors, such as S-slips, drive slips, and tapped connections. We also explain how to make pattern allowances for these seams and joint connections as well as how to notch, form, and assemble them.

Although there are other types of seams and joint connections, we have chosen to discuss only the ones that you are most likely to encounter. You need this knowledge of seams and joint connections when you fabricate, install, and repair ducts annd other sheet metal components.

2-1. Lap and Lock Seams

In this section, we will discuss seams, seam allowance, and the forming of seams. This information is vital to your job progression.

417. List the general types of lap seams and give some features of lap seam design.

Lap Seams. A lap seam, as its name implies, is a seam or lap joint in which one piece of metal partially extends or laps over another. There are three general types: the flat lap seam, offset lap seam, and corner lap seam. They are usually joined with rivets, spot welds, bolts, or screws. Lap seams may be sealed with solder or sealing tape.

You must allow extra metal in a pattern for the seam, the amount depending on the thickness of the metal and the method of fastening to be used. In Chapter 1 of this volume you learned how seam allowances are made on patterns, and how rivets are spaced for lap seams. In volume 2, you learned how folding and forming machines are used, and how hand and bench tools are used.

The next several seams are shown in figure 2-1 and will be referred to by a letter and number.

Flat lap seam. The flat lap seam, shown in A-1, is made by simply lapping one edge of sheet metal over another edge. The allowance for the lap is usually determined by the thickness of the two sheets and the method of fastening the sheets.

For example, light-gage sheet metal (such as 26--gage) which is to have a riveted flat lap seam should have a 1/4 inch lap. This means that the centerlines for the rivet holes should be made 1/4 inch from each edge. The total amount of material allowed for a 1/4 inch flat lap seam is 1/2 inch. In this case, the tinner's rivets should be the 1 pound size and should be spaced a maximum of 2½ inches apart unless otherwise specified by the working drawing.

If medium-gage sheet metal (such as 24 gage) is used, the flat lap seam should have a 3/8 inch lap; and the 2 pound tinner's rivets should be spaced a maximum of 2¼ inches apart.

If heavy gage sheet metal (such as 16 gage) is used, the flat lap seam should have a 1/2-inch lap and the 4-pound tinner's rivets should be spaced a maximum of 3½ inches apart.

Offset lap seam. The offset lap seam, shown in A-2, is very similar to the flat lap seam except that one edge is offset so that one sheet will be flush with the other. An offset lap seam is used where the lap needs to appear as neat as possible. Seam allowances for offset seams are determined in the same way as the allowances for flat lap seams.

The cornice brake is used to form offset bends, as shown in figure 2-2. Notice in step A how the bending leaf is pulled forward to make a 30° to 35° bend. In step B, a spacer, with the same thickness as the desired amount of offset, is placed on the bending leaf, and the sheet metal is turned over. In step C, the offset is completed when the top leaf is

Inside and outside corner la[illegible]s. Inside corner lap seams and outside corner lap seams, such as those illustrated in B-2,3, (fig. 2-1), are used on any gage of

metal, especially on heavier gages of sheet metal. Seam allowances for inside and outside corner seams are determined in a manner similar to that for flat lap seams except that the allowance is made for one edge only. For example, the seam allowance for 26 gage metal is 1/2 inch on the folded side. In this case, the centerline for the rivet holes is 1/4 inch from both edges. The inside and outside corner lap seams are used on boxes and pans and other items with square corners.

Seam allowances for lap seams. We have described how various types of lap seams are made and how the seam allowances are determined. Figure 3-3 is a chart that summarizes seam allowance information for your use and quick reference as you train on the job.

Exercises (417):

1. List the general types of lap seams.

2. What is the seam allowance for a 1/4-inch flat lap riveted seam?

3. Where is the offset lap seam used?

4. What type of seam is used when a 90° bend is needed?

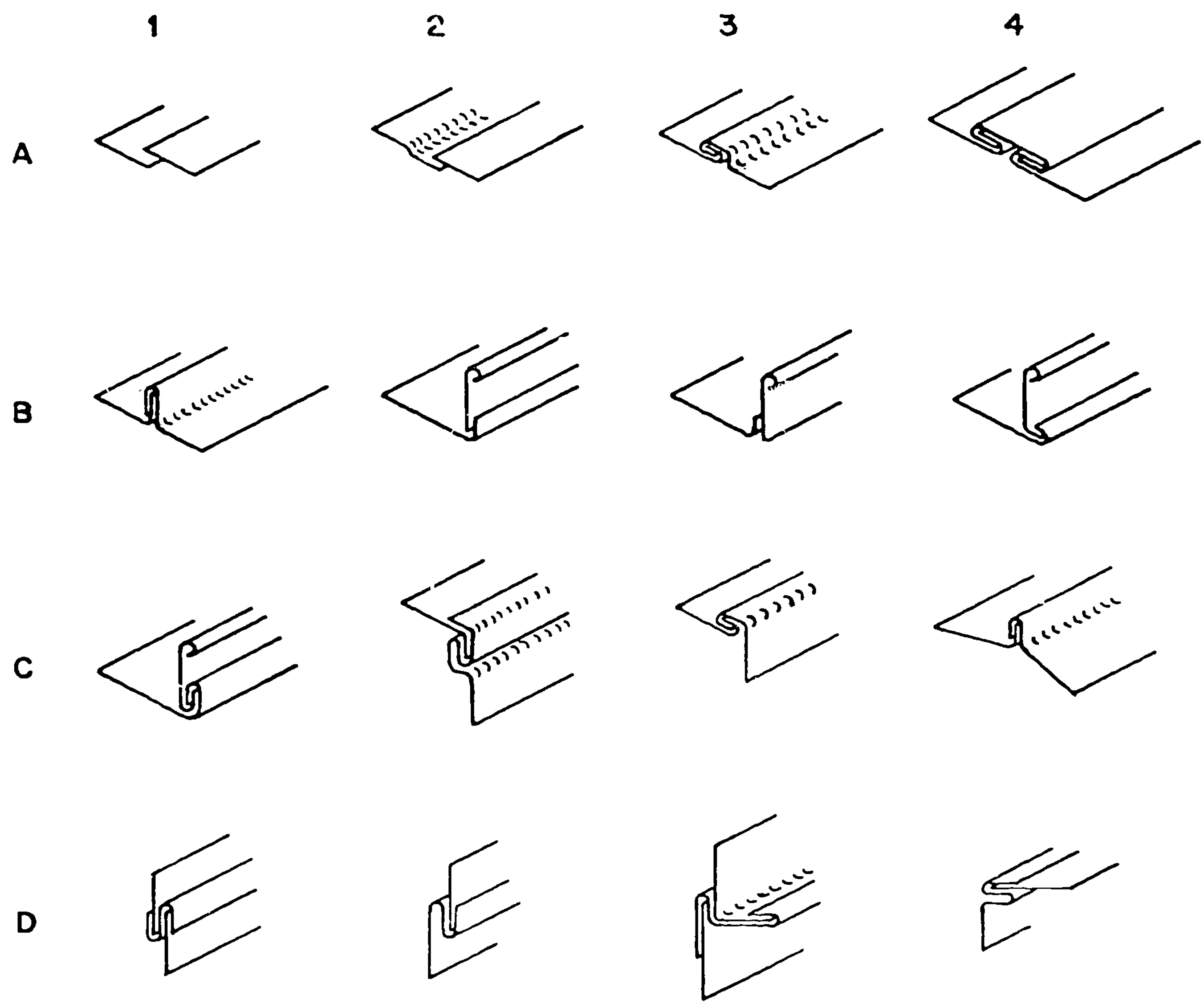

Figure 2-1. Sheet metal seams.

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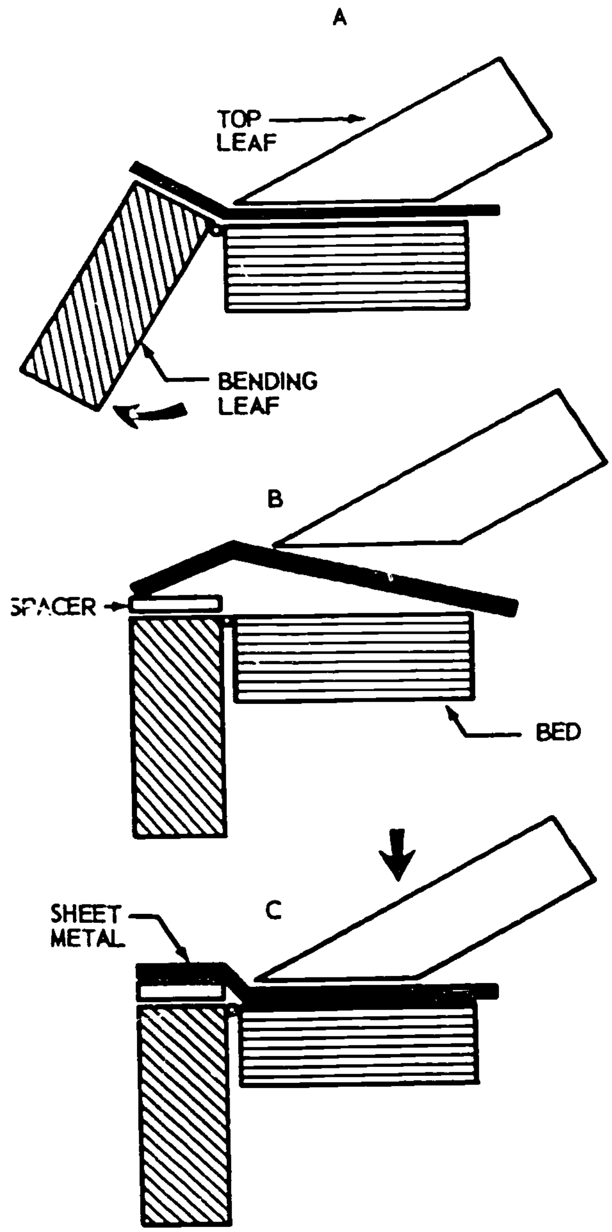

Figure 2–2. Making an offset bend with a cornice brake.

418. Describe lock seams and give their uses.

In the fabrication of sheet metal components, you will be faced with many problems about the way to connect two pieces of sheet metal together. The easiest way is not always the best way. A few things to consider when you choose the best fastening method are: (1) how big is the item, (2) how much does it weight, (3) what load must it hold, and (4) is it to be watertight.

Lock Seams. There are several types of lock seams for connecting two pieces of metal together without the use of rivets, spot-welds, bolts, or screws. Lock seams are used in many places, such as metal roofs, cylinders, bottoms on cylinders, and stiffeners on ducts. In a lock seam, two pieces of metal are formed in a series of bends and so interlocked that they cannot come apart. They are held in place by themselves. Many lock seams, like those on a roof, are weatherproof.

Exercises (418):

1. How are lock seams fastened?

2. List at least three uses of lock seams.

419. Give the uses of the standing seam and some features of its pattern development.

Standing Seam. Standing seams are used in several differenct ways in fabricating sheet metal components. In B-1 and C-4 (fig. 2-1 two views show you how the two parts are assembled. B-1 shows the seam on a flat surface and C-4 shows it on an angle (Roof Ridge). Although used primarily to join two pieces of sheet metal, the standing seam also acts as a stiffener because the metal is folded three times. Standing seams are sometimes used to connect joints of rectangular duct, to stiffen the long joints across the top and bottom of long ducts, to install covers over the ends of ducts, and to connect the corners of exhaust hoods over kitchen stoves.

The seam allowance for a standing seam is determined by the size of the seam and the thickness of the sheet metal. For example, if a standing seam is to be made of 16 gage (0.062 inch) sheet metal and is to be 1 inch high, the seam allowance must be 3 inches plus twice the metal thickness. An easy way to remember this is by the formula **3H + 2T (H is the height of the** seam and T is the thickness of the sheet metal). Applying this formula, three times 1 inch plus two times 0.062 inch equals 3.124 inches. Remember, however, that this is the total allowance and includes both sides of the seam. The decimal 3.124, when converted to a fraction, is approximately 3⅛ inches-the total allowance for the standing seam in this example. Piece 1 of the seam will have 1 inch allowed for the 90° flange, and piece 2 will have 2⅛ inches allowed for the 180 degree standing fold. When fabricated, the standing seam should have flush surfaces. When two sections of duct are joined with a standing seam one piece is bent out 1 inch, the other piece gets two 90° bends (one up and one down). Note: If the seam is to be on the inside (used when insulating the inside of the duct) then the first bend is to the inside.

We have described how allowances are determined and how standing seams are fabricated. Now we will examine a standing seam that is used to connect two duct joints.

When the 2 pieces are placed together the second bend on piece two is bent over piece 1 and riveted, forming the finished standing seam joint. To form a 1 inch standing seam piece 1 is bent up 90° at a brake line

Type of Seam	Gage of Metal and Decimal Equivalent	Lap Allowance (Width = W)	Size of Tinner's Rivets	Material Required		
				Formula	Side 1 or Piece 1	Side 2 or Piece 2
Flat Lap	26 (0.018")	1/4"	1 lb	2 X W	1/4"	1/4"
	24 (0.025")	3/8"	2 lb	2 X W	3/8"	3/8"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	3/8"	3/8"
	20 (0.037")	3/8"	3 lb	2 X W	3/8"	3/8"
	16 (0.062")	1/2"	4 lb	2 X W	1/2"	1/2"
Offset Lap	26 (0.018")	1/4"	1 lb	2 X W	1/4"	1/4"
	24 (0.025")	3/8"	2 lb	2 X W	3/8"	3/8"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	3/8"	3/8"
	20 (0.037")	3/8"	3 lb	2 X W	3/8"	3/8"
	16 (0.062")	1/2"	4 lb	2 X W	1/2"	1/2"
Corner Lap	26 (0.018")	1/4"	1 lb	2 X W	——	1/2"
	24 (0.025")	3/8"	2 lb	2 X W	——	3/4"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	——	3/4"
	20 (0.037")	3/8"	3 lb	2 X W	——	3/4"
	16 (0.062")	1/2"	4 lb	2 X W	——	1"

Figure 2-3. Seam allowances for lap seams.

1 inch from the edge. Piece 2 is also bent up 90° at a brake line 2⅛ inch from the edge. Then you reposition piece 2 (turn it over) and place 1 inch of the bent up portion in the break. Make the next bend 1 inch from the edge, this bend is to be 160°. Remove from the brake and flaten bend to 180°. Leave the channel open just enough to insert the bent-up part of piece 1. The standing seam makes a good tight joint connection but is open at the corners. These corners may be strengthened by corner clips. You should remember corner clips from your study of Volume 2.

The standing seam can also be used across the center of long duct joints when two pieces of metal are used to make the top or bottom sides. Used this way, the standing seam gives additional bracing and allows smaller pieces to be used. The strength added by the standing seam, the four Pittsburg corner seams, and the cross bracing makes a very strong duct.

Exercises (419):

1. Give the uses of the standing seam.

2. Give the formula for determining the seam allowance.

3. To develop a pattern for a 3/4-inch standing seam, the second bend should be ____________ from the edge of the metal (pattern).

420. Cite some of the important procedures in forming a grooved seam.

Grooved Seam. A grooved seam is shown in A-3 (fig. 2-1). Note how it resembles a standing seam that has been bent over and then shaped with a hand groover. One of the main uses for grooved seams in duct construction is to join the edges of round duct joints. Grooved seams are also used for joining sheets of metal roofing and for seams not located in the corners of rectangular ducts. In the following paragraphs we will describe how grooved seam allowances are determined and how the seams can be made with a Pittsburg lock-forming machine or with a bar folder and handtools.

Grooved seam allowance. The metal allowance for a grooved seam made with a Pittsburg lock-forming machine is the same as the allowance for a grooved seam made with a bar folder and handtools. As with other seams, you must allow for the width of the seam and the thickness of the metal. The allowance for a grooved seam is three times the width of the seam plus the total thickness of the metal. Sheet metal that is

24-gage or lighter requires an allowance of three times its thickness, and sheet metal that is 22 gage or heavier requires an allowance of five times its thickness. Thus, the grooved seam allowance formula for the lighter gages is 3W + 3T and for the heavier gages, 3W + 5T. Remember, this is the total allowance and includes both sides of the seam.

An example of making the allowance for a 1/2-inch grooved seam in 26 gage sheet metal is $(3 \times 1/2) + (3 \times 0.018) = 1\frac{1}{2} + 0.054$ or $1\frac{1}{2} + 1/16 = 1\frac{9}{16}$ inches.

Making a grooved seam with a bar folder. Now that you can figure seam allowances, let's see how a grooved seam is made on a bar folder. (A cornice brake can also be used.) To make a 1/2-inch grooved seam, set the depth gage of the bar folder for 1/2 inch, as you learned in Volume 1 of this CDC. Place the edge of the metal between the ... d folding blade, and pull the wing forward and up ... the position shown in step A of figure 2-4. After the wing is returned to the down position, take the metal out of the folder and turn it over. Pull the wing forward and up until the folded metal is bent 180°, as shown in step B. You use this same procedure for the other half of the seam. If you make a grooved seam on round duct or pipe, make the two 180° folds on opposite ends of the same piece of metal but bend them up at one end and down at the other.

Now look at figure 2-5. In step A, you can see the two 180° folds that were made on the bar folder. In step B, the two folded edges have been hooded together but have not been locked with a groove. In step C, a hand groover is placed over the seam and struck with a tinner's riveting hammer to form the groove and lock the seam together. You must use a suitable backing plate or bench stake. The shape of the component determines whether a flat plate or a bench stake should be used as a backing surface. The grooved seam should be well set to prevent slipping. Sometimes it is desirable to make a series of indentations along the seam with a center punch as a further precaution against slipping.

Making a grooved seam with a Pittsburg lock-forming machine. Making a grooved seam with a Pittsburg lockforming machine is much easier and faster than the multistep hand method described in the preceding paragraph ... g lock-forming machines make 5/16-, ... or 1/2-inch grooved seams, depending on the make and model of the machine.

After making the allowance for the grooved seam, adjust the thickness gage on the Pittsburg lock-forming machine to correspond to the thickness of the sheet metal. If the gage is set too loose, the result is a loose seam. If the gage is set too tight, the metal may break at the bends. Also, if the adjustment is too

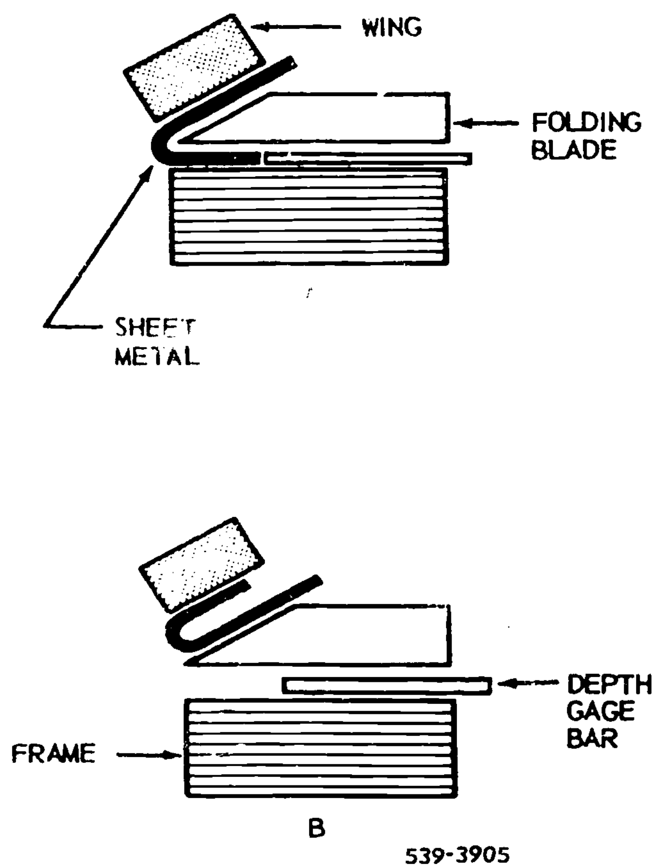

Figure 2–4. Making folded edges with a bar folder.

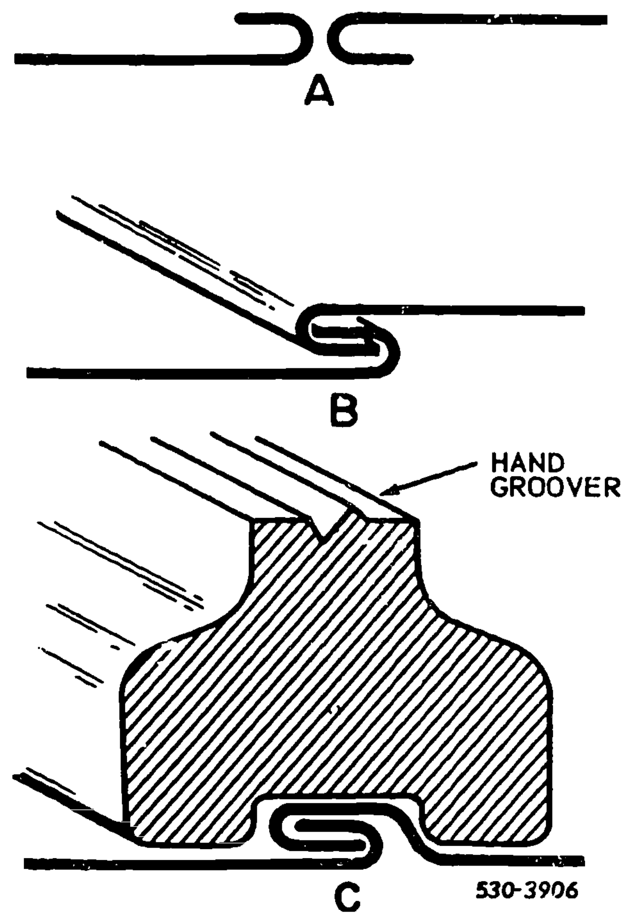

Figure 2–5. Making a grooved seam with handtools.

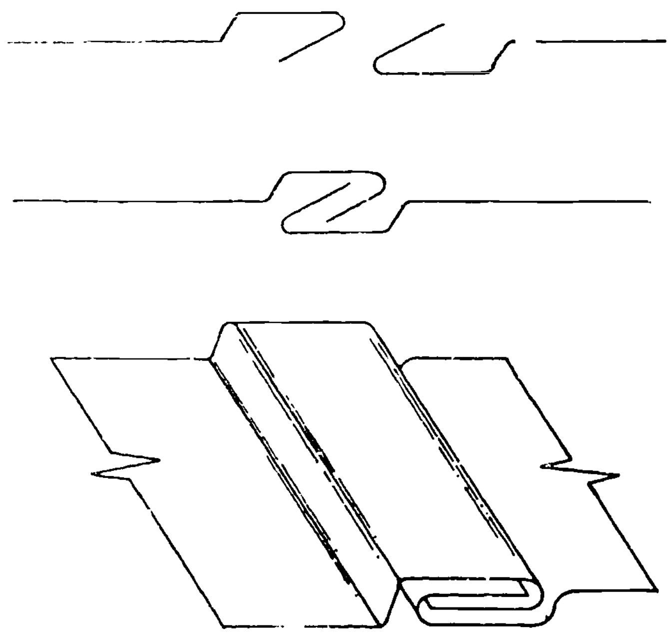

Figure 2–6. Grooved seam made with a Pittsburg lock-forming machine.

tight, the machine may be damaged. After you make this adjustment, turn the machine on and feed the metal into the rollers. Hold the metal flush against the guide as it passes through the forming rollers. It is important to keep the metal straight as it starts through the rollers because the machine will complete the operation whether it is straight or not. After the two

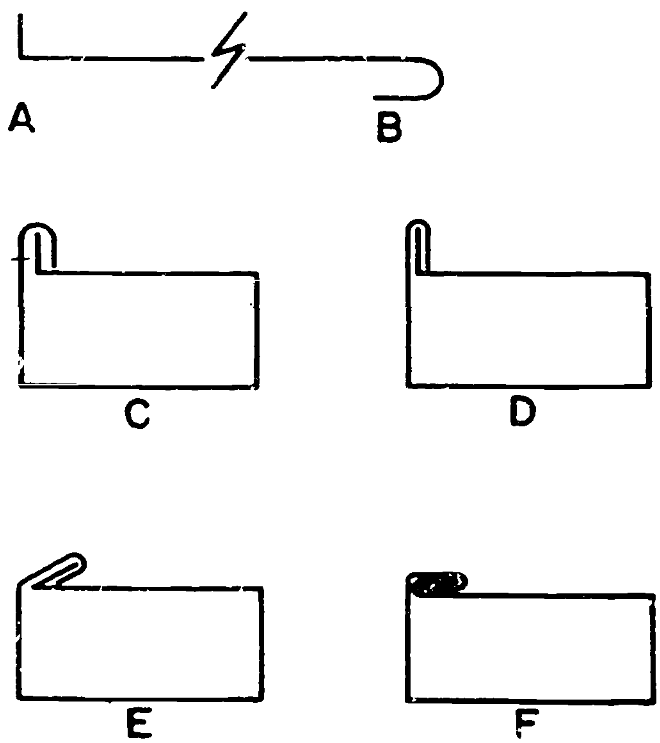

Figure 2–7. Making a corner double seam for articles with square corners.

machine, place them together, as shown in figure 2-6. The final step is to set (tighten) the assembled seam with a mallet or hammer and a suitable backing plate or bench stake. Although a grooved seam made on a Pittsburg machine is tighter than the handmade seam, it is sometimes desirable to center-punch the seam in several places to prevent slippage.

Exercises (420):

1. To form a grooved seam with a bar folder, the wing is pulled forward and up __________ times.

2. List three machines that you can use to make a grooved seam.

3. What tools do you need to set a grooved seam that was formed on a Pittsburg lock-forming machine?

4. Give the formula for the seam allowance of a grooved seam.

421. Give a selected step in forming a double lock seam, determine the proper seam allowance, and list some applications of the double lock seam.

Double Seams. Two types of double seams are the corner double seam, used to seam the square corners in square and rectangular ducts, pans, boxes, etc., and the bottom double seam, used to fasten bottoms on cylinders. Notice, in figure 2-6, 2-7, and 2-8, that double seams are somewhat like grooved seams except that they are located on the corners and edges of components.

Seam allowances for double seams. The seam allowance for a corner or a bottom double seam is three times the seam width plus twice the metal thickness (3W + 2T). This allowance is slightly less than the allowance for a grooved seam because the double seam is not offset. A 1/4-inch double seam is often used with 28- to 24-gage sheet metal, and a 3/8-inch double seam is used with 22- to 18-gage sheet metal.

Corner double seam. A corner double seam can be partially made on a bar folder or cornice brake, depending on the length of the component. For example, suppose you must make a 1/4-inch double seam on a 24-gage square duct. Before the duct can be formed into a square shape, you must form the two parts of the seam, which are shown in steps A and B of figure 2-7. If the duct joints are 20 inches or less in length, you can make the bends for the double seam on a bar folder by setting the depth gage bar for 1/4 inch,

bending one edge 90°, and bending the opposite edge 180°, as shown in steps A and B. Make these bends first because they are difficult to make after the joint is formed into a square. To form the joint into a square, use the cornice brake to bend the metal 90° along each of the three element (brake) lines. After you have made these bends, join the edges as shown in step C of figure 2-7. The next step is setting down the seam as shown in D.

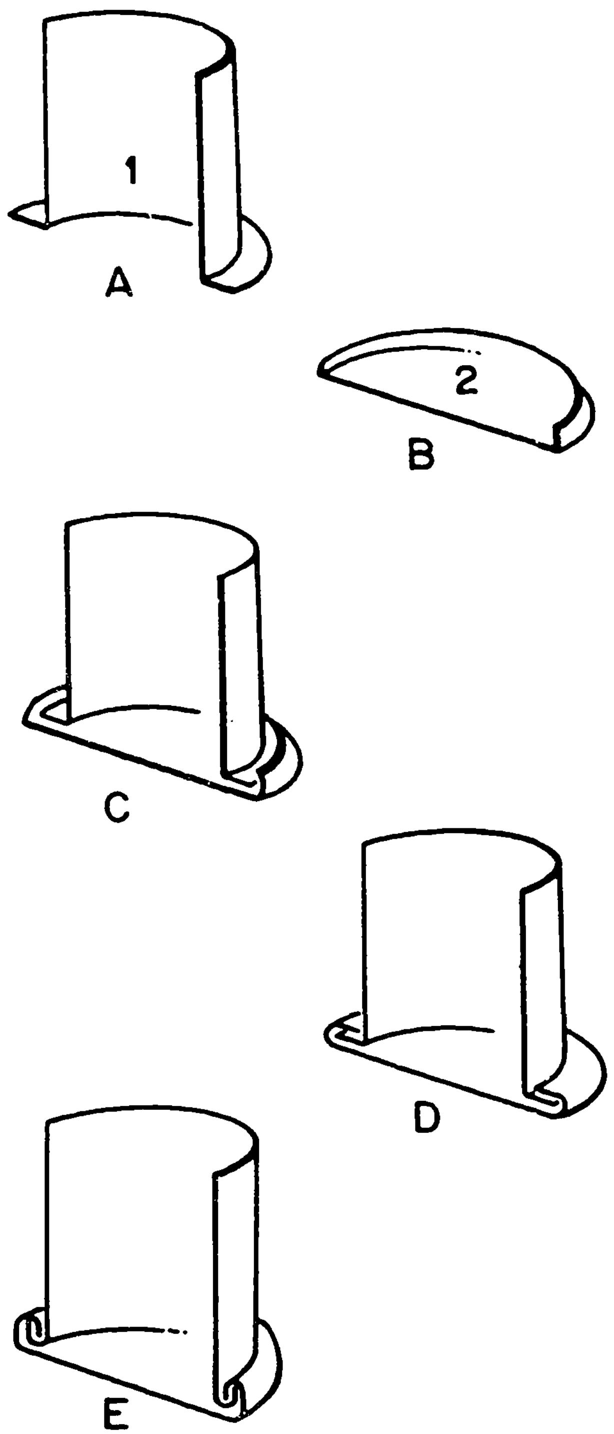

Figure 2–8. Making a bottom double seam for cylindrically shaped articles.

You can do this setting-down operation with a setting hammer or with the cornice brake. If you use a setting hammer, you must have a backing plate or suitable bench stake. In step E of the illustration, the corner double seam begins to take shape. Bend the seam over with a mallet on the square end of a solid mandrel stake. When completely set down, the corner double seam will be like the one shown in step F of figure 2-7. As with other lock seams, indentations made with a center punch will keep the seam from slipping.

Bottom double seam. A bottom double seam, like the one shown in figure 2-8, is used to fasten a bottom or end on a cylinder. The illustration shows cutaway views so that you can see the shape of the seam as it is made. As we have already mentioned, the seam allowance for a bottom double seam is three times the width of the seam plus twice the metal thickness.

Now let's see how the 1/4-inch bottom double seam shown in figure 2-8 is made. The cylinder is identified as piece 1 in step A, and the bottom is identified as piece 2 in step B. These two pieces are the starting parts for the seam. Using the formula 3W + 2T, the seam allowance is 1/4 inch for piece 1. Piece 2 is 1/2 + 1/16 or 9/16 inch. You use a burring machine, which you studied in Volume 2, to turn 1/4 inch 90° flanges on both pieces. In step C, you place the bottom on the cylinder. In step D, you turn down the flanged edge of piece 2 with a tinner's setting hammer or mallet. You can further tighten this edge with a setting down machine. To complete the seam, as shown in step E, use a mallet and double seaming stake. The bottom double seam is now complete, unless you must make it liquid-tight by soldering.

Exercises (421):

1. What is the first step in forming a bottom double seam?

2. What is the seam allowance for a 20 gage 5/16-inch corner double seam?

3. List at least three applications of the double seam.

422. State the uses, seam allowance, and forming steps of the Pittsburg lock seam.

Pittsburg Lock Seam. The Pittsburg lock seam, shown in C-2 (fig. 2-1), is most often used along one edge or corner of a rectangular duct and on all four sides of such fittings as transitions and elbows. The Pittsburg lock seam is made in two parts. The flanged edge is usually formed on a cornice brake or on a bar folder if the point is straight. However, if a rectangular-shaped

offset or elbow is to be joined with a Pittsburg lock seam, the flanged edge is turned on a rotary burring machine or by hand with a round bench stake and mallet. The pocket side of the seam is made on a Pittsburg lock-forming machine or a cornice brake. You join the seam by inserting the flanged edge into the pocket and bending the locking edge, which extends above the pocket, to a 90° angle until it is locked and looks like view C-2.

Seam allowances for Pittsburg lock seams. The allowance for a Pittsburg lock seam made with a cornice brake is different from the allowance for a seam made with a Pittsburg machine. Pittsburg lock seams made with a Pittsburg machine usually require an allowance of 15/16 inch, 1 inch, or $1^1/_{16}$ inches (depending on the make and model of the machine) for the pocket side of a seam. The flanged edge is usually 1/4 inch, though some sheet metal workers prefer a 5/16-inch flange.

The allowance for a 1/2-inch Pittsburg lock seam made on a cornice brake is $1\frac{1}{4}$ inches for the pocket side and 1/4 inch for the flanged side.

Making a Pittsburg lock seam with a cornice brake. To make a Pittsburg lock seam with a cornice brake, several steps are required. After you make the seam allowance for both sides, you form the flanged side and the pocket side be the safe procedure as the first four steps for making a standing seam. Where the metal is clamped under the top leaf and the bending leaf has been used to bend a 160° angle. To make the pocket side of the Pittsburg seam, return the bending leaf to its down position, and use a mallet to bend the 90° angle to a 180° angle. Next, release the clamping pressure of the top leaf, and slip the metal back so that you can lower the top leaf to form a tighter 180° bend. The seam will need to be offset; do this by turning the metal over in the cornice brake and lowering the top leaf until a groove is formed. The final step in making the pocket side of the Pittsburg lock seam is to strike the folded metal with a mallet until the edges are parallel, as illustrated in the lower part of C-2 (fig. 2-1).

Making a Pittsburg lock seam with a Pittsburg lock-forming machine. To use a Pittsburg lock-forming machine to make a Pittsburg lock seam, set the metal thickness gage according to the thickness of the metal being formed. If the gage is set too loose, a loose seam will be made; if it is set too tight, the metal may break at the bends. Also if the adjustment is too tight, the machine may be damaged.

After setting the thickness gage, turn the motor on and hold the sheet metal flush against the guide as you feed it into the rollers. Be sure to start the material straight. As this sheet comes out of the Pittsburg lock-forming machine, the open side of the pocket will be facing up.

Exercises (422):

1. Where is the Pittsburg lock seam most frequently used?

2. What is the seam allowance for a Pittsburg lock seam made with a Pittsburg machine?

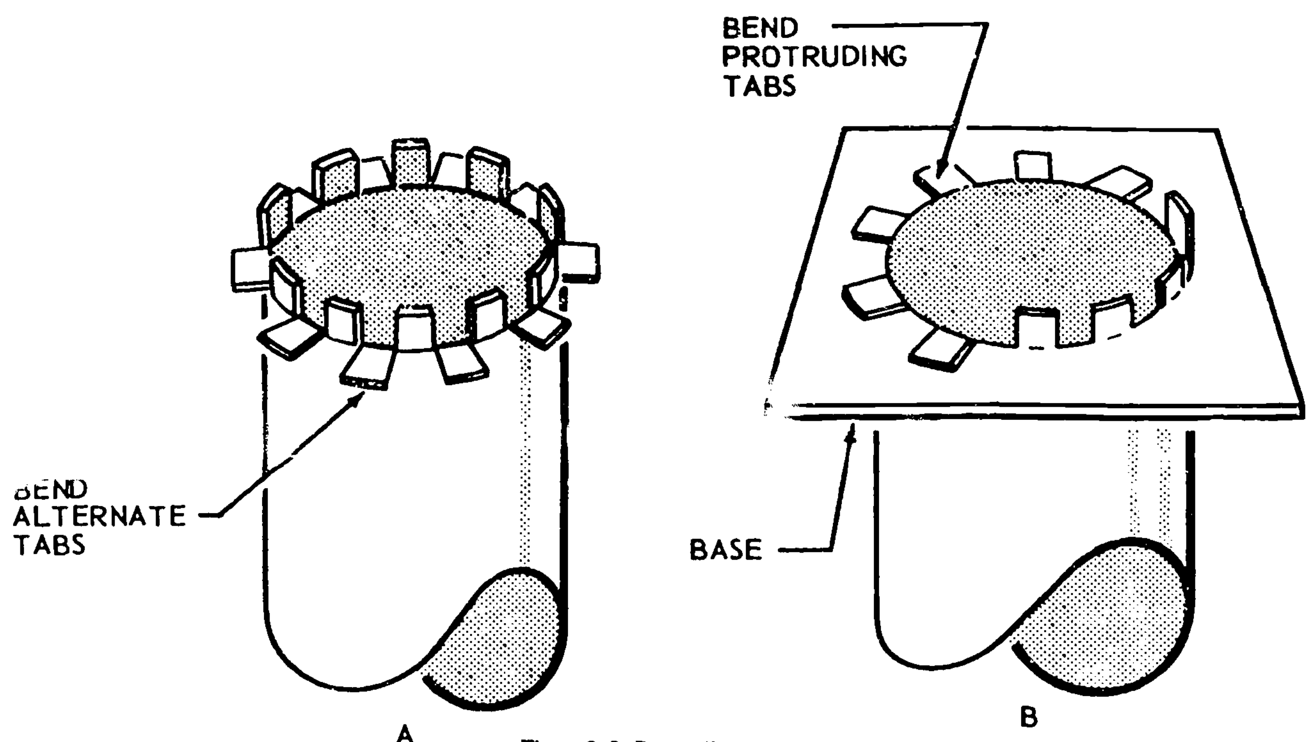

Figure 2-9. Dovetail seam.

3. How do you form the offset on a Pittsburg lock seam formed with a cornice brake?

423. Identify procedures used in making a dovetail seam.

Dovetail Seam. A dovetail seam, illustrated in figure 2-8, is often used to connect cylinder-shaped ducts or pipes to flat surfaces, such as the base of a roof jack. View A in the illustration shows how 1/2-inch square tabs have been cut and every other one bent down 90° with a tinner's hammer and bench stake. This bending operation can also be performed with a pair of common pliers. A hole the size of the cylinder is cut in the flat piece of metal that is to be the base. The base is then placed over the cylinder, as shown in view B. The remaining tabs are bent 90°. As this row of tabs is turned down, the blows from the hammer cause both rows of tabs to tighten against the flat base.

Determining seam allowances for a dovetail seam is quite simple. The flat base does not need an allowance because the hole size is the same as the cylinder that will fit over it. The allowance for the 1/2 inch-dovetail seam for the cylinder is the length of the tabs, which are normally 1/2 inch in height. After cutting, each tab should be 1/2 inch-high and 1/2 inch-wide.

If a dovetail seam is used to fasten the base of a roof jack, the seam (tabs) must be soldered to make a watertight seam. However, the dovetail seam is usually strong enough to hold the base securely without rivets, screws, soldering, or spot welding.

In this section, we have discussed how various types of lock seams are made and how the seam allowances are determined. The chart in figure 2-10 summarizes the seam allowance information for your convenience.

Exercises (423):

1. The dovetail seam is used to attach ____________ or ____________ duct to a flat surface.

2. Describe how to make a dovetail seam.

Type of Seam	Size of Seam (Width = W) (Height = H)	Gage of Metal and Decimal Equivalent	Material Required		
			Formula (Thickness = T)	Side 1 or Piece 1	Side 2 or Piece 2
Standing	1" H 1" H	24 (0.025") 18 (0.050")	3H + 2T 3H + 2T	1" 1"	2 1/16" 2 1/8"
Grooved	1/2" W 1/2" W	24 (0.025") 20 (0.037")	3W + 3T 3W + 5T	1/2" 1/2"	1 1/8" 1 3/16"
Corner Double	1/4" W 3/8" W	24 (0.025") 20 (0.037")	3W + 2T 3W + 2T	1/4" 3/8"	9/16" 7/8"
Bottom Double	1/4" W	24 (0.025")	3W + 2T	1/4"	9/16"
Pittsb[illegible] Lo[illegible] Ma[illegible]h Pi[illegible]rg Ma[illegible]	———	2[illegible] (0.[illegible])	[illegible]mined b[illegible] model of Machine	1/4" or 5/16"	1" or 1 1/16"
Pittsburg Lock Made With Cornice Brake	1/2" W	24 (0.025")	2W +1/4" +1/4"	1/4"	1 1/4"
Dovetail	1/2" H & 1/2" W	26 (0.018")	———	1/2"	———

Figure 2-10. Seam allowances for lock seams.

3. On a 1/2-inch dovetail seam, the seam allowance on the flat surface is __________ . Why?

2-2. Joint Connections

In this chapter, you have learned how seams are used to join pieces and corners during the [illegible]bricatio[illegible] [illegible]f sheet metal compon[illegible] [illegible] we [illegible] [illegible]urn to joint connectors, s[illegible] [illegible]lips, drive slips, tapped connections, and slip joints which are used to connect the joints of ducts or fittings.

424. Given information on metal gage and duct size, determine the type of joint connector to use.

Joint Connectors, Gage of Metal, and Bracing. Since joint connectors and bracing are often fabricated in the sheet metal shop, you must know how to determine the type of construction that is appropriate to a specific duct system. Since standing S-slips are stronger than flat S-slips, we have included a chart (fig. 2-11) to show the gages of metal, types of joint connectors, and type of bracing recommended for various sizes of sheet metal ducts.

Notice in the chart that the th[illegible] of the aluminum is measured in B&S (Brov[illegible] [illegible]d Sharp) gage, which is recognized as standard in the United States for wire and sheet metal not made of iron or steel. Galvanized sheet iron is measured with USS gage (US Standard). If a coating, such as zinc, is applied to sheet iron or steel to form galvanized sheet metal, the material is approximately 0.004 inch thicker than the gage shown on the chart. The recommendations shown on the chart are suitable for actual use, though your work orders or job specifications may give other instructions.

You can see in figure 2-11 that, as duct width increases, it is necessary to increase the thickness (gage) of the metal, to use joint connections with additiona[illegible] strength, and to use appropriate bracing. For example,

ALUMINUM B&S (GAGE)	GALVANIZED IRON USS (GAGE)	WIDTH OF DUCT	TYPE OF JOINT CONNECTOR	BRACING
24	26	Up to 12"	Flat S-slips and drive slips, up to 35" centers. Standing seam or standing S-slips, up to 7'11" centers.	Cross brake
22	24	13" to 24"	Standing S-slips and drive slips, up to 35" centers.	Cross brake
22	*24	25" to 30"	Standing S-slips and drive slips, up to 7'11" centers.	Cross brake and use 1" X 1" X 1/8" angle iron or 1" standing seam[illegible]
22	*24	31" to 40"	Standing S-s[illegible]ps and drive slips, up to 7'11" centers.	Cro[illegible] [illegible]e and use 1 1/2" [illegible] 1/2" X 1/8" angle iron or 1 1/2" standing seams on 4' centers.
20	*22	**41 to 60"	Standing S-slips (1 1/2" pocket and 1 1/2" standing reinforced edge with 1 3/8" X 1/8" bar) and drive slips up to 35".	Cross brake
20	*22	**41" to 60"	Standing S-slips (1 1/2" pocket and 1 1/2" standing reinforced edge with 1 3/8" X 1/8" bar) and drive slips up to 7'11" centers.	Cross brake and use 1 1/2" X 1 1/2" X 1/8" angle iron or 1 1/2" standing seam on 4' centers.

*For maximum strength, increase metal thickness by two gages.
** Consider hangers when using ducts this size.

Figure 2–11. Joint connectors, metal gates, and bracing recommended for sheet metal duct. 530-3921

26 gage galvanized iron (or 24-gage aluminum) sheet metal is adequate for ducts up to 12 inches wide if the metal is braced with cross brake bends. Notice that the type of joint connector is determined by the length of the duct joints. If the joints are 35 inches or less in length, they may be connected with flat S-slips and drive slips. If the joints are longer than 35 inches (up to 7-foot 11-inch centers), they should be connected with standing seams or standing S-slips.

Exercises (424):

1. What type of joint connection and bracing is recommended for a 24-gage galvanized iron duct 27 inches wide?

2. For maximum strength, a duct 58 inches wide should be made of __________ metal with __________ standing seams on __________ centers.

425. Identify fabrication procedures and state the use of S-slips.

S-Slips. S-slips are used to join sections of ducts or fittings during the installation of duct systems. In figure 2-12, you can see how two pieces of sheet metal can be joined with an S-slip. When an S-slip is used with a rectangular shaped duct, it connects the two sides that have the greatest width. As this width increases, the need for stiffening and bracing also increases, and variations of the S-slip have been developed. Figure 2-12 illustrates three types: the flat S-slip, the standing S-slip, and the reinforced standing S-slip. Standing S-slips are stronger than a flat S-slip. A reinforced standing S-slip with its inclosed flat bar is the strongest of the three types.

Flat S-slip. In figure 2-12, you can see that the flat S-slip is the basic construction of all three types. Two parts of the S-slip are 1 inches wide and one part is 1 inches wide. When an S-slip is constructed to these dimensions, it allows metal to overlap 1 inch at the joint. However, don't let this mislead you about the amount of sheet metal to be allowed when you are figuring the length of the duct joints. When any of these S-slips are used to join ducts, each duct should be made 1/2 inch longer at the end that fits into the pocket of the S-slip. It is a common mistake to allow 1 inch for each piece being joined.

Fabricating a flat S-slip is not illustrated here, but it is bent (formed) as indicated in D, E, and 1 of figure 2-13. To make a flat S-slip, the standing edges are omitted from the pattern and steps B and C are not performed. The following paragraphs will clarify this explanation.

Standing S-slip. The standing S-slip is used the same way as the flat S-slip because the S-slip portions are identical. The difference is the standing edge, shown in figure 2-12. This standing edge is usually 1 inch high but can range from 3/4 to 1½-inches, depending on the strength required. Standing S-slips, like other S-slips, are used to join the widest sides of a rectangular duct.

Fabricating a standing S-slip is not difficult and is usually done with a cornice brake. The first step is to determine the dimensions and lay out the pattern. The pattern should look like step A in figure 2-13, if you are making standing S-slips with 1⅛ inches pockets and a 1 inch standing edge. The length of the standing S-slip should be approximately 1/4 inch less than the width of the duct, to give clearance for the corner lock seams. Notice how the 1¼ inch portion of the pattern is cut at a 45° angle to make installation easier. For training

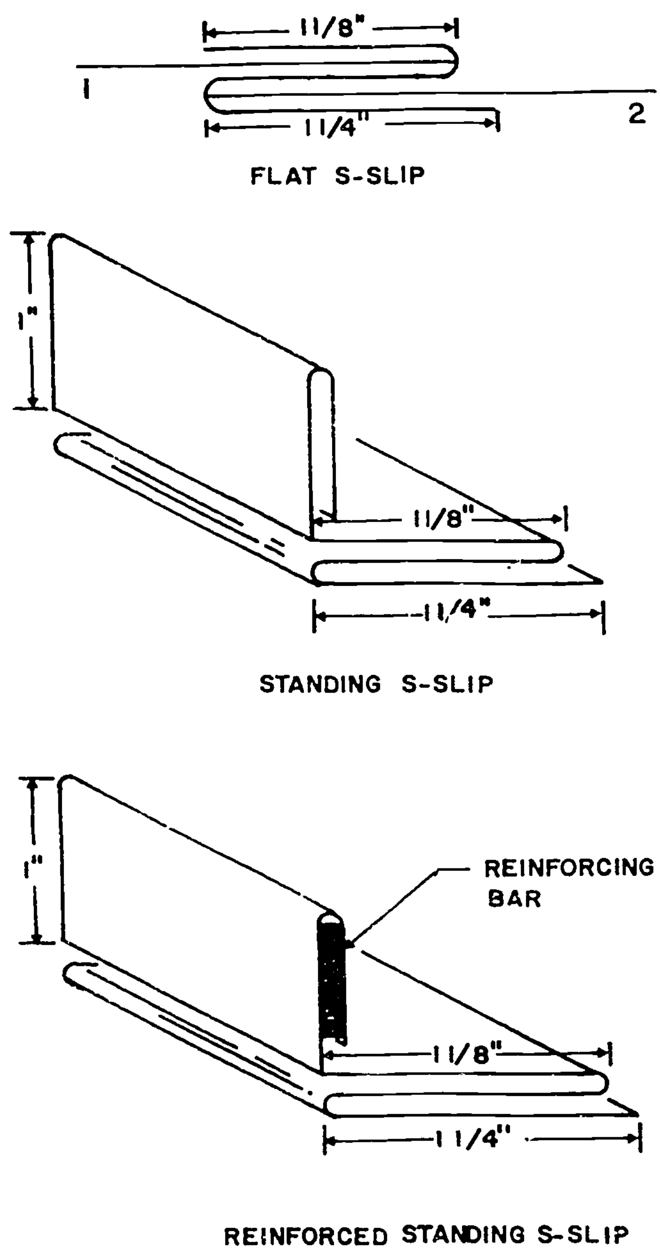

Figure 2-12. Types of S-slip.

purposes, we have included the braking instructions on the pattern, and in steps B through F of figure 2-13, the directions of the bends are indicated.

In step B of figure 2-13, the standing edge is bent 180° at the 1 inch line. Next, in step C, the metal is bent up 90° at the second 1 inch line. In step D, the metal is turned over in the cornice brake, and then bent approximately 150° at the third line between the two 1 inch measurements. In step E, the metal is again turned over in the cornice brake and bent approximately 150° at the fourth line between the 1 - and 1¼-inch measurements. In the final step (F), the two 150° bends are flattened with the cornice brake until they are each 180°.

Reinforced standing S-slip. A reinforced standing S-slip, like the one illustrated in figure 2-12, is similar to the standing S-slip but has a flat bar in the standing edge to increase its strength. The procedure for fabricating a reinforced standing S-slip is similar to making a standing S-slip as explained in the previous paragraphs. The reinforced standing S-slip illustrated in figure 2-12 has a 1 inch standing edge, which is reinforced with a 3/4-inch x 1/8-inch flat bar. Flat bars of other widths and thicknesses can be used if the dimensions of the standing edge are increased proportionately.

Exercises (425):

1. To form a 1-inch standing S-slip, the first two bends are for the ________.

2. What is the last step in forming a standing S-slip?

3. For what purpose is the standing S-slip used?

426. Given uses of the drive slip and cite the steps needed in cutting and forming them.

Drive Slip. The drive slip (sometimes called a drive cleat), illustrated in figure 2-14 and A-4 of figure 2-1, is used as a joint connector to secure piece 1 to piece 2. Notice how the drive slip and the turned back edges of pieces 1 and 2 form a lock joint. You install the drive slip by striking it lightly with a hammer in the direction indicated by the arrow. Although drive slips can be used to connect flat sheets of metal, they are most often

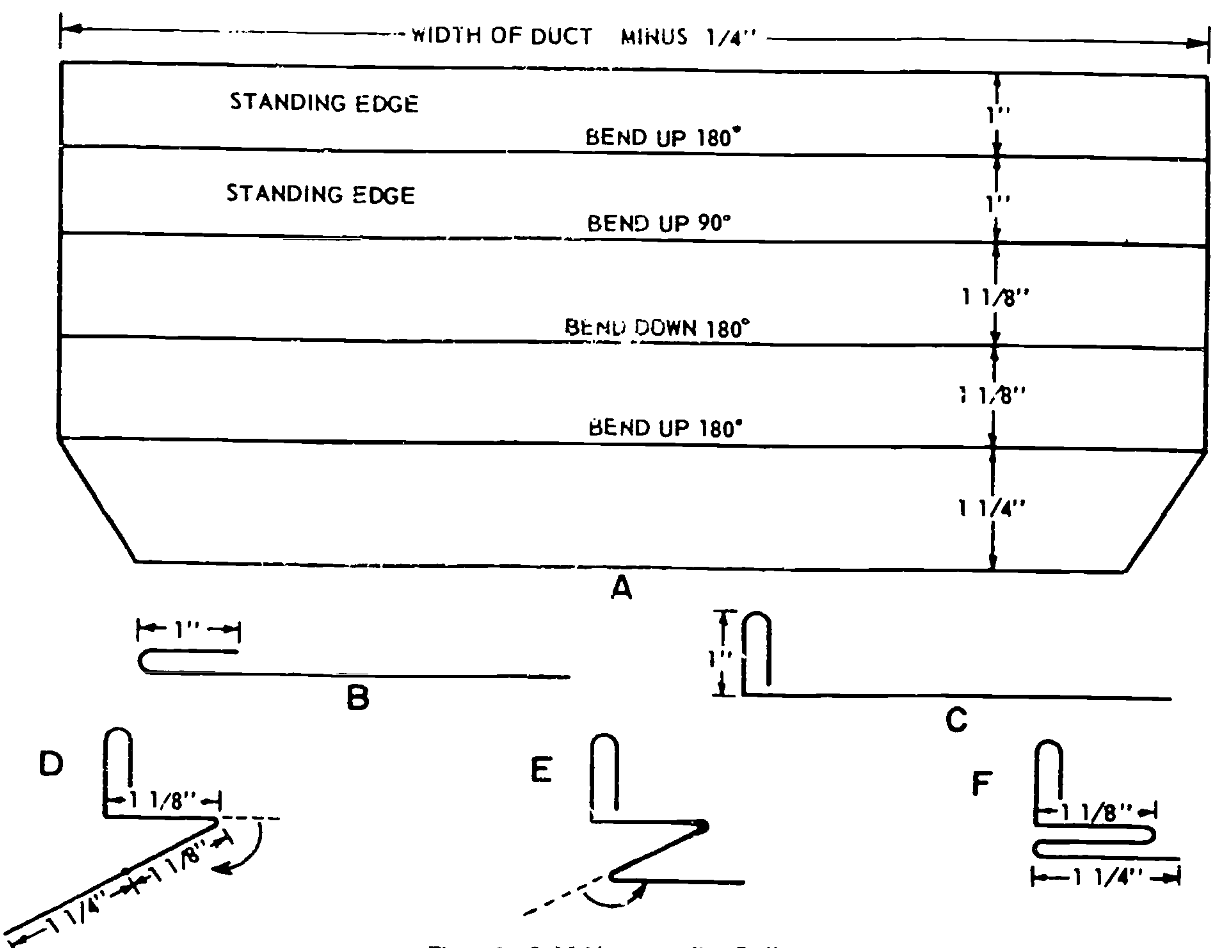

Figure 2–13. Making a standing S-slip.

used (in conjunction with S-slips) to connect joints of duct. In the preceding text segment, we said that S-slips are used to join the widest sides of the duct. Thus, it is appropriate to use S-slips across the top and bottom of the duct and drive slips on the sides, as shown in figure 2-15. When S-slips and drive slips are combined in this manner, the term "S-and-drive slips" is used.

Duct joints connected with S-and-drive slips are firmly locked together, though they can be easily removed if it is necessary to dismantle the duct.

The material needed to fabricate a drive slip is determined by the width of the drive slip and the dimensions of the duct, usually its height. The first step is to lay out the pattern, shown in Step A of figure 2-16. This figure illustrates the often-used 1 -inch drive slip. Notice that an extra allowance of—inch is made on the center section to allow easier installation. If you are making a drive slip for an 18 x 12-inch duct, make the drive slip 14 inches long so that 1 inch extends past each end and can be bent down to keep the drive slip in place.

After you have made the pattern, cut the metal and use the bar folder to turn each edge 180° along the brake lines, as shown in steps B and C of figure 2-16. With 45° angles cut at one end, the drive slips can be installed with less effort. When completed, the 1 inch drive slip should have the dimensions and appearance shown in step C.

Exercises (426):

1. Drive slips are used with ____________ .

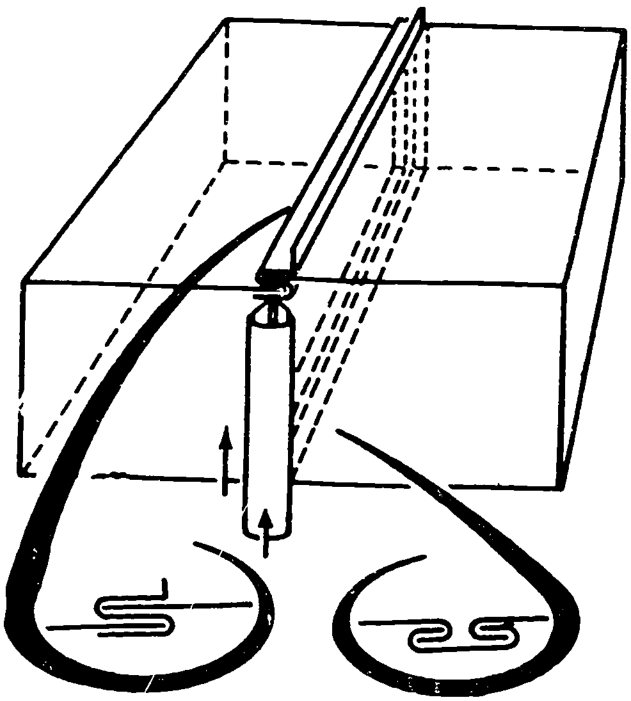

Figure 2-15. Duct joints connected with S-and-drive slips.

2. The drive slip pattern for an 18-inch duct should measure ____________ inches.

3. How can the installation of a drive slip be made with less effort?

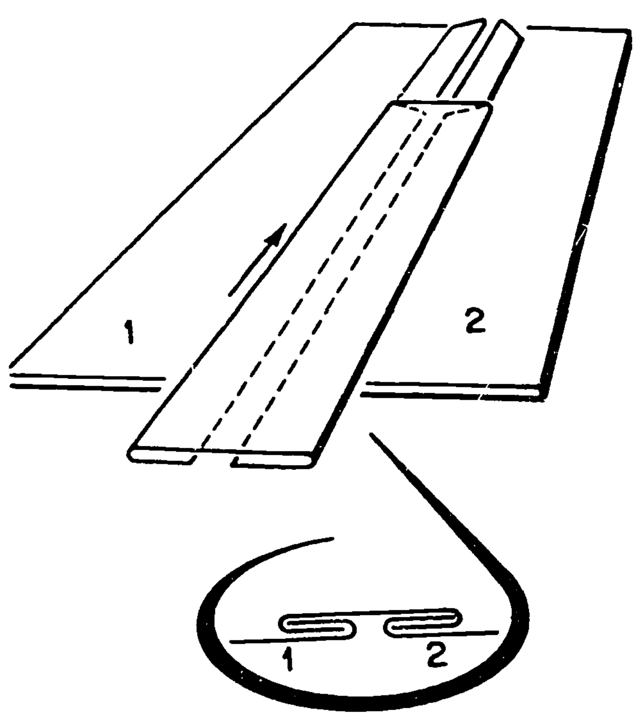

Figure 2-14. Drive slip.

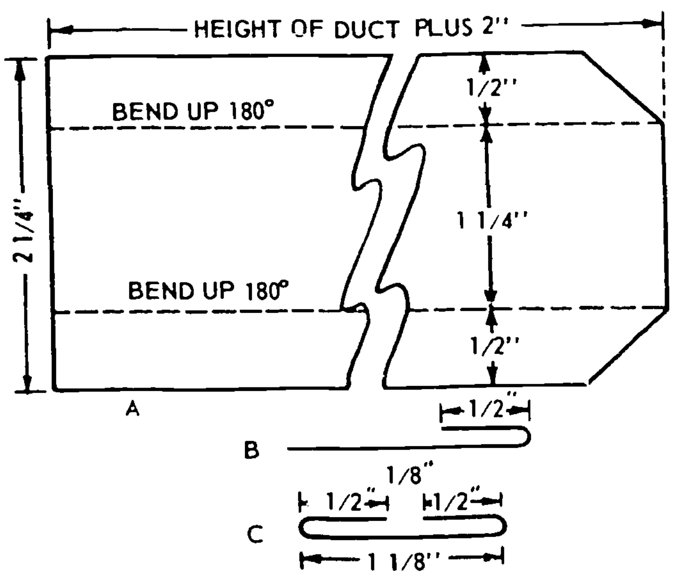

Figure 2-16. Making a drive slip.

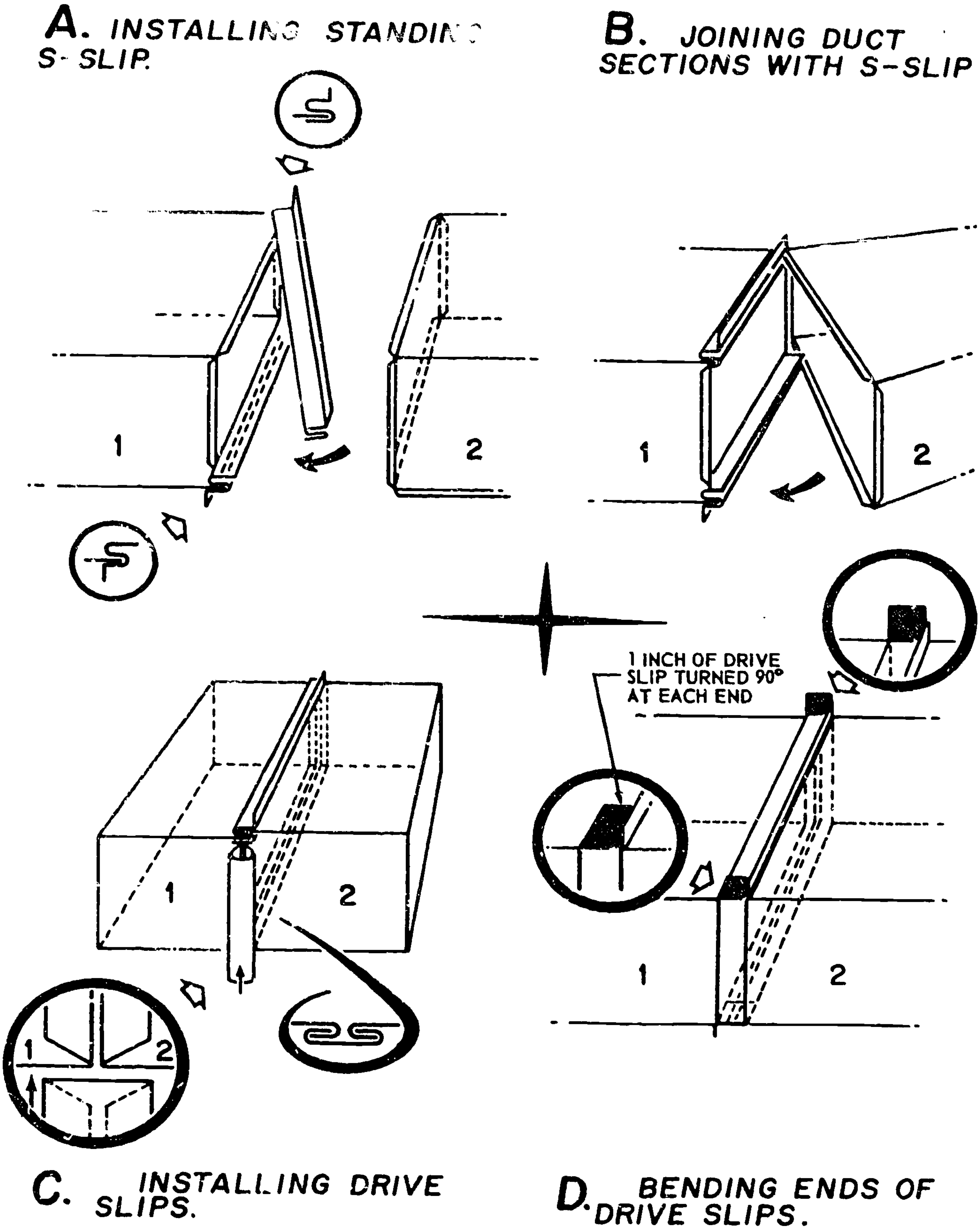

Figure 2–17. Connecting duct joints with S-and-drive slips.

427. Give selected steps in assembling the S-and-drive slip connection.

Installing S-and-Drive Slips. Figure 2-17 illustrates the complete process of using S-and-drive slips to connect joints of duct. View A shows standing S-slips being installed on the top and bottom sides of a duct joint. Notice how the top S-slip is started at a 45° angle because the channels are usually tight fitting. After the S-slip is started at one end, you can tap it into place with a hammer or mallet until it is in the same position as the bottom S-slip in the illustration. Notice the position of the standing edges of the top and bottom S-slips. Figure 2-17 also shows the allowance for the overlap of joints 1 and 2. This allowance is 1/2 inch on each edge when 1⅛-inch S-and-drive slips are used. The additions on both joints have been notched 45° at the corners.

View B of figure 2-17 shows how joint 2 is inserted at one end into the S-slip. Start a drive slip on the end just inserted to hold it in place, and move joint 2 firmly in the direction of the arrow until all of the top and bottom joint addition is inserted into the pockets of the S-slips. Now joints 1 and 2 should be in perfect alignment. However, the two S-slips do not lock the joint. The next step is to install the drive slips on the sides of the duct to lock the points together. View C of figure 2-17 shows how you insert a drive slip over the turned back edges of the two joints. The drive slip should drive on easily with light taps of a hammer if the patterns were correctly made and the edges turned properly. When both drive slips are installed, the two joints are firmly held together. One more step is taken to insure that the drive slip does not come off.

View D in figure 2-17 shows how the extra 1 inch, which was added to each end of the drive slip, is turned down to form a positive lock. This operation completes the connection of two duct joints with S-and-drive slips. This is an excellent connection and has the additional feature of being easy to disconnect if the duct should ever need to be dismantled.

Exercises (427):

1. What is the first step in connecting two duct sections with S-and-drive slips?

2. Why is a drive slip started before the duct is fully in place in the S-slips?

3. Give the last step of an S-and-drive slip installation.

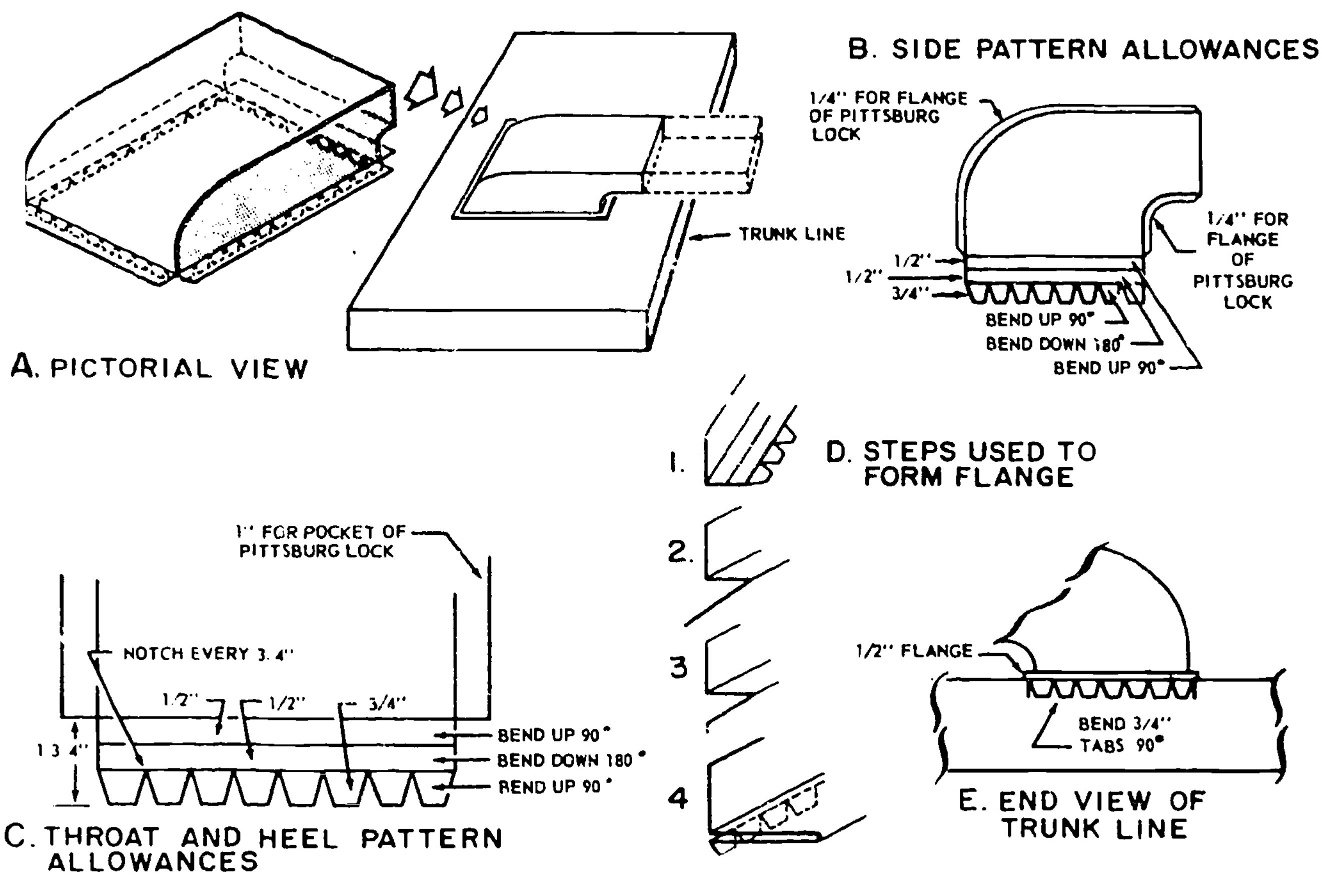

Figure 2-18. Making a tapped connection for a curved takeoff fitting.

428. Point out selected steps in the fabrication and installation of tapped connections, takeoff fittings, and slip joints.

Tapped Connection. A tapped connection, like the one shown in view A of figure 2-18, is used to join a takeoff fitting to a duct. A takeoff fitting (also called a takeoff or simply a fitting) is used to connect a smaller duct or branch line to a larger duct, such as a trunkline. You may find some sheet metal workers using other names of the tapped connection of a takeoff. ("Clinch lock", "P-lock," and "tap connector" are often used. In step 4, view D, of figure 2-18, you can see the flange (sometimes called a frame or collar), which forms a base for the takeoff fitting when it is installed in the trunkline opening. After the tabs are inserted in the opening, they are bent 90° to lock the fitting to the trunkline. A takeoff fitting may be curved, straight, or tapered, making a neat flush fit.

The curved tapped connection illustrated in figure 2-18 is in the form of an elbow, and four pieces are required for its fabrication: two sides, a throat, and a heel. Pittsburg lock seams are used to join all four corners. The material allowance to make this tapped connection is included in each pattern. Note in view B and view C of the illustration that the allowance on each pattern is 1¾ inches.

Before you form the tapped connection with a cornice brake, you must form the flanges and pockets for the Pittsburg lock seams. Turn the 1/4 inch flange on the two side patterns, and form the pocket on the throat and heel patterns. Next, form the 1/2 inch flange for the tapped connection, as shown in steps 1 through 4 of view D in figure 2-18. Bending this flange with a cornice brake is the same procedure used earlier in this chapter to form a standing seam.

After you have formed all four pieces and assembled the elbow, cut a hole in the trunkline, insert the tapped connection in the hole, and bend the tabs outward 90° with a hammer, or mallet, using with a dolly or bucking bar as a backing surface.

Fabricating a Takeoff Fitting. The fabrication procedure is similar for all takeoff fittings and includes making ·· seams, joint connectors, and tapped connectio.. . We will explain making the pattern and allowances, notching, forming, and joining a tapered takeoff fitting, such as that illustrated in figure 2-19. Notice that it connects a branch line to the side of a trunkline.

Making a flat pattern. From the information shown in figure 2-19, it is not difficult to develop the flat patterns shown in figure 2-20. You should remember from the sheet metal layout chapter in Volume 3 that the first step is to draw a plan view with the dimensions, as shown in figure 2-20. From the plan view, you develop the pattern (stretchout) by the parallel line method (except for the slanting sides). The pattern for the top and sides is in one piece because you will use two Pittsburg lock seams to join the bottom piece. Lay out flat pattern A by drawing a straight line (stretchout) equal to the perimeter of the top and two sides. Next, draw the two perpendicular element lines where the corners of the joint will be folded. The length of the upper stretchout line in view A is equal to the perimeter of the 12- by 6-inch opening of the transition. With the ends of the two stretchout lines connected, you can determine the length of the slanting sides (true length). Flat pattern B for the bottom of the takeoff fitting is the same length as the slant length of the side that it will join.

Making allowances. After you have laid out the flat patterns, the next step is to determine the seam allowances and additions, shown in figure 2-20. This includes the allowances and for the S-and-drive slip connections, the Pittsburg lock seams, and the tapped connection. It doesn't make any difference which allowance you develop first. We have elected to develop the allowances for the S-and-drive slips first. They require a 1/2-inch allowance on both patterns. You make the allowance for the Pittsburg lock seams by allowing 1/4 inch on each of the slant sides in pattern A (fig. 2-20) and 1 inch on two sides of pattern B. Make the allowance

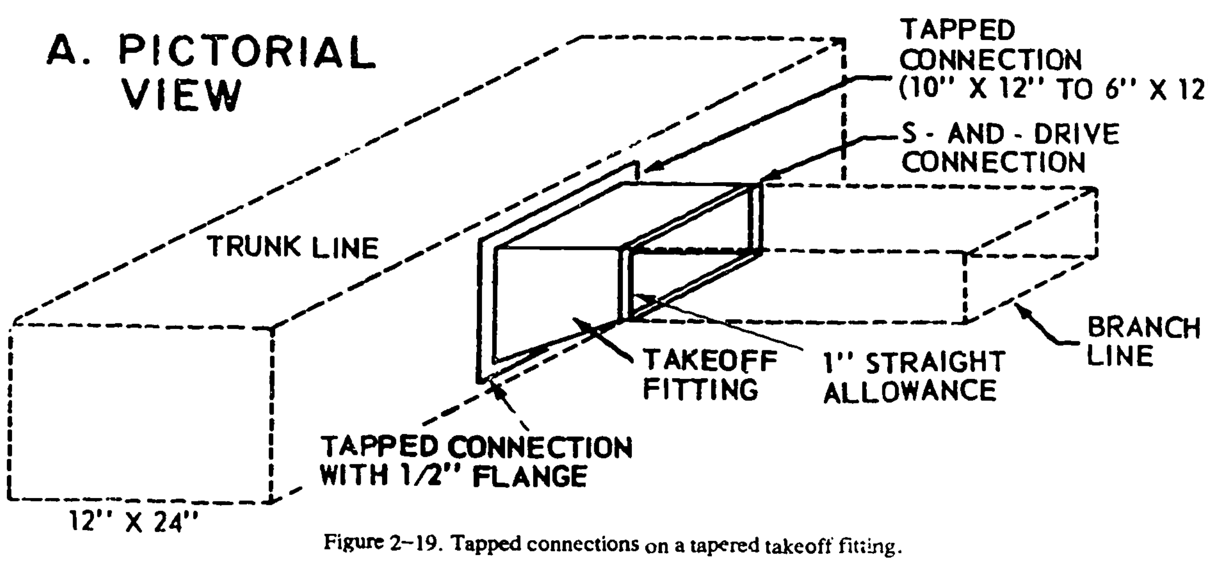

Figure 2–19. Tapped connections on a tapered takeoff fitting.

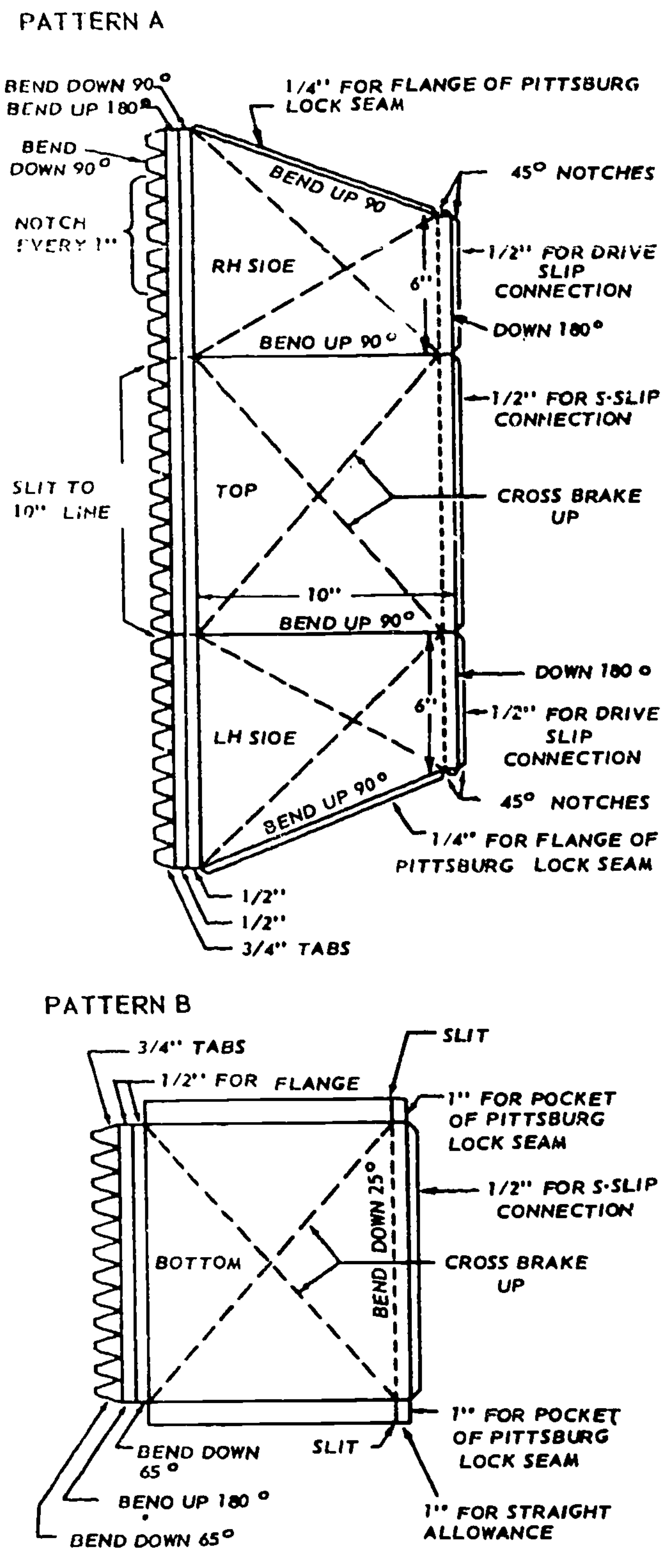

Figure 2–20. Making allowances for S-and-drive connections, Pittsburg lock seams, and tapped connections.

for the tapped connection on both patterns and include 1/2 inch plus 1/2 inch for the flange and 3/4 inch for the tabs, a total of 1¾ inches allowed for the tapped connection.

Notching. After you have determined and marked the allowances, cut the notches and slits, as indicated on patterns A and B of figure 2-20. Each notch that forms a 3/4 inch tab requires two cuts and is placed 1 inch apart in this example. However, in other patterns, the length of each tab may be less or greater depending on the strength desired, on the size of the takeoff fitting, and on the effort needed to reach and turn down the tabs after you have joined the fitting to the duct. Notice that each end of the S-and-drive connection allowance is notched with a 45° cut. The ends of the Pittsburg lock seam pocket allowance in pattern B are notched (cut) at 90° angles.

Forming. You can make all of the bends indicated in figure 2-20 with a cornice brake, a mallet, and a Pittsburg lock-forming machine. It is important to follow the proper sequence for making the bends so the top leaf of the cornice brake will not crush a fold already made. For example, cross brakes are always made first, but the sequence of other bends may vary depending on the shape and direction of the bends. A sequence that works in most cases for square or rectanglular duct components is as follows: (1) make the cross brake, (2) bend the side allowances according to the seam procedure, (3) bend the end allowances according to the procedure for the type of joint, and (4) make the corner bends indicated on the pattern.

To make the bends for the takeoff fitting (fig. 2-20), the first step is to do the prescribed cross braking. Pattern A (piece A) is placed in the cornice brake so that the metal is at a 45° angle to the top leaf, the metal is clamped with the top leaf, and the bending leaf is raised 10° to 15°. Repeat this procedure along the other cross brake lines.

Continuing with piece A only, the second step is to bend the 1/4-inch flange 90° for the Pittsbrug lock seam. This operation, shown in figure 2-21, is performed with the cornice brake and mallet. This lets you bend the 1/4 inch flange without bending the end of the 1 inch straight and the end of the allowance for the drive slip connection. After bending to 90° the flanges at each side of piece A, you must straighten out each end for about 2 inches so that you can clamp the metal in the cornice brake to make the tapped connection bends.

The third step for piece A (fig. 2-20) is to make the bends that will be at the two ends of the takeoff fitting. Make the bends for the tapped connections with the cornice brake, as described in the next paragraph.

The 180° bends for the drive slip connection are made as illustrated in figure 2-22. Use the mallet only to fold the bends for the 1/2 inch allowance for the two side pieces. (The 1/2 inch allowance for the S-slip connection on the top and bottom pieces must remain straight). If desired, you can use a hand seamer to make the bend instead of the cornice brake and mallet. The 1/4-inch 90° flange for the Pittsburg seam, which was

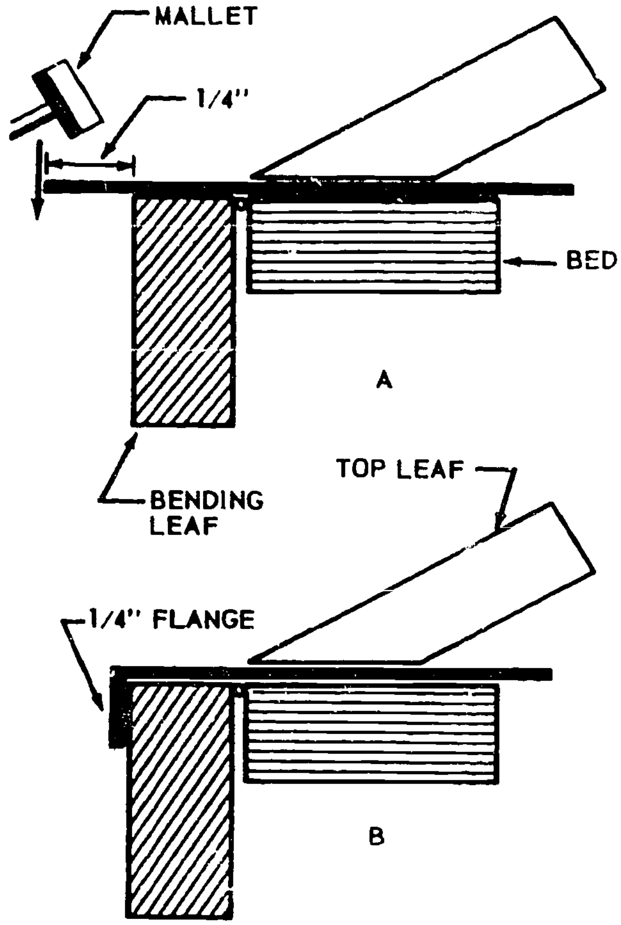

Figure 2–21. Bending 1/4-inch flange with cornice brake.

temporarily straightenend for 2 inches on each end of piece A, is now returned to the 90° angle with a hand seamer.

Step 4 of the forming process for piece A in figure 2-20 is to use the cornice brake to make the two 90° corner corner bends. Make the first corner where the top side and the left side meet, with the pattern positioned at the left end of the cornice brake. This prevents damaging the flange of the tapped connection. Next, bend the 90° corner, where the top side and the right side meet, in the same way. This is the final step for piece A, which should now look like a finished takeoff except for the sloping bottom, not yet in place.

Pattern B (piece B), the bottom of the takeoff (fig. 2-20), is formed by a similar sequence. The first step is cross braking the pattern along the diagonal lines. The second step is making the pocket side of the Pittsburg lock seams on the 1 inch allowance on each side of the bottom piece. Do this with a Pittsburg lock-forming machine if available; if not, with a cornice brake. The third step is forming the flange for the tapped connection end of the takeoff. You must make a 25° bend downward along the straight allowance line, returning the bottom to the same plane as the duct branch. When you are making this 25° bend, do not use excessive clamping pressure with the top leaf of the cornice brake. Too much pressure can damage the Pittsburg seams. The fourth step is omitted in forming the bottom piece of this component.

Assembly and joining. The takeoff fitting, which we have discussed in the preceding paragraphs, is easy to assemble. Place piece A (fig. 2-20) so that it rests on the top side. Install the bottom piece (B) so that the 1/4 inch flanges of the two sides fit into the pockets of the Pittsburg seam, and the locking edges of the Pittsburg seam are folded over. This completes the assembly, and you can join the takeoff fitting to the hole in the trunkline by inserting the tabs into the hole until the flange rests against the edges of the hole. Bend the tabs

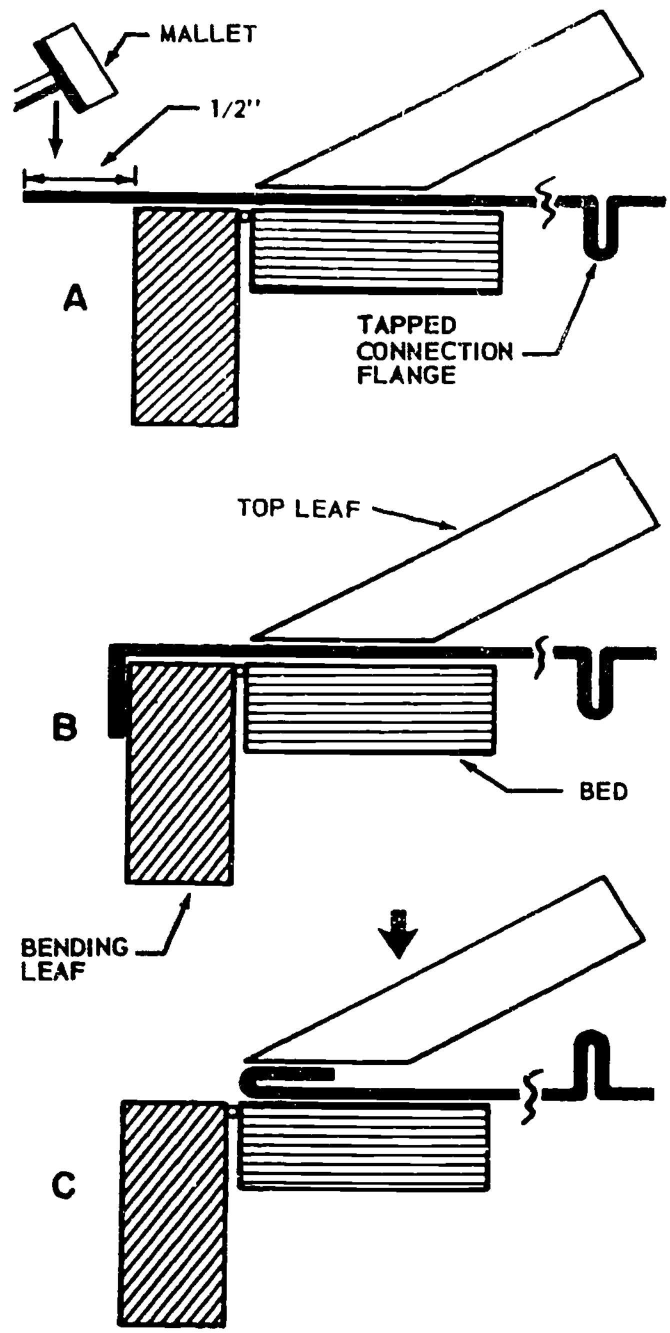

Figure 2–22. Using cornice brake to bend 180° fold for drive slip.

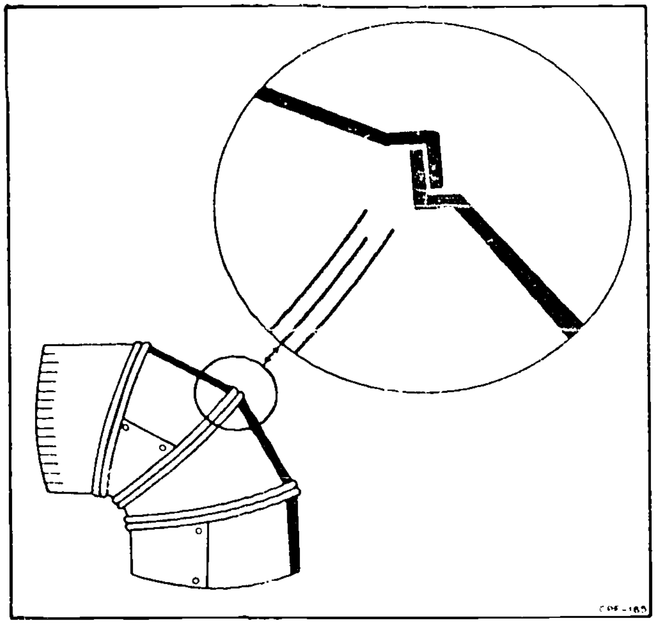

Figure 2–23. Elbow edge joint.

90° outward to make a tight connection. To join the branch duct to the takeoff fitting, use S-and-drive slips.

Elbow Edge. The elbow edge is a joint used to connect small sections of round duct to transition pieces, such as, adjustable elbows, diffuser box, and register box. The elbow edge is made by bending the edges of two items of the same size so that they will lock together, as seen in figure 2-23. To assemble an elbow edge joint, leave one rivet out to allow the section to be spread and slip over the edge of the other piece. Then push the ends back into place and install the second rivet. Check the joint to ensure everything is properly aligned.

Slip-Joint. Joint connections for round ducts are somewhat different from those for rectangular ducts. Figure 2-24 shows a 1½-inch slip joint. One end of each piece of pipe is crimped with a crimping machine, as you learned in Volume 2. A bead made with a beading machine strengthens the duct and helps align the joints during installation. This connection is sometimes called a slip joint and you assemble it by slipping the crimped end into the plain end of another joint until the bead is flush with the plain end. The slip joint is fastened together with sheet metal screws or rivets, and the airflow must be in the direction indicated in view C.

Exercises (428):

1. To fabricate a tapped connection, what step must you complete before you form the parts with a cornice brake?

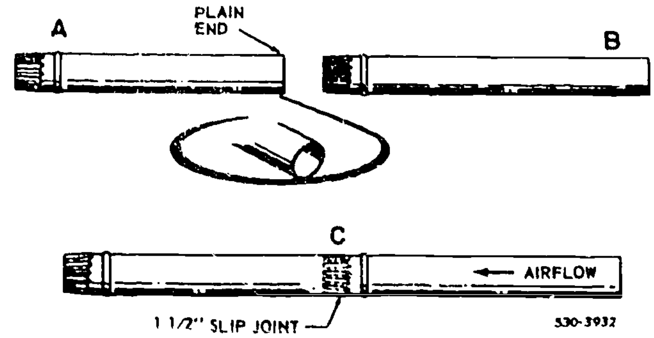

Figure 2–24. Joint connections for round duct.

2. What are tapped fittings used for?

3. How do you lock a takeoff fitting in place?

4. In forming the bottom of a takeoff fitting, what step do you omit?

5. How many parts are there in a slip-joint connection?

6. How are the joints constructed to form a slip joint?

429. State the requirements for a spot weld of a seam or joint.

Spot Welds. Spot-weld seams are like riveted seams because one piece must lap over the other. The radius of the electrode face determines the size of the spot weld. If the contact face is too smmall, the weld may be sound but low in strength. If the contact face is too large high current will be required to overcome the increased resistance. This condition produces localized heating and results in poor weld surface appearance. A good rule to follow when you select electrodes for a given job is to select those whose contact face diameter equals four times the thickness of one of the pieces of metal being welded. Then you can vary the pressure on the electrodes slightly to provide more or less indentation and thereby arrive at the proper diameter of contact area and the proper size of the spot weld.

Seam Allowance. The seam allowance for a spot-welded seam is determined in the same way as the seam allowance for a riveted seam. As a general rule,

the distance from the center of the weld to the edge should be twice the diameter of the weld. If the weld's diameter is 1/8 inch, the seam allowance should be ¼ inch on each side of the joint.

Exercises (429):

1. Give the basic requirement for a spot-weld seam.

2. How is its seam allowance determined?

3. How should you determine the size of a spot weld?

Characteristics and Control of Airflow

IN THIS CHAPTER we are concerned with the airflow through duct systems. You will find that air, like water, passes easily through straight ducts, but at turns (elbows), the flow becomes turbulent, forms eddies and whirlpools, and moves against the main current. To minimize this turbulence and resistance to airflow, you must understand the characteristics of airflow through duct systems. For example, you must know what size and shape of elbow permits the best airflow. You must also know how splitters and turn vanes can improve airflow, how dampers can restrict airflow, and how deflectors can detect airflow. This chapter will help you to understand airflow characteristics, to determine the dimensions of duct system components, and to fabricate and install duct system components.

3-1. Characteristics and Control of Airflow Through Duct Systems

Though your working drawings and blueprints specify how new systems must be fabricated to provide a maximum flow of air, you need to know how to apply the principles of good airflow as you fabricate and install ducts that carry air from heating, ventilating, and air-conditioning units to different parts of a building. In Chapter 1 we gave you some of the symbols used on working drawings for ducts, dampers, registers, grilles, and louvers. Now is a good time to review these illustrations and refresh your memory.

430. Give the reason for air turbulence in duct systems and some of the rules of air distribution.

Airflow. Forced air systems for heating, ventilation, and air-conditioning include: motor-driven blowers; coils, filters, and associated components of the heating and cooling units; the supply duct system; and the return duct system. When engineers design a forced air system for a building, they consider many factors. For example, after they determine the load requirements for heating and cooling, they must design a duct distribution system that will carry the required flow of air with the least amount of resistance. Some of the factors they consider are static pressure, velocity pressure, friction loss, and dynamic loss. Some of these factors are directly related to your job of fabricating and installing duct systems. Therefore, for instructional purposes, we will use the term "pressure loss" to describe the conditions that are affected by the quality of your work.

Like water, air flowing through a duct system loses some pressure because of friction with the sides of the duct and because of turbulence resulting from changes in the direction of the duct or changes in the cross-sectional area of the duct. In figure 3-1 you can see examples of turbulence in duct system components as the flow of air tends to whirl and move in different directions. There is less pressure loss in the straight duct with a uniform cross section than in the other examples that involve a change in direction or a change in the cross-section area.

Some of the general rules that apply to air distribution systems are:

- Select the proper size of duct.
- Pipe the air as directly as possible to the required location.
- Avoid sharp turns.
- If you must alter the size or shape of a duct, make the change as slight as possible.
- Avoid restriction of flow in elbows and transformation pieces.
- Make rectangular ducts as nearly square as possible.
- Reduce friction by using smooth duct material.

Exercises (430):

1. Give the two main causes of air turbulence in a duct system.

2. State the air distribution rule that describes the proper duct material.

3. State the rule that affects the length of a duct.

431. Point out problems in fabricating straight ducts with elbows, and compute the ratio of a given elbow.

Straight Duct. Air being forced through a straight duct encounters less pressure loss than through elbows or transitions. The loss through a straight duct is caused primarily by friction as the air touches the sides of the duct. The loss increases when the inside of the duct is rough, when the length of the duct is increased,

or when a smaller duct is used. The pressure loss is less through a round duct than through a square or rectangular duct, though the square duct is better than the rectangular duct.

Since, when you are fabricating straight duct, its size, shape, and length are usually specified in the working drawings, your main consideration is to make the joint connections and seams as smooth as possible to keep friction at a minimum.

Diverging and Converging Duct. It is sometimes necessary to enlarge a straight duct, as shown in figure 3-2, to install a cooling or heating coil. Coils like this are often larger than the duct and make it necessary to install two transitions. In the illustration, angle A is in the diverging transition, and angle B is in the converging transition. In both transitions, it is important to make the changes as gradual as possible. In a diverging transition, angle A should not exceed 20°. Splitters should be installed to reduce pressure loss and to insure an even distribution of the air through the coil. A converging transition usually does not require splitters, but angle B should not exceed 60°. (We will further discuss splitters later.)

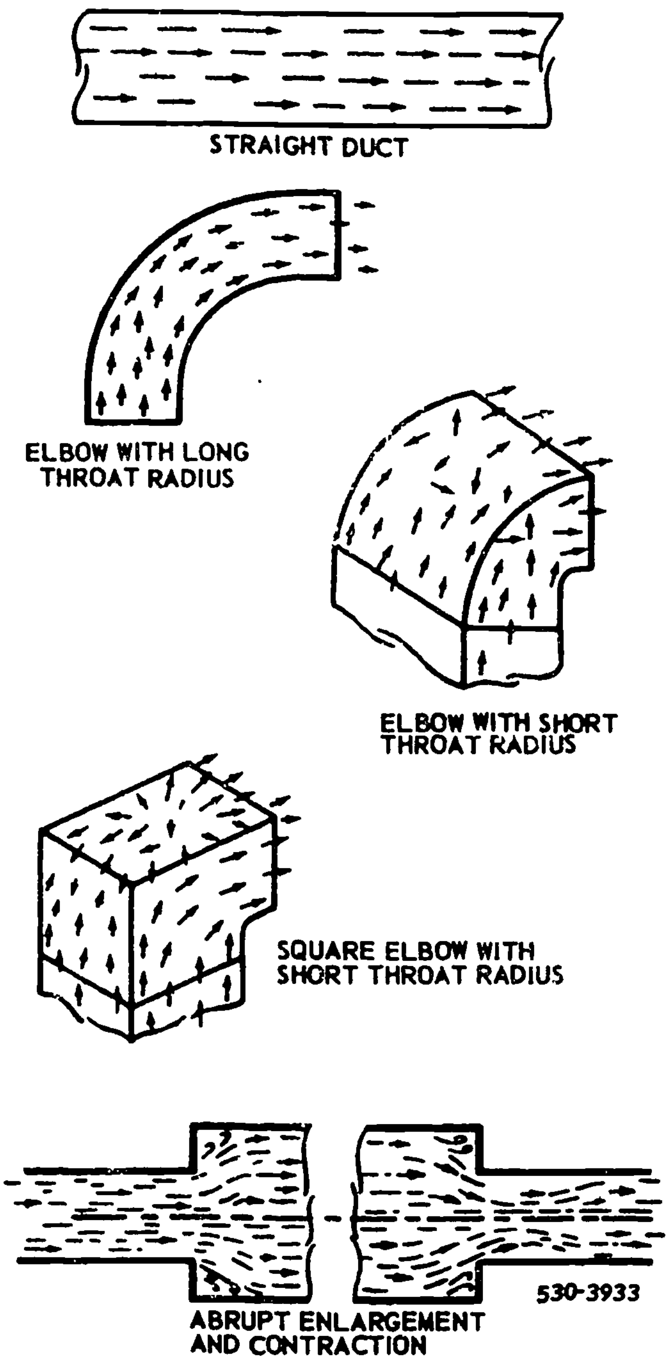

Figure 3-1. Air turbulence in duct components.

Elbows. The elbows used in duct systems cause air turbulence and pressure loss, which can be minimized by their proper design and fabrication. Avoid sharp turns by using elbows with larger throat radii and duct dimensions that allow a maximum airflow.

The elbows in square or rectangular ducts have a dimensioning characteristic that you must understand if you want maximum airflow. This characteristic concerns the width of the elbow, which is somewhat different from the width of the straight duct sections. Figure 3-3 illustrates two elbows in a rectangular duct. Notice that the width of elbow A is 12 inches, and the width of elbow B is 6 inches. The width of an elbow in a square or rectangular duct is always the dimension that lies in the same plane as the radius of the elbow.

Elbow A in figure 3-3 has more turbulence and the resulting pressure loss than elbow B because of the ratio between the throat radius (R) and the elbow width (W). A ratio between 1 to 1 and 2 to 1 is desirable, the latter ratio being the more desirable. The throat radius ratio is also called inside radius ratio and you find it by dividing throat radius (R) by width (W). For example, the inside radius ratio for elbow A is 1 to 1, determined by substituting the width and throat radius dimensions ($\frac{R}{W}=\frac{12}{12}=\frac{1}{1}=1$). In speaking of ratios, it is common practice to use the equivalent value, such as 1:1 = 1. Thus, a ratio of 2 to 1 is called a ratio of 2, and a ratio of 1 to 2 is called a ratio of 0.5, etc.

Elbow B in figure 3-3 has an inside radius ratio of 2, or $\frac{12}{W}=\frac{12}{6}=\frac{2}{1}=2$, which is more desirable than a ratio of 1. Both elbows in the illustration have a satisfactory airflow, although elbow B has the better airflow.

Exercises (431):

1. To reduce friction in a straight duct, what is your main consideration?

2. List two tupes of ducts that are used as transitions to enlarge a straight duct.

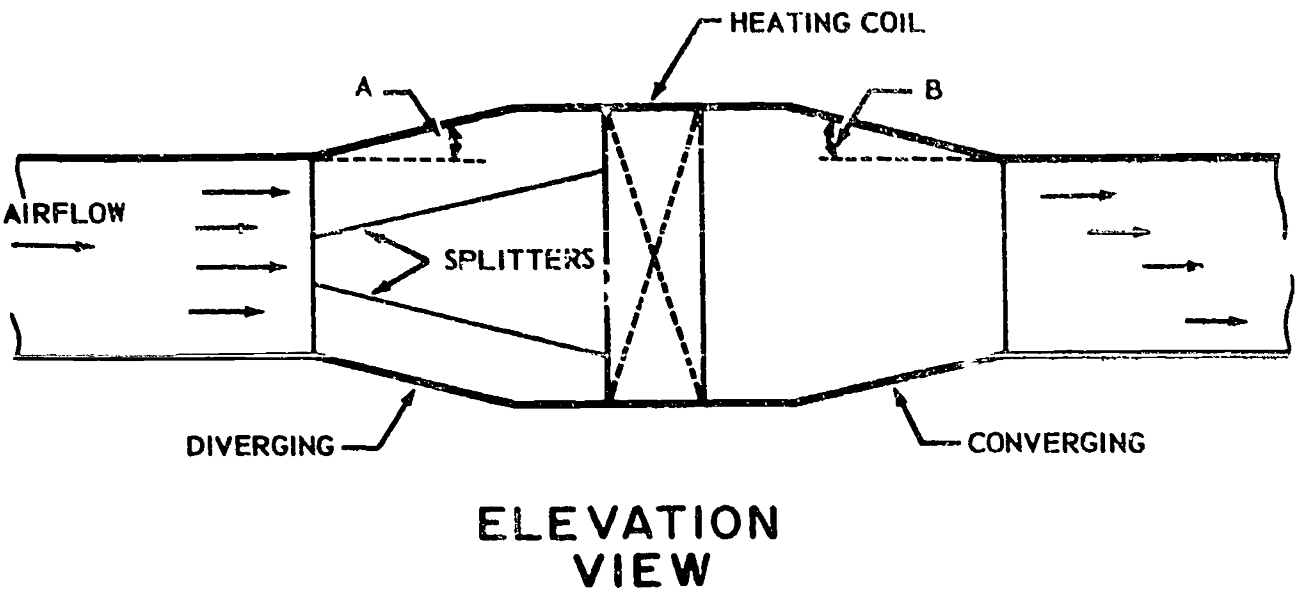

Figure 3–2. Diverging and converging ducts.

3. What is the ratio of a square elbow with an inside radius of 12 inches and a width of 8 inches?

4. The width of an elbow in a square or rectangular duct is always the dimension in what plane?

3-2. Duct System Components for Control of Airflow

Several devices are used inside duct systems to control airflow. Splitters and turn vanes are used to prevent turbulence as the air flows around turns inside of square or rectangular ducts. Such devices as volume dampers are installed inside duct systems to reduce or shut off the airflow. Diffusers and registers at supply outlets control the volume and direct the airflow in desired directions.

432. Locate the turn vanes in a given elbow and describe the way to install splitters in rectangular elbows.

Splitters. Splitters, like those shown in figure 3-4, are used to improve the flow of air through elbows that do not have a desirable inside radius ratio. Splitters reduce the turbulence of the airflow as it passes through an elbow by dividing the flow of air into passages with better inside radius ratios. Splitters are also used when the outlet end of an elbow does not connect to another duct of the same size and the air is discharged into a large space or into the atmosphere.

Elbow A in figure 3-4 (if used without a splitter) has an inside radius ratio of 0.33, or $\frac{R_1}{W} = \frac{6}{18} = \frac{1}{3} = 0.33$ which will produce an excessive turbulence in the air passing through the elbow Notice in the illustration that the splitter is not through the center of the elbow but divides it into one 6-inch passage. The inside radius ratio for 6-inch passage is 1, or $\frac{R_1}{W} = \frac{6}{6} = \frac{1}{1}$ 1. The

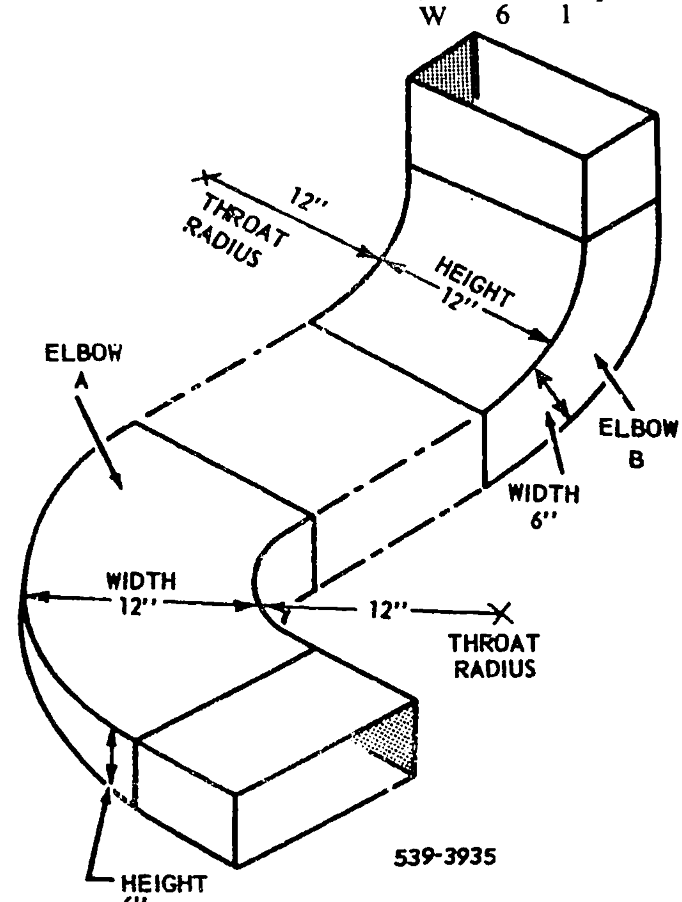

Figure 3–3. Rectangular duct elbows.

inside radius for the 12-inch passage is also 1, or $\frac{R_2}{W} = \frac{12}{12} = \frac{1}{1} = 1$. Thus, by placing a splitter in the proper location, we have reduced the turbulence and pressure loss through the elbow.

Elbow B in figure 3-4 (if used without splitters) has an inside radius ratio of 0.25, or $\frac{R}{W} = \frac{5}{20} = \frac{1}{4} = 0.25$ which will also produce excessive turbulence and pressure loss. When two splitters are installed, as shown in the illustration, each passage will have an inside radius ratio that permits air to flow with a minimum of turbulence and pressure loss.

Figure 3-5 shows how splitters are installed during the fabrication of elbows for square or rectangular ducts. You can see how difficult it would be to install the splitters after an elbow is assembled. Notice how the tabs on the splitters permit their being fastened with rivets or spot welds. After the splitters have been fastened to the bottom of the elbow, the top is attached with Pittsburg lock seams. The last step is to fasten the splitters to the top. Remember that allowances (3/4 inch in this example) must be made on the pattern of each splitter before it is cut to size.

Turn Vanes. Turn vanes (see fig. 3-6) are used in the elbows of square or rectangular ducts to reduce turbulence and pressure loss and to provide a more uniform distribution of air. Turn vanes are especially valuable in the elbows connected to supply registers and grilles.

In figure 3-6 you can see that the turn vanes form several small elbows that function very much like splitters. However, you determine the number of turn vanes and their distances apart in a different way from those for splitters. For best airflow, the turn vanes should be spaced so that they have an aspect ratio of 5 (5 to 1). The aspect ratio of an elbow is equal to the height of the elbow divided by its width $(\frac{H}{W})$. (Remember that the width of an elbow is in the same plane as its radius.) For example, if the elbow in figure 3-6 is 15 inches high, we can substitute 15 for H, solve for W (width or radius of the turn vanes), and find that the turn vane width should be 3 inches if maximum airflow is to be obtained. Therefore, the turn vanes should be installed 3 inches apart to divide the elbow into several effective smaller elbows, each with the desired aspect ratio of 5:

$$\frac{H}{W} = 5$$

$$\frac{15}{W} = 5$$

$$W = \frac{15}{5}$$

$$W = 3$$

To determine how many turn vanes you need, measure the distance from the throat corner to the heel corner of the elbow and divide it by the 3-inch radius. For example, if in figure 3-6 the distance from throat to heel is 24 inches and each turn vane is to be 3 inches apart, you should divide 24 by 3 to find that you need 8 turn vanes.

Notice in figure 3-6 that each turn vane is straight on both sides of the 90° radius bend. The length of each straight edge is equal to 1/2 the distance (radius) between the turn vanes. Since in this example the turn vanes must be 3 inches apart, each straight edge should extend 1½ inches past the 90° radius bend.

Turn vanes are installed with tabs and rivets (or spot welds) in a manner similar to that for splitters. Figure

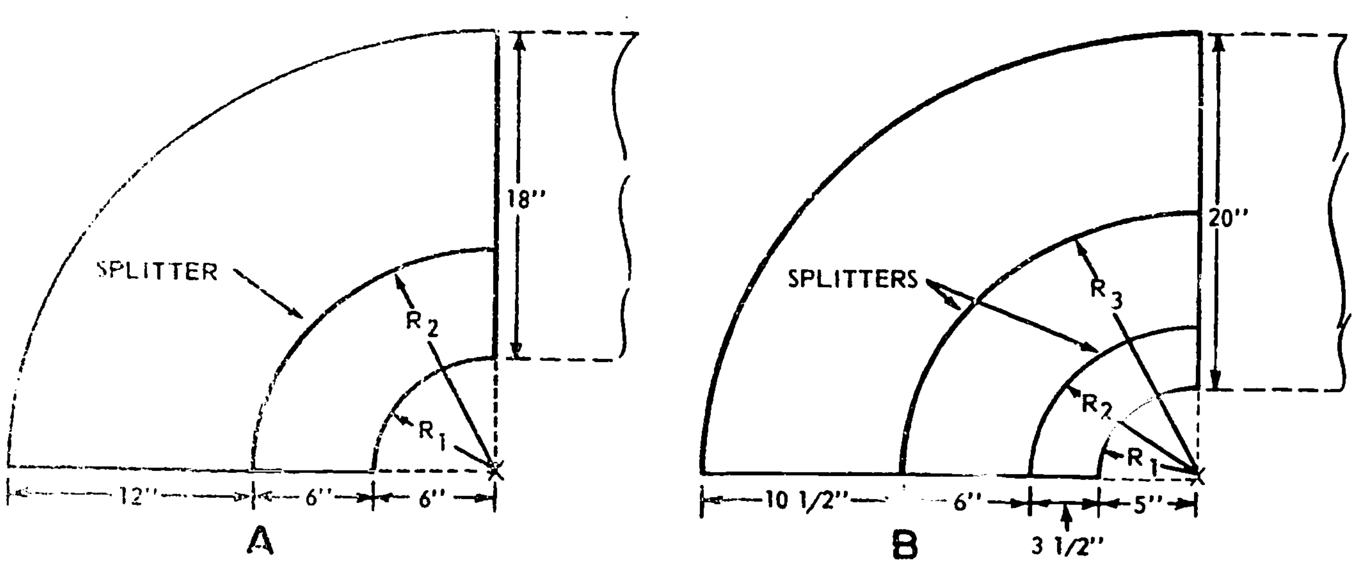

Figure 3–4. Splitters in rectangular duct elbows.

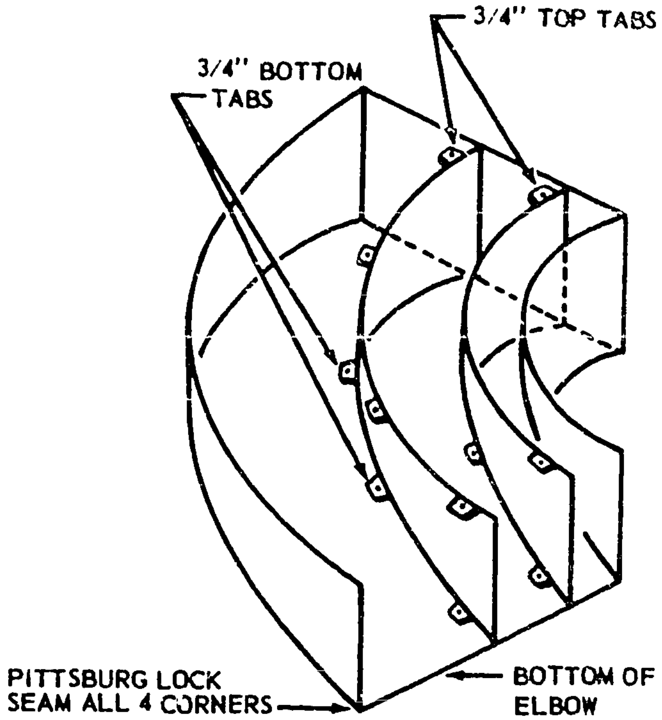

Figure 3-5. Installing splitters.

3-6 does not show the tabs, but each end of each turn vane should have at least three tabs, one in the middle of the bend and one on each straight edge.

Exercises (432):

1. An elbow with a height of 26 inches should have a turn vane every ________ inches.

2. How should you install splitters in rectangular duct elbows?

433. Identify procedures in the use and placement of volume dampers in a duct system.

Volume Dampers. A damper is a movable blade used to vary the volume of air flowing through a duct system. Some dampers make only minor changes in volume, some completely shut off airflow, and others adjust the range of airflow from maximum to zero. Types of volume dampers discussed in this chapter include deflecting dampers, butterfly dam pers, and louver dampers.

Deflecting damper. A deflecting damper, illustrated in figure 3-7, is sometimes called a splitter damper. It is a single blade hinged at one edge, and can be positioned with an accessible control handle. You install this directional control for airflow on the outside of the duct so that the damper can be

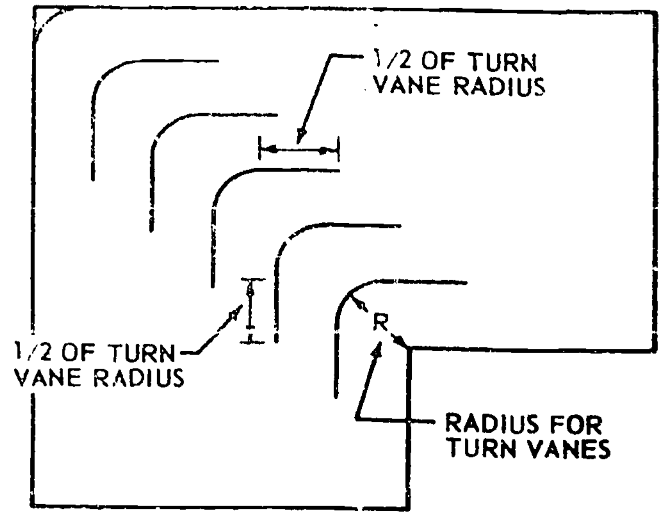

Figure 3-6. Turn vanes in square elbow.

positioned after you have assembled and installed the duct system. In the illustration, you can see how you can increase or decrease the airflow in the branches by changing the position of the deflecting damper. Deflecting dampers are usually positioned (set) during the first operational checkout of the airflow system. After a balanced air flow is achieved, the damper is locked in position with a wingnut.

Deflecting damper blades are usually made from material that is 2 gages heavier than the duct and are attached to shop-made shafts and handles or to factorymade directional control quadrants. The length of the damper blade is the same as the height of the duct, less a clearance of approximately 1/4 inch. The

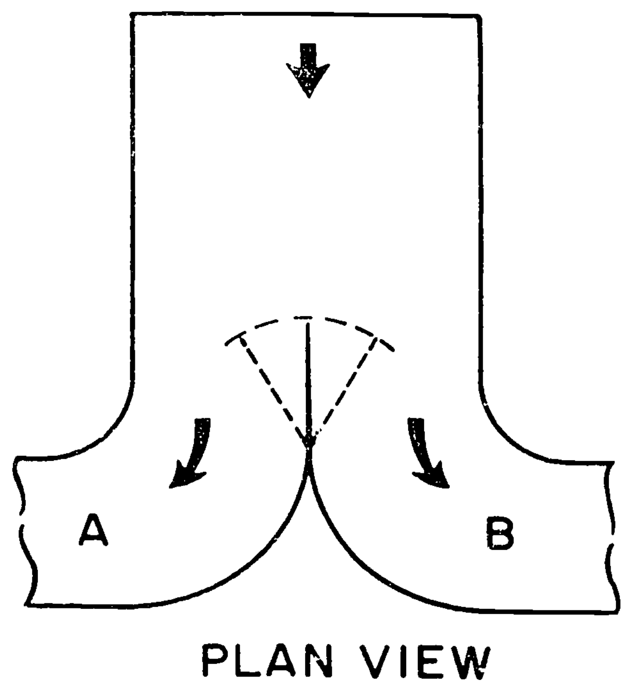

Figure 3-7. Deflecting damper in a duct system.

width of the blade varies according to the amount of airflow to be deflected. Usually, the width of the deflecting dampers is approximately 3/4 the width of the branch line, as shown in figure 3-7.

Butterfly damper. A volume control damper like that shown in figure 3-8 is commonly called a butterfly damper. It has a blade made from sheet metal, is hinged in the middle, and is usually located in the middle of a straight duct. With this damper, you can adjust the airflow from zero to full flow by positioning the angle of the blade with the handle of the control quadrant. Notice in the illustration that the butterfly damper is located near the branch takeoff. It should not be located near the outlet of the branch duct because, if the damper is partly closed, it creates two high-velocity airstreams along the duct instead of a uniform flow. Also, the angle of the damper blade causes the air to flow from the duct at an undesirable angle.

The blade of a butterfly damper is usually made of sheet metal, which is 2 gages heavier than the duct. The size of the blade is the same as the inside dimensions of the duct, except for a clearance of 1/4 inch. If a tight fit is desired, a strip of felt can be installed around the edges of the blade.

In figure 3-8 you can see how a butterfly damper is installed in a branch line. Now look at figure 3-9 and see the various pieces of hardware that are used with a butterfly damper. Notice that the control quadrant, which has a removable handle, is riveted to the outside of the duct and is the pivot for the square shaft, which is riveted to the damper blade. At the other end of the centerline, the round shaft attachment plate is riveted to the blade. Notice that the round shaft bushing plate is riveted to the inside of the duct.

Before you can rivet the bushing plate and control quadrant to the duct, you must drill holes so that the two shafts can extend through the duct. To install the assembled butterfly damper in a duct, position the blade inside the duct and insert the square shaft into the square hole of the quadrant. The round shaft is spring-loaded and can retract enough to allow the round shaft to be inserted into the bushing plate with the round hole. Next, install the control handle in the square shaft extending through the control quadrant. Tighten the wingnut to lock the handle and damper blade at the desired angle.

Louver dampers. Many designs have been developed that use a series of adjustable louvers inside of the ducts or at their outlets. On some working

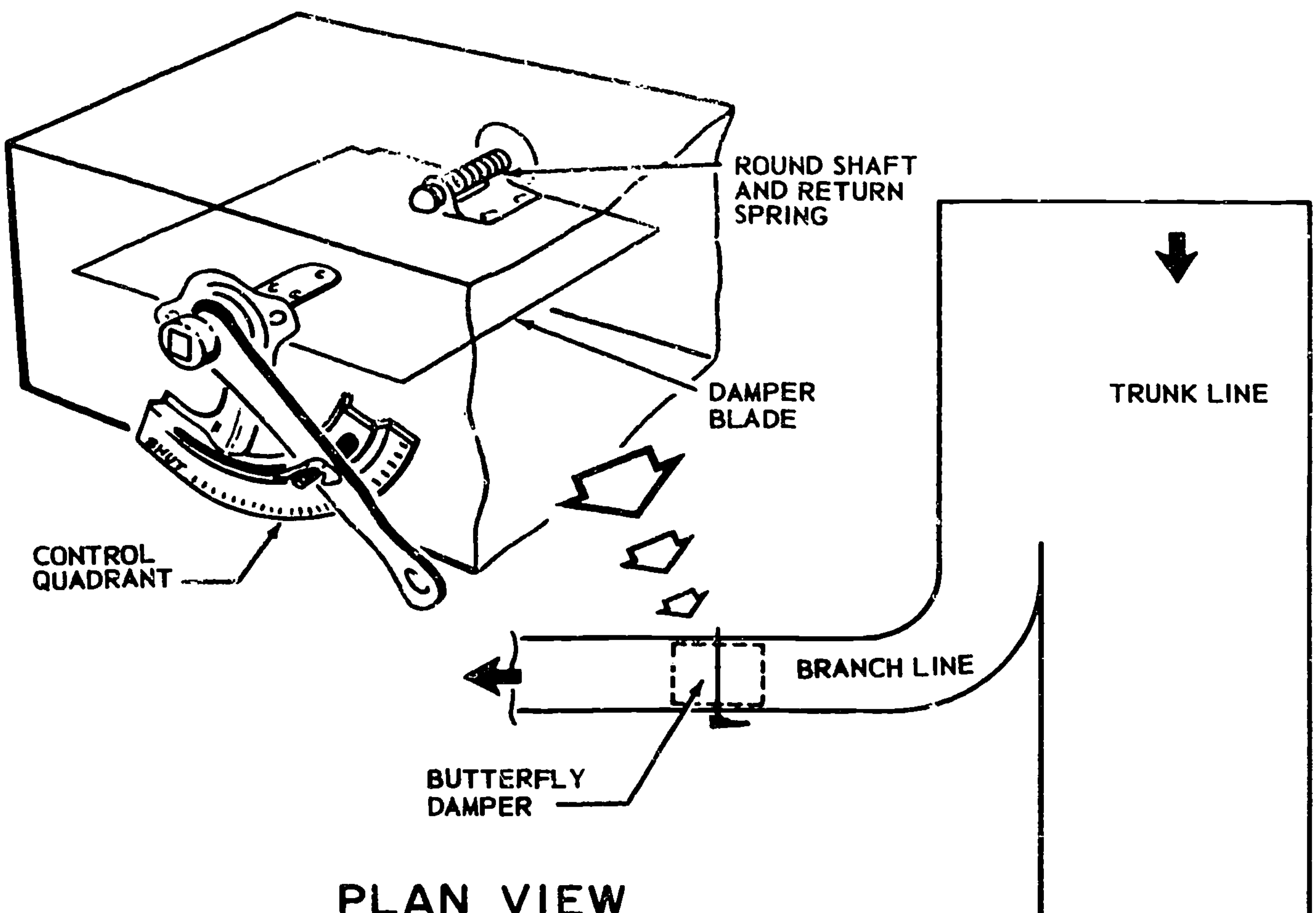

Figure 3–8. Butterfly damper in a branch line.

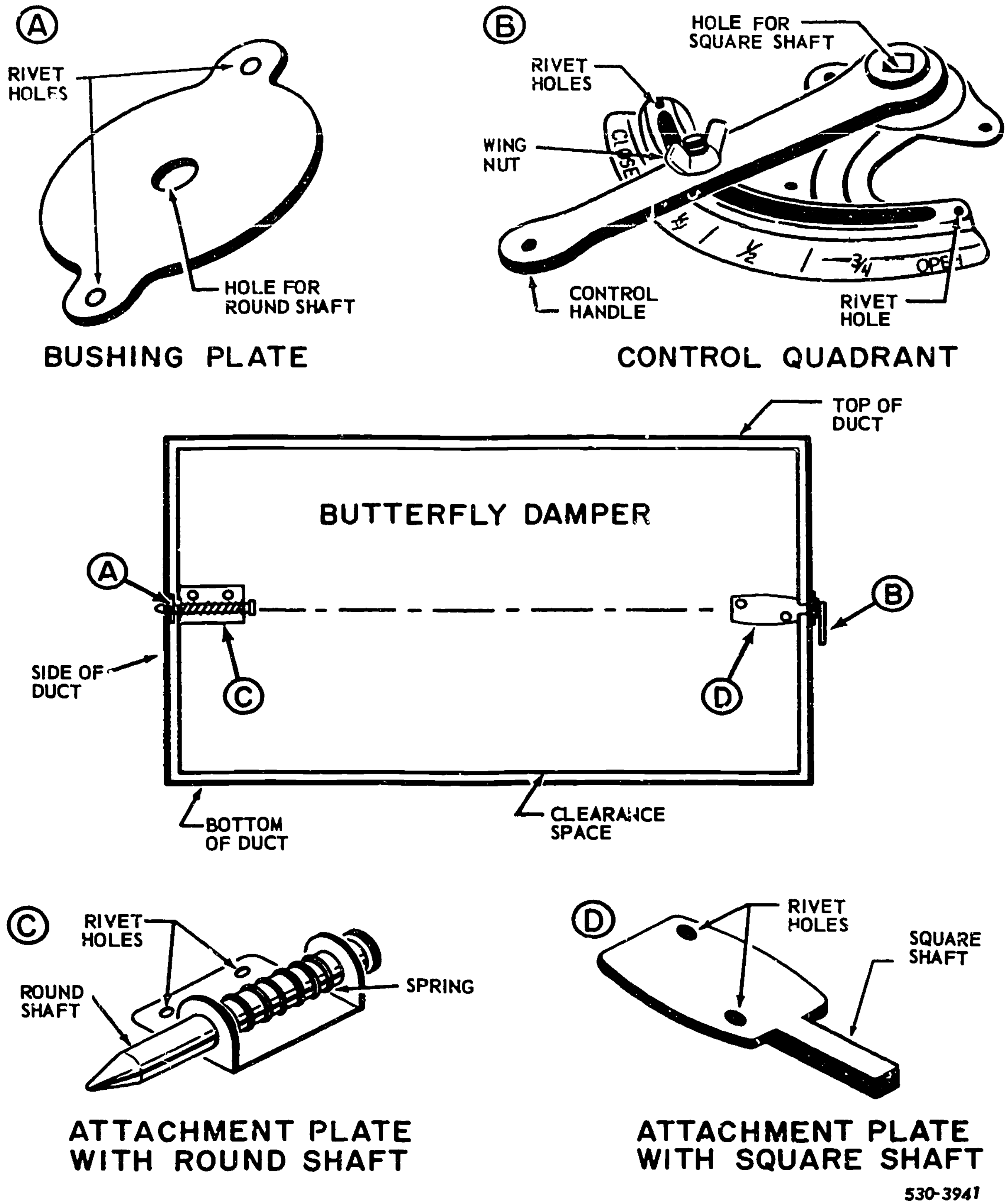

Figure 3–9. Butterfly damper components.

drawings this type of volume damper is labeled a multiblade damper, whereas on the other drawings the same damper is labeled a louver damper. Figure 3-10 shows a louver damper used to reduce or shut off the flow of air through a duct. Each of the four damper blades pivots on its centerline axis when the connecting linkage is moved. Although not shown, the linkage can be operated by various means, such as motors, springs, weights, and airflow, or can be manually positioned with gears or quadrant handles. Notice in figure 3-10 how the edges of each blade have V-grooves so that, when the blades are tilted to verticcal position, the grooves fit together to make a better seal.

These grooves also act as stiffeners for each blade and redu vibration as air flows between the blades.

Louver dampers are usually purchased as factory-made assemblies, and your job will be to install them correctly. You attach the louver damper, shown in figure 3-10, to the inside of the straight duct with bolts before you install the duct and connect the louver blade linkage to its actuating device. Notice the access hole and cover plate so that inspection or maintenance can be performed when necessary. During installation be sure to use boltheads that do not interfere with the movement of e blades.

An automatic louver damper is used as a fire damper at exhaust outlets or in a duct that passes through a firewall. This type of damper is set, at the time of installation, to permit full airflow. If a fire occurs, a fusible link melts and lets the spring-loaded damper blades close. This shuts off the airflow and prevents a draft that could intensify the fire. The installation of an automatic louver fire damper is similar to the installation of other louver damper assemblies. Louvers with fusible links also require an access door or panel in the duct so that the fusible link can be checked.

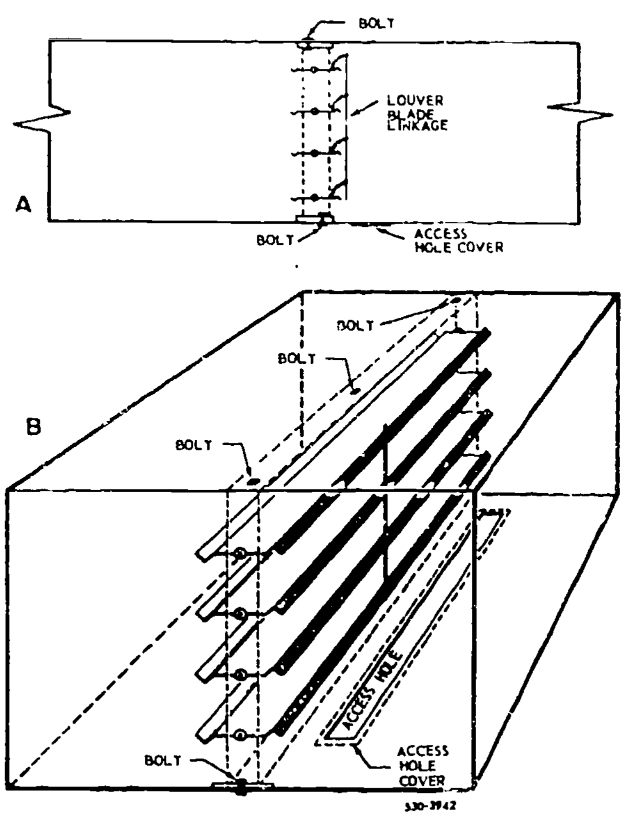

Figure 3-10. Louver damper.

Figure 3-11 shows another variation of a louver damper. The blades are normally closed but open automatically when the exhaust fan is in operati .. The exhaust system illustrated is for ceiling installation, but similar units are available for wall installation. When you are installing or replacing this kind of louver damper, be sure to use the correct type so that the blades fully close when the fan is not operating and the wind cannot pass through the damper in the wrong direction.

Exercises (433):

1. Dampers are used in duct systems to ____________

2. The butterfly damper is usually located ___________

3. Deflecting dampers are used to ____________.

4. The type of damper in a duct that goes through a firewall is usually a __________ .

434. State the function of diffusers, registers, and grilles.

Ceiling Diffusers. Several types of ceiling diffusers are used at the supply outlet of some duct systems. Figure 3-12 shows a round diffuser with an adjustable damper assembly. View C shows the diffuser as it appears when installed over the damper assembly (B). View D is a cutaway view of the diffuser showing how the turn vanes diffuse the airflow. Notice how the airflow is dispersed in all directions from the diffuser. View B shows the parts of the volume damper assembly, including the frame (ring), adjustable butterfly damper blades, and control knob. You can open and close the blades by turning the knob, which is attached to a threaded shaft. Some damper assemblies of simmilar design have a pull chain to open or close the blades.

The frame of the damper assembly, shown in view B, has a 1-inch flange that fits into the supply duct (A). Four sheet metal screws secure the flange to the inside of the duct, which has been previously secured with hangers so that its edges are flush with the ceiling. Therefore, when the damper assembly is inserted and

secured with screws, the damper frame fits snug against the ceiling. The diffuser is attached to the damper with four sheet metal screws. Notice in view D that a circular gasket on the diffuser prevents air from leaking and smudging the ceiling (streaks of dust or dirt around diffusers). Ceiling diffusers and volume dampers are also available for square supply duct outlets, their main differences being square-shaped damper assemblies and square-shaped diffusers.

Registers. Several types of registers are used at duct supply outlets to control the volume and direction of the airflow. The device shown in figure 3-13 is a multipleblade register with two sets of blades. The horizontal row of blades connects with linkage that is controlled by the hand-operated lever on the right side of the face frame. You can adjust the horizontal blades from full-flow position to full-closed position. The horizontal blades operate somewhat like louver damper blades in figure 3-10, although the pivot axis is usually at the back of each blade instead of at its center. During the adjustment of the horizontal blades from the full-open to the closed position, the front edge of the blades lowers through a 90° arc.

The vertical blades shown in figure 3-13 are not linked together but are set individually to the desired angle of deflection. You can adjust the vertical blades with your fingers or with a small wrench that fits one blade at a time. For a register to give maximum control of airflow, the air coming through the duct must be evenly distributed over the entire area of the register. If the register is located near an elbow, turning vanes are usually used to insure an even distribution of the air flow.

View B in figure 3-13 shows a side view and the way the blade frame is attached with sheet metal screws to a 3/4-inch flange turned 90° at the end of the rectangular duct. The blade frames should have approximately 1/4 inch clearance when they are installed in a duct.

Grilles. Several types of grilles may be used if directional airflow is not important. Grilles do not have adjustable blades or louvers. They cover the return air openings of ducts and are installed in doors or walls for ventilation. Figure 3-14 shows a grille installed in a door. The blades in this type of grille allow air to pass but limit sound and sight. Grilles are usually factory-made, though some of the simple designs can be made in the shop. View B in figure 3-14 is the front side of the grille and shows the face frame and face bars. View C is a side view showing the shape of the blades, which are held in place by the blade frame. Notice that the blade frame is inserted into a cutout made in a door and held in place with screws.

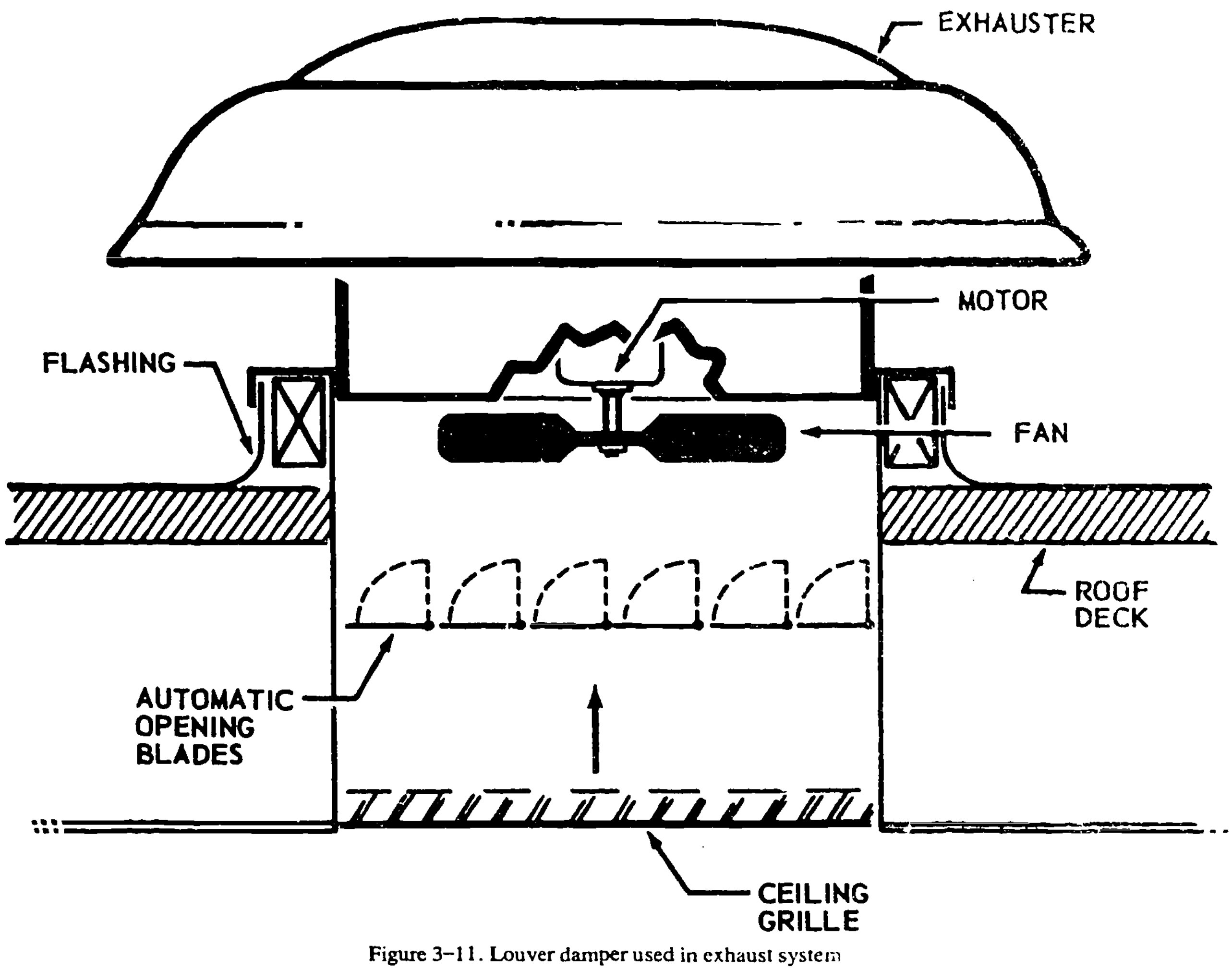

Figure 3-11. Louver damper used in exhaust system

Not all grilles use blades or louvers. Sometimes perforated metal grilles are used to cover ventilators or return air openings in doors or walls. Perforated grilles have various ornamental patterns, such as squares, diamonds, and circular shapes. The perforated metal grille shown in figure 3-15 has a diamond pattern.

Exercises (434):

1. What are diffusers used for?

2. What are registers used for?

3. How are grilles used?

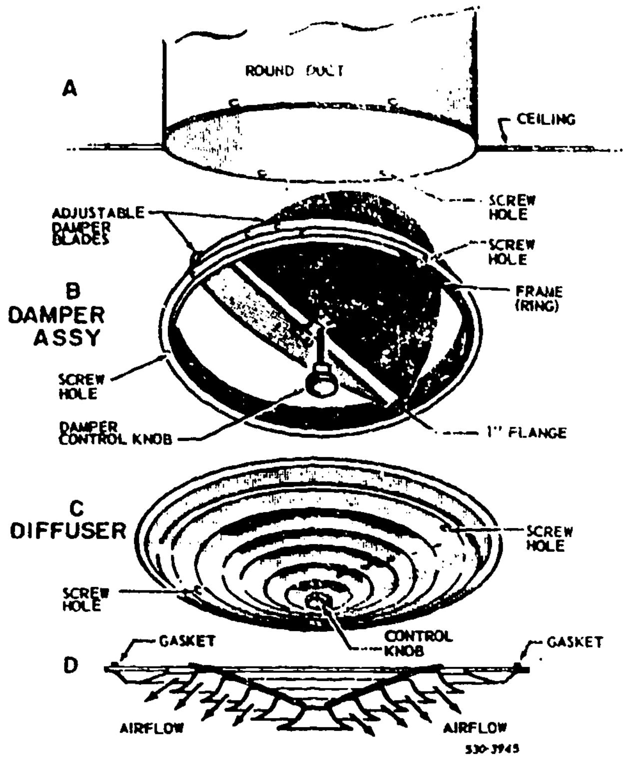

Figure 3–12. Ceiling diffuser and volume damper.

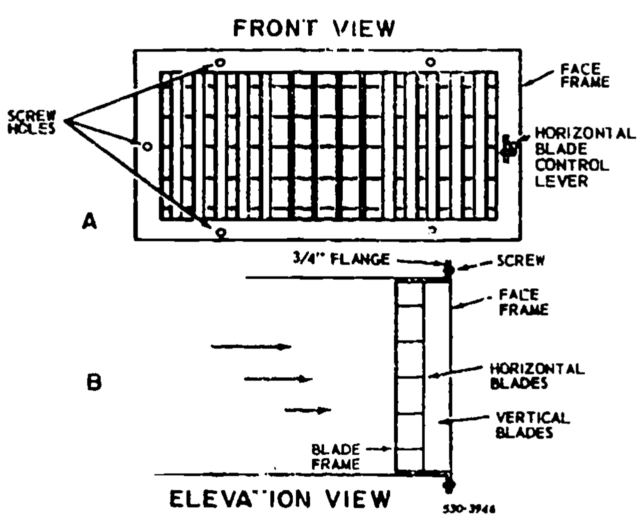

Figure 3–13. Multiple blade register.

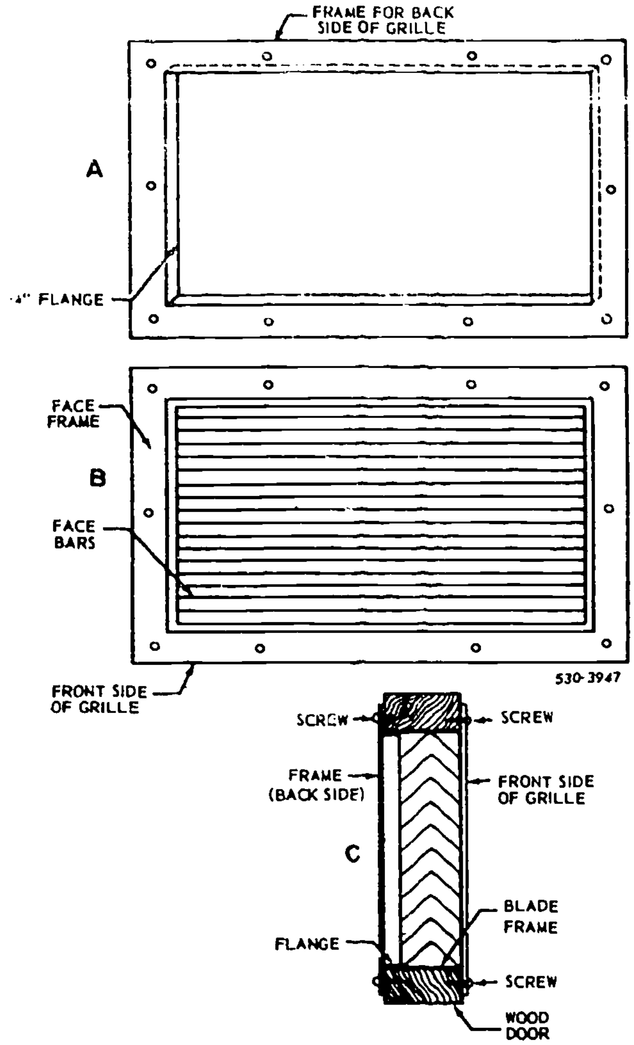

Figure 3–14. Door return grille.

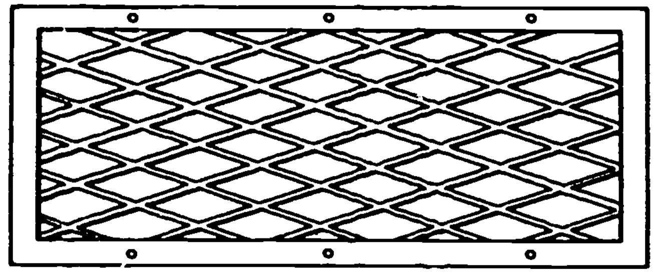

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Figure 3–15. Perforated metal grille.

Duct Systems

THIS IS THE turning point in your Career Development Course because now you are ready to "put together" the many bits of information you have already learned. In this chapter, as weell as in the remaining chapter of the volume, you will use this information as you learn how to fabricate, install, and repair a complete duct system.

This chapter is concerned with a duct job from the initial planning through its fabrication and installation to the repair of its various components. Our discussion is based on the working drawings in foldouts 1 and 2 (located at the back of the text). The duct system they illustrate is typical of other duct systems you will encounter. You will recall previously learned information as you plan, lay out, fabricate, and install components of this duct system. For example, in the planning stage, you will determine the seams, joints, and bracing to use. You will select the proper materials, including sheet metal, registers, grilles, diffusers, louvers, dampers, and insulation. You will lay out the patterns (with allowances) and accomplish the cutting, notching forming, and assembling. You will hang, align, and insulate the duct sections and install the registers, grilles, and diffusers. At the close of the chapter, we will include the repair jobs that can occur in the system.

It is appropriate to begin with a duct system that distributes air through a building because, as a sheet metal worker, you will spend a lot of your time working with duct systems like the one described here.

4-1. Planning a Duct System

Now that you know what ducts are for and what parts make up a duct system, we will go through the complete process of fabricating and installing a duct system. In this section you will do the preliminary planning and the selection of the materials and components to be used. Although AF Form 1445, Materials and Equipment List, includes the materials and components for a new job, you must select what you need for repair jobs. Therefore, for training purposes this section includes how the materials and components shown on the working drawings are selected. You need to know how to identify items listed on AF Form 1445 and where and how they are to be used. For example, when you pick up several sheets of metal at the material holding area, you must know where you will use each sheet and how to cut it without waste.

435. List the steps in planning for a duct system, and give an example of a decision made in each step.

Preliminary Planning. The working drawings shown on foldouts 1 and 2 (located at back of volume) do not specify the types of seams, joints, or bracing to be used; therefore, you must study and analyze the drawings to determine how the system should be fabricated and installed.

System breakdown. The first step in preliminary planning is to break down the system into subsystems, sections, and joints. Refer to foldout 1 as we describe how the system is broken down into trunklines A, B and C.

The supply duct system begins at the heater room in the middle of the working drawing (FO 1). Notice that trunkline A is a 24" x 14" duct that connnects the supply plenum of the heating and cooling units to the trunklines that branch to the right and left wings of the building. Trunkline B supplies the right wing, and trunkline C supplies the left wing. You can find the length of these three trunklines by measuring with an architect's scale or a conventional rule and converting to feet in accordance with the scale shown on the drawing.

Trunkline A measures 9'2" between the plenum chamber and the end of the duct. It is not necessary to break down trunkline A into sections of different sizes because it is the same size its entire length.

Trunkline B is 37'6" long, with sections of different sizes. Therefore, it should be broken down by sizes. Beginning at the takeoff from trunkline A, trunkline B has the following sections:

a. 6" for takeoff fitting reducing 18" x 12" to 18" x 10".
b. 3' of 18" x 10" rectangular duct.
c. 12" for an 18" x 10" to 16" x 10" transition.
d. 12'8" of 16" x 10" rectangular duct.
e. 12" for a 16" x 10" to 14" x 8" transition.
f. 9' of 14" x 8" rectangular duct.
g. 12" for a 14" x 8" to 12" x 8" transition.
h. 9'4" of 12" x 8" rectangular duct.

Trunkline C is 42 feet long and should be broken down into 4 sizes of ducts and 3 sizes of transitions. This breakdown will look like the breakdown for trunkline B.

You continue breaking down of the system in the branch line ducts. In foldout 1, you can count 15 branch lines: 12 are 6 inches in diameter and 3 are 8

inches in diameter. Since the lengths differ, you must measure them to determine the breakdown into 6-inch and 8-inch sizes.

Starting with room 1, you measure the 6-inch diameter branch lines from the side of the trunkline to the center of the outlet and the breakdown is as follows:

Room 1, 7'8" (6'11" straight duct plus 9" for the elbow).

Room 2, 7'7" (6'10" straight duct plus 9" for the elbow).

Room 3, 7'6" (6'9" straight duct plus 9" for the elbow).

Room 5, 7'6" (6'9" straight duct plus 9" for the elbow).

Room 6, 7'7" (6'10" straight duct plus 9" for the elbow).

Room 7, 7'8" (6'11" straight duct plus 9" for the elbow).

Room 8, 7'8" (6'11" straight duct plus 9" for the elbow).

Room 9, 7'7" (6'10" straight duct plus 9" for the elbow).

Room 10, 7'6" (6'9" straight duct plus 9" for the elbow).

Room 11, 7'6" (6'9" straight duct plus 9" for the elbow).

Room 12, 7'7" (6'10" straight duct plus 9" for the elbow).

Room 13, 7'8" (6'11" straight duct plus 9" for the elbow).

The 8-inch diameter branch lines are located in the latrine and two hallways. They break down as follows:

- Latrine 6'6" (5'6" for straight duct plus 12" for elbow).
- Hallway 7'6" (6'6" for straight duct plus 12" for for elbow).
- Hallway 7'6" (6'6" for straight duct plus 12" for for elbow).

Now return to the heater room and figure the dimensions of the supply plenum and the return air duct. To determine these dimensions, you must use foldout 1 (1/4" = 1'—0" scale) and the heater room detail on foldout 2 (1/2" = 1'—0" scale). Since the detail drawing is the larger scale and easier to measure, you find that the supply plenum is 24" wide, 36" high, and 24" long.

The height of the return air duct (return air and outside air plenum) is shown on foldout 2, and the length is measured from end to end. The width is measured on foldout 1. The dimensions of the return air duct are 10' 6" of 36" x 18" rectangular duct.

In the preceding paragraphs, we have broken the heating and air-conditioning duct system down into 3 trunklines, 15 branch lines, the supply plenum, and the return air duct. We then broke these subsystems down into sections with the same dimensions. Now we will take the next step, which is to break down the various sections into appropriate lengths (commonly called joints). For example, the 16" x 10" section of trunkline B contains several joints of 16" x 10" rectangular duct. The appropriate length of these joints depends primarily on the *width of the duct*. Since the width of each duct section is shown on the working drawings, refer to figure 2-11, which shows the duct width, recommended gage of metal, type of joint connectors, length of each joint, and bracing to be used. After finding the length of the joints to use from the chart in figure 2-11, it is not difficult to determine how many joints you need to make up a section.

At first glance it appears to be a matter of simple arithmetic, dividing the section length by the length of each joint. But it is somewhat more complex, since you must consider the economical use of materials. You achieve economy by selecting the right size of sheet metal, getting the most pieces out of each sheet, and using leftover pieces wherever possible. For example, the section of 6" round duct in room 1 (FO 1) is 6'11" long. This appears to require a sheet of metal 6 feet long and 18.8 inches wide; however, when other factors are considered, you find that the best procedure is to make the 6-inch branch line in two 36-inch joints plus a 6 inch tap connection at one end and an 8 inch short joint at the other. In the following discussions, you will learn why 36 inch-wide sheets are best for this section of duct.

Type of seam. The type of seam to use is an important decision in the preliminary planning of a duct job because the seam allowances must be included in the patterns. The size of each pattern determines the size of sheet to use. From the dimensions specified for rectangular ducts in foldout 1, you can see that none of the joints is too large to be made from a single sheet of metal. Thus, if each joint can be cut and formed from one sheet, each joint will require only one corner seam. Earlier in this course, you learned that the Pittsburg lock seam is a good choice for a corner lock seam and that it can be made with a Pittsburg lock-forming machine or with a cornice brake.

Deciding on the type of seam for the round ducts in foldout 1 is easy because grooved seams are most often used when a lock seam is desired. Remember that grooved seams can be made with a Pittsburg lock-forming machine or with handtools and a bar folder or cornice brake.

The corners of the transitions in foldout 1 are jointed with Pittsburg lock seams, and the number of seams depends on how many pieces are used in each transition. Later in this chapter, you will see how to use leftover pieces of metal to fabricate small items, such as transitions and short joints.

The branch lines in foldout 1 include 6- and 8-inch elbows that connect the round, straight duct to the ceiling diffusers. Each elbow is made of five pieces, or gores. Each gore is rolled up into a circular shape 6 or 8 inches in diameter, and the ends are fastened with a grooved seam.

Other components of the duct system in foldout 1 requiring seams include the round takeoff fittings for

the branch lines (dovetail seams), the covers for the ends of the trunklines (standing seams), and the top for the plenum chamber (standing seams).

Type of joint connection. Another part of your preliminary planning is to determine the type of joint connection to be used throughout the duct system because you must know the amount of material required for the additions to the patterns to determine the size of sheets to use. According to figure 2-11, rectangular duct joints up to 24 inches wide can be made on 35-inch centers and should be connected with standing S-and-drive slips. Figure 2-11 also shows that rectangular duct joints measuring 12 inches wide by 8 inches high can be made for 7'11" centers and can use a different type of S-and-drive slip. In foldout 1, you can see that only 1 duct is wider than 24 inches. This is the return air duct, which is 36 inches wide.

To figure the joint connections for round duct, you need not refer to a chart because it is common practice to use a slip joint connection made with a crimping machine, and slip joints usually require an allowance of 1½ inches for the crimp. Add this allowance in figuring the material for the round ducts. Dovetail seams are used to connect the round ducts to the rectangular trunklines.

Other joint connections for the duct system in foldout 1 include the tapped connections for the takeoff fittings that join rectangular duct of different dimensions and the V-grooves to connect the gores of elbows. When the gores are assembled, these V-grooves form lock joints between the gores. The V-grooves are made with an elbow-edging machine, which was discussed in Volume 2 of this course.

Type of bracing. Determining the bracing for the duct system shown in foldout 1 is not difficult, as you may have already noticed in the chart of figure 2-11. Since most of the rectangular ducts in this system are less than 24 inches wide, you can see that the type of bracing recommended is the cross brake. Only the return air duct is wider than 24 inches, and it will not require as much bracing as the chart indicates because it iss installed on the floor and is supported throughout its length. If the return air duct is made on 35-inch centers, the standiing S-and-drive slips and cross braking will provide sufficient bracing. The round duct in the branch lines is not long enough to require bracing.

Exercises (435):

1. List the steps in planning for a duct system.

2. What type of seam is used on round duct if a lock seam is desired?

3. Slip joints require how much seam allowance for a crimp?

4. Ducts less than 24 inches wide require what type of bracing?

436. Give the correct material for selected items in a duct system.

Selecting Sheet Metal. From the data you gather in the preliminary planning of the duct system, you can determine the kind of sheet metal to use, as well as its thickness, sheet size, and quantity. You may want to review the portion of Volume 1 of this course that pertains to sheet metals.

Kind of material. Most heating, air-conditioning, and ventilating ducts are made from galvanized sheet iron. This is true for the duct system shown in foldout 1 for several reasons. Since the air supply system is installed above the ceiling, there is no need for the minimum weight to be gained from aluminum, and there is no need for the extra corrosion resistance of stainless steel. But there will be enough exposure to moisture (condensation) to rule out the use of black iron, and to require the corrosion resistance of galvanized sheet iron. Galvanized sheet iron has a smooth surface, which is necessary for minimum friction loss as air is forced through the ducts. Also, galvanized sheet iron is available in various sizes and gages at a reasonable cost. The return air duct will not be exposed to excessive condensation, but since it is installed at floor level, it should also be made of galvanized sheet iron.

Thickness of material. The recommended thickness or gage of sheet metal to use for the rectangular ducts shown in foldout 1 can be found in figure 2-11. The thickness of galvanized sheet iron for round ducts can be determined from the following list (for aluminum duct, increase the thickness of each of the following by 2 gages):

a. For diameters up to 13 inches, use 26-gage galvanized.

b. For diameters over 13 inches to 33½ inches, use 24-gage galvanized.

c. For diameters over 33½ inches to 67½ inches, use 222-gage galvanized.

Exercises (436):

1. What type of material is used for ventilating ducts?

3_0

2. What gage of material is used for round ducts with diameters over 13 inches but less than 33½ inches?

3. What gage of galvanized iron should be used for a rectangular duct 14 inches wide?

437. Determine the size of sheet metal sheets for a given job.

Size and Quantity of Sheets. Galvanized sheet iron is available in several sizes, but the most frequently used sizes for duct construction are 3- and 4- foot widths in 8- and 10-foot lengths, as shown in figure 3-1. Although this may lead you to think that duct joints are usually 8 or 10 feet long, this is not true because most rectangular duct joints are made in 3- or 4-foot lenghts. The perimeter of a duct joint is usually greater than 4 feet and is made in one piece with one corner seam. For example, a 20" x 14" joint that is 47" long requires a piece of sheet metal that is 48" x 69¼" (including seam and connector allowances), and should be made from a sheet 4 feet wide and 8 or 10 feet long. The length of the sheet selected depends on how the leftover material can be used.

Another reason for using sheets in 3- or 4-foot widths is that they need the least bracing. Figure 2-11 will quickly remind you that longer joints require more bracing than short ones. The Chart will also remind you that joints are often listed as *on 35-inch centers or on 7-foot 11-inch centers*. The reason is that the length given on working drawings is usually the distance from center to center of the connectors at each end of the joint. A joint 36 inches long will have 1/2 inch allowance at each end for the S-and-drive slips and therefore measures only 35 inches center to center.

In figure 4-1, a 36" x 97¼" pattern is to be made. Of the 4 available sheet sizes, the two 8-foot sheets are too short, and the choice is between the 3' x 10' and 4' x 10' sheets. The leftover pieces are indicated by the dotted lines. You can see the best choice is probably the 3' x 10' sheet. However, your choice really depends upon how you can use the leftover material.

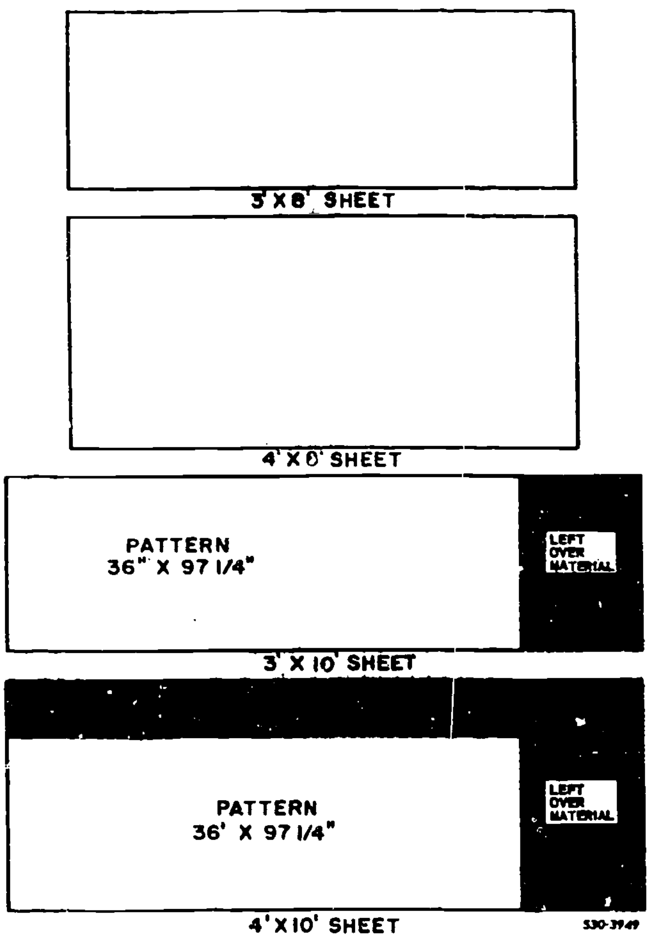

Figure 4-1. Selection of sheet sizes.

Exercises (437):

1. What size sheet should you use for a 20-inch by 14-inch joint that is 47 inches long?

2. How do you decide which size of sheet metal to use if two sizes can do the job?

438. List the steps in determining material requirements for trunkline A.

Trunkline A and Plenum. Figure 4-2 is a breakdown of trunkline A in foldout 1. This shows how you divide trunkline A into joints and takeoff fittings To break down a trunkline like this, your first step is to make a scale drawing of the plan view, showing only the outline of the trunkline. Since trunkline A is connected to the supply plenum of the heating and air-conditioning units, the plenum is also included in the drawing. As stated earlier in this chapter, the plenum is 24 inches wide, 36 inches high, and 24 inches long. Trunkline A is 24 inches wide, 14 inches high, and 9 feet 2 inches long. No joint connection allowances are needed for either the top or bottom of the plenum.

Since the height of the plenum is 36 inches, lay out its pattern on a sheet that is 36 inches wide. Since the stretchout (including 1¼ inch Pittsburg seam allowance) is 97¼ inches, you must decide whether it should be made from an 8- or a 10-foot sheet. (Look at fig. 4-1 and you will see the answer.) the top opening of the plenum is 24" x 24"; the plenum will have a cover (top) of the same size, attached with 1-inch standing seams. For the allowance for the standing seams on all four edges of the cover, the pattern must be 28" x 28", which is larger than the leftover piece of the sheet just

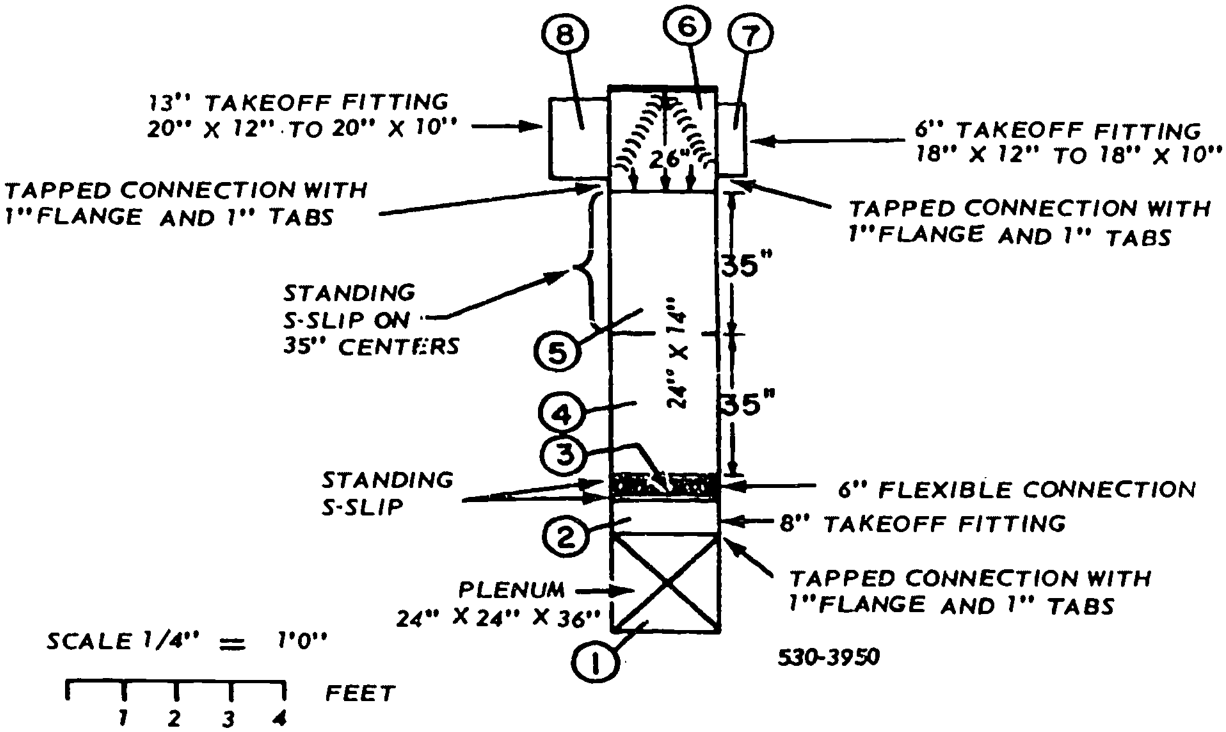

Figure 4-2. Breakdown of plenum and trunkline A.

used for the plenum. It is good practice on large jobs like this to *not* cut the 28" x 28" from another whole sheet but to wait for a leftover piece from the next group of patterns, which in this example will be from trunkline A.

Thus far the material required for the two patterns has been determined, and you can see that you need one whole 3' x 10' sheet (with 36" x 22¾" left over) and another sheet from which the 28" x 28" cover can be made. This indicates that you need some sort of bookkeeping system to identify the parts by size and quantity, to identify the sheet from which the pattern will be cut, and to indicate how many and what size of sheets you need. Figure 4-3 is an example of such a record. You will find that it is also helpful to make a sketch of each sheet of metal, showing how the patterns should be arranged to avoid unnecessary waste. Figure 4-4 shows how the trunkline and plenum can be made from four sheets. The sequence for determining the size and quantity of sheets required is to: (1) make a drawing, like figure 4-2, to show the dimensions of the ducts and joints; (2) start a materials-required list, like figure 4-3, and (3) make sketches of the sheets, as in figure 4-4.

The materials needed for the plenum and for the plenum cover are the first two entries on the materials-required list (fig. 4-3). Although the illustration shows the chart filled out, we will start from the beginning and see how it was developed. By doing this, you will learn how to determine the sheet sizes and the number of sheets required for the job. You can later use similar procedures for other jobs.

First, write "plenum" in the Item Identification column, followed by the dimensions and number of patterns needed. Since we have already determined that a 3' x 10' sheet should be used, enter this information in the Source of Materials column. At this time you make a sketch of sheet number 1 (fig. 4-4), showing the plenum as 36" x 97¼" with a single piece 22¾" x 36" left over. This piece is not large enough to make the 28" x 28" plenum cover. (A leftover piece from joint 4 in sheet 2 will be suitable for the plenum cover.) The second entry in figure 3-3 is for the plenum cover, including its size and the quantity needed. The source of material will be entered later.

Trunkline A has the same dimensions (24" x 14") for its entire length. Therefore, its stretchout, including Pittsburg lock seam allowance, is 77¼ inches. Its length, as previously determined, is 9'2", which can be divided into joints as shown in figure 3-2. Beginning with joints 4 and 5, you should enter the pattern dimensions and requirements on lines of the materials chart (fig. 4-3). These patterns, including allowances, are each 36" x 77¼" and should be made from two 3' x 10' sheets with two 36" x 42¾" pieces left over. (One of these leftover pieces can be used to make the plenum cover.) You determine these dimensions by making sketches of sheets 2 and 3, as shown in figure 4-4. In figure 4-2, you can see that joints 4 and 5 occupy only 70 inches of the total length (110 inches) of trunkline A. This leaves 40 inches for joints 2, 3, and 6.

The size of joint 6 is determined by the size of its two takeoff fittings and the size of joints 2 and 3. Remember, only 40 inches are available for joints 2,3,

and 6. In figure 4-2, you can see how these 40 inches are used to make joints of appropriate sizes. Joint 6 is shown to be on 26-inch centers and is connected to joint 5 with S-and-drive slips. The pattern for joint 6 measures 26½" x 77¼", which will need part of another whole sheet (sheet 4, fig. 4-4), with two leftover pieces. One of these pieces is large enough to make the 18" x 28" end cover for joint 6. The joint 6 entry is now made in figure 4-4, and the sketch made on figure 4-3 for joint 6 and its end cover. This end cover is to be installed with standing S-seams similar to those for the plenum cover.

Joint 2 in figure 3-2 is a 24" x 14" takeoff fitting that, with seam and connection allowances, has pattern dimensions of 11½" x 77¼" This pattern can be made from the leftover material from joint 5 (sheet 3) if joint 2 is made in two pieces (11½" x 39¼") with two Pittsburg lock seams. You now make the line entry for joint 2 in figure 4-3 and make the sketches on sheet 3 of figure 4-4.

Joint 7 in figure 4-2 is a takeoff fitting 6 inches long, which reduces from 18" x 12" to 18" x 10". It has a tapped connection at one end and S-and-drive connections at the other. Since this transition tapers on two sides, it should be made in four pieces with four Pittsburg lock seams. The pattern for each piece is 9½ inches wide (6-inch length plus 3-inch allowance for the tapped connection and 1/2-inch allowance for the S-and-drive connection.) The two patterns for the top pieces are 9½" x 20" (2 inches are allowed to make the pockets for the Pittsburg lock seams). The two patterns for the side pieces are 9½" x 12½" (1/2 inch is allowed to make the 1/4-inch flanges for the Pittsburg lock seams). These four pieces are entered as line items in figure 4-3. Notice in the sketches that the piece left over from the joint 6 end cover (sheet 4) is large enough to make two top pieces 9½" x 20". Also, notice that the two 9½" x 12½" side pieces are made from sheets 2 and 4.

MATERIALS REQUIRED				
ITEM IDENTIFICATION	MATERIAL NEEDED FOR PATTERNS (INCLUDING ALLOWANCES)		SOURCE OF MATERIAL	
	Dimensions	Quantity	Sheet Number	Size
PLENUM	36" X 97 1/4"	1	1	3' X 10'
Plenum Cover	28" X 28"	1	2	
TRUNK LINE A	————	——	——	————
Joint 4	36" X 77 1/4"	1	2	3' X 10'
Joint 5	36" X 77 1/4"	1	3	3' X 10'
Joint 6	26 1/2" X 77 1/4"	1	4	3' X 10'
End Cover (Joint 6)	18" X 28"	1	4	————
Joint 2	11 1/2" X 39 1/4"	2	3	————
Joint 7 Top and Bottom Pieces	9 1/2" X 20"	2	4	————
Joint 7 Side Pieces	9 1/2" X 12 1/2"	2	2 and 4	————
Joint 8 Top and Bottom Pieces	11 1/2" X 22"	2	1	————
Joint 8 Side Pieces	11 1/2" X 12 1/2"	2	3 and 4	————
Joint 3 Metal Strips	3 1/2" X 77 1/4"	2	4	————
Joint 3 Cloth	6" X 77"	1	From Roll	————
Standing S-Slips	5 1/2" X 23 3/4"	2	1	————
Standing S-Slips	5 1/2" X 23 3/4"	3	2	————
Standing S-Slips	5 1/2" X 23 3/4"	2	3	————
Standing S-Slips	5 1/2" X 23 3/4"	1	4	————
Drive Slips	2 1/4" X 16"	7	4	————
Drive Slips	2 1/4" X 16"	1	2	————

CP-33

Figure 4-3. Materials required for plenum and trunkline A.

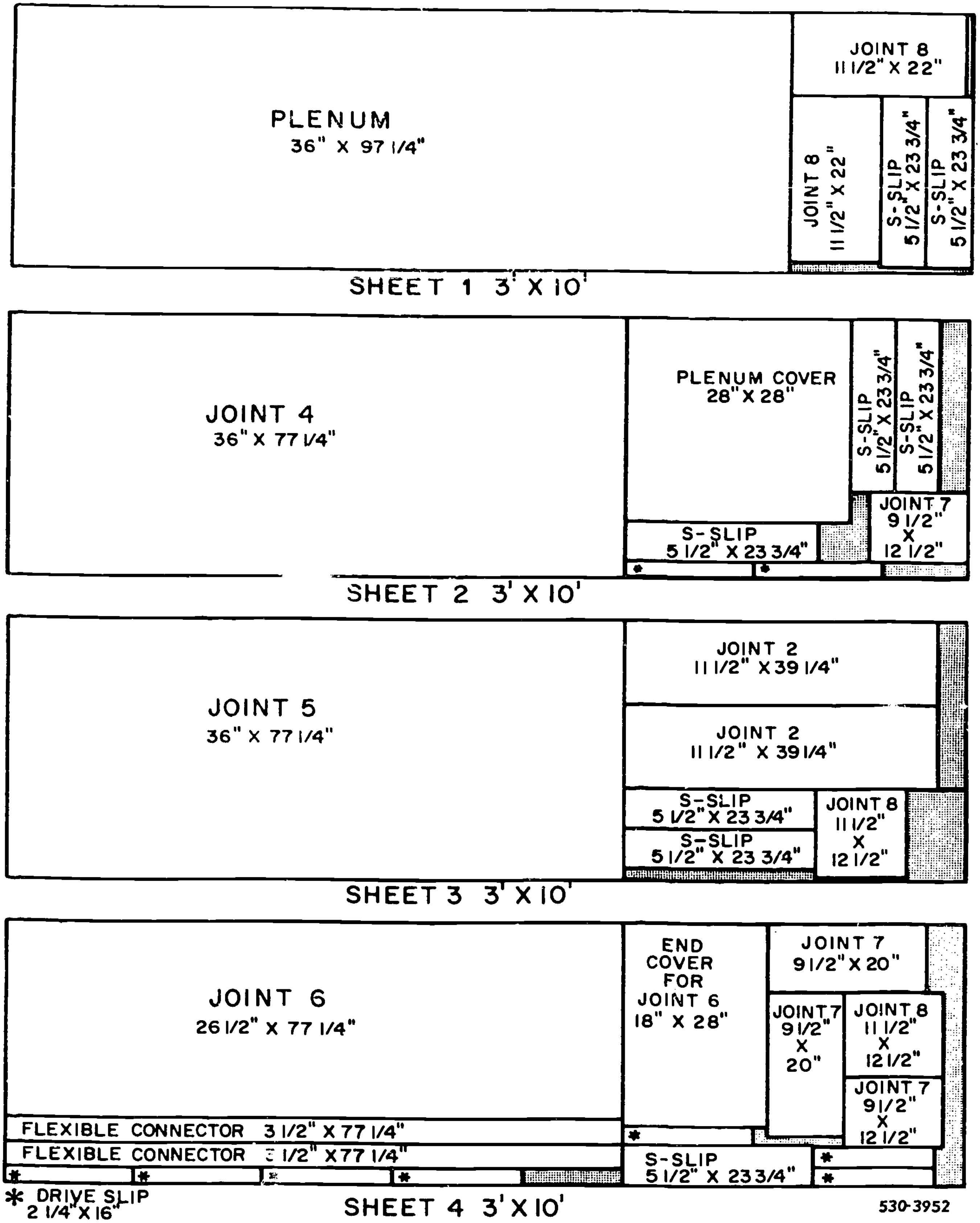

Figure 4–4 Determining size and quantity of sheet metal for plenum and trunkline A.

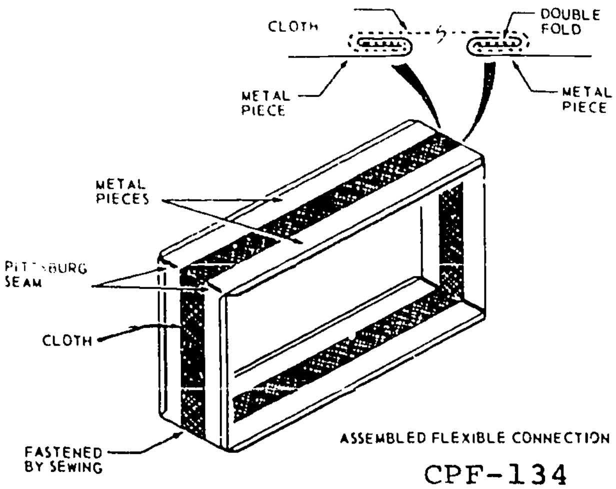

Figure 4-5. Flexible connection (joint 3) used in trunkline A.

Joint 8 in figure 4-2 is a takeoff fitting 8 inches long, which reduces from 20" x 12" to 20" x 10". It is the same shape as joint 7 but has different dimensions. Joint 8 will require four pieces and four Pittsburg lock seams. The two 11½" x 22" pieces for the top and bottom can be made from the leftover piece from the plenum (sheet 1). The two 11½" x 12½" side pieces can be made from leftover pieces in sheets 3 and 4.

Joint 3 is a flexible connection made of a flexible cloth and metal. The connection is 6 inches long, 24 inches wide, and 14 inches high. Figure 4-5 shows how the flexible cloth is connected to the metal strips that connect to the S-and-drive slips of joints 2 and 4. Notice how the metal strips hold the cloth in double folds. The materials needed for this flexible connection arre a piece of flexible cloth 6 inches wide and 77 inches long (76-inch perimeter plus 1-inch allowance for the stitched lap seam), and 2 pieces of metal, 3½ inches wide and 77¼ inches long. The cloth is available in bulk lengths in various widths, including a 6-inch width. The 3½ inch-wide metal strips can be made from the 9½" x 77¼" piece leftover from sheet 4. These entries are recorded in the materials-required list (fig. 4-3).

The last step in determining the size and quantity of material for trunkline A involves the standing S-slips and-drive slips th t connect the joints. In figure 4-2 you can see that S-and drive slips are used in four places. This means that you need 8 standing S-slips, with 5½" x 23¾" of metal each. The 8-drive slips need 2¼" x 16"

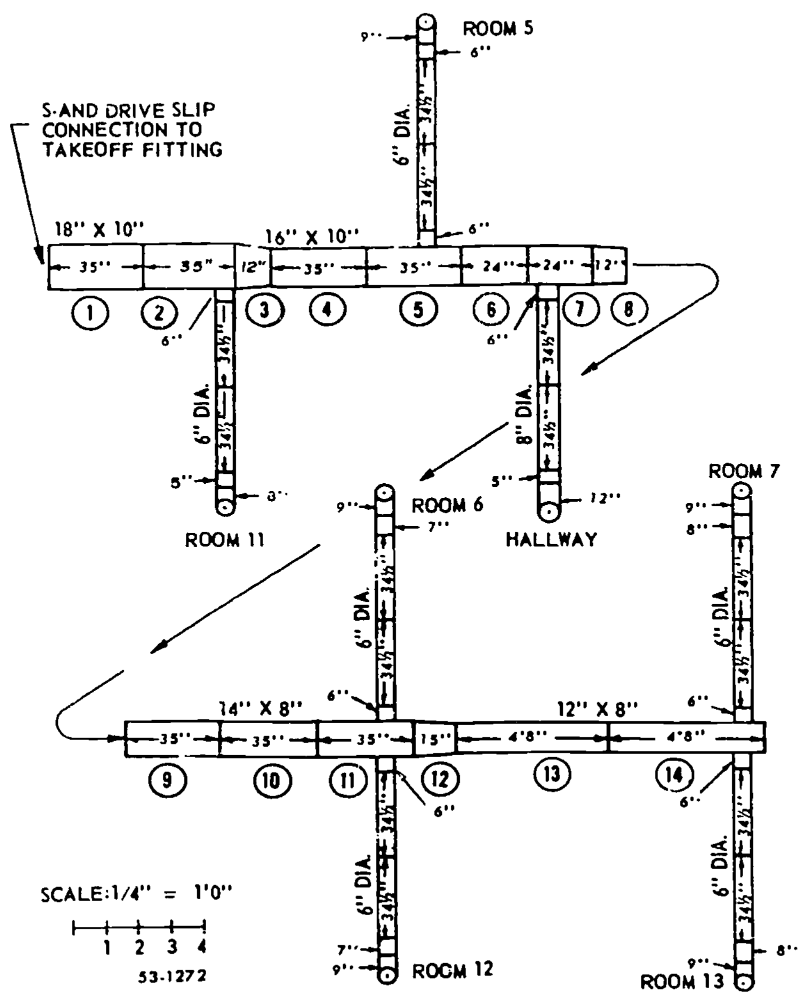

Figure 4-6. Breakdown of trunkline B and branch lines.

of metal each. According to the sketches in figure 4-4, 7 drive slips can be made from sheet 4 and one can be made from sheet 2. These entries are recorded in the materials required list (fig. 4-3).

Sometimes all of the pieces cannot be made from the sheets, as in this example of trunkline A. It may be necessary to wait and get the additional material from the leftover pieces of the next duct, which in this example is trunkline B.

Exercises (438):

1. List the steps in breaking down a trunkline to find the materials you need.

2. What is the allowance for a Pittsburg seam?

3. In which of these steps do you show how to avoid unnecessary waste?

439. Point out important characteristics in trunkline B.

Trunkline B. Earlier in this chapter, we discussed the preliminary planning for a duct system, breaking down the system into subsystems, and deciding on the type of seams, joint connections, bracing, kind of material, thickness of material, and size and quantity of sheets. If you have carefully studied the text and illustrations, you will find that trunkline B is similar to trunkline C. Look at trunkline B in foldout 1. It has four different sizes of duct, which are connected with transitions; it has seven round duct branch lines; and it is closed at the end with an end cover.

Now let's determine the size and quantity of sheets needed to plan and fabricate trunkline B. Our first step again is to make a scale drawing of the plan view. Figure 4-6 shows the complete breakdown of trunkline B and its branch lines (Remember to draw only the outside lines and add the joint connection lines and dimensions as you determine the length of each joint). Although we have divided the trunkline into two parts in order to fit them on one page, we recommend that you make your own drawings larger and draw the trunkline in a straight line. The four sections of trunkline B all have the same centerline.

To find the length of the joints for trunkline B, draw the joint connection lines as shown in figure 4-6,

MATERIALS REQUIRED				
ITEM IDENTIFICATION	MATERIAL NEEDED FOR PATTERNS (INCLUDING ALLOWANCES)		SOURCE OF MATERIAL	
	Dimensions	Quantity	Sheet Number	Size
TRUNK LINE B				
Joints 1 and 2	36" X 57 1/4"	2	1	3' X 10'
Joints 4 and 5	36" X 53 1/4"	2	1, 2	3' X 10'
Joints 6 and 7	25" X 36"	2	3	3' X 8'
Joints 9, 10, and 11	36" X 45 1/4"	3	3, 4	3' X 8'
Joints 13, 14	41 1/4" X 4' 9"	2	5	4' X 10'
Joint 3 (Transition Top & Bottom)	13" X 20"	2	6	3' X 8'
Joint 3 (Sides)	10 1/2" X 13"	2	6	———
Joint 8 (Transition Top & Bottom)	13" X 18"	2	6	———
Joint 8 (Sides)	10 1/2" X 13"	2	6	———
Joint 12 (Transition Top & Bottom)	16" X 16"	2	6	———
Joint 12 (Sides)	8 1/2" X 16"	2	6	———
End Cover (Joint 14)	16" X 16"	1	6	———
Standing S-Slips	5 1/2" X 17 3/4"	6	7	3' X 10'
Standing S-Slips	5 1/2" X 15 3/4"	10	7	———
Standing S-Slips	5 1/2" X 13 3/4"	8	7	———
Standing S-Slips	5 1/2" X 11 3/4"	4	7	———
Drive Slips	2 1/4" X 12"	16	7	———
Drive Slips	2 1/4" X 10"	12	7	———

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Figure 4-7. Materials required for trunkline B.

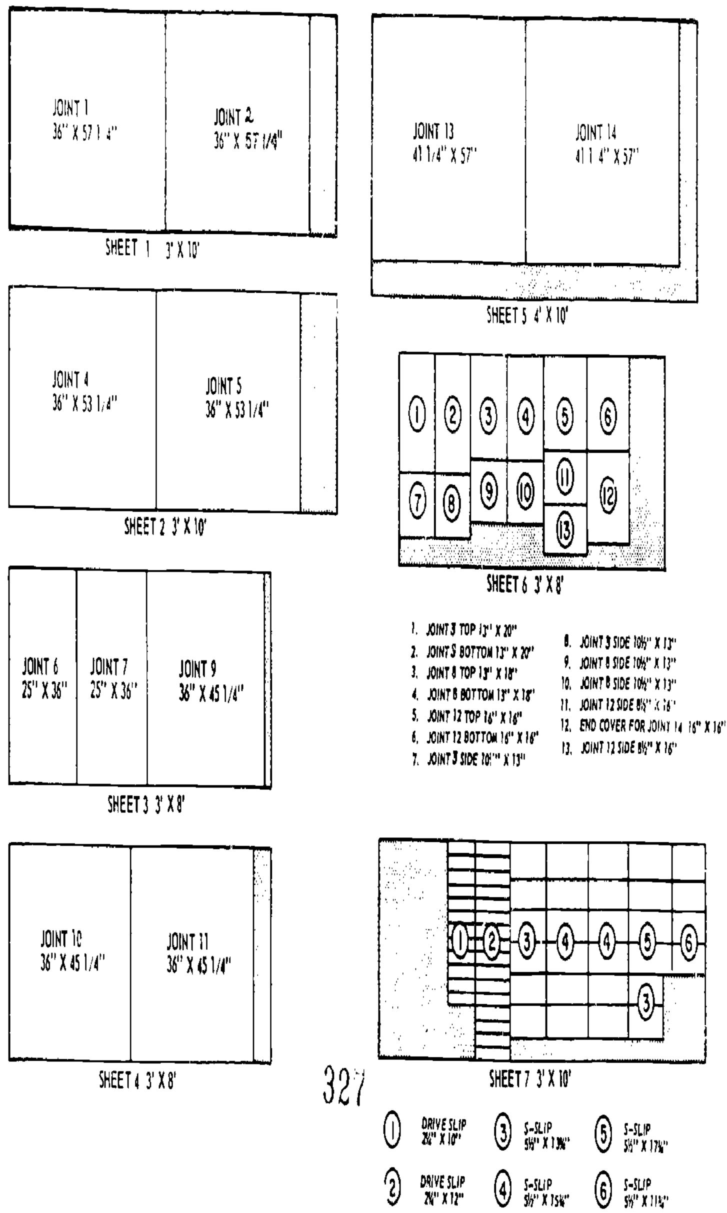

Figure 4-8. Determining size and quantity of sheet metal for trunkline B and branch lines.

beginning with joint 1, which is 35 inches long, center to center. You may think this should be 41 inches, but 6 of the 41 inches are included in the takeoff fitting from trunkline A. Joint 1 has a perimeter of 56 inches which, with 1¼ inches added for the Pittsburg lock seam allowance, makes a stretchout of 57¼ inches. The allowance for the S-and-drive connections at each end of the joint is 1/2 inch. Thus, the pattern, including allowances, for joints 1 and 2 will be 36" x 57¼", which can be made from a sheet of metal 3' x 10'. Record this information about joints 1 and 2 on the materials-required list (fig. 4-7), and make sketches showing how the pattern for joint 1 can be made from sheet 1. Figure 4-8 shows how you should make these sketches to determine the size and quantity of sheets you need.

Continuing with the larger joints of trunkline B, notice that joints 4 and 5 have the same dimensions; therefore, a one-line entry can be made in the materials required list (fig. 4-7). Joints 6 and 7 are the same; joints 9, 10 and 11 are the same; and joints 13 and 14 are the same. In the sketches (fig. 4-8) notice that joints 1 and 2 are on sheet 1; joints 4 and 5 are on sheet 2; joints 6, 7 and 9 are on sheet 3; joints 10, and 11 are on sheet 4; and joints 13 and 14 are on sheet 5.

The transitions in trunkline B are joints 3, 8, and 12, as shown in figure 4-6. Transitions 3 and 12 are made in four pieces like the takeoff fitting 7 of trunkline A because only one of the two dimensions reduces. Transition 8 is also made in four pieces but is somewhat different because both dimensions reduce. Later in this chapter when you lay out the patterns for these transitions, you will find that the true length of the sloping sides requires 1/16-inch additional material. Look at sheet 6 in figure 3-8, and you can see that there is sufficient leftover material on the sheet to include the extra 1/16 inch needed for joints 3, 8, and 12.

The end cover for joint 14, including the allowance for 1-inch standing seams on each of the four sides, is sketched on sheet 6 of figure 4-8. The standing S-slips and drive slips are sketched on sheet 7 to show how you can save time when you are making pattern layouts and cutting the materials if you group small, similar-shaped patterns like these together. In each of the seven sheets in figure 4-8, several pieces are left over. These, along with the leftover pieces from trunkline A, can be used later for trunkline C and branch lines.

Exercises (439):

1. How does trunkline B differ from trunkline A?

440. Cite significant features in trunkline C and in the branch lines.

Trunkline C. In foldout 1, you can see that trunkline C is similar to trunkline B except for the dimensions. In our first breakdown of the duct system, we found that trunkline B is 36'6" long and that trunkline C is 42 feet long. Notice in foldout 1 that some of the sections have the same dimensions and that some of the material from trunkline B can be used in trunkline C if the joints are the same length. Follow the same procedures for determining the size and quantity of sheets for trunkline C. Make a scale drawing of trunkline C, as shown in figure 4-9. Remember that this drawing begins with the outlines only and you add the joint connection lines one at a time.

Branch Lines. Earlier in this chapter, when you were breaking down the duct system, you learned that trunklines B and C had a total of twelve 6-inch and three 8-inch round duct branch lines. You also found the length of each branch line. Now you are ready to determine how much material they will require and the size and quantity of sheets needed. As with the rectangular duct, the first step is to make scale drawings of the round duct branch lines, as we have done in figure 4-6, 4-9, and 4-10.

In these figures, notice that round joints on 34½ inch centers are used in most branches. Remember that the allowance for a slip joint is 1½ inches. Thus, you can see that 36 inch-wide sheets are a good choice. For this example, we are using a Pittsburg lock-forming machine that can make 5/16-inch grooved seams, requiring a 1-inch seam allowance. Now figuring the size, you can see that the material needed for a 34½-inch joint in the 6-inch branches is 19⅞" x 36".

34½"	center to center
+1½"	slip joint allowance
36"	length of joint

18⅞"	circumference of 6" duct ($C = \pi d$)
+ 1"	grooved seam allowance
19⅞"	stretchout

Enter the dimensions 19⅞" x 36" in the materials--required list for the branch lines (not illustrated) before determining what size and how many sheets are needed. In this example, you will find that you can make 6 pieces 19⅞" x 36" from a 3' x 10' sheet with ¾" x 36" leftover.

You find the pattern dimensions for the 8-inch round duct joints in the same way. Notice in figures 4-6 and 4-9 that not all of the 8-inch diameter joints are on 34½-inch centers.

As you continue determining the materials for the branch lines, you notice in figures 4-6 and 4-9 that all of the takeoff fittings are 6 inches long. These takeoffs are simply 6-inch joints of round duct fastened to the trunklines with dovetail seams. Remember from Chapter 1 how dovetail seams are made and that the seam allowance is 1/2 inch. Also you note in figures 4-6, 4-9, and 4-10 that the center-to-center lengths of the 6-inch elbows are 9 inches and of the 8-inch elbows are 12 inches. This leaves one short joint in each branch line to compensate for the differences in the length of the

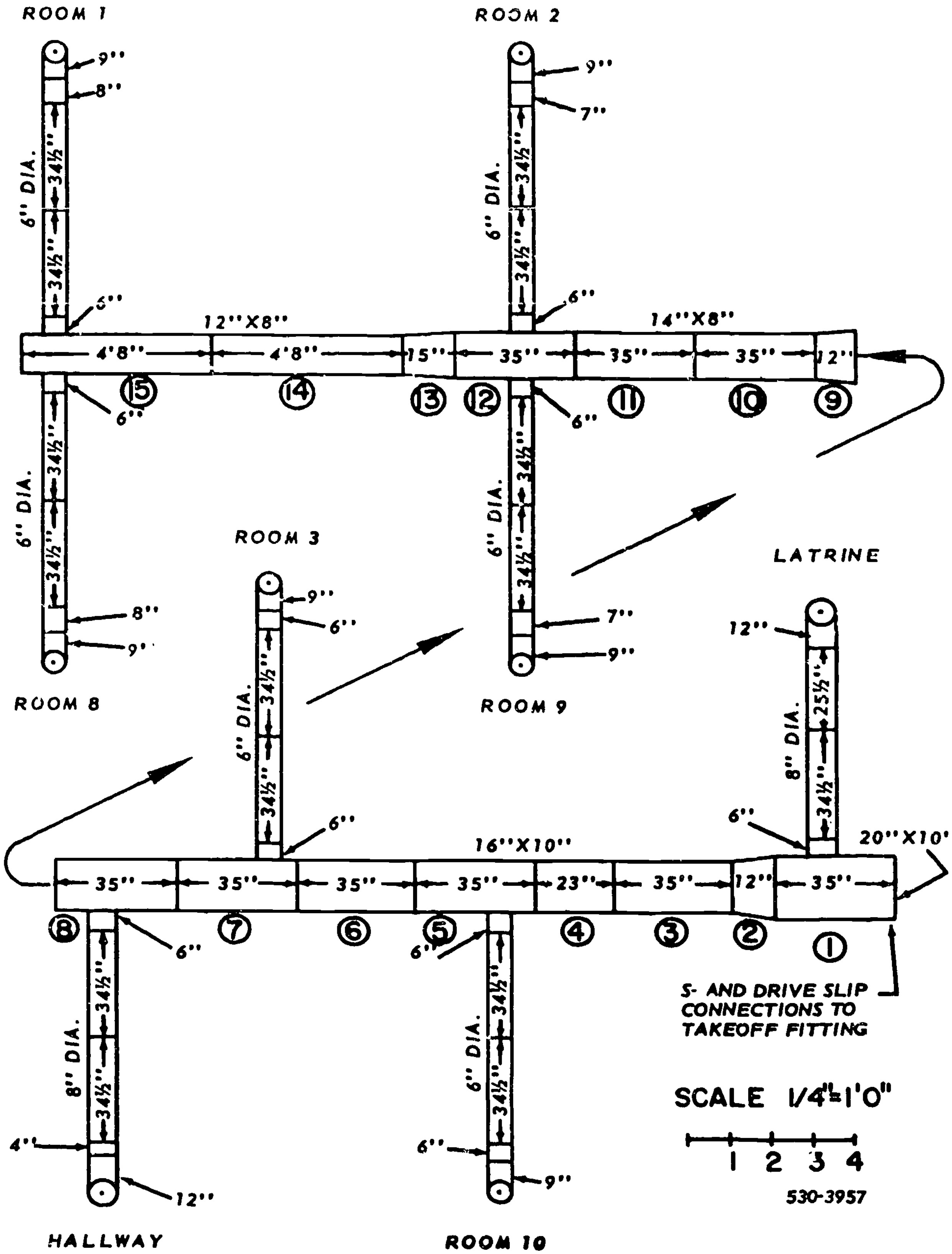

Figure 4–9. Breakdown of trunkline C and branch lines.

branch lines. You have previously determined that the branch line lengths varied in different rooms because of the transitions in the trunklines.

If you are required to make elbows, you will find that, if the patterns for the 5 gores of each elbow are laid out side by side, the 6-inch elbow requires a 12¼" x 19⅞" piece of material and the 8-inch elbow requires a 15½" x 26⅛" piece of material. The branch lines shown in figures 4-6, 4-9, and 4-10 include twelve 6-inch elbows and three 8-inch elbows. With this information, you can easily determine how many sheets of metal you need to make the 15 elbows.

The next parts of the branch to be figured are the joints that connect the elbows of the branch lines to the ceiling diffusers. Since these joints drop the flow of air from the previous centerline, they are sometimes called drop joints. Figure 4-10 shows a drop joint like those used in the 6-inch branch lines in rooms 1, 7, 8, and 13 in foldout 1. The length of the drop joints in 6-inch ducts is different from those in 8-inch ducts because of the difference in the length of 6- and 8-inch elbows. The actual drop in this example is 20 inches, which is the distance from the centerline of the duct system to the ceilings of the rooms. (This distance is determined from foldout 2 by measuring the distance from the centerline of trunkline A to the ceiling. This distance continues to be 20 inches throughout the system because the centerline of this duct system is the same until the elbows in the rooms change the direction of airflow.) In figure 4-10, you can see that 9 inches of the 20-inch drop are taken up by the 6-inch elbow, leaving only 11 inches for the drop joint. This is the center-to-center length of the drop joint, which must be increased by 1½ inches for the crimped connection allowance, making an actual joint length of 12½ inches. In the rooms that have 8-inch elbows, the elbow extends 12 inches below the centerline, and the length of the drop joint is shorter.

Return Air Duct. In foldout 2, you can see an elevation view of the return air duct (return air and outside air plenum) to the heating and air-conditioning system we have been discussing. Earlier in the chapter, we broke down the return air duct and found the dimensions to be 18 inches high, 36 inches wide, and 9 feet 6 inches long. In figure 4-11 we have further broken the duct down into joints. Notice that joint 4 is located to contain the multiblade damper. Determining the size and number of sheets for this duct is similar to determining the material for the other rectangular ducts except that these dimensions are large enough to take nearly a whole 3' x 10' sheet for each joint. The stretchout including the Pittsburg seam allowance is 109¼ inches. The ends of joints 1 and 4, shown in figure 4-11, are plain and do not have flanges because the duct openings through the walls will be boxed in (framed) by the carpenters. The hall register and the outside wall louver will be fastened to the wood framing. The joints are connected with S-and-drive slips between each joint.

Exercises (440):

1. How should you measure the distance of the drop when installing a trunkline?

2. How are the joints connected when you are fabricating a square or rectangular duct?

3. What is significant in joints 1 and 4 in the return air duct?

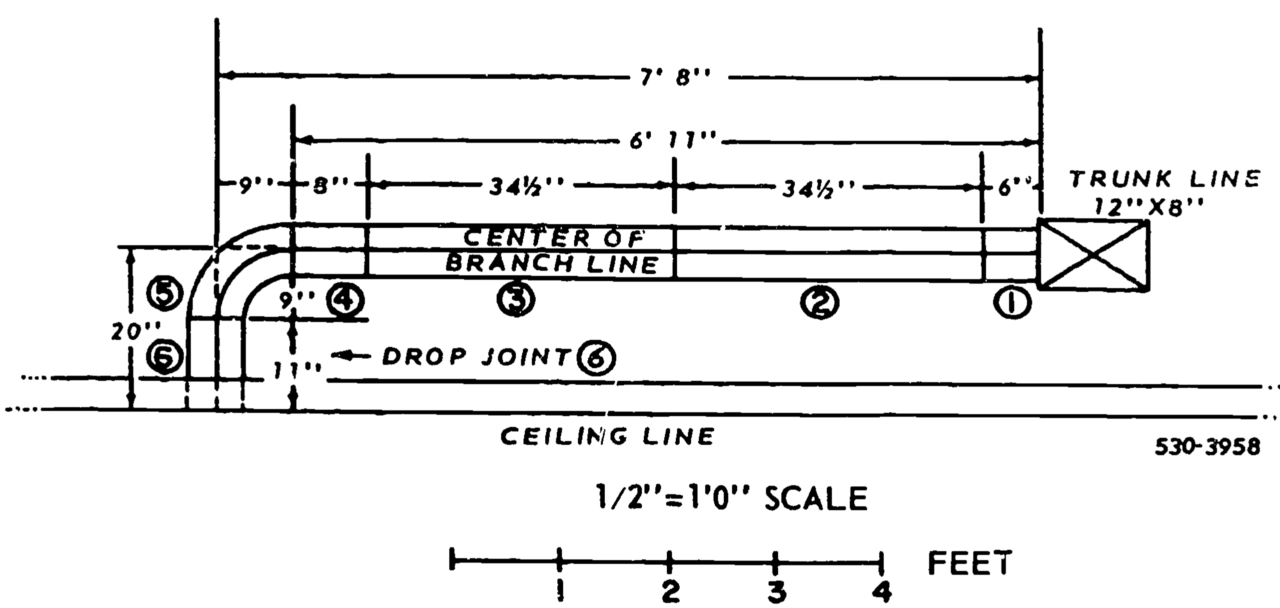

Figure 4–10. Elevation view of 6-inch branch line used in rooms 1, 7, 8, and 13.

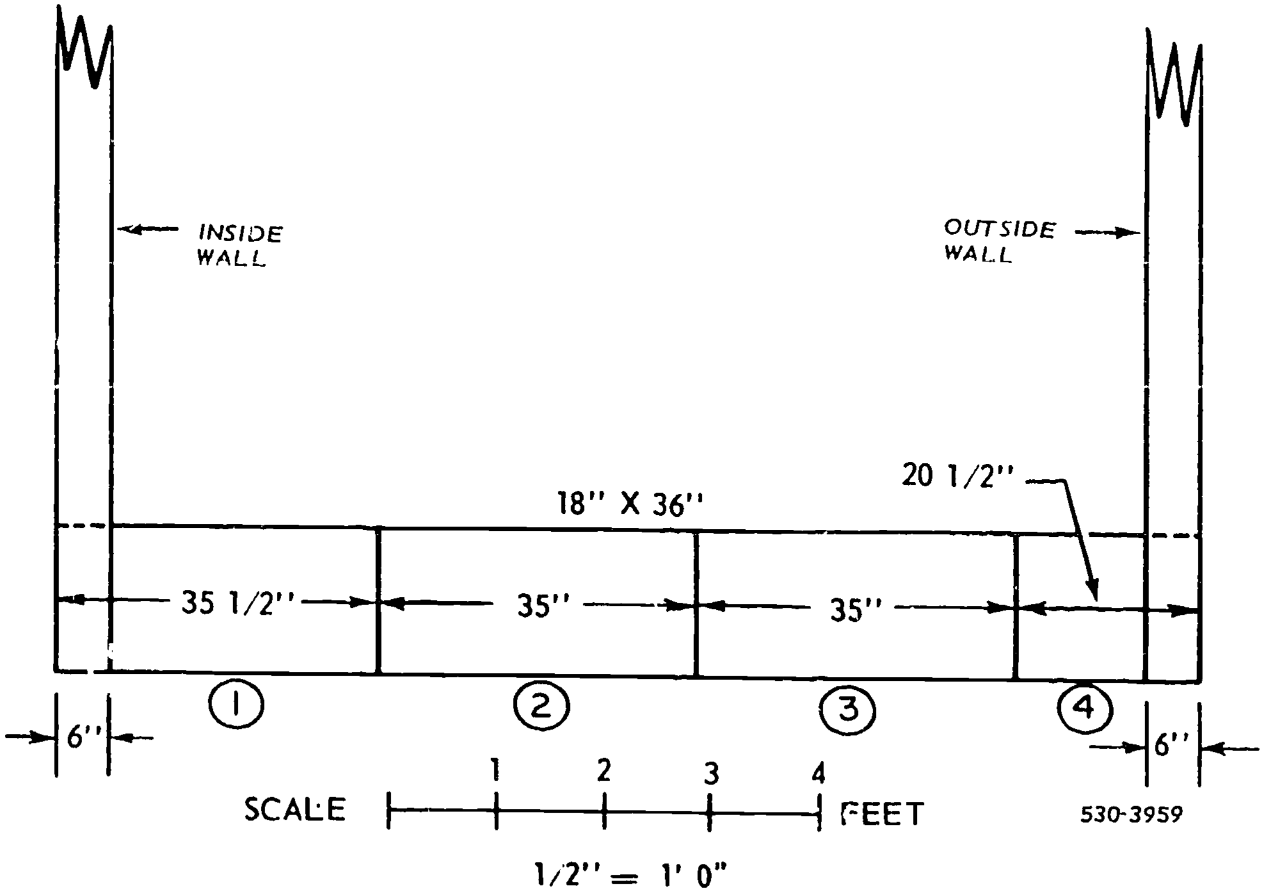

Figure 4–11. Breakdown of return air and outside air plenum.

441. Cite the uses of some of the airflow control devices in the duct system.

Selecting Registers, Grilles, and Diffusers. The registers, grilles, and diffusers for a duct system are not difficult to select because most of the needed information is in the working drawings or blueprints. In the system we are describing, you can use both foldouts for selecting the registers, grilles, and diffusers. You add each item to the materials-required lists (shown in figs. 4-3 and 4-7) and make an appropriate statement in the Source of Material column. For example, if any of the items are to be made in the shop, you enter the estimated amount of material needed. If the items are to be purchased as factory-made units, the source column entry is "Factory-made."
"Factory-made."

The only register used in this system is the 18" x 36" return air register in the return air duct. The register is to be installed at floor level.

Two types of grilles are used, wall and door. Some of the grilles are 10" x 6", some are 12" x 6", and one is 12" x 8".

In each room and hallway, there is a round ceiling diffuser with an adjustable volume damper. Two sizes are used, 6-inch diameter and 8-inch diameter. These diffusers are the air supply outlets for the duct system. After the diffusers are installed, the dampers will be adjusted for the designated cfm (cubic feet per minute).

Selecting Louvers and Dampers. You can also select the louvers and dampers from the information contained in foldouts 1 and 2. The system uses two louvers. One of these is 18" x 36" and is located on the outside air intake of the return air and outside air plenum. The other is 18" x 24" and is also located on the outside wall but with a different function; it allows filtered combustion air to enter the furnace room. Note the description given on foldouts 1 and 2 concerning both of these louvers.

The system uses 16 volume dampers. In foldout 2, the multiblade volume damper is located in joint 4 of the return air and outside air plenum (return air duct). This damper must be installed in joint 4 when the joint is fabricated. The damper blades are adjusted by the hand quadrant to obtain the desired mixture of inside and outside air for circulation through the heating and air-conditioning system. In foldout 1 you can see that 15 other volume dampers are located in the ceiling diffusers.

Selecting Insulation. Soft flexible blankets of glass fiber, with aluminum foil bonded to each side, are wrapped around the exterior of heating and air-conditioning ducts for thermal insulation. The foil-backed insulation prevents excessive cooling of

heated air as well as excessive warming of cooled air, as air passes through the duct system. Insulation around the air-conditioning ducts also prevents condensation and dripping of moisture. Foil-backed insulation is available in rolls up to 100 feet long; in thicknesses of 1, 1½, and 2 inches; and in widths of 18, 24, 36, 48, and 72 inches. The foil on the rolls that are 48 and 72 inches wide extends 2 inches past both edges of the glass fiber, forming tabs to lap during installation. On rolls that are less than 48 inches wide, the 2-inch tab is usually on one edge only.

When you are selecting insulation for a duct job, you will find the type and thickness described on the working drawing or blueprint. Note 2 in foldout 1 specifies 1-inch foil-backed glass fiber insulation. Your job is to determine the amount of insulation to be used, including length and width. For example, in foldout 1 the perimeter of trunkline A is 76 inches; the insulation is wrapped around the duct and joint with a taped seam. If insulation 48 inches wide is used for trunkline A, each full sized piece should be 48 inches wide annd 82 inches long. You determine the number of pieces of this size you need by the length of the duct. Trunkline A is 9'2" long; therefore, you need two pieces, 48" x 82", and one piece, 14" x 82", to cover trunkline A. The joints between these sheets are butt joints with the blankets fitting together and the foil tabs overlapping to make a lap joint. The end joint cover, which is 24" x 14" needs a piece with 4 inches allowance on each of the 4 sides for a lap joint.

You can insulate such ducts as the 12" x 8" section of trunkline B in foldout 1 with 1 piece of foil-backed insulation 48 inches wide and 9 feet 4 inches long. There will be no joints and only 1 seam 9 feet 4 inches long. You can see that it is easier, quicker, and cheaper to use single pieces when possible.

While you are figuring the amount of insulation for a duct, also select the type of fastener to use and determine the number you need. Although you have joined the seams and joints between sheets of foil-backed insulation by folding the edges, you also use other fasteners, such as staples, tape, adhesives, or wire. Soft zinc-coated 20-gage wire is usually used around the joints to make sure that the insulation blanket does not come off the duct. The amount of wire is determined by the number of joints and the perimeter of each, plus a wire band at each end of the duct. For example, in trunkline A three sheets of insulation (two 48" x 82" and one 14" x 82") are needed. This requires four wire bands around the two joints and two ends. Since 2 inches are allowed for twisting the ends together, each band of wire should be 78 inches long (76 plus 2). Thus, the wire requirement for trunkline A is 78 inches multiplied by 4, for a total fo 26 feet.

We have now explained the selection of materials for a typical heating and air-conditioning system. You have enough information to make a materials-required list for the entire duct system, and sketches of the sheets of metal showing how each sheet can be cut with a minimum amount of waste.

Exercises (441):

1. What airflow control device is used for the air supply outlets in a duct system?

2. What material is used to wrap the exterior of heating and air-conditioning ducts for thermal insulation?

3. How do you usually fasten the insulation around joints to insure that it does not come off the duct?

4-2. Layout and Fabrication of Duct System Components

This section deals with laying out, cutting, notching, and forming patterns into components. We will continue to use the heating and air-conditioning duct system in foldout 1 to explain the procedures. By now you should have a good understanding of the system. We suggest that you refer to the appropriate portions of Volume 2 when necessary.

442. List the methods for pattern development, and name the patterns made by specified methods.

Pattern Layout. In Chapter 1 of this volume, you learned three methods of pattern development: the parallel line method, radial-line method, and triangulation method. Most of the ducts and components shown in foldout 1 have parallel sides, and their patterns can be made by the parallel-line method. When you are examining the patterns illustrated in this chapter, remember that the bending instructions are written so that they will be on the inside of the joint when it is assembled.

Rectangular duct joint patterns. The parallel-line method is used to lay out the pattern for joints 4 and 5 of trunkline A (fig. 4-2); each joint is 24" high x 14" wide x 35" long. Joints 2 and 6, also in trunkline A, are laid out the same except for length; joint 2 is on 8-inch centers, and joint 6 is on 26-inch centers. The 76-inch stretchout and the 1¼-inch Pittsburg seam allowance are the same for all 4 of these joints except that on joint 6 the 1/2-inch joint allowance is on 1 end only.

The first step in laying out the pattern is to draw a straight line equal to the perimeter of the 4 sides, which in this case is 76 inches long. Draw the 5 element lines 35 inches long, perpendicular to the stretchout line, and space them 14, 24, 14, and 24 inches apart. When you add the upper stretchout line, you have a 76" x 35" rectangle. Next, add the Pittsburg lock seam allowances (1 inch at one end and 1/4 inch at the other). Then add the 1/2-inch S-and-drive slip allowances at each side for the joint connections. Don't

forget that the 76-inch length of the stretchout will not be the length of the assembled joint. The joint will be 35 inches long, plus allowances. The final step is to mark the notches and cross brake lines.

Round duct joint patterns. All round duct joints in the branch lines are made in the same way except for the dimensions. In figures 4-6 and 4-9, most of the round duct has a 6-inch or 8-inch diameter, with the length made on a 34½ inch center. Since the sides of the pattern are parallel, the parallel-line method of layout is used. Without allowances, the pattern for a 6-inch round joint on a 34½-inch center is a rectangle 18⅞" x 34½", as shown in figure 4-12. The 18⅞-inch side of the pattern is the circumference of the 6-inch joint, and each edge has 1/2-inch allowance for the 5/16-inch grooved seam. Notice that one edge is to be bent up and the other is to be bent down. The length of the pattern is 34½ inches plus 1½ inches for the crimped slip joint, making a total length of 36 inches. The patterns for the other round duct joints in the branch lines are like this one, except for their dimensions. The seam and connection allowances are the same for all round joints, except for the round joints that attach to the trunklines with dovetail seams.

Transition patterns. Trunklines B and C in figures 4-6 and 4-9 have three transitions each. These six transitions are similar, except for the two that have a reduction in both dimensions (joint 8 of trunkline B and joint 9 of trunkline C). Figure 4-13 shows the development of the patterns by the triangulation method for the sides, top, and bottom of the transition. First, draw a plan view of the larger rectangle (16" x 10"), as shown in figure 4-13. Next, draw the smaller 14" x 8" rectangle inside the larger rectangle. Note the corner diagonals and the centerlines. The next step is to project the vertical lines and make the top elevation view. The height of the transition is 12 inches, but you must leave 1/2 inch straight at each end so that the S-and-drive slips will connect properly. This makes the height of the elevation view (not counting the straight) 11 inches, as shown in figure 4-13. The true length (height) of the sloping sides when they are drawn to actual size (or scale) is 11 1/16 inches, making the total length of the pattern, including allowances, 13 1/16 inches.

The patterns for the top and bottom, before the S-and-drive allowances are included, are identical to the elevation view except that the true length is used. To the top and bottom pattern in figure 4-13, you must make 1/2 inch S-and-drive allowances at each end, and make 1-inch Pittsburg seam pocket allowances at both edges. Notice how the straights are bent, one up 5° and one down 5°. The patterns for the two sides of the transition are identical. In figure 4-13, the 1-inch straight on the widest end is 10 inches long, and the other straight is 8 inches long. These straights are 11 1/16 inches apart. Notice the allowances of 1/2 inch at each end and 1/4 inch at each side. In both patterns, the bending instructions, notching instructions, and cross brake lines are shown.

The patterns for transitions (joints) 3 and 12 of trunkline B and transitions 2 and 13 of trunkline C are developed in a similar manner, except that only the width of the transition reduces; the height remains the same.

Plenum top and duct end patterns. The pattern for the top of the plenum is shown in figure 4-14. This pattern, except for its dimensions, is the same as the patterns for the end covers of trunklines A, B, and C. The standing seams in these pieces are shaped like the seam in figure 1-1 B-1. With standing seams on all four sides, the 24" x 24" plenum top fits tightly over the 24" x 24" opening in the plenum, as shown in figure 4-15. When the top is installed, the standing seam acts as a stiffener and strengthens the plenum. In figure 4-14 you can see how 2 inches are allowed on all four sides for the standing seams, and the instructions for bending, corner notching, and cross braking are given. This pattern is developed by the parallel line method of layout.

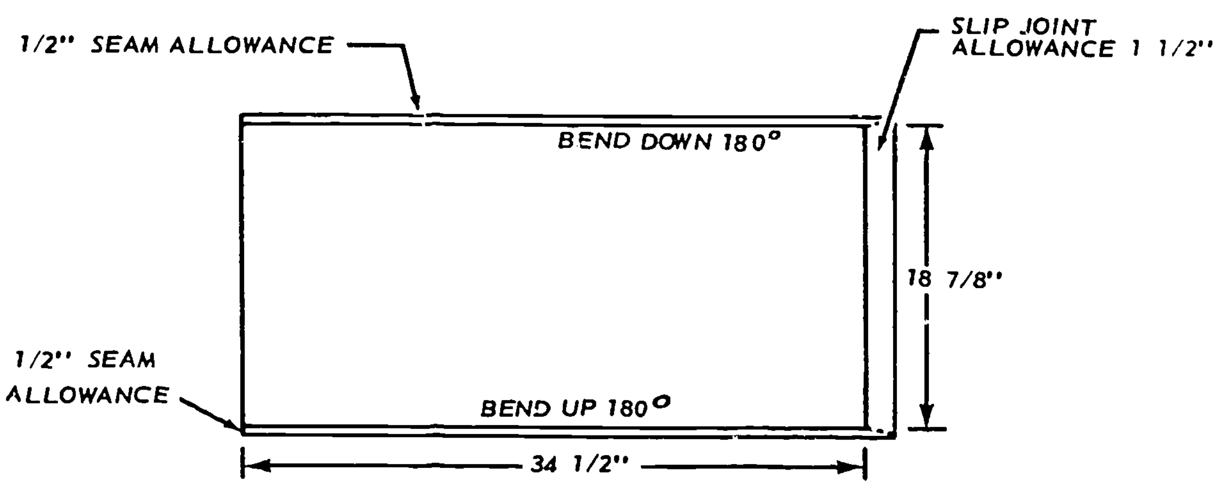

Figure 4-12. Pattern for 6-inch round duct joint.

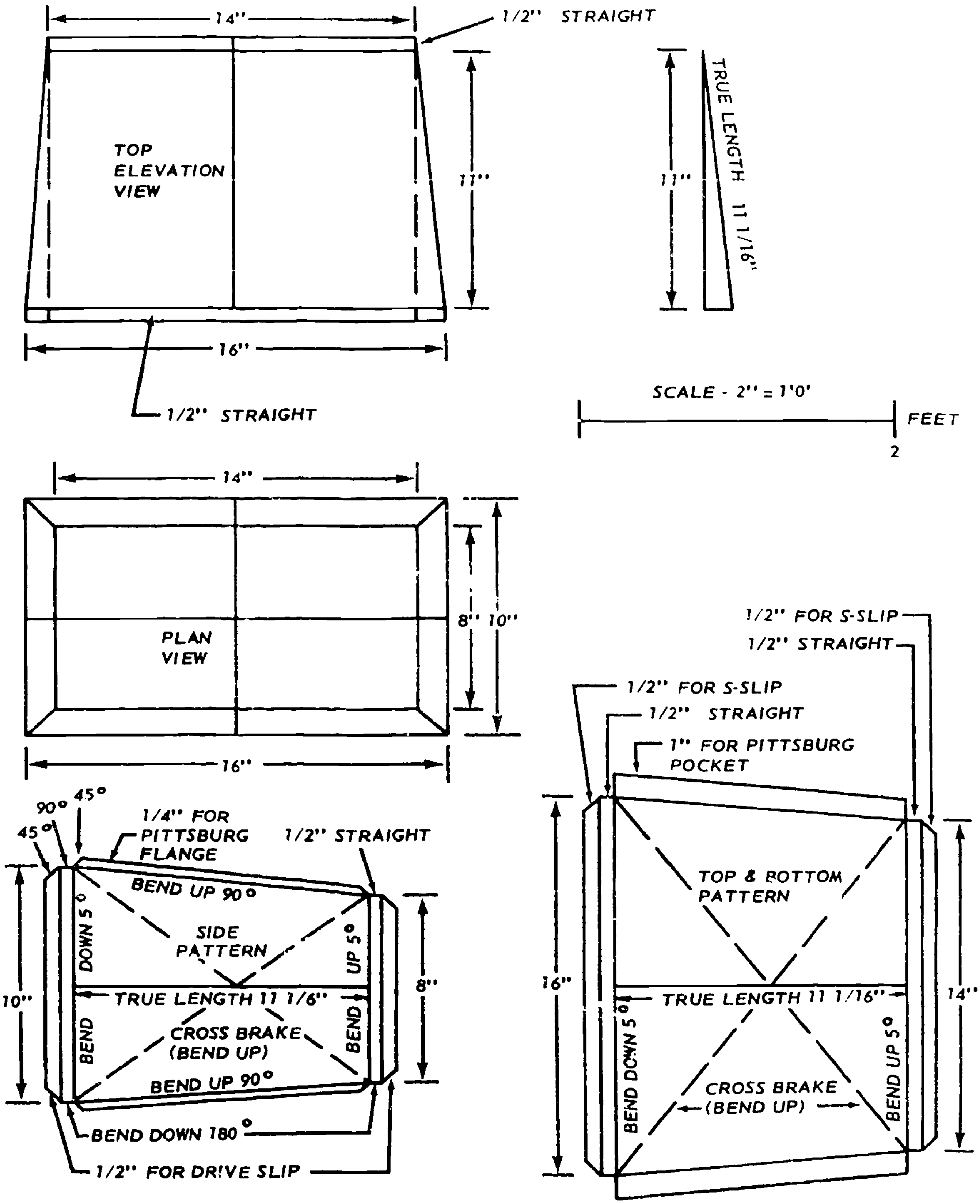

Figure 4–13. Patterns for 16" x 10" to 14" x 8" transition for trunklines B and C.

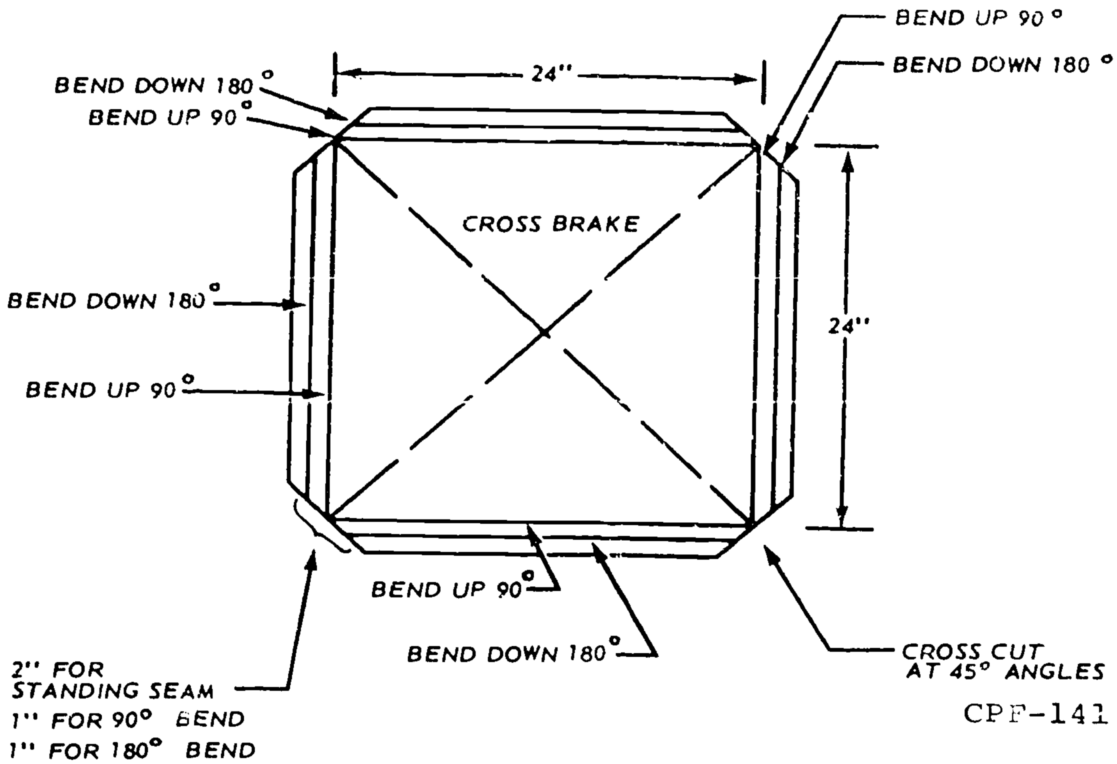

Figure 4–14. Pattern for top of plenum.

Elbow patterns. The branch lines of the duct system in foldout 1 have similar elbows except for size. We will not consider the pattern development for elbows because of their availability on local markets, costing less than the time it takes to make them.

Exercises (442):

1. List three methods for pattern development.

2. Which patterns are developed using the triangulation method?

3. Which patterns are made by the parallel line method?

443. Identify factors in turn vane development.

Turn Vane Patterns. In an earlier chapter of this text, you learned how to determine the width, length, spacing, and number of turn vanes to achieve maximum airflow through a 90° rectangular elbow. You must have this information before you make the pattern. Figure 4-16 is an enlarged plan view of joint 6 of trunkline A, which contains two sets of turn vanes. This illustration is derived from the breakdown of trunkline A in figure 4-2. Remember that, for best airflow, turn vanes must be spaced so that they have an aspect ratio of 5. Using the formula $\frac{H}{W} = 5$ and substituting the height of the duct (14 inches), we get $\frac{14}{W} = 5$, or $2\,^4/_5$ inches for the spacing between the turn vanes.

The next step is to determine how many turn vanes you need. Divide the $2\,^4/_5$ (2.8) inch spacing into the length of the turn vane rows. As you can see in figure 4-16, the row for trunkline B has eight turn vanes and the row for trunkline C has nine turn vanes. In both computations, the actual number of turn vanes is a mixed number that has been rounded off to the nearest

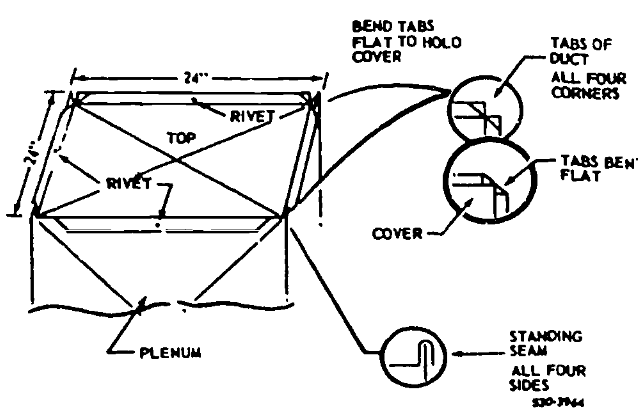

Figure 4–15. Standing seam used with plenum top.

whole number. In this step you also find that the curved part of the turn vane is 4½ inches and each straight is 1½ inches. Thus, the dimensions for each turn vane are 7¼" x 14". (If necessary, refer to fig. 3-6 to refresh your memory concerning dimensions of turn vanes.) When you add the 3/4-inch tab allowance to each end of the pattern, the total dimensions become 7½" x 15½", as shown in figure 4-16. Notice also that the 3/4-inch tab allowance has been marked to show the slits, which are approximately 1 inch apart. During installation, these tabs are bent 90° and riveted to the top and bottom of the duct joint.

You can make the patterns for the components of the duct system directly on the metal sheets. If several like items are needed, you can make paper patterns or metal templates. You should recall how you transfer patterns from paper patterns or metal templates.

Exercises (443):

1. What are turn vanes used for in a 90° rectangular duct elbow?

2. Give the formula for spacing turn vanes.

3. How much tab allowance is added to each end of a turn vane pattern?

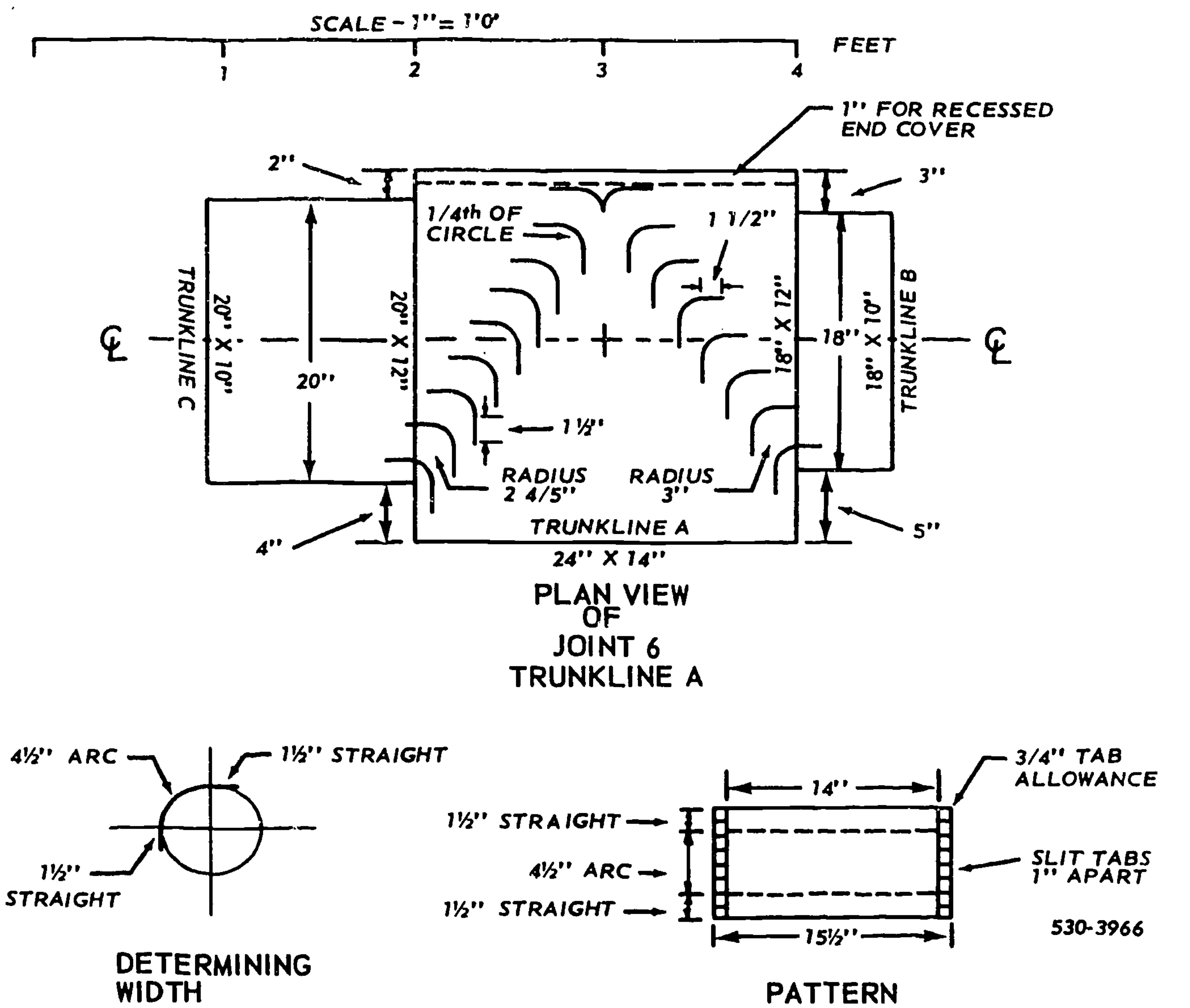

Figure 4–16. Pattern for turn vanes.

444. Explain key points in cutting and notching the components of sheet metal duct systems.

Cutting and Notching. Such patterns as those shown in figures 4-13 and 4-14 contain information you can use for cutting and notching. For example, figures 4-4 and 4-8 show how you can arrange the patterns on full-si. sheets in such a way that you will have very few leftover pieces after cutting. This information, combined with what you learned about sheet metal cutting equipment in Volume 2 of this course, should help you cut and notch patterns of almost any shape. Most of the patterns for this heating and air-conditioning duct system can be cut with squaring shears or unishears and notched with straight snips.

Cutting patterns. The patterns for joints 4 and 5 of trunkline A are cut from sheets 2 and 3 (fig. 4-4) with power or manually operated squaring shears. After you scribe or mark the pattern on the 3′ x 10′ sheet, you place the sheet in the squaring shears and cut along the 77¼-inch line. You will find that you can cut pieces up to 48 inches long to the desired sizes by setting the front gage of the squaring shears. You can cut pieces up to 24 inches long to desired sizes by using the back gage of the squaring shears. These gages are particularly helpful if several pieces of the same size are to be cut. When you are cutting patterns, be sure to include the seam and joint connection allowances. For example, when allowances are included with the basic pattern size 35″ x 76″, the completed pattern is 36″ x 77¼″. Several rectangular joints of the duct system in foldout 1 require holes for the takeoff fittings. The plenum must have a 24″ x 14″ opening to accept joint 2 of trunkline A. Joint 6 of trunkline A must have 18″ x 12″ and 20″ x 12″ openings for the takeoff fittings for trunklines B and C respectively. Several joints in trunklines B and C have round openings to accept the 6- and 8-inch round takeoff fittings for the branch lines. You can make the rectangular cutouts with straight snips or portable unishears, and the round cutouts with aviation snips or portable unishears. It is best to cut out the openings for the branch lines at the job site rather than in the shop.

The patterns for the round duct joints are easy to cut because they are rectangular and do not have notches. Figure 4-12 shows the pattern for the 6-inch round joint used extensively in the branch lines. Note that the size of the pattern, including allowances, is 19⅞″ x 36″. Patterns this size can be cut from 3′ x 8′ or 3′ x 10′ sheets with very little leftover material. Since several joints of this size are to be made, you can save time by setting the back gage of the squaring shears for 19⅞ inches and cutting all of the pieces from whole sheets of metal.

The patterns for the transitions shown in figure 4-13 are to be cut from sheet 6 in figure 4-8. Notice that we estimated the top and bottom patterns to be 13″ x 18″, but because of the true length of the sloping sides, the pattern requires 13   ″ x 18″. This additional 1/16 inch can be obtained from the leftover space on sheet 6 (fig. 4-8) without affecting the other patterns. This same additional 1/16 inch is needed for the 2-side patterns, which have an actual size, including allowance, of 10½″ x 13 1/16″. Notice on sheet 6 in figure 4-8 that, when this extra 1/16 inch is cut for the top and bottom pieces, it also provides the extra 1/16 inch for the two side pieces. You can cut sheet 6 easily with squaring

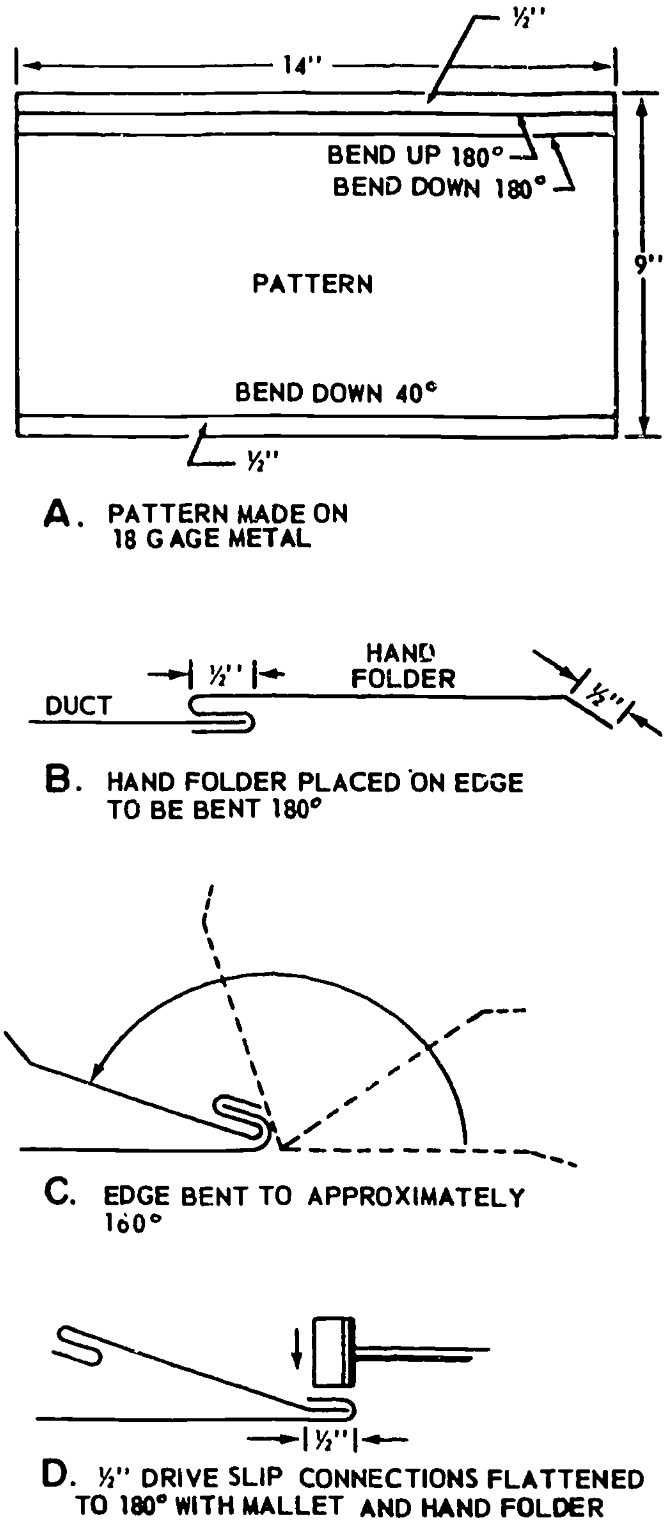

Figure 4-17. Hand folder to make 180° bend for 1/2-inch drive slip connections.

shears by making the first 36 inch cut along the line between joints 2 and 8. The next 36-inch cut should be between the 4 pieces of joint 8, but allowing 13 $^{1}/_{16}$ inch width instead of the 13 inches shown. The next cut should make another piece 13 $^{1}/_{16}$" x 36". The other 36--inch cuts across sheet 6 are made as marked. Now, going back to the 26⅛" x 36" piece cut for the transition, 3 cuts are needed to separate the 4 pieces of the transition and the 7½" x 26⅛" leftover piece. Remember to use the 13 $^{1}/_{16}$-inch measurement instead of the 13-inch measurement.

Notching patterns. You make the slits and notches in patterns with straight snips or throatless shears. The straight snips are used most often, but throatless shears have more leverage and require less effort. When using either of these, you must be careful not to make the cuts any longer than is specified on thee pattern. Notching is needed so that you can bend the sheet metal along the brake lines indicated on the pattern and can assemble the Pittsburg lock seams more easily, assemble S-and-drive slip joint connections more easily, and install the drive slips more easily. You cut V-notches and slant notches at 45° angles, and square notches at 90° angles. In figure 4-13 you can see examples of these notches. You use V-notches along the 1/2-inch allowances for the S-and-drive connections, slant notches at each end of these 1/2-inch allowances, and square notches at each end of the 1-inch Pittsburg seam allowance. You can cut all of these with straight snips. Notice at the righthand end of the pattern how one cut makes the slant notches for two sides at one time.

The pattern for the round duct joint in figure 4-12 does not require any notches because there are no cross bends to make when you assemble the joint.

The patterns for the 16" x 10" to 14" x 8" transition shown in figure 4-13 have 45° and 90° notches at each corner. Although these notches are arranged somewhat differently from the notches for the rectangular-shaped duct, they are cut with the straight snips in the same manner.

The corners of the patterns for the plenum top in figure 4-14 are cut at 45° angles. See how a single cut at each corner makes the slant notches for each adjoining side of the pattern plus slant notches for each 1-inch portion of the standing seam. Make these slant notches with squaring shears or straight snips.

The 3/4-inch slits in the pattern for the turn vane shown in figure 4-16 are spaced approximately 1 inch apart so that the tabs can be bent 90° for fastening to the duct. When you cut slits like these, be careful to make all of them exactly 3/4-inch long so that the tabs can be bent properly.

Exercises (444):

1. What is used to cut the joints after the pattern is scribed on a metal sheet?

2. Why are round duct joints the easiest to cut?

3. What notches are cut at a 45° angle?

4. Where are square notches used?

445. Name some of the equipment used in forming and assembling sheet metal duct system components.

Forming and Assembly. Forming patterns into shape is the next step in fabricating sheet metal components. In Chapter 2, we described how the patterns shown in figure 2-20 were formed by a 1-2-3-4 sequence of operations: (1) cross braking, (2) seam allowance bending, (3) joint connection allowance bending, and (4) corner bends.

Rectangular duct joints. The regular sequence for forming sheet metal components is sometimes changed to make the operation easier. For example, to form the metal for rectangular joints, you will find it easier to do the folding in a 1-2-3 sequence because of the length of the stretchout. By forming the corners second, the metal is much easier to feed through the Pittsburg-lock forming machine, because it is easier to handle the metal when the dimensions are 14" x 24" x 36" instead of 36" x 77¼". To form the rectangular duct, you first use the cornice brake to bend the metal up along the cross brake lines. A 10° to 15° bend should be sufficient on the cross brake lines of any square or rectangular duct joint. Next, in step 4, you use the cornice brake to make the 90° corner bends along the three element lines and the 1/4-inch Pittsburg flange line. This changes the flat sheet into a rectangular shape. Now, resuming the regular sequence with step 2, you make the bends for the Pittsburg seam pocket by feeding the 1-inch allowance for the pocket through the Pittsburg machine, as you learned in Chapter 2. In step 3, you make the 180° bends for the drive slip connections with a shop-made hand folder. If you perform step 3 ahead of step 4, you can use a mallet and cornice brake.

The rectangular duct we are discussing will need a hand folder that is 14 inches long. You can make this hand folder from a 9" x 14" piece of 18-gage metal, as shown in A of figure 4-17. In step B, you place the hand folder over the edge to be bent. In step C, you bend the 1/2-inch allowance of the duct joint to 160°, and in step D you turn the hand folder around and use the other end for a spacer while you flatten the folded edge to 180° with the mallet. This shopmade tool does the same job as a hand seamer except that it is long enough to bend (as in this example) the whole 14 inches in one operation. When you are making a hand folder, it is a

good idea to make several standard sizes that can bend edges that are 6", 8", 10", 12", 14"and 16"long.

Assembling the 24" x 14" joint is quite simple, because all that remains to be done is to joinn the Pittsburg lock seam. In figure 4-18, you can see the steps in "locking" the Pittsburg seam of a 35-inch joint. If the pocket of the seam is tight, you must insert the 1/4-inch flange first at one end, as shown in step A of

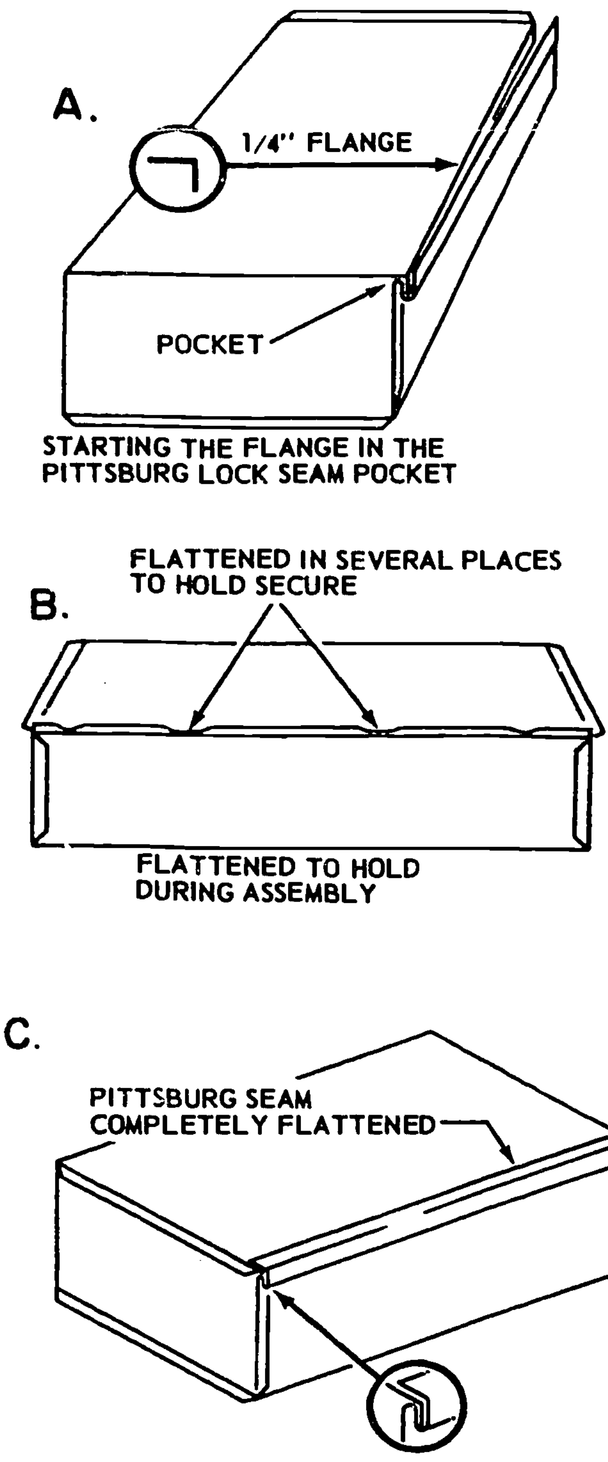

Figure 4-18. Assembly of a Pittsburg lock seam.

figure 4-18. Start the flange by hand but after a few inches you may need to use a hammer and a tool, such as a hand groover, to seat the flange firmly in the pocket. As you insert the flange, flatten the locking edge of the pocket, as shown in step B of figure 4-18. After the flange is completely seated, flatten the locking edge as shown in step C. This completes the assembly of one joint of the rectangular duct.

All of the other rectangular joints in the system in foldout 1 are formed and assembled in the same way, except joint 6 and joint 2 of trunkline A. During the assembly of joint 6, you must install the turn vanes with rivets or sheet metal screws. You attach the two takeoff fittings to joint 6 by bending the tabs of the tapped connections. The attachment of joint 2, which is a takeoff fitting in trunkline A, is somewhat different because only the top and bottom have flanges and tabs, since the width of the plenum is the same as that of trunkline A. The two sides of the takeoff fitting are formed into an S-shape similar to an S-slip instead of a flanged tapped connection. When you attach joint 2 to the plenum, the S slips over the plenum sides and you bend the tabs on the top and bottom as with other tapped connections.

Round duct joints. Forming and assembling a round duct joint is not difficult. Although round duct joints can be made with handtools, several machines can make the job much easier. Squaring shears cut the patterns, and the machines you can use for the forming processes include a Pittsburg machine for making the grooved seams (fig. 2-6), a slip roll machine for forming the sheet into a cylindrical shape, and a crimping machine and beading machine for making the crimp and bead of a slip-joint connection. The pattern shown in figure 4-12 is .ssembled with a grooved seam, which was discussed in Chapter 3. A Pittsburg machine can be used to turn back the 180° edges of the grooved seam, as shown in figure 2-6. Notice that one edgge of the pattern must be turned up and the other edge must be turned down so that they will lock when the piece is rolled up and joined. When the Pittsburg machine is used, the turned-back edges will fit tightly enough so that you can lock the seam with a mallet and hollow mandrel. All of the round duct joints in foldout 1 are the same, and only the dimensions of the patterns differ. If you need to refresh your memory about these machines, refer to Volume 2 of this course.

Transitions. Forming and assembling the transition patterns shown in figure 4-13 are more complex than forming and assembling round or rectangular joints because of the multiple bends required. However, if you first determine the best sequence for making the bends, the job is not difficult. Since these patterns are not too large, the standard 1-2-3 folding sequence can be used. (Step 4 is not needed for this component.) First, use the cornice brake to bend the metal up 10° to 15° along the cross brake lines on all four patterns.

Second, make the Pittsburg seam pockets on the top and bottom patterns with the Pittsburg machine, and make the 1/4-inch flanges on the side patterns with the

cornice brake (or bar folder). By now you should understand why so much effort is made to cut the notches correctly. You cannot make good bends if you don't make the notches correctly. Third, make the 5° bends for the straight portions of the four pieces and the 180° bends for the drive slip connections. These can both be made with the cornice brake.

After you have formed the transition patterns according to the instructions on the patterns, you are ready to assemble the four pieces by fitting and locking the Pittsburg lock seams in each of the four corners.

Plenum top and duct ends. You form the top for the plenum and the ends for the three trunklines by cross braking and making the bends indicated in figure 4-14 with a cornice brake. These components do not need to be assembled because they are in one piece.

Turn vanes. Seventeen turn vanes for joint 6 in trunkline A are to be made from the pattern shown in figure 4-16. After you have done the cutting out and slitting, you bend each turn vane to a radius of 2.8 inches with 1½-inch straight edges. Then you bend the alternate 3/4" x 1.07" tabs for 90° so that you can fasten the turn vanes inside the duct joint somewhat like the splitters shown in figure 3-5. Rivet or spot weld each turn vane to the top and bottom of joint 6.

Flexible connection. In many parts of the United States, flexible connection joint material, preformed in lengths of 50', is available on the local market. The 24" x 14" x 6" flexible connection used in trunkline A is shown with detail views in figure 4-5. For shop manufacture, the patterns for the cloth and metal connector pieces are shown in figure 4-19. Instructions for forming and assembling are included in this illustration. As you can see in step A, the flexible cloth pattern is 77 inches long (including a 1-inch seam allowance) and 6 inches wide. The overall dimensions of the pattern for the two metal connector strips are 3½" x 77¼", which includes seam and S-and-drive connection allowances (step B). The ends of the pattern for the metal have Pittsburg seam allowances. One side has a 1/2-inch allowance for S-and-drive connections, and the other side has a 1-inch allowance for the double seam. Notice the 45° and 90° notches that make it possible to bend the corners after you make the double folded seams.

These metal patterns are small and do not require stiffening along cross brake lines. Therefore, your first forming step is to make the pocket for the Pittsburg lock seam. Next, use the cornice brake to make the 90° flange for the Pittsburg seam and the 180° bend to start the double seam. You start this double seam, as shown in step C of figure 4-19, by bending the outside 1/2-inch strip 180° along its 76-inch length. Next, insert the long side of the cloth into the 180° fold, and flatten the metal with the cornice brake. In step D of figure 4-19, you use the cornice brake to make another fold and to flatten the metal to secure the cloth with a double seam. Repeat these steps to attach the other metal connector strip, and attach both connectors with double seams, as shown in step D.

Your next step is to use the cornice brake to make the corner bends (along the ellement lines) and the 1/4-inch flange for the Pittsburg seam. Since the flexible cloth and both connector strips are attached (step E), the cornice brake can make the 90° bends across all three pieces. Next, assemble and lock the Pittsburg seams on both of the metal connector pieces. Your last step is to use a shop-made hand folder (fig. 4-17) to make the 180° folds for the drive slip connections. This completes the flexible connection, which should now look like the drawing in figure 4-5.

Exercises (445):

1. When you are forming metal, what piece of equipment should you use to make the first bend in the metal?

2. What machine is used for making grooved seams?

3. What should you use in the last step to make the 180° folds for the drive slip connections?

4-3. Installation of Duct System Components

After duct system components are fabricated, they are taken to the designated site and installed in a building. The installation procedures include locating centerlines for routing the duct; hanging and joining duct joints; insulating; and installing registers, grilles, and diffusers.

446. Describe the centerlines of a duct system, its hanger requirements, and the sheet metal specialists' responsibility in preparing for a duct system installation.

Centerline and Duct Routing. You can determine the routing and the centerline of a duct system from the working drawings or blueprints of the system. The centerline is an imaginary line that passes through the middle of all the duct joints as the horizontal and vertical center. For example, if you stretch a chalkline (without sagging) through trunkline B from the center of the first 18" x 1" joint to the center of the end 12" x 8" joint, the chalkline will pass through the center of each joint and transition. Each transition is designed to maintain the same centerline (horizontal and vertical). The horizontal centerline can be determined from a plan view drawing, and the vertical centerline can be determined from an elevation view drawing.

In foldout 1 you can see that the horizontal centerline of trunklines B and C is halfway between the walls of the hallway. If you take a rule or an architect's

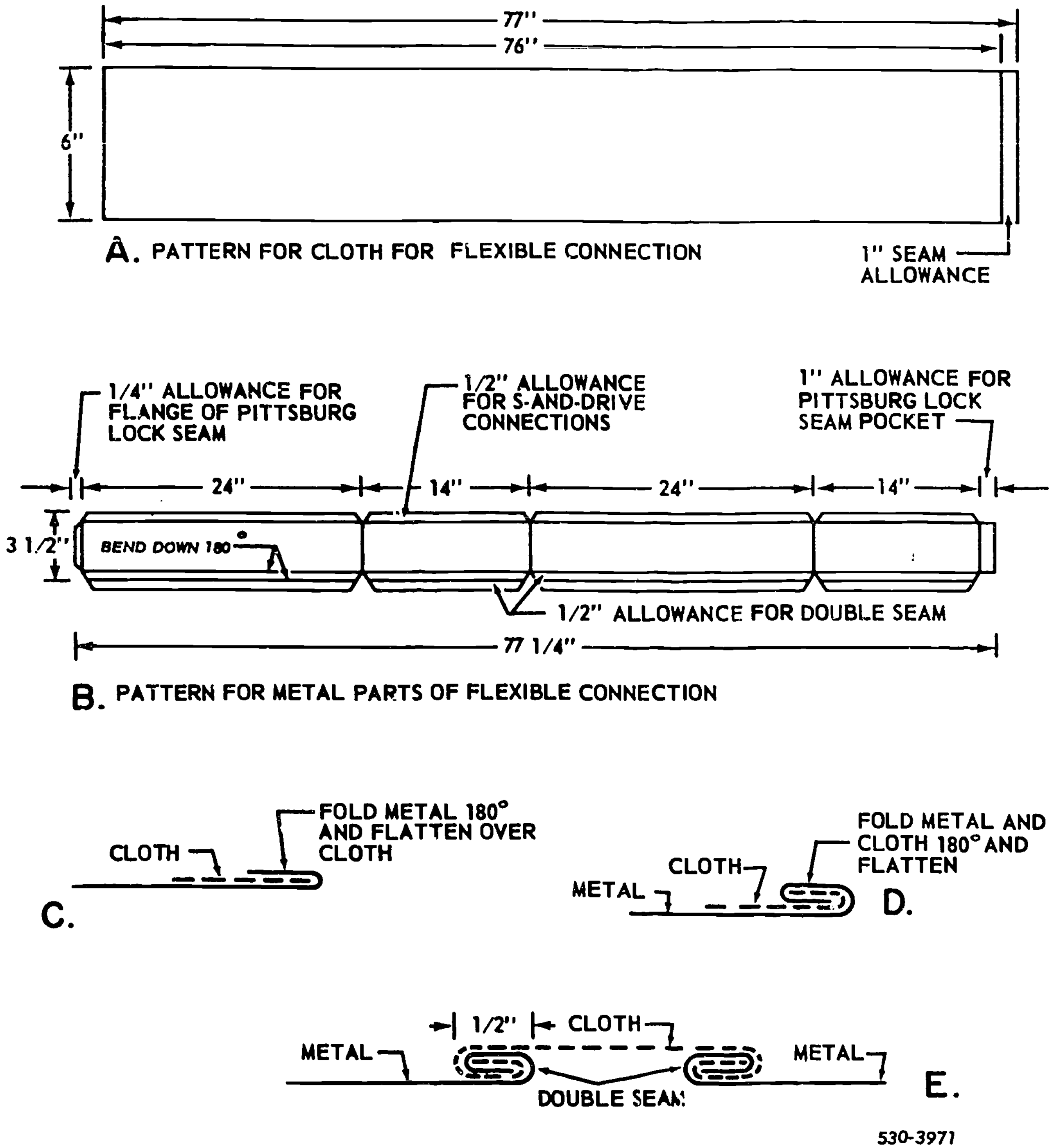

Figure 4–19. Flexible connection-patterns and assembly.

scale, you will find the centerline to be 12 inches from each side of the hall. Later when you are hanging and aligning joints in the building, you will use a chalkline (or chalk marks) to locate the horizontal centerline in the attic of the building. If the building in foldout 1 has a pitched roof with the ridge running parallel to the length of the building, you can use a plumb line to locate the horizontal centerline because the centerline of trunklines B and C will be directly below the ridge.

You can determine the vertical centerline of the duct system by using the elevation view in foldout 2, where the centerline of trunkline A is 20 inches above the ceiling. In figure 4-10, this vertical centerline is also shown going through the round duct; notice that it is also 20 inches above the ceiling. Although all of the duct joints are installed with their centerlines 20 inches above the ceiling in this system, in some situations, the vertical centerlines change. In either case, the working drawings or blueprints include the information you need to locate the vertical centerlines.

Hangers. In volume 2 of this course, you learned that hangers are used to support and level the heating and air-conditioning ducts. The size and shape of the hangers are determined by the size, weight, and material of the duct and by the characteristics of the structure to support the duct. Hangers made of angle iron are used for heavy duct joints that require extra support. The duct joints on foldout 1 are supported with strap hangers made of 16-gage sheet metal cut in 1-inch strips or of lighter gages (such as 24-gage) cut in 2-inch strips and folded like a drive slip to make double thickness 1-inch strips. These hangers are nailed at one end to the rafters or to other structures in the attic, as shown in figure 4-20. Notice how you turn the ends of the hangers around the lower corners of the duct and secure them with sheet metal screws. Use a Whitney punch to make the holes in the hangers. Use a portable electric drill to make the holes of the duct for the sheet metal screws.

Two kinds of hangers for round duct are shown in figure 4-21. These hangers are made of 16-gage material 1-inch wide or of a double thickness of lighter gage materials. Note how you loop each hanger around the pipe and fasten it with stove bolts instead of sheet metal screws. One type (on the right in the illustration) has a single strap nailed to a rafter; and the other type has a double strap, also nailed to a rafter.

Planning for the Installation. Most of the planning and scheduling for the installation of a duct system is done by the superintendent and the shop supervisors, but you will be responsible for taking the tools, equipment, and materials you need to the job site. It is important to have everything needed at the job site to eliminate the lag time caused by extra trips back to the shop. Most of the duct system shown in foldout 1 is in the attic of the building and, if possible, should be installed before the ceiling is covered. You can hang and align the duct joints more rapidly and safely if you are standing on scaffolds than if you are working in the attic. Some of the items that should be taken to the job site to install this duct system include the following:

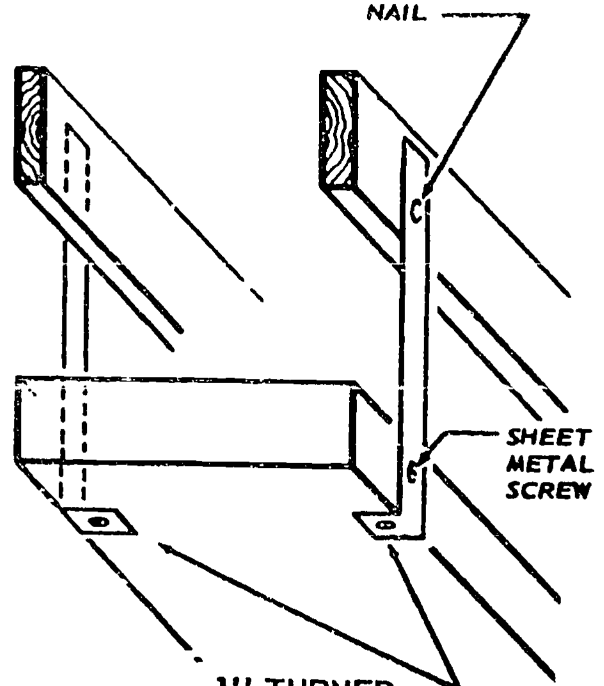

Figure 4-20. Strap hangers.

Toolkits (one per man).
1/4-inch portable electric drills and twist drills.
Electrical extension cords of sufficient length.
Whitney hand punches.
Chalklines and chalk.
Scaffolds or ladders.
Fabricated duct joints for the job.
S-and-drive slips.
Hangers.
Sheet metal screws, nails, and stove bolts.
Insulation and fasteners.

Exercises (446):

1. What is the centerline of a duct system?

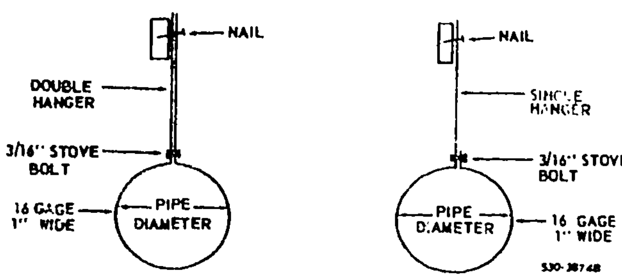

Figure 4-21. Hangers for round duct.

2. How can you determine the vertical centerline?

3. How are the size and shape of the hangers determined?

4. What is your responsibility in preparing to install a duct system?

447. Give key points in the installation of duct joints and duct insulation.

Installing Duct Joints. In our previous discussions of the duct system shown in foldout 1, we have described layout; fabrication; centerline; duct routing; and the tools, equipment, and materials needed at the job site. Now let's see how the duct joints are installed. If the heating and cooling unit is already installed when you get to the job, you must install the plenum first. If the heating and cooling unit is not yet installed, the first joint to install is the flexible connection (joint 3) of trunkline A. Remember that, in this example, the rectangular joints are connected with S-and-drive slips, the round duct joints are connected with slip joint connections, the rectangular takeoff fittings are connected with tapped connections, and the round duct takeoff fittings are connected with dovetail seams.

The supply plenum, as you can see in foldout 2, rests on top of the cooling coils. The coils are in a housing with a 1-inch turned-up flange over which the 24" x 24" plenum fits. Sheet metal screws are used to fasten the plenum to the flange. Before you install the plenum top cover, you should install the takeoff fitting (joint 2 in fig. 4-2). (This takeoff fitting is usually installed at the sheet metal shop before it is delivered to the job site.) The takeoff fitting is attached to a 14" x 24" side opening in the plenum. The tabs along the top and bottom edges of this takeoff fitting are bent like those shown in figure 2-18. However, the sides are not bent because, when this takeoff fitting was fabricated, the forming of the sides was slightly different from the forming of a regular tapped connection. These sides are S-shaped to fit over the plenum like S-slips. With the takeoff fitting installed on the plenum, this S-connection makes a tight fit for the sides and the tabs along the top and bottom hold the fitting to the plenum. You do not need to support the takeoff fitting with hangers because it is firmly attached to the plenum.

The flexible connector (joint 3) is attached to the takeoff fitting and to joint 4 with S-and-drive slips, as shown in figure 2-17. It is a good idea to install hangers on the joint 4 side of the flexible connector to prevent tearing the flexible cloth when you connect joint 4. The alignment of trunkline A begins with these first two hangers, which must be installed so that the duct is on the centerlines.

You can connect joints 4 and 5 with S-and-drive slips before hanging and connecting them to the flexible connection. Remember, you have a vertical and a horizontal centerline to maintain. You can use a chalkline to locate the horizontal centerline of trunkline A, which will be easy to follow. As you install each joint, make sure that the points of intersection of the cross brake lines are directly over the chalkline. Suspend the hangers from the rafters so that the vertical centerline of the duct is 20 inches above the ceiling. Attach the first hangers (in fig. 4-2) to the joint 4 end of joint 3. Install the remaining hangers on 48-inch centers (or less). When you are securing the hangers to the duct with sheet metal screws, be sure to punch (or drill) holes in the hangers so that they are larger than the screws.

The remaining rectangular joints of trunklines A, B, and C are joined, aligned, and hung in the same manner as joints 4 and 5. But, install the turn vanes and the two takeoff fittings in joint 6 before hanging it. Install the top for the plenum and the ends of the three trunklines as shown in figure 4-15.

You install the branch lines after you have installed the trunklines. Begin by attaching the round takeoff fittings to the trunklines by bending the tabs of the dovetail seams. Hang the other joints of the branch lines by connecting the slip joints and fastening them with three sheet metal screws at each joint connection. These joints are supported on 48-inch centers (or less). The branch lines continue on the centerlines that are 14 inches above the ceiling joints and follow the horizontal centerlines (chalklines). Figure 4-10 shows a 6-inch branch line with the centerline 20 inches above the ceiling.

If the ceiling has not been installed, place the ends of the drop joints so that they will be flush with the ceiling when it is installed. If the ceiling has already been installed, cut a hole and install the drop joint withh a flush fit. In either case, the outlets should be in the location designated by the working drawing or blueprint.

Duct Insulation. The ducts must be insulated before or after they are installed. You install the insulation either inside or outside the duct depending on the type of insulation you are using. To install insulation inside a duct, use a type of duct liner that will not pick up odors or erode under high air velocities. This type of insulation is attached to the inside of the duct sections by adhesives. When and where to install this insulation? The best time and place is in the shop when there are enough sections ready for insulation so that two or three workers can keep working a reasonable length of time. Most workers don't like to jump from one job to another, so do the insulating with as few job changes as practical.

To insulate the outside of a duct system, the duct must be installed first. Since the insulating is to be done on the job, it is recommended that three workers do the

job together, one cutting and two installing. To install the insulation on the outside of a duct, you must first decide how to attach it to the duct. You can wrap it and tie it with wire, you can glue it on, or you can use pin weld fasteners. Look more closely at each choice. Remember that an insulation with an outside cover or backing that forms a vapor barrier is recommended, and consider the manufacturer's recommendations.

When you are wrapping insulation, do not make it too tight because the material insulates better if it is not compressed. Also, if you wrap it too tightly, the standing edges of the S-slips can punch through the foil and insulation. Be sure to cover the entire surface of the duct; any exposed portion will be subject to condensation when the air-conditioning system is in operation. You can wrap irregularities in the duct, such as transitions, by shaping or cutting the foil-backed insulation to fit the joint, and folding the excess material. The foil makes the insulation easy to form, since it retains almost any desired shape. Tape all joints and seams to insure a complete vapor barrier.

The remaining trunklines and branch lines are insulated in the same manner as trunkline A, except for the dimensions of the insulation pieces. The 12" x 8" sections of trunklines B and C can each be wrapped with one long piece. Apply the insulation for the elbows carefully because of the 90° turn. If the insulation is cut to cover only the elbow, it can be creased across the throat radius to make a good wrap. The insulation around the straight joints can lap the elbow insulation to make a good fit. Use tape to secure the blanket where the pieces join.

Blanket-type, foil-backed insulation is available in thicknesses from 1/2" to 2", in widths from 24" to 48", and in rolls 100' long. To install blanket-type insulation with glue (adhesive), you first cut the insulation to the proper size and then apply the adhesive to the duct. Next, carefully place the insulation around the duct and make sure you get it in the proper place the first time. If you have to move the insulation, it may pull apart before the glue lets go. After the insulation is in place, use pressure-sensitive duct tape and seal all of the joints.

To install blanket-type insulation with pin weld fasteners, start cutting the insulation to the proper size and then install it over the pins. Be careful not to jab a pin into your hand when you ppush the insulation over the pin and install the retainer clips over the pins. Tape the joints as previously advised.

To install blanket-type insulation with the wire tie method, the cutting and installing are about the same. The only difference is in the way the insulation is secured to the duct. After you have installed the insulation and taped the joints, use 20-gage wire and wrap or tie it around the duct as needed to hold the insulation firmly in place. Twist the ends of the wire together and bend them flat so that they will not pierce the insulation.

Exercises (447):

1. What should you install first if the heating and cooling unit is already installed?

2. What type of fastener is used to install the plenum to the flange of the unit?

3. What should you use to locate the horizontal trunk centerline?

4. How should you attach insulation to the inside of duct sections?

5. Why must all joints and seams of insulation be taped?

448. Describe some of the final steps in the installation of a duct system.

Installing Registers, Grilles, and Diffusers. In the final steps of a duct installation job, you install the registers, grilles, and diffusers. You may install these components after you hang the joints. They are usually not installed until after the painting and wall finishing is completed. Registers, grilles, and diffusers are often purchased factory-made and unpainted. Since they may need to be painted to match the color of the walls, you should make arrangements with the paint shop to do this before you install them. If the items are spray-painted in the paint shop, they will have a better appearance than if they are painted at the job site. Coordinate with the carpenters to insure that the openings are the correct size and at the correct locations.

Installing registers. The duct system we have been describing has one register, the 18" x 36" return air register shown in the return air duct (return air and outside air plenum) in foldout 2. This return air register differs from the supply register with adjustable louvers, shown in figure 3-13. The 18" x 36" return air register (foldout 2) has fixed louvers very much like those in return air grilles. (You will find that return air registers with fixed louvers are also called return air grilles by some manufacturers.) The return air register to be installed in the return air duct has fixed louvers with a 35° down deflection; from the front side, it looks like view B in figure 3-14, but the louvers are flat instead of V-shaped. The face frame has screw holes and you install it with screws that attach to the wood frame, which is a part of the wall. Because of this wood frame, 90° flanges at the end of the duct are not needed.

Installing grilles. Grilles are installed as we explained in Chapter 3 and illustrated in figure 3-14 of this text. Our explanation did not include how you are to determine the location of the holes for the grilles. Location information is usually given on the working drawings or blueprints and shows the vertical and horizontal location. In some cases, you may need to make minor changes in the location of the door grilles if panel doors are used instead of hollow core doors. In panel doors, the opening for the grilles should be made in the panel nearest the floor rather than at the usual 6 inches above the bottom of the door. If the grilles must match the color of the rooms, they should be sent to the paint shop before installation. To install grilles in metal doors, the procedure is the same as that shown in figure 3-14 except that you use sheet metal screws.

The return air grilles for the walls in rooms 2,3,5, 6,9,10,11, and 12 in foldout 1 are boxed in (framed) by the carpenters and are located at floor level between the wall studs, which are on 16-inch centers. Use screws to install the front and back frames, as shown in figure 3-14. Install the door grilles in rooms 1, 7, 8, 13, and latrine in essentially the same way as shown in figure 3-14. They must be 6 inches above the bottom of the hollow core doors.

Installing diffusers. Figure 3-12 shows a typical diffuser and damper assemblly used at the supply outlets of round ducts. These are factory-made units and should be painted to match the room before installation. They are easily installed if the round duct ends are flush with the ceiling. Like the installation of registers, and grilles, installing diffusers is one of the last jobs in the installation of a complete duct system. Fit the damper assembly (B, fig. 3-12) into the round duct and mark the location of the screw holes. After you drill the holes in the round duct, attach the damper assembly with sheet metal screws. Next, attach the diffuser (C, fig. 3-12) to the damper assembly with countersunk ovalhead sheet metal screws that come with the units. After tightening the screws, adjust the damper blades to the approximate position shown in figure 3-12. The diffusers in foldout 1 are like the one shown in figure 2-12, except that some are for a 6-inch duct and some are for an 8-inch duct.

Exercises (448):

1. What are the final steps in completing a duct installation?

2. With what other shops must you coordinate as you complete your installation and why?

449. Given specific duct system repair problems, state the correct action to take.

Repair of Duct System Components. You will find that very little repair is needed in most duct systems. Some duct systems have been in buildings for many years and are just as good as they were when they were installed. There are occasions, however, when portions of ducts may need to be repaired or replaced. The joints in an air conditioning duct with its insulation removed or torn may contain holes caused by condensation and rust. The exhaust duct system in the plating shop may need repair or replacement because of the corrosive action of the acid fumes. A portion of a building damaged by fire may need duct repair or partial replacement. Other repair jobs are as simple as covering (patching) a hole in a duct.

Patching. Patching is usually done on small repair jobs that do not require the replacement of whole joints or sections of a duct. For example, suppose you must cover a hole in a 26-gage duct joint because a 6-inch branch line has been removed. You make a patch from 26-gage metal (same kind as the duct) to cover the hole. The patch must be large enough to cover the hole plus the amount needed for the seam. From your study of Chapter 2, you know that a riveted lap seam is satisfactory for fastening the patch over the hole. Remember that, when you are using rivets with lap seams, the allowance is 1/4-inch from the center of the rivets to each edge of the metal. Therefore, for a 1/4-inch lap seam, you need a 1/2-inch allowance on the circular (disc) patch. The rivet holes should be 1/4-inch from the outside edge of the patch, and spaced 2 inches apart. If you need a square or rectangular patch to cover a square or rectangular hole, the allowance and rivet spacing is the same as for round patches. When you must use heavier gages of metal, your lap seam allowance should be in accordance with the information in Chapter 2, and the rivet spacing and size should be in accordance with Volume 2 of this course.

In the preceding example, you must have access to both sides of the hole to attach the patch with rivets. If the duct is assembled and you cannot reach behind the hole with a hand dolly, you will have to attach the patch with sheet metal screws. Using sheet metal screws does not change the requirements for the size of the patch or the spacing of the holes, but the holes punched in the patch must be larger than the screws. Use these holes in the patch to locate and mark the spots to drill in the duct for the screw holes. You can find the correct size of the sheet metal screws and holes from charts, such as those discussed in Volume 2.

Exercises (449):

1. What allowance is needed for a 1/4-inch lap seam on a circular patch?

2. On a riveted lap joint, what is the centerline for the rivet holes, and what should be the distance between the rivets?

3. When do you use sheet metal screws instead of solid rivets when applying a patch?

Stacks and Ventilators

THIS CHAPTER deals with the fabrication, installation, and repair of stacks and ventilators and the eff‧‧ᵗ of wind on their efficiency. Stacks exhaust heated gases from stoves, furnaces, and hot water heaters; and ventilators remove hot air and exhaust harmful and unpleasant fumes.

You will repair and replace stacks and ventilators more frequently than duct system components because they are installed on the outside of buildings and are exposed to moisture, temperature changes, and wind In addition to corrosion and damage from the weather, stacks and ventilators are subject to deterioration from the heat, moisture, and corrosive vapors that they exhaust.

The knowledge and skills you have already gained will be useful when you are working with stacks and ventilators because their layout, fabrication, and assembly are similar to those of other round duct components. The main exceptions are the fire safety precautions that you must take with stacks that carry heated gases from stoves and furnaces.

5-1. Stacks and Ventilators and Associated Components

Stacks and ventilators are affected by many conditions. By understanding the conditions that affect stacks and vents, you can understand why they are built as they are.

450. Characterize the effect of temperature and wind on stacks and ventilators.

Stacks and Ventilators. Stacks and roof ventilators should be located above the roofs of buildings so that the natural updraft will receive maximum assistance from the suction areas caused by the wind. Natural updraft is a characteristic of heated air that makes it flow upward through a stack or ventilator when the inside temperature is higher than the outside temperature. Heated air from a furnace will flow upward through a vertical stack because the temperature at the top of the stack is lower than at the bottom of the stack. The same principle applies to a ventilator, although the temperature difference is not as great. Wind is also a natural force and assists or increases the natural updraft, though its effect varies from time to time because of the variation in its direction and velocity.

Figure 5-1 shows the airflow over a building. The area of greatest suction on top of the building is at point B, which is located near the upwind edge where the wind is forced upward. If possible, the outlet of a stack or ventilator should be located in this suction area. At the end of area A in figure 5-1, the wind is flowing downward and tends to flow into a stack or ventilator located there. To prevent this unfavorable condition, the stack should be located in a more favorable position or raised to a point where the wind flows straight across the opening. A stack or ventilator located at point B will have the greatest suction from the wind. Second best is any location where the wind is flowing straight across the roof. The least desirable location is at the end of area A, where the air is turbulent and flowing downward. In all cases, the opening of the stack or ventilator should be above the highest part of the roof in order to take advantage of the wind from any direction. The downwind side of a building (C, fig. 5-1) is also a low-pressure area. The upwind side is a high-pressure area.

The location and height of the ventilators are given on heating and ventilation blueprints or working drawings. For example, foldout 1 in this text shows the location of the furnace flue (stack), and foldout 2 shows the height and details of its construction. Notice that the flue is 30 inches high. Normally, it will not be your responsibility to determine the location or height of the stacks and ventilators; but since you will be replacing them from time to time, your replacements should have the correct height. Usually, the size of the replacement is the same as the original, but if you suspect that the old one is not correct, consult your supervisor before making the replacement.

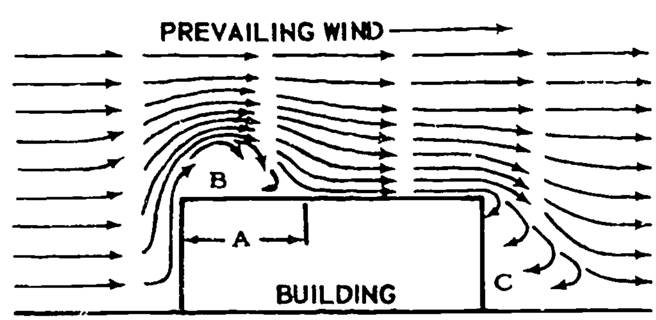

Figure 5-1. Airflow over a building.

Exercises (450):

1. Name the two forces that make heated air (gases) flow upward through a ventilator.

2. Give the best location for a ventilator on a roof.

3. What is a good rule to follow when you are deciding how high a stack or ventilator should be?

451. Describe the construction and use of double-wall stacks and selected stack components.

Stacks are sometimes called by other names, such as heating vents, vertical flues, and chimneys. In this text, the term "stack" means the sheet metal round duct (pipe) used to exhaust hot gases from stoves, furnaces, and hot water heate . By "associated components," we mean the items used with stacks, such as draft diverters, thimbles, roof jacks, storm collars, and vent caps. Figure 5-2 shows a typical stack and its associated components. Note the names of the components in the illustration.

Single-Wall Stacks. Single-wall stacks, as the name suggests, have only one wall. The single-wall stack shown in figure 5-2 has joints of round pipe, like those shown in figure 2-24. The fabrication of the joints in single wall stacks is the same as described previously. The fabricat n of the associated components will be discussed later in this chapter. The joints in the single-wall stack are available in straight pipe, elbows, and tee joints.

Double-Wall Stacks. A double-wall stack (pipe) consists of one single-wall joint installed inside another with approximately 1/2 inch of airspace between. This airspace, which you can see at the ends of several joints in figure 5-3, acts as insulation and prevents the outer wall from overheating. The inner wall is usually made of aluminum, and the outer wall may be made of aluminum or galvanized iron. Double-wall stacks are used to vent gas-fired heaters, furnaces, and water heaters. The aluminum inner wall resists corrosion, and the airspace prevents condensation. Therefore, double-wall stacks have a longer life than stacks of single wall construction.

Double-wall stacks can be fabricated in the shop but are usually purchased as factory-made items. In figure 5-3 you can see that a locking slip joint is used instead of the conventional crimped slip joint used with single-wall pipe. Most manufacturers have their own patented type of joint connection for double-wall pipe. When you are ordering double-wall pipe, be sure to order the appropriate type so that the joints can be connected.

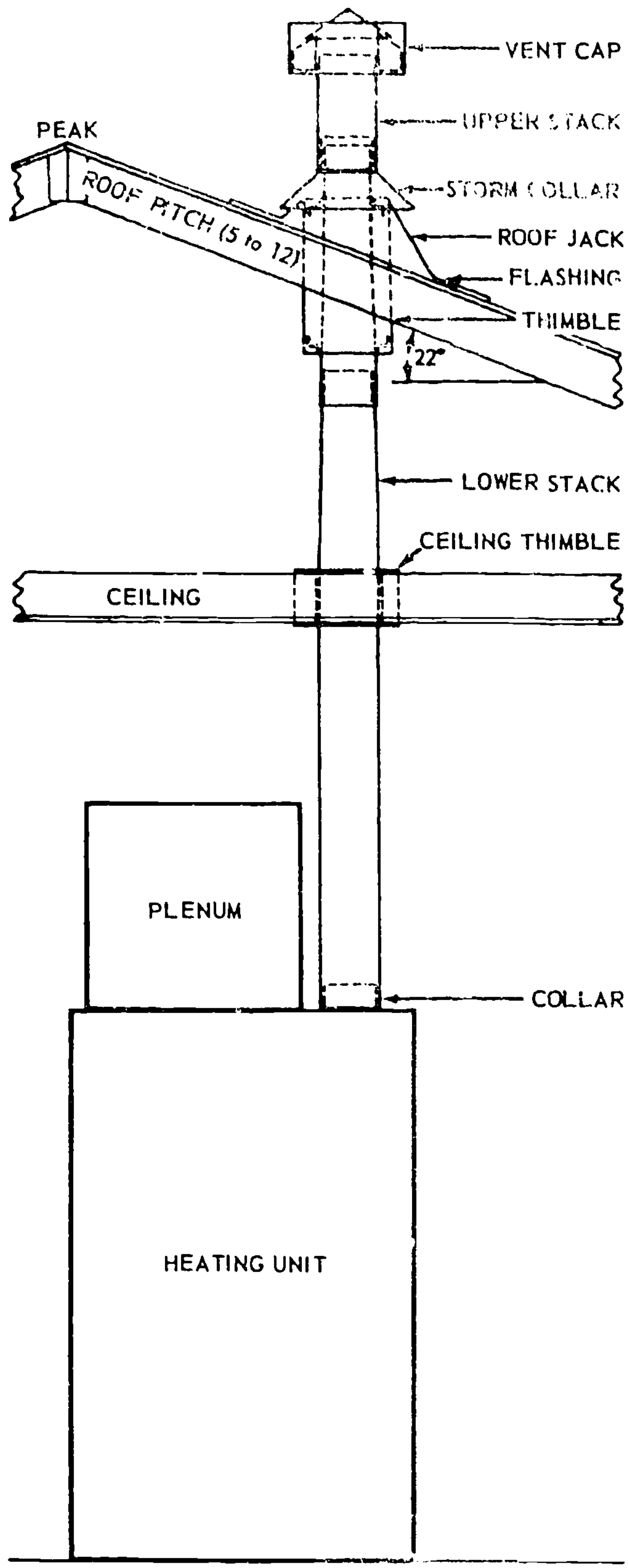

Figure 5-2. Single-wall stack and associated components.

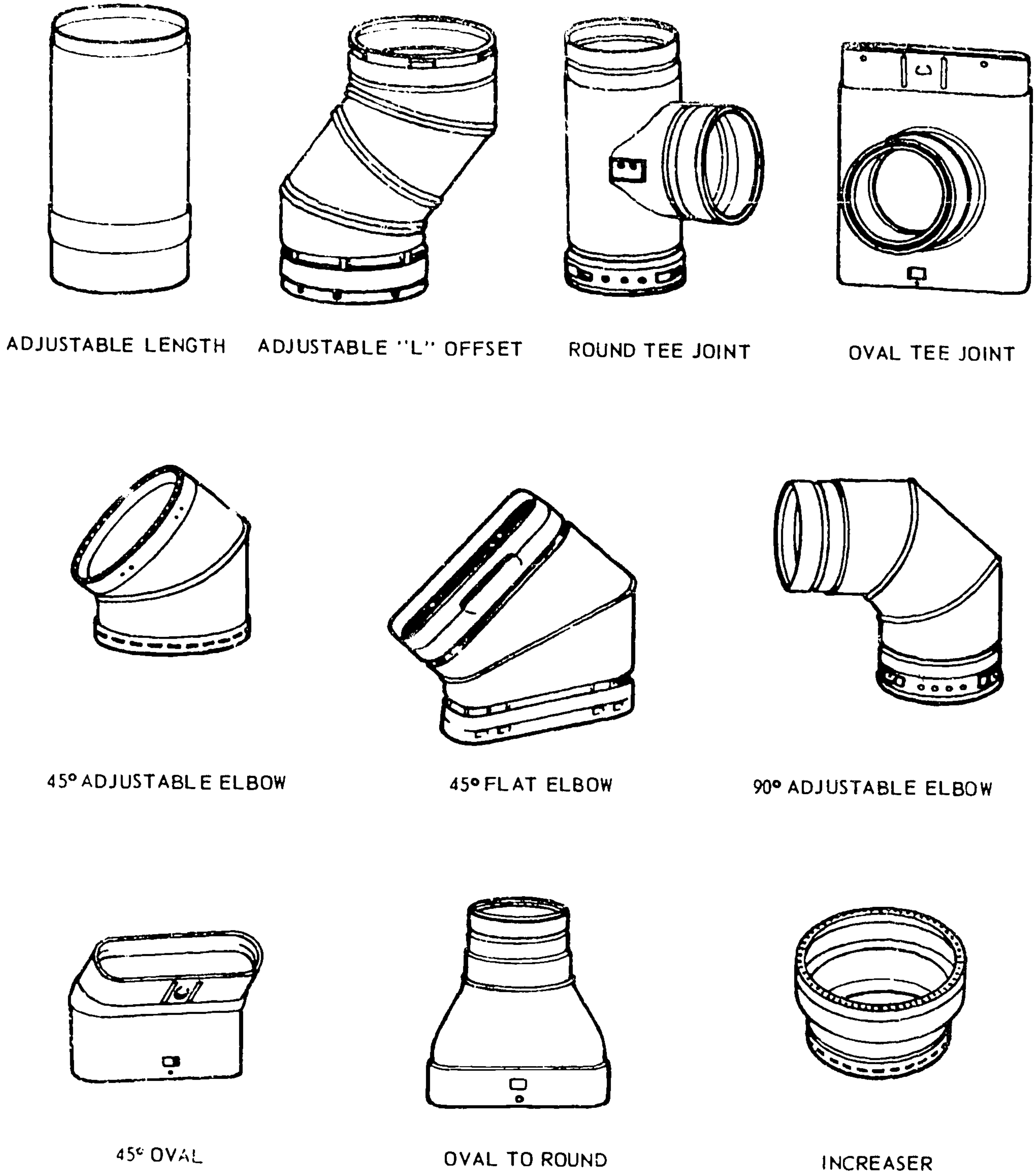

Figure 5–3. Double-wall stack components.

The joints of double-wall stacks (pipe) can be purchased in various shapes, diameters, and lengths. Some of the shapes, available in various sizes, are shown in figure 5-3. The round joints are available in diameters (of the inside pie) from 3 to 1[illegible] inches and in lengths from 6 to 60 inches. For in-between lengths, the adjustable length straight joint is used. It is similar to the ordinary straight joint and is made in two sections that telescope to make any combination of length. The tee joints in figure 5-3 are straight joints with a branch attached.

Draft Diverters. Draft diverters are used with the vent stacks for heaters and furnaces and are available in various sizes and types. These devices prevent excessive updrafts or downdrafts in the vent stacks. The draft diverter shown in view A of figure 5-4 has no movable parts and consists of the frustum of a cone with collars attached at each end to act as slip joint connections. The clips center the bottom of the cone so that there is an equal airspace all around the lower collar. The lower collar is the same size as the vent outlet on the heating unit and is installed as the first joint in a stack. The upper collar is the same size as the stack.

The double-acting draft diverter, shown in view B of figure 5-4, is another type of damper used for gas fired furnaces. It is installed horizontally as a tee, off one of the joints of a stack close to the heating unit. Notice its hinge which allows the blade to swing in to dampen updrafts and to swing out to dampen downdrafts. The blade has an adjustable knob for balancing the blade. Always install the hinge on the blade parallel to the floor.

The single-acting draft diverter, shown in view C of figure 5-4, is used for oil-fired furnaces. The blade on this type swings inward only. This draft diverter is also installed horizontally to the floor as a tee, off a horizontal or vertical joint of a stack close to the heating unit. The single-acting and double-acting draft diverters are used with stacks that are 7 to 10 inches in diameter.

Wall Thimbles. Wall thimbles are a safety feature in the stack assembly. They are constructed in such a way that air can circulate between the stack and the wall.

The shop-made, double-wall thimble, shown in figure 5-5, is often used in ceilings as well as in walls. To fabricate this type of thimble, make a length of stack and an outside piece (shown in fig. 5-5) which is 4 inches shorter than the inside wall. This accommodates the 1½-inch slip joints and allows a smooth joint connection. After you have made thimble parts A and B, join them with the Z-clips shown in figure 5-5. The Z-shaped clips are 2-inch wide with 1-inch spaces on each end to which you rivet the inside and outside parts of the thimble. You can assemble the thimble more easily if you rivet the Z-clips to the outside piece first.

Roof Jacks. A roof jack, like the one shown in figure 5-6, is the part of a vent system that is attached to the roof to weatherproof the opening through which the stack passes. Roof jacks may be fabricated or

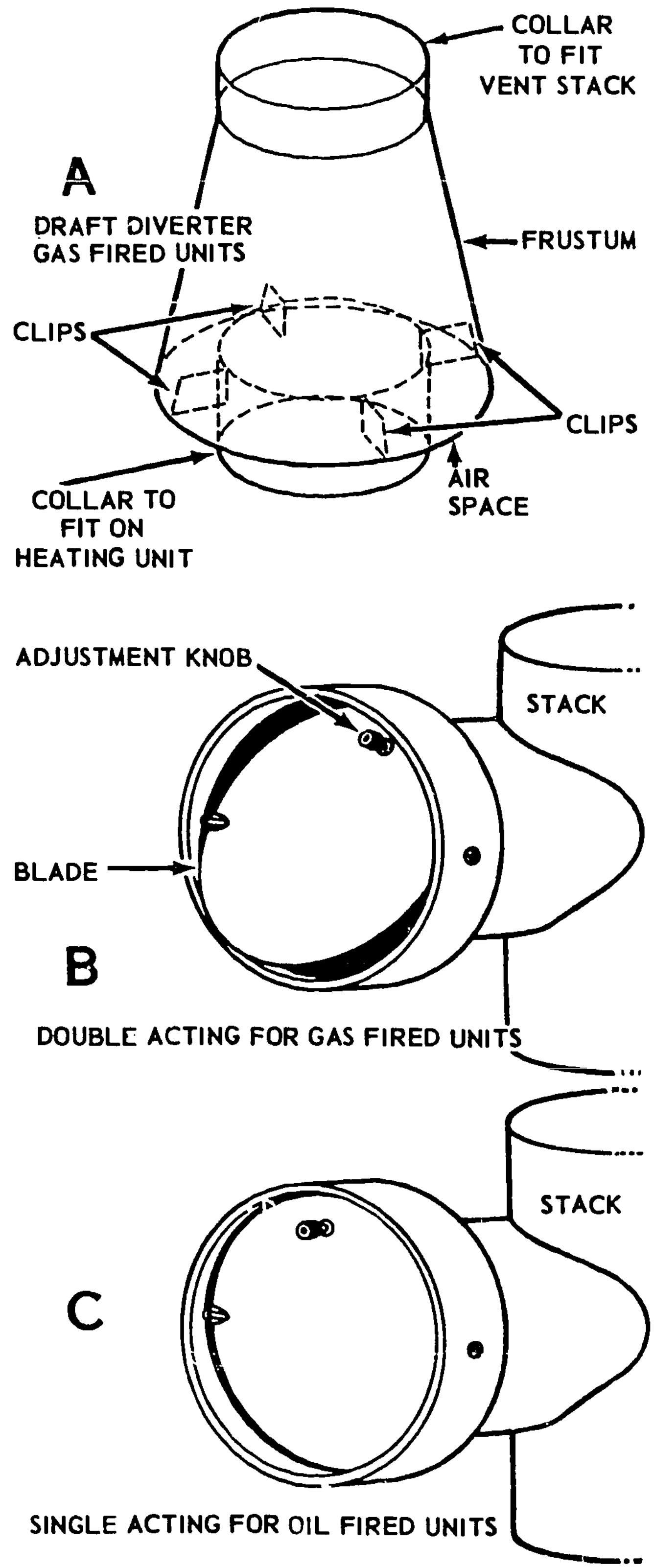

Figure 5–4. Three types of draft diverters.

purchased "ready made" for different sizes of vent stacks and roofs of a different pitch. (The roof jack in foldout 2 is for a flat roof.) The dimensions for roof jacks are shown on the drawings, or if you are replacing one, you can take the dimensions from the old roof jack. As you can see in figure 5-6, the base of the roof jack acts as a flashing and secures the jack to the roof deck.

Storm Collars. A storm collar is the part of a stack assembly that prevents leaks around the top of a roof jack. Storm collars used on double-wall vent pipe are usually purchased as "ready-made" items, but storm collars for single-wall vent pipe are usually fabricated in the shop. To make a storm collar, obtain the correct dimensions from a drawing, or the old collar. Using the proper dimensions, make piece A, as shown in figure 5-6, with a slight taper so that the top stack will fit over it; then turn a flange about 3/8-inch wide on the bottom at the angle of the collar. Next, make piece B and join A and B to make C (fig. 5-6). Spot-weld or rivet the joint and then solder it to prevent leakage.

Now you can install the collar as shown in view D of figure 5-6. With the thimble installed on the roof jack, the top of the outside piece of the thimble should fit flush with the top of the roof jack. The storm collar should completely cover the top of the thimble opening to prevent rain from blowing in through the airspace. In view D of figure 5-6, you can see that the vent stack above the roof is installed through the storm collar with a tight fit to prevent rain from entering. Each component is installed over the part below it to completely cover the seams in the assembly.

Vent Caps. Vent caps are installed at the outlet end (top) of a stack vent. Several different types are used on heating equipment stacks, five of which are shown in figure 5-7. Vent caps A and B are usually purchased "ready made" and are used with double-wall stacks.

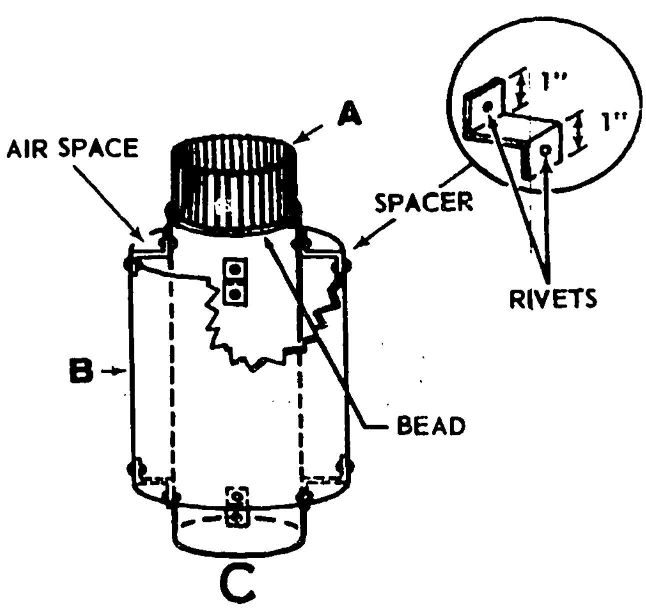

Figure 5-5. Shop-made double-wall thimble.

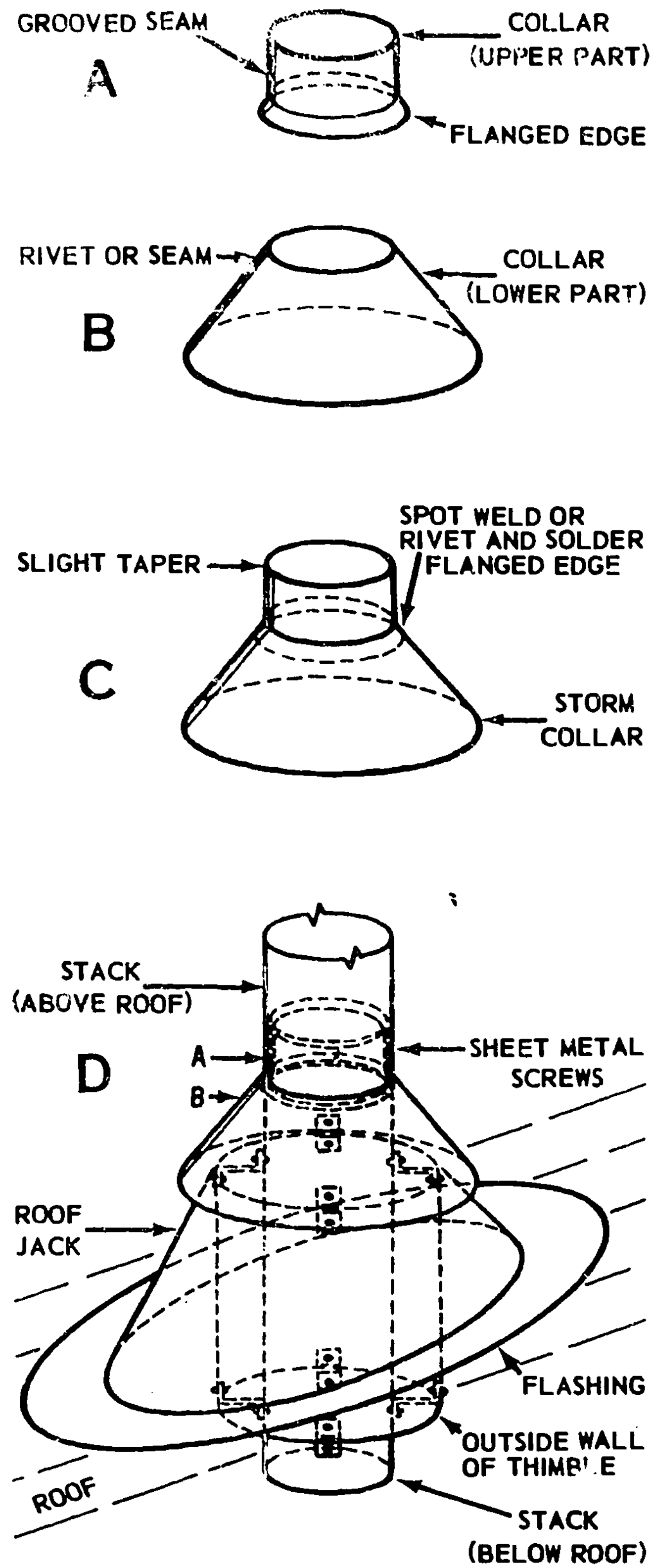

Figure 5-6. Storm collar, roof jack and double-wall thimble.

Vent caps C, D, and E can be purchased or fabricated in the shop and are used with single-wall stacks. The vent cap illus trated in view A is often referred to as a Belmont cap. Vent cap C is better known as an A cap because of its shape. Vent cap E is sometimes called a china cap because of its shape and the opening all around the top. Vent caps B and D are called rainproof or draftproof caps.

The type of stack used for each installation is specified on the working drawing. In foldout 2, you will note that a weatherproof downdraft diverter is specified. Therefore, a vent cap like the one shown in view D of figure 5-7 is required for the installation.

Exercises (451):

1. How are double-wall stacks usually constructed?

2. Where are double-wall stacks usually used?

3. What is the purpose of a draft diverter?

4. What is the purpose of a roof jack?

5-2. Repair, Fabrication, and Installation of Stacks and Associated Components

As we have already pointed out, stacks are subject to corrosion from heat, moisture, and fumes and to damage from wind. Most of the repairs you will make are the replacement of parts or the complete stack assembly. If a stack, collar, vent cap, or roof jack is corroded (rusted out), it needs to be replaced. Visually examine the assembly to determine which parts need replacement. If you find that a stack is badly corroded, probably the collar and vent cap are also defective. In any event, you must replace all damaged sections of the assembly. To fabricate a stack assembly (such as the one illustrated in foldout 2) or any of its components, make the patterns and cut, form, and assemble the pieces.

452. List the shop-made parts and the ready-made parts of a stack assembly, and state the layout method used in making a roof jack.

From the drawing in foldout 2, you find that double wall aluminum vent pipe is specified from the furnace stack outlet to the top of the roof jack. The working drawing also specifies 24-gage galvanized metal for the roof jack, upper stack, and vent cap, and the thimble is made from 20-gage galvanized sheet metal. For repair

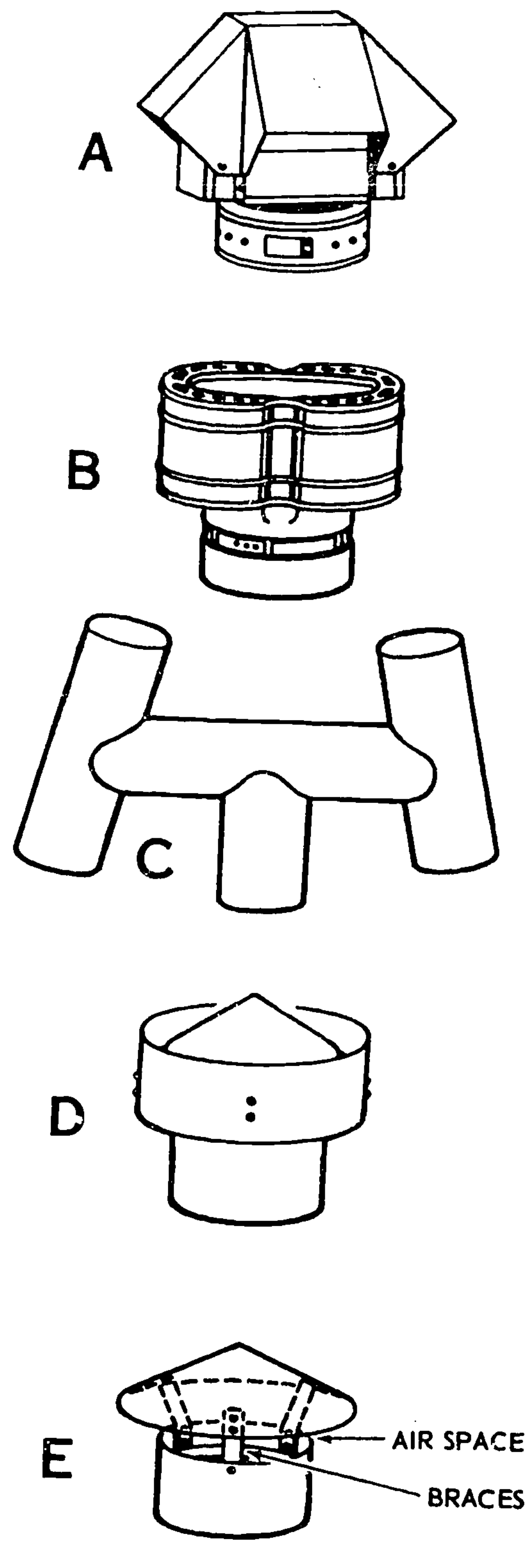

Figure 5-7. Vent caps.

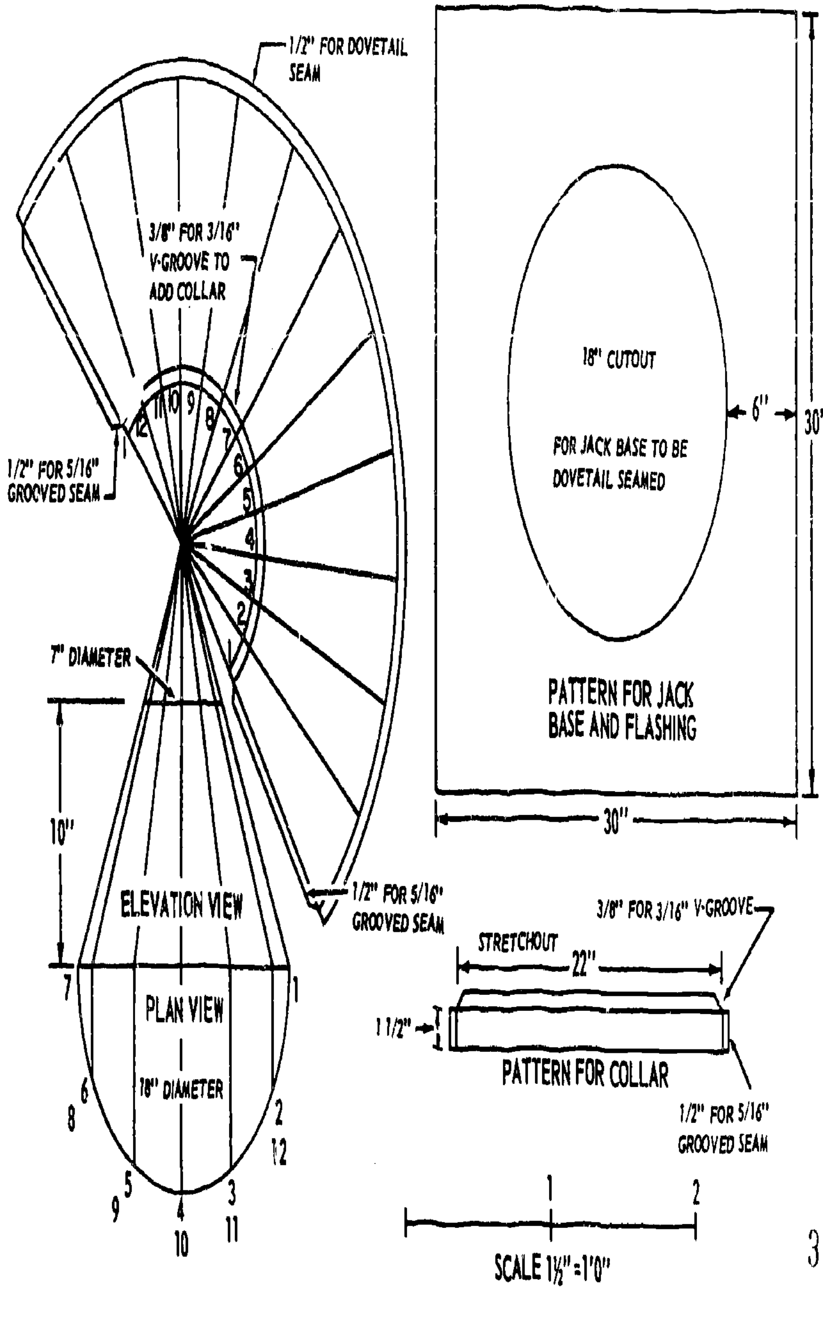

Figure 5-8. Patterns for a roof jack.

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jobs, use the old assembly to determine the metal thickness.

After you know the material specifications, you need to know the length and size of the double-wall stack. For this example, assume that the vent outlet on the heating unit is 6 inches in diameter and 6 feet from the top of the heater stack outlet to the top of the roof jack. With these requirements in mind, you can see that two 3-foot joints of 6-inch double-wall stack should be purchased.

Making Patterns for Stacks and Associated Components. The vent stack shown in foldout 2 must be fabricated and installed. The assembly is similar to the one shown in figure 5-2, except that you need a conical-shaped roofjack for the flat roof. The roof jack is 10 inches high, and 6-inch flashing is needed for the base; the sides of the roof jack are designed for a 60° angle.

Pattern for a roof jack, base, and collar. Patterns for the jack, base, and collar are illustrated in figure 4-8. You use the radial line layout method to develop the pattern for the roof jack (frustum). The diameter of the top opening is 7 inches, and the diameter of the base opening is 18 inches. You need the 7-inch top opening because the double-wall vent stack includes a 1/2-inch airspace. After you develop the pattern, you make allowances for the seams, as shown in the illustration. The pattern for the roof jack base (flashing) is 30 x 30 inches, with an 18-inch diameter cutout in the center. The collar for the top of the roof jack is 1/2 x 22 inches with allowances added.

Pattern for a stack joint. The next pattern for the vent assembly is the top stack joint, shown in figures 5-2 and 5-9. This single wall stack joint is 20 inches long because the roof jack is 10 inches high, and you must maintain a distance of 30 inches from the bottom of the

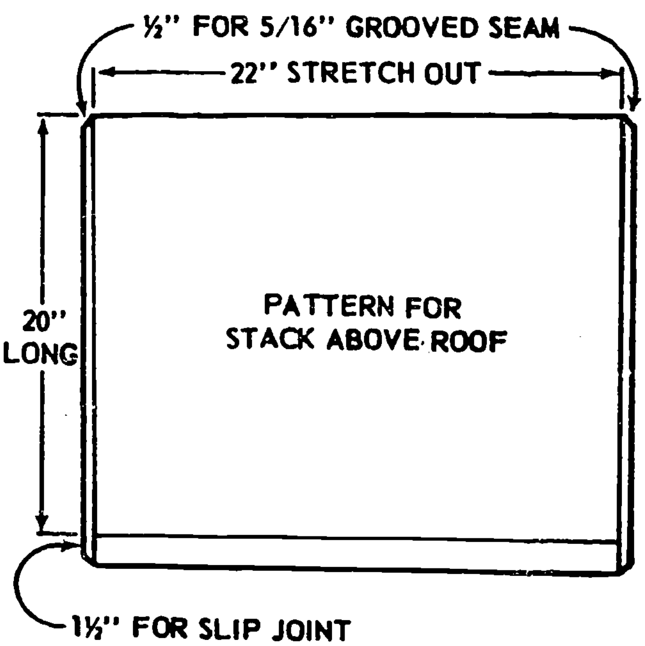

Figure 5–9. Pattern for a single-wall stack joint.

vent cap to the roofline. Remember to make the diameter 7 inches so that it will fit over the roof jack collar. The stretch out is 22 inches long and 20 inches high plus the allowances. Make a 1½-inch slip joint allowance for the connection with the vent cap.

Pattern for a vent cap. The next pattern of the stack assembly, shown in foldout 2 and figure 5-2, is the vent cap, which contains several parts. The vent cap is a draftproof and weatherproof type with a top, ring, collar, and braces.

The cover (top) is the first pattern of the vent cap, as shown in view A of figure 5-10. To lay out the cover, draw an elevation view 9 inches in diameter and 2 inches high. Notice on the elevation view that you have a slant height which is represented by line AB. Set a pair of dividers equal to the distance of line AB and draw a circle. This is the beginning of the pattern for the vent cap cover. To obtain the dimensions for the cutout, set your dividers equal to the distance of 1/2 the cap's diameter (from the elevation view). Next, use point B as a radius point and strike an arc on line AB to form line CB. Measure the distance from point A to point C, which in this example is 1/2 inch. Now multiply 1/2 inch x 6.28 (2π) to obtain the length of the arc for the cutout. In this case, it is 3.14 inches (3⅛ inches). Mark off this distance on the pattern, as shown, and make the seam allowance. In this example, an allowance of inch is required on each edge for the riveted lap seam. The same seam allowance is used for spot welding.

The next pattern for the vent cap is the ring shown in view B of figure 5-10. The ring is 5½ inches wide and 11 inches in diameter, so the stretchout is 5½ x 34 inches. Make a seam allowance of 1/2 inch on each end of the stretchout for the grooved seam, and make a 1/4-inch hem allowance on the top and bottom.

The next pattern is the collar, which is 4 inches high and 7 inches in diameter. The stretchout is 4 x 22 inches, as shown in view C of figure 5-10. Make the grooved seam allowance of 1/2 inch at each end as shown in the example.

View D of figure 5-10 shows the brace pattern. The vent cap needs 4 braces made from 16-gage metal. Each brace is 1 inch wide and 9¾ inches long. The braces hold the vent cap assembly together and are riveted to the top, collar, and ring.

Pattern for a ceiling thimble. The ceiling thimble shown in foldout 2 and figure 5-2 should be purchased "ready made," though you may be required to make one. The ceiling thimble shown in the foldout permits the heating unit stack to run through the ceiling. The same type of thimble can be used to run a stack through a wall. Steps in fabricating a ceiling thimble are shown in figure 5-11. To fabricate this type of thimble, make two rings, as shown in view A. The inside hole of the ring should be 7 1/16 inches in diameter so that a stack with a 7-inch diameter can pass through the opening. A 2-inch airspace is needed between the stack and sleeves, as shown in view D. Add a 1/2-inch flange to the ring

so that it will fit against the ceiling. Punch screw holes in the 1/2-inch flange on centers of 1/4 inch from the outside edge and spaced 5⅝ inches apart (center to center). Punch the 5/16-inch airholes 2 1/16 inches apart (center to center).

Two sleeves for the thimble are made as shown in views B and D of figure 5-11. Note that you add tabs to the outside sleeves only. Spot-weld or rivet the tabs to the sleeve and space them to match the screw holes in the ring. Set the tabs back from the flange of the sleeve for 5/8 inch or 1/2 inch, according to the thickness of the gypsum board used in the ceiling. Make the diameter of the outside sleeve 1/16 inch larger than the diameter of the inside sleeve so that the inside sleeve will slide inside the outside sleeve. Both sleeves should be 6 inches long. Turn a 3/8 inch-flange on one end of each sleeve so that you can spot-weld the flange to the ring. View C in figure 5-11 shows how the inside sleeve should look when completed. When it is installed, the position of the ceiling thimble is like view D in figure 5-11.

Pattern for a vent stack brace. The next part of the vent stack assembly is the brace, shown in foldout 2 and figure 5-12. You make the brace in two pieces from 1/8 x 2-inch flat bar stock or 10-gage steel. The length of the brace should be 14½ inches if the rafters are located on 16-inch centers. Since the outside diameter of the stack is 7 inches, make the brace in two half-round pieces, each with a 3¼-inch radius. Fasten the brace to the rafters with 1/4-inch stove bolts.

The pattern for piece 1 of the brace, shown in view B of figure 5-12, is made of flat bar stock. Use a vise to make the 90° bends, and use a slip roll machine to form an 11-inch half-round radius bend. You can use a heavy-duty brace and wire bender, if available, to form the 90° bends. You form piece 2 in the same way as piece 1 without as many 90° bends. After you complete the bending process for both pieces, drill four 5/16-inch holes with a drill press.

Exercises (452):

1. List the shop-made parts and the ready-made parts of a stack assembly.

2. What layout method is used for making a roof jack (frustum)?

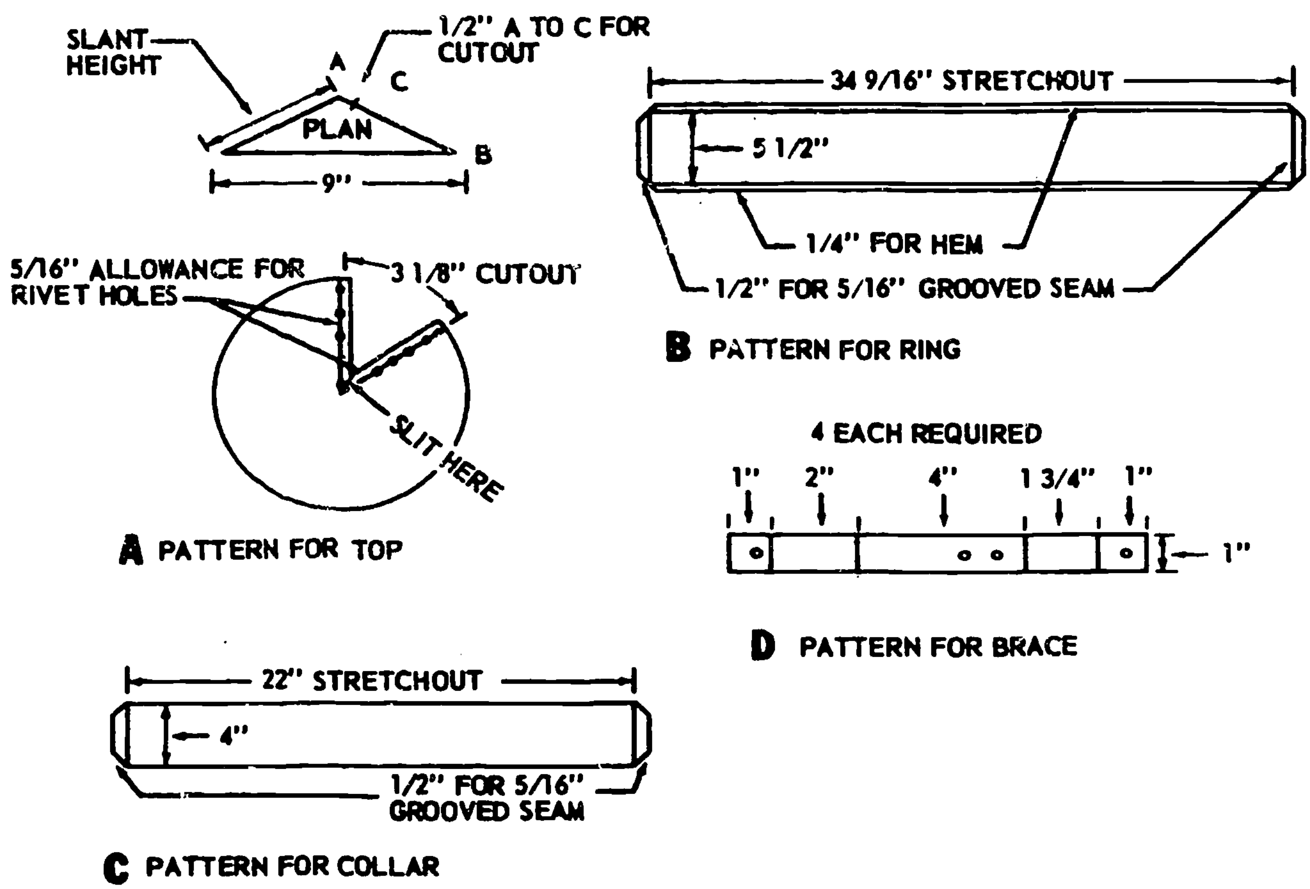

Figure 5-10. Patterns for a vent cap.

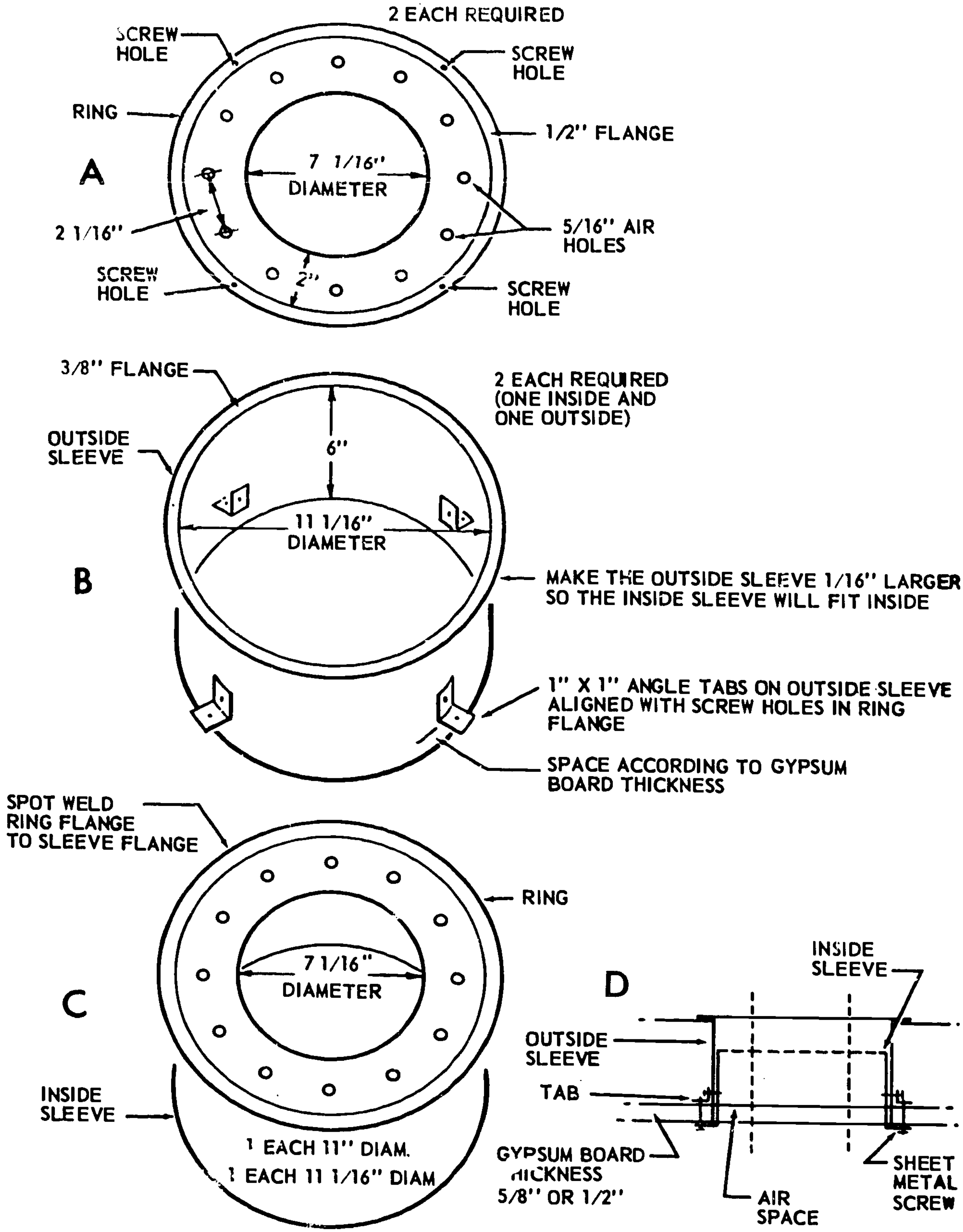

Figure 5–11. Thimble fabrication.

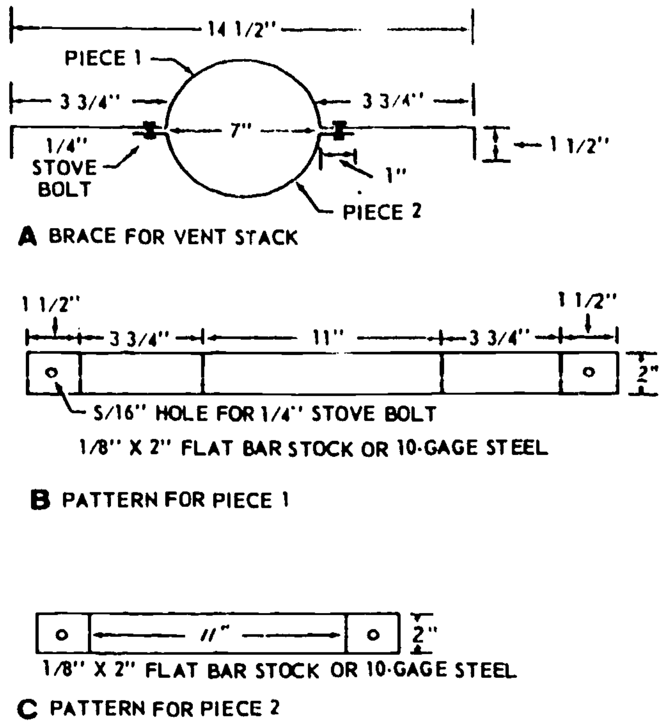

Figure 5-12. Making a brace for a vent stack.

453. Point out the equipment you need to cut, form, assemble, and install stack components, and state specified tasks to be performed.

Cutting Patterns for Stocks and Associated Components. Starting with the frustum pattern for the roof jack, shown in figure 5-8, you make the outside radius cut with straight-cut snips, the inside radius with aviation snips, and the straight cuts with straight-cut snips. You cut the pattern for the flashing and base with ring and circle shears and squaring shears. You cut the collar with straight snips or squaring shears. Cut all the notching with straight cut snips.

You cut the pattern for the roof stack, shown in figure 5-9, with squaring shears and notch it with straight snips. Cut all the patterns in figure 5-10 with squaring shears and notch with straight cut snips, except for the top pattern, which you must cut with ring and circle shears or circle shears. Make the cutout with straight snips.

Cut the patterns for the pieces shown in figure 5-11 with ring and circle shears and squaring shears. The patterns illustrated in figure 5-12 do not require cutting, except for length, if you are using 1/8-inch x 2-inch flat bar stock. If the bar stock is not available, use power squaring shears to cut the 10 gage metal.

Forming Patterns for Stacks and Associated Components. The next step in the fabrication process is the forming of patterns. Form the patterns for the roof jack, shown in figure 5-8, on the bar folder, slip roll machine, hand groover, and elbow-edging machine. When forming the frustum, set the slip roll machine for a 7-inch circle on one end and for an 18-inch circle on the other end. Turn the grooved seam edges for the frustum and collar on the bar folder and form them with a hand groover on a bench stake. Form the V-groove on the elbow-edging machine and use it to join the frustum and collar. In forming the V-groove, remember that one component should have the V-groove inside and the other outside. We suggest that you make the inside V-groove on the collar.

You can form the roof stack, which is shown in figure 5-9, with a Pittsburg lock-forming machine and the slip roll machine. First, make the two pockets of the grooved seam (as shown in fig. 2-6) with the Pittsburg lock-foring machine. Next, run the sheet through the slip roll machine to form the cylindrical shape. After forming, join the pockets and flatten the seam.

You form the vent cap patterns shown in figure 5-10 with a cornice brake, the Pittsburg lock-forming machine, a bar folder, and the slip roll machine (except for the top pattern). You form the top pattern on a blow horn stake by placing the center of the pattern on the point of the horn and lightly bending the top. To assemble it, pull the pattern so that one allowance for the lap joint will slip over the top of the other allowance. You can then rivet the top of the blow horn stake.

Hem the pattern for the ring (B in fig. 5-10) on the bar folder, and form the groove on the Pittsburg lock forming machine. Roll the pattern into a cylinder on the slip roll machine. A bead 2 inches from the edge will stiffen the ring and improve its appearance. Make the bead with a beading machine after you have joined the grooved seams. Form pattern C the same as pattern B, except for the hems and bead. Form the brace (pattern D) on the cornice brake by making two 90° bends, one 125° bend, and one 55° bend. The 90° bends are on the bottom of the brace, and the 125° and 55° bends are on the top of the brace.

Form the ceiling thimble patterns, shown in figure 4-11, with the Pittsburg lock-forming machine, slip roll forming machine, hollow mandrel stake, and burring machine. Two sleeves are required. Form them by making the grooved seam on the Pittsburg machine, forming the cylinders on the slip roll machine, locking the grooved seam on the hollow mandrel stake with a mallet, and turning the 3/8-inch flange on the burring machine. You can form the clips for the outside sleeve on the bar folder or the brace and wire bender.

Assembly of Stack Components. Next in the fabrication process is the assembly of the formed parts of the stack assembly. Join the roof jack, shown in figure 4-8, to the base (flashing) with a dovetail seam. Slip the 1/2-inch allowance on the frustum baase at 1/2-inch intervals to make 1/2 x 1/2 inch tabs, and bend every other tab 90°. After joining, bend the remaining tabs 90°. Solder the dovetail seam to prevent leakage. Install the collar at the top of the frustum by placing the V-grooves together. Solder the grooved seams about 4 inches up the side to prevent leakage.

You assemble the vent cap components, shown in figure 4-10, by riveting the top and collar to the braces. There are two rivets in the collar and one in the top of each brace. After you have riveted the four braces, install the ring with sheet metal screws on each brace.

To assemble the ceiling thimble, illustrated in figure 4-11, you spot-weld the rings to the flanges of both sleeves. Align the 1 inch x 1 inch tabs with the screw holes in the ring, 1/2 inch or 5/8 inch from the edge (according to the thickness of the gypsum board in the ceiling), and spot-weld or rivet the ring to the outside sleeve.

Installation of Stack Components. You begin the installation of the stack components that are shown in foldout 2 by locating the center points where the stack passes through the ceiling and roof. Use a plumb bob to locate the ceiling hole center point by suspending from the ceiling and aligning it with the center of the stack collar outlet on the heating unit. With the center located, cut an 11⅛ inch hole. You can find the location of the roof jack by the same method. Cut the roof jack outlet 14½ inches in diameter. Then set the roof jack directly over the roof outlet and nail it to the roof. Do not install the jack until a layer of roofing felt has been installed.

When the roof jack is in place and the ceiling thimble is installed (see view D, fig. 5-11) place the double-wall stack over the collar outlet of the heating unit. Install the inside sleeve in the ceiling outlet (11 -inch hole) from the bottom, and install the outside sleeve from the top. Align the outside sleeve tabs with the screw holes of the ring on the inside sleeve. Drill screw holes in the tabs so that you can use sheet metal screws to secure the thimble to the ceiling.

As you install the double-wall stack through the thimble and into the roof jack, fasten the joints together. Fasten the brace to the stack and ceiling rafters as shown in foldout 2. Install the single-wall roof stack through the roof jack and fasten it with sheet metal screws. Your last step is to fasten the vent cap to the roof stack with sheet metal screws. This completes the installation of the stack components.

Exercises (453):

1. What handtool is used to cut the inside radii of a roof jack?

2. Name the handtool used most often for notching.

3. List the equipment used to form patterns for a roof jack.

4. What tool do you use to locate the point where the vent stack will pass through the ceiling?

5. Why must the tabs on a ceiling thimble line up with the holes in the ring?

6. Why should the grooved seam on a roof jack be soldered for about 4 inches up the side?

454. State the main points to consider in repairing, fabricating, and installing ventilators and associated components.

Repair, Fabrication, and Installation of Ventilators. Ventilators exhaust the air from buildings either by

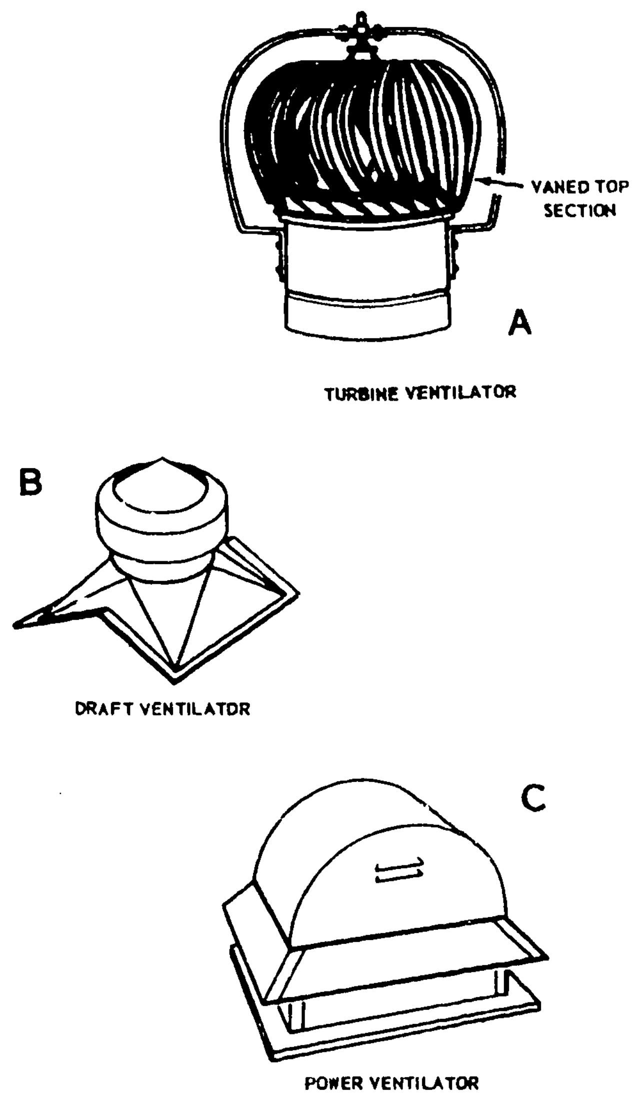

Figure 5–13. Ventilators.

gravity flow or by forced air. In figure 5-13,you can see three types of ventilators. View A is a turbine (spin cat) ventilator. When the wind blows, the vaned top rotates, and the centrifugal action pulls air out of the building. The ventilator shown in view B operates like a stack, and the air removal depends on the wind and the temperature inside and outside the building. This ventilator is designed to be installed on the peak of the roof so that the wind can blow across it from any direction. In the ventilator shown in view C, a motor-driven fan pulls the air out of the building. It does not rely on the wind or temperature differences. There are design variations in all three types of ventilators. Some ventilators, depending on the use and the manufacturer, exhaust air from range hoods, and others exhaust attack heat from buildings. Attics with ventilators usually have louvers that let the cooler outside air enter the attic and then pass out through the ventilator. The louvers usually face toward the wind, increasing the airflow into the louvers and out through the roof ventilators.

In most ventilators, dampers regulate the airflow. In the summer the dampers are usually left open, and in the winter they are opened or closed as required. Most power-operated ventilators, such as the one shown in view C of figure 5-13, have automatic louvers that open or close when the motor is turned on or off. This operation controls the backdraft in the system.

Ventilator repair is similar to the repair of other sheet metal components—according to the damage. When ventilators are damaged by wind, hail, or corrosion, inspect the bad parts and decide whether the unit should be repaired or replaced. It may be possible to repair the damage with a simple patch. However, if the damage is severe, a duplicate ventilator should be installed.

In some cases, you must fabricate a new or replacement ventilator. For example, assume that you must make the draft ventilator shown in view B of figure 5-13. Notice that it consists of a square base that gradually changes to a round pipe, which is covered with a draftproof vent cap, such as that shown in view D of figure 5-7 and in foldout 2. In this example, the transition is 10 inches high with a 12- x 12-inch base that fits over the ridge of a roof with a 5 to 12 pitch. The transition is joined to a 1½-inch collar, which joins a straight pipe that is 6 inches long and 8 inches in diameter. The vent cap has a 2-inch airspace between the collar and top and a 2-inch airspace between the collar and ring.

Exercises (454):

1. Name two factors to consider when you are planning to make a ventilator for a building.

2. What factors determine the repair that must be done on a damaged ventilator?

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

400 − 1. Orthographic and pictorial drawings; and plan, elevation, and detail views.
400 − 2. Orthographic projection.
400 − 3. Elevation.
400 − 4. All features are shown in their true shapes.
400 − 5. Plan.
400 − 6. Detail.
400 − 7. To show the length, width, and thickness.
400 − 8. Plan views, elevation views, and detail views.

401 − 1. Length, width, thickness, height, and depth.
401 − 2. Centerlines.
401 − 3. Inside or outside of the angle.
401 − 4. Hidden lines.
401 − 5. To clearly show the dimension of an object outside its outline.
401 − 6. Surface visible to the eye.
401 − 7. Hidden lines to indicate surfaces that are invisible.
401 − 8. By placing the angle in degrees between the intersecting lines.
401 − 9. By drawing parallel extension lines from the outer surface of the circle and indicating dimensions between these two lines.
401 − 10. By placing an X at the center point.
401 − 11. Usually indicated from center to center.
401 − 12. Two.
401 − 13. Three-slant height, diameter, and vertical height.

402 − 1. First.
402 − 2. Round duct supply system, nonwatertight.
402 − 3. Deflecting.
402 − 4. Louvers.
402 − 5. W and A.
402 − 6. Near the floor.
402 − 7. Top grill.

403 − 1. Specific instructions used to explain the drawing. On the drawing.
402 − 2. They are very general in nature and apply to more than one job.
403 − 3. The working drawings.
403 − 4. Individual projects that cover quality of material, details of construction, working drawings, and other special features.
403 − 5. To allow for expansion.

404 − 1. Rules, tapes, squares, protractors, twist drill size gages, adjustment gages, and thickness gages.
404 − 2. A fraction.
404 − 3. 1/2, 1/4, 1/8, 1/16, 1/32, and 1/64.

405 − 1. a. 6′ x 22′ 9 ″.
b. 1′ x 3′3″ x 1′8″.

406 − 1. 6-, 12-, and 15-inch wood or plastic rule; steel tape; power return steel tape; and circumference rule.
406 − 2. False.
406 − 3. Power-return steel rule.
406 − 4. To account for the thickness of the ring or hook at the end of the tape.
406 − 5. 1/64.
406 − 6. Inside, outside, hermaphrodite.
406 − 7. The approximate circumference of any circle within the range of the rule.
406 − 8. This stiffens the tape when it is extended from the case.

407 − 1. Blade, square and miter head, turret protractor head, and the center head.
407 − 2. Blade, square, and miter head.
407 − 3. Tongue, body, and heel.
407 − 4. Framing square.
407 − 5. To make layouts, to check squareness of metal, to measure, and to determine the pitch of a roof.
407 − 6. The face is graduated in eighths and sixteenths; the back is graduated in tenths and twelfths.
407 − 7. The turret protractor head.

408 − 1.

(1) g.
(2) c.
(3) j.
(4) a.
(5) f.
(6) i.
(7) h.
(8) e.
(9) b.
(10) d.

409 − 1. To obtain measurements and a description of the object.
409 − 2. Parallel line, radial line, and triangulation.
409 − 3. All needed descriptive information.

410 − 1. Parallel; perpendicular.
410 − 2. Plain or elevation views.
410 − 3. The more gores, the less resistance.
410 − 4. Circumference.
410 − 5. All element lines must be parallel or perpendicular to each other.
410 − 6. Perimeter.
410 − 7. Elbow.
410 − 8. The sum of the four sides.
410 − 9. The throat radius and the diameter or duct width.
410 − 10. The cross sections are identical on each end of each component.

411 − 1. Vertex.
411 − 2. In order to obtain the true height of the pyramid.
411 − 3. Horizontally.
411 − 4. Two.
411 − 5. Vertex.
411 − 6. Right cone.

412 − 1. 7 inches.
412 − 2. To avoid confusion when transferring element lines.
412 − 3. By leaving them set for the distances between equal points, you can save time.
412 − 4. b and d.

413 − 1. No.
413 − 2. Depending on the type of seam used, but most often part on each side of a layout.
413 − 3. 3/8 inch.
413 − 4. To permit the duct to continue in the same direction.
413 − 5. Framing square, combination set, dividers, and scribe.

414 − 1. Mark all points and lines while transferring the pattern.
414 − 2. Paper.
414 − 3. A prick punch.
414 − 4. Hold pattern in place with weights.
414 − 5. Use one-half of the pattern.
414 − 6. Two half patterns.
414 − 7. Mark outside edge and inside edge.

415 − 1. e.
415 − 2. h.
415 − 3. i.
415 − 4. k.
415 − 5. a.
415 − 6. b.
415 − 7. g.

416 − 1. $ba = \pi \times \theta$

$\pi = 1.0 + .750 = 1.25$

$\theta = 0.017453 \times 45 = .785385$

$ba = 1.25 \times .785385 - .98173125$

416 − 2. 0.017453.

416 − 3. ba = bend allowance

r = radius of the neutral axis

θ = bend angle in radians

416 − 4 The radius of the bend and the degree of angle in the bend.

416 − 5. $ba = r \times \theta$

$r = 2 + .125 = 2.125$

$\theta = 0.017453 \times 180 = 3.14154$

$ba = 2.125 \times 3.14154 = 6.6757725$

CHAPTER 2

417 − 1. Flat, offset, and corner.
417 − 2. 1/2 inch.
417 − 3. Where appearance needs to be neat.
417 − 4. Corner lap seam.

418 − 1. Two pieces of metal are formed around each other and interlocked.
418 − 2. On cylinders, metal roofs, and stiffeners on ducts.

419 − 1. To connect two pieces of metal together and stiffen the metal.
419 − 2. Three times the height of the seam plus twice the thickness of the material.
419 − 3. 3/4 inch.
420 − 1. Two.
420 − 2. Bar folder, cornice brake, and Pittsburg lock forming machine.
420 − 3. A backing plate or stake and a mallet.
420 − 4. 3W + 3T for lighter gages and 3W + 5T for heavier gages.

421 − 1. Turn a 1/4-inch flange on the bottom of the cylinder.
421 − 2. 1.012 inches.
421 − 3. Bottom of a cylinder, corner of a square duct, bottom and end of a pan or box.

422 − 1. For the corners and edges of square and rectangular ducts, and on transitions and elbows.
422 − 2. 15/16 inch, 1 inch, or 1 inches for the pocket side and 1/4 inch for the flanged side.
422 − 3. Turn the metal over in the cornice brake and lower the top leaf until a groove is formed. Strike the folded metal with a mallet until the edges are parallel.

423 − 1. Cylinder; round.
423 − 2. Make a cut every 1/2 inch all around the duct and bend every other tab out 90°. Place unbent tabs through the flat surface and then bend them out 90°.
423 − 3. 0; because all seam allowances are on the round duct.

424 − 1. Cross brake and 1 inch standing seam on 4 foot centers.
424 − 2. 20 gage; 1½ inch; 4 foot.

425 − 1. Standing edge.
425 − 2. To flatten the S portion (last 2 bends) to form 180°.
425 − 3. To connect the long sides of duct sections.

426 − 1. S-slips.
426 − 2. 20.
426 − 3. By cutting the bend allowances at a 45° angle at one end.

427 − 1. Attach both S-slips on one piece of duct.
427 − 2. To hold the duct sections in place.
427 − 3. Bend the ends of the drive slips over the corners of the duct to hold the drives in place.

428 − 1. Form the Pittsburg seams.
428 − 2. To connect a small duct to a trunkline.
428 − 3. By bending the tabs over inside the duct.
428 − 4. The fourth step.
428 − 5. Two.
428 − 6. One end of each piece is crimped.

429 − 1. The seam must be a lap seam.
429 − 2. By the diameter of the weld.
429 − 3. Four times the thickness of one of the pieces of metal being welded.

CHAPTER 3

430 − 1. Changes in the direction of the duct and air friction with its sides.
430 − 2. Reduce friction by using smooth duct materials.
430 − 3. Pipe the air as directly as possible to the required location.

431 − 1. To make the seams and joints as smooth as possible.
431 − 2. Diverging and converging duct.
431 − 3. $\frac{R}{W} = \frac{12}{8} = \frac{3}{2} = 1½ = 1.5$; thus it is called a ratio of 1.5.
431 − 4. The same plane as the radius of the elbow.

432 − 1. 5.2
432 − 2. Rivet or spot-weld the splitter tabs to the side of the elbow before you attach the top of the duct.

433 − 1. Vary the volume of air flowing through the system.
433 − 2. At the middle of the duct.
433 − 3. Balance airflow in a duct system.
433 − 4. Louver damper.

434 − 1. To disperse air in all directions from the ceiling.
434 − 2. To control the volume and direction of airflow from a duct outlet in the wall.
433 − 3. To cover return air openings and permit ventilation through doors and walls.

CHAPTER 4

435 − 1. a. Break down the system into subsystems, sections, and joints.
b. Determine the types of seams.
c. Determine the types of joint connections.
d. Determine the types of bracing.
435 − 2. Grooved seam.
435 − 3. 1½ inches.
435 − 4. Cross brake.

436 − 1. Galvanized sheet iron.
436 − 2. 24-gage galvanized.
436 − 3. 24 gage.

437 − 1. 4 feet wide and 8 or 10 feet long.
437 − 2. How you can use the leftover material.

438 − 1. a. Make a drawing showing the dimensions of the duct and joints.
b. Start a materials-required list.
438 − 2. 1¼ inches.
438 − 3. In the third step.

439 − 1. It has 4 different sizes of duct—connected with transitions; it has round duct branch lines; and it is closed with an end cover.

440 − 1. From the center of the trunkline of the ceiling.
440 − 2. With S-and-drive slips between each joint.
440 − 3. They do not have flanges because they will be boxed in.

441 − 1. Diffusers.
441 − 2. Soft flexible blankets of aluminum foil backed fiberglass insulation.
441 − 3. Soft zinc-coated 20-gage wire.

442 − 1. Parallel line, radial line, and triangulation methods.
442 − 2. Transition patterns.
442 − 3. Any duct or component with parallel sides.

443 − 1. To achieve maximum airflow.
443 − 2. $\frac{H}{W} = 5.$
443 − 3. 3/4 inch.

444 − 1. Squaring shears.

444 – 2. They are rectangular and do not have notches.
444 – 3. V-notches and slant notches.
444 – 4. At each end of the 1-inch Pittsburg seam allowance.

445 – 1. Cornice brake.
445 – 2. Pittsburg lock-forming machine.
445 – 3. Shop-made hand folder.

446 – 1. An imaginary line passing through the middle of the duct joints as their horizontal and vertical center.
446 – 2. From an elevation view drawing.
446 – 3. By size, weight, and material of the duct and the characteristics of the structure that supports the duct.
446 – 4. To take all the tools, equipment, and materials you will need to the job site.

447 – 1. Plenum.
447 – 2. Sheet metal screws.
447 – 3. A chalkline.
447 – 4. With adhesives.
447 – 5. To insure a complete vapor barrier.

448 – 1. Install the registers, grilles, and diffusers.
448 – 2. You must coordinate with the paint shop for painting the diffusers, and with the carpenter shop to insure that the wall openings are the right size and in the right places.

449 – 1. 1/2-inch allowance.
449 – 2. 1/4 inch from edge; 2 inches apart.
449 – 3. When you do not have access to both sides of the hole.

CHAPTER 5

450 – 1. Inside air temperature and wind.
450 – 2. Where the wind is forced upward across the vent opening.
450 – 3. Above the highest part of the roof.

451 – 1. They have an inner and outer wall with about 1/2 inch of airspace between them.
451 – 2. To vent gas-fired heaters, furnaces, and water heaters.
451 – 3. A draft diverter prevents excessive updrafts and downdrafts.
451 – 4. To weatherproof the roof opening through which the stack passes.

452 – 1. Make the vent stack; the roof jack, base, and collar; the cover, ring, collar, and braces for a vent cap. The ceiling thimble is usually ready made.
452 – 2. Radial line.

453 – 1. Aviation snips.
453 – 2. Straight snips.
453 – 3. Bar folder, slip roll, hand groover, and elbowedging machine.
453 – 4. Plumb bob.
453 – 5. So that you can install the installation screws through the tabs to secure the thimble to the ceiling.
453 – 6. To prevent leakage.

454 – 1. Whether it needs a gravity flow or a forced-air ventilation.
454 – 2. The type and extent of the damage.

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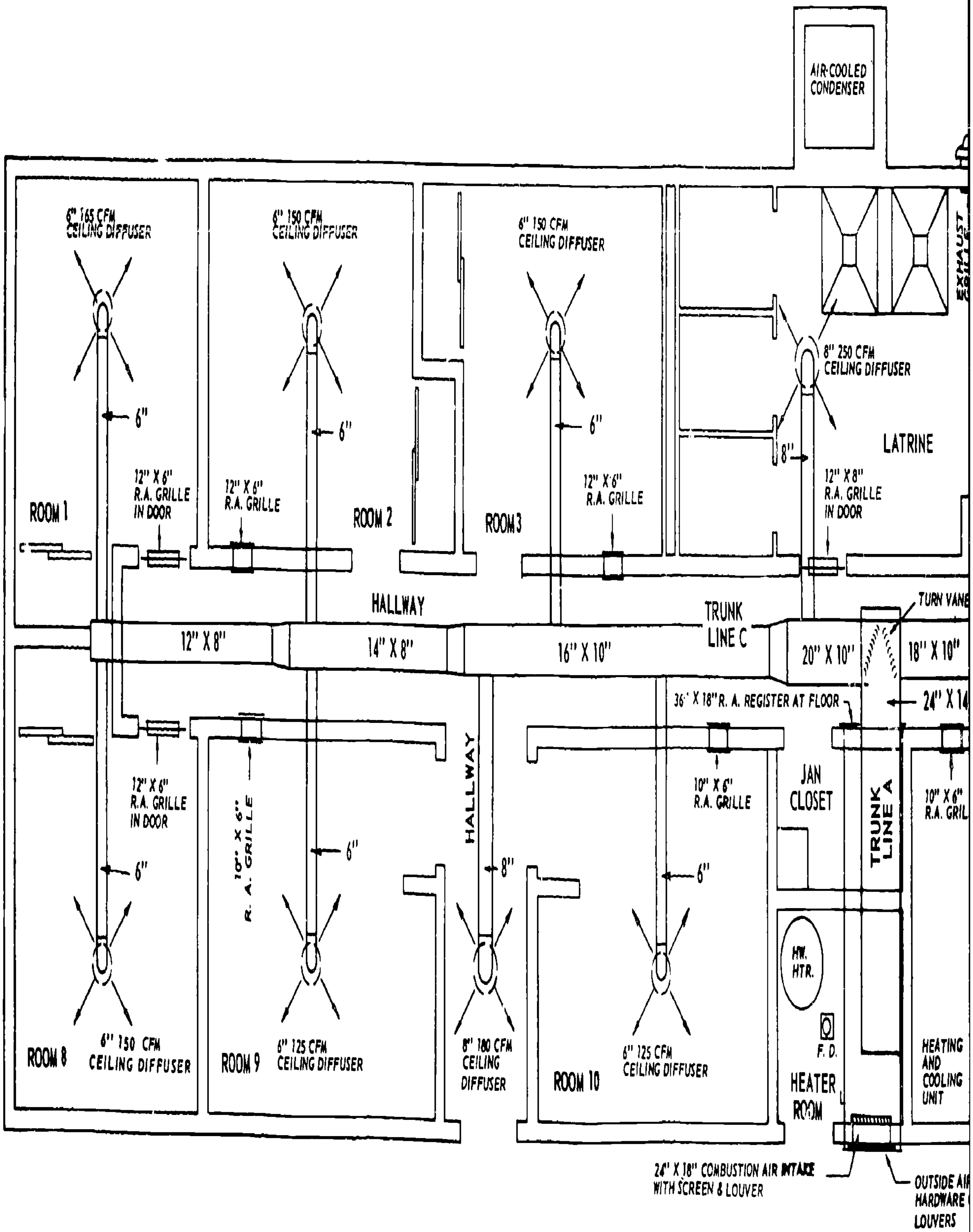
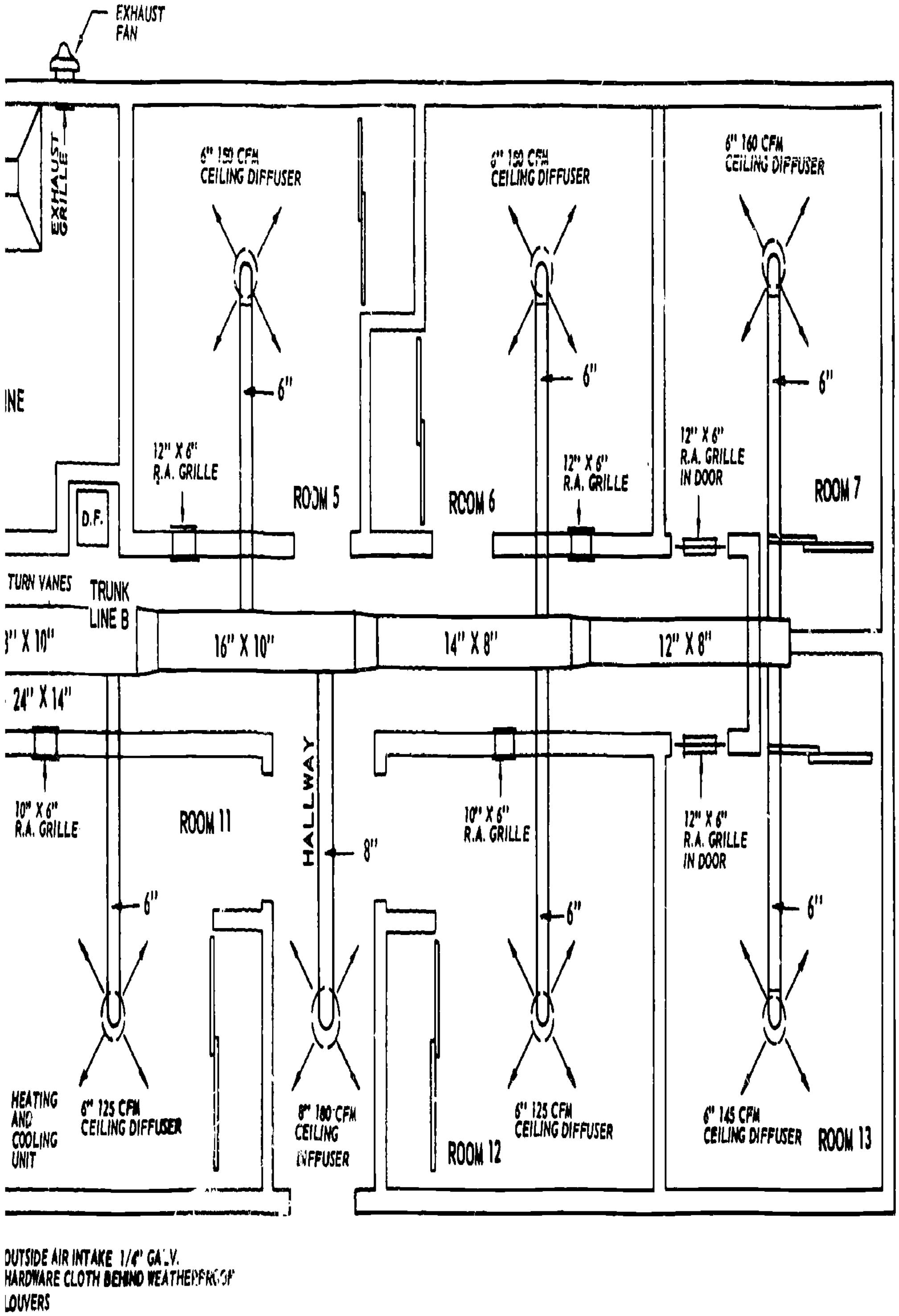

AIR-COOLED CONDENSER
EXHAUST
6" 165 CFM CEILING DIFFUSER
6" 150 CFM CEILING DIFFUSER
6" 150 CFM CEILING DIFFUSER
8" 250 CFM CEILING DIFFUSER
LATRINE
ROOM 1
ROOM 2
ROOM 3
12" X 6" R.A. GRILLE IN DOOR
12" X 6" R.A. GRILLE
12" X 6" R.A. GRILLE
12" X 8" R.A. GRILLE IN DOOR
HALLWAY
TRUNK LINE C
TURN VANE
12" X 8"
14" X 8"
16" X 10"
20" X 10"
18" X 10"
24" X 14
36" X 18" R. A. REGISTER AT FLOOR
10" X 6" R.A. GRILLE
10" X 6" R.A. GRIL
JAN CLOSET
TRUNK LINE A
12" X 6" R.A. GRILLE IN DOOR
10" X 6" R. A. GRILLE
HALLWAY
HW. HTR.
F. D.
HEATER ROOM
HEATING AND COOLING UNIT
ROOM 8
6" 150 CFM CEILING DIFFUSER
ROOM 9
6" 125 CFM CEILING DIFFUSER
8" 180 CFM CEILING DIFFUSER
ROOM 10
6" 125 CFM CEILING DIFFUSER
24" X 18" COMBUSTION AIR INTAKE WITH SCREEN & LOUVER
OUTSIDE AI HARDWARE LOUVERS



NOTE:

1. ALL DUCT WORK TO BE RUN ABOVE CEILING
2. INSULATE WITH ONE LAYER OF 1" FOIL BACKED GLASS FIBER INSULATION
3. ALL CEILING DIFFUSERS HAVE VOLUME DAMPERS
4. ALL RETURN AIR GRILLES ARE TO BE INSTALLED NEAR THE FLOOR

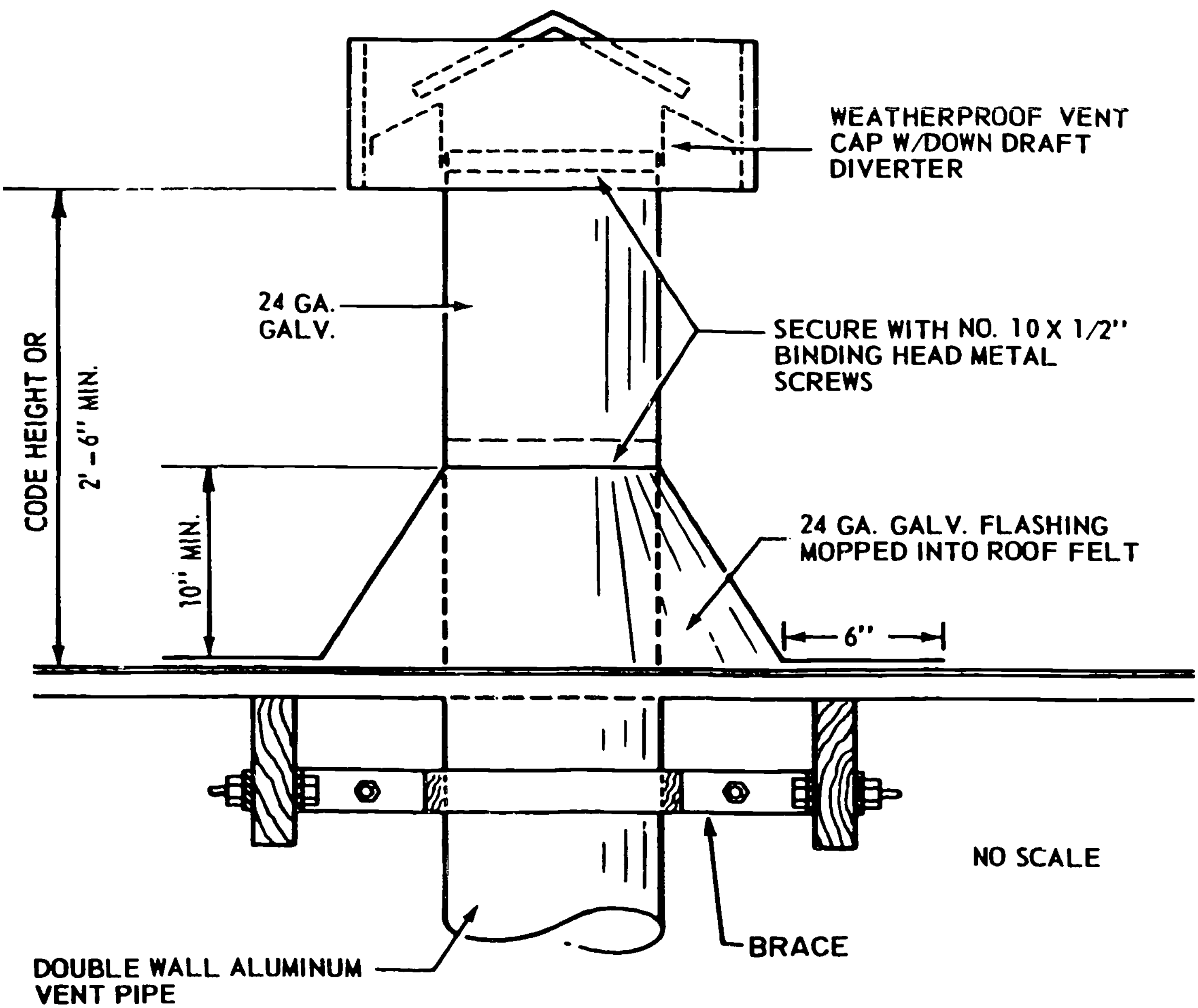
SCALE - 1/4" = 1'0"

1 2 3 4 FEET

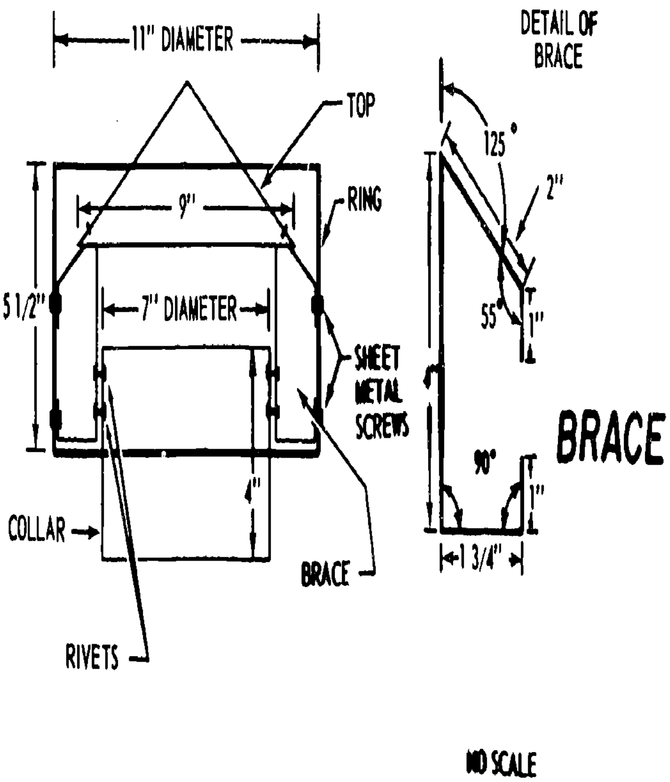
53-1276

Foldout 1. Heating and air-conditioning floor plan.

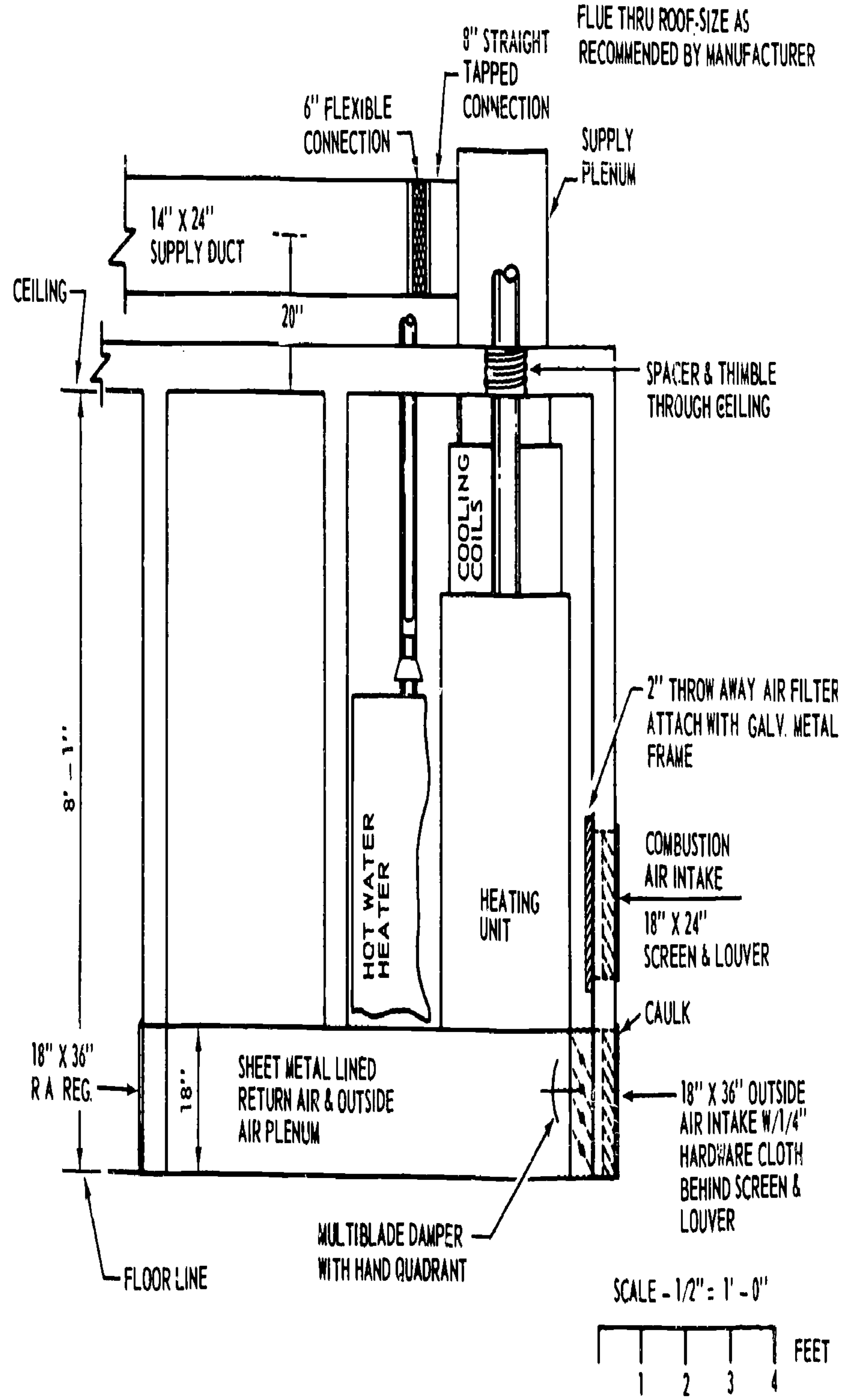
DETAIL OF TYPE B FLUE FLASHING



DETAIL OF VENT CAP



SECTION A-A THRU HEATER ROOM



Foldout 2. Elevation views of heater room and flue assembly.

S T O P - 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

55252 03 22
LAYOUT AND DUCT SYSTEMS

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet .
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover your answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you have to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If mandatorily enrolled student, process questions or comments through your unit trainer or OJT supervisor. If voluntarily enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the Learning Objective Number where the answer to that item can be located. When answering the items on the VRE, refer to the Learning Objectives indicated by these Numbers. The VRE results will be sent to you on a postcard which will list the actual VRE items you missed. Go to the VRE booklet and locate the Learning Objective Numbers for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the best answer to each question.

1. (400) An orthographic projection drawing is used to show

   a. details of seams and joints.
   b. the height and length of an item.
   c. the true size of each side or part of an object.
   d. the relation of each part or side to the other parts or sides.

2. (400) What type of drawing is used to show clearly the shape, size and material of an item?

   a. Orthographic projection.
   b. Elevation view.
   c. Detail view.
   d. Pictoral.

3. (401) What does the term thickness refer to when applied to working drawings of sheet metal components?

   a. The smallest dimension of an object.
   b. The greatest dimension of an object.
   c. The dimension from the front of an object to the back.
   d. The dimension of that part of object than cannot be seen.

4. (401) How are the distances between holes in an object indicated?

   a. Usually from center to center.
   b. Usually from outside to outside.
   c. Always from the inside to the inside.
   d. Always from the edge of the object to the edge of the hole.

5. (402) What type of duct symbol is used on working drawings to identify a section of a recirculation duct?

   a. A rectangle with two broken diagonal lines and the letter "R" in an upper section.
   b. A rectangle with one line drawn on a diagonal.
   c. A rectangle with two lines drawn on diagonals with an "R" in the upper section.
   d. A rectangle with one diagonal line and the letters "RA" in the upper section.

6. (403) Where on working drawings would you look to find specific instructions and explanations of the drawing?

   a. Notes.
   b. Plan view.
   c. Detailed drawings.
   d. None of the above.

7. (404) What is the smallest fraction of an inch found on most tapes or rules?

a. 1/8.
b. 1/16.
c. 1/32.
d. 1/64.

8. (405) On a working drawing, what is the correct way to list the measurements of a duct section 18 inches high, 22 inches wide, and four feet long?

a. 18" X 22" X 48".
b. 48 inches by 18 inches by 22 inches.
c. 18 inches by 22 inches X 48 inches.
d. Four feet by 18 inches by 22 inches.

9 (406) Which one of the following is most frequently used in the metal shop for taking measurements?

a. Steel rule.
b. Steel tape.
c. Folding rule.
d. Circumference rule.

10. (406) The most practical measurement tool to measure a roof for a rain gutter would be a

a. folding rule.
b. power return steel tape.
c. handcrank steel tape.
d. circumference rule.

11. (407) The blade of a combination set is held to the various heads by the

a. centerhead and thumb screw.
b. central groove and locknut.
c. 90 degree and 45 degree angles.
d. slot in the head and the set screw.

12. (407) The main use of the framing square in the metal shop is to

a. transfer or duplicate angles.
b. locate roof stack location in a roof.
c. assist the carpenters under heavy workloads.
d. check corners on sheet metal for squareness.

13. (408) Which one of the following best identifies equipment that can be used as layout tools?

a. Plumb and chalk line.
b. Protractor and triangles.
c. Irregular curves and trammel points.
d. All of the above.

14. (408) What are the layout tools used primarily in the shop?

a. Steel rule, T-square, and divider.
b. Divider, framing square, pencil compass.
c. Architect's scale, triangle, and calipers.
d. Framing square, pencil compass, and hermaphrodite calipers.

15. (408) What shop layout tools are most often used to transer measurements?

a. T-square and triangles.
b. Steel tape and T-square.
c. Dividers and pencil compass.
d. Architect's scale and dividers.

16. (409) When making the pattern of a sheet metal component, what is the first step?

a. Develop the true length charts.
b. Develop the stretchout pattern.
c. Determine the method of layout to be used.
d. Obtain measurements and description of components.

17. (409) Drawings which show sheet metal components in flat or strectched out position are called.

a. a precision pattern layout.
b. a half pattern layout.
c. a stretchout of the elevation.
d. none of the above.

18. (410) How many half plan views will you need to draw when developing a pattern for a T-joint that has an eight inch main pipe and a four inch collar?

a. One.
b. Two.
c. Three.
d. Two of each size.

19. (410) How will the cross section of each end of a component developed by the parallel line method compare?

a. The same shape, but different in size.
b. The same area, but different in shape.
c. The same shape, but different areas.
d. The same shape and areas.

20. (411) What must be perpendicular to the base of each cover or pyramid developed by the radial line method of layout?

a. Vertex.
b. Center line.
c. Slant height.
d. Stretchout line.

21. (411) A cone with the top cut off parallel to the base or on an angle is identified as a

a. right cone.
b. truncated cone.
c. regular frustum.
d. irregular frustum.

22. (411) What is the unusual feature of a tapering roof collar as compared with the regular and irregular frustums?

a. There are two frustums.
b. There is no difference.
c. The top is cut on an angle.
d. The bottom is cut on an angle.

23. (412) True length charts are required for which method of layout?

a. Radial line.
b. Parallel line.
c. Triangulation.
d. All of the above.

24. (412) How many true length charts are necessary to lay out a square to square twisted pattern?

a. One.
b. Two.
c. Three.
d. Four.

25. (413) Seam allowances or additions must be added to all sheet metal patterns before they are

a. laid out.
b. cut out.
c. formed and assembled.
d. installed in a system.

26. (413) What is the seam allowance for one end of a duct section that is to be assembled with S and drives?

a. 3/8 inch.
b. 1/2 inch.
c. 15/16 inch.
d. 1 1/8 inch.

27. (414) To transfer break lines from a template to metal sheet, use a

a. pencil.
b. scribe.
c. prick punch.
d. sharp center punch.

28. (415) Where is the bend allowance computed on thick plate?

a. Outside of the bend.
b. Inside of the bend.
c. Neutral axis.
d. Bend mold line.

29. (415) What is the longer part of a formed angle called?

a. Flange.
b. Leg.
c. Web.
d. Flat.

30. (416) What two factors must be known to compute a bend allowance?

a. Degree of bend angle and material composition.
b. Degree of bend angle and the radius of the bend.
c. Material composition and radius of the bend.
d. Length of the neutral axis and degree of the bend.

31. (416) Using the formula ba = r X θ compute the bend allowance for a 90° bend made in 1/4 inch plate, with a 1/4 inch bend radius.

a. .475.
b. .588.
c. .625.
d. .755.

32. (417) What is the seam allowance for a 1/4 inch outside lap seam?

a. Twice the seam lap.
b. Three times the seam lap.
c. Twice the seam lap plus the thickness of metal.
d. Twice the seam lap plus three times the metal thickness.

33. (417) How is an offset lap seam formed?

a. Bend one side 25-30 degrees and the other over a spacer.
b. Bend one side 30-35 degrees and the other over a spacer.
c. Bend 40-45 degrees, then back 40-45 degrees.
d. Bend 45-60 degrees, then back 45-60 degrees.

34. (418) Lock seams are fastened by being

a. formed around each other.
b. lapped and spot welded.
c. soldered and screwed.
d. none of the above.

35. (419) The seam allowance of a 1 1/2 inch standing seam in 16 gage metal is

a. 3.00 (3) inches.
b. 3.50 (3 1/2) inches.
c. 4.25 (4 1/4) inches.
d. 4.62 (4 5/8) inches.

36. (419) How is the seam allowance for a standing seam added to the pattern?

a. Equal amounts to each half.
b. The full seam allowance to each half.
c. More to one half than the other.
d. One half the allowance to each half.

37. (419) Standing seams are normally used in duct fabrication to connect end caps and stiffen

a. bottoms to rectangular pans.
b. the sides of rectangular duct.
c. take off fittings for a branch line.
d. side seam of a cylinder or vent stack.

38. (420) The first step in forming a grooved seam is to

a. adjust the bar folder for the width of the seam.
b. turn on the Pittsburg lock forming machine.
c. turn the edges of the metal 180 degrees.
d. adjust the cornice brake for the metal thickness.

39. (421) The corner double seam is used to

a. make a neat branch line connection.
b. make a water tight connection.
c. seam bottoms on cylinders.
d. seam some duct work.

40. (422) The Pittsburg lock seam is used

a. to connect the corner of rectangular duct.
b. for the connection of a branch line.
c. with grooved seam on round duct.
d. on most overhead hoods.

41. (422) After setting the machine, which one of the following is the most important step in using a Pittsburg lock forming machine?

a. Keep the metal flat.
b. Hold the metal tight.
c. Start the metal straight.
d. Let the metal start itself.

42. (423) The principle of a dovetail seam is that a cylinder

a. is held to a flat surface by alternating tabs.
b. is held to a flat surfact by all tabs bent on one side.
c. or round duct is attached to a flat surface with a clip.
d. or tapering item is held to a flat surface with cleats.

43. (424) Recommended joint and bracing for a galvanized iron 24 gage duct, 23 inch wide and 35 inch centers consists of

a. standing S-slip and drive slip with cross brake.
b. standing S-slip and drive slip with 1 X 1 X 1/8 inch angle iron on 48 inch centers.
c. flat S-slip and drive slip with 1 X 1 X 1/8 inch angle iron on 48 inch centers.
d. standing S-slip and drive slip with 1 1/2 X 1 1/2 X 1/8 inch angle iron on 48 inch centers.

44. (425) To fabricte a standing S-slip, it is necessary to

a. bend the S section first.
b. turn the pattern over twice.
c. bend the standing section last.
d. turn the pattern over only once to make the 180 degree downward bend.

45. (426) Drive slips are used on

a. stacks and ventilator systems.
b. rectangular shaped duct systems.
c. tapered fittings for duct systems.
d. round air conditioning and heating systems.

46. (426) Drive slips are cut with 45 degree angles on one end

a. so they can be installed with less effort.
b. so they can be bent over with less effort.
c. to allow the necessary joint clearance.
d. to make forming easier.

47. (427) On a duct joint, the drive slips are held in place

a. with nails.
b. with spot welds.
c. by sheet metal screws.
d. by bending the ends over the duct.

48. (428) The first step used to form a tapped connection is to

a. cross brake.
b. form the corners.
c. match the seams.
d. form the Pittsburg lock seam.

49. (428) Sections of round duct such as vents, stacks and branch lines should be joined with a

a. slip joint.
b. V-grooved lock seam.
c. double lock seam.
d. dovetail lock seam.

50. (429) The diameter of an electrode for a spot weld should be

a. four times the thickness of one of the pieces being welded.
b. three times the thickness of the metal being welded.
c. twice the distance of the seam allowance.
d. twice the thickness of the metal being welded.

51. (429) The seam allowance for a spot welded seam is equal to

a. twice the diameter of the weld.
b. three times the diameter of the weld.
c. one quarter of an inch from the edge.
d. four times the thickness of the material being welded.

52. (430) Air turbulence in a duct is the

a. affect of the duct being too large.
b. affect of the duct being too small.
c. tendency of air to whirl and move in different directions.
d. tendency of air to travel in a straight line.

53. (431) What areas, if any, should you identify to diagnose trouble spots in air duct systems?

a. Areas that have a rough surface inside.
b. Ducts that are longer than necessary.
c. Ducts that are more rectangular than square.
d. All of the above.

54. (431) When figuring radius ratio for square or rectangular elbows, the width should be the

a. shorter of the two dimensions of the duct.
b. dimension that equals the height of the duct.
c. dimension that lies in the same plane as the radius of the elbow.
d. dimension that lies in the same plane as the width of the duct.

55. (432) In a rectangular duct elbow with an inside radius of 12 inches and a width of 36 inches, you should install

a. one splitter 12 inches from the inside radius.
b. two splitters, 12 inches apart.
c. three splitters, 9 inches apart.
d. no splitters.

56. (433) Dampers are used in duct systems to

a. increase the flow of air.
b. restrict the flow of air.
c. vary the volume of airflow.
d. increase the volume of airflow.

57. (433) Where and why are an access hole and cover plate placed in a duct?

a. at louver dampers, so inspection and maintenance can be performed.
b. At fire dampers, so a fire extinguishing agent can be injected into the duct system.
c. At dampers, so inspection and maintenance can be performed.
d. At butterfly dampers, so they can be adjusted.

58. (434) The function of a ceiling diffuser or register is to

a. cover return air openings.
b. regulate the air volume in a room.
c. cover the duct opening in a room and disperse air.
d. cover the duct opening in a room and control air volume.

59. (435) What type seam is best suited for a corner seam on an air duct?

a. Pittsburg lock seam.
b. Flanged lock seam.
c. Single lock seam.
d. Double lock seam.

60. (435) What type bracing is used for ducts that are less than 24 inches wide?

a. Cross break.
b. 1 inch standing seam, 60 inch on center.
c. Flat S-slip only.
d. 3.4 inch standing seam, 48 inch on center.

61. (436) What material is used to fabricate heating, cooling, and ventilating ducts?

a. Tin plate.
b. Bonderized sheet.
c. S-O aluminum sheet.
d. Galvanized sheet iron.

62. (437) On each end of a duct section, how much allowance is required for the S-and-drive?

a. 1/2 inch.
b. 3/4 inch.
c. 1 inch.
d. 1 1/4 inch.

63. (438) The last step in determining size and quantity of materials for a duct system is

a. layout the plenum tap.
b. layout all of the S-and-drive slips.
c. complete the flexible connection.
d. cut the braces from left over material.

64. (439) Which of the following is included in the preliminary planning breakdown of the systems?

a. Quantity and sheets needed.
b. Kind of material needed.
c. Size of sheets needed.
d. All of the above.

65. (440) How many 6-inch X 36-inch pipe patterns can be cut from a piece of metal 36 inches X 60 inches?

a. Three.
b. Four.
c. Six.
d. Ten.

66. (440) Why would branch line lengths vary in different rooms?

a. Some branch lines carry more air volume.
b. Because of transitions in the trunk lines.
c. The center line of the trunk line varies.
d. Because of the size of the rooms.

67. (441) What are the two types of grilles used?

a. Wall and door grilles.
b. Wall and ceiling grilles.
c. Door and ceiling grilles.
d. All of the above.

68. (442) What method is used to layout a rectangular duct joint?

a. Parallel line method.
b. Triangulation method.
c. Radial line method.
d. Trimulation method.

69. (443) How does the length of the curved portion of a turn vane compare to the straight portion?

a. 1/2 as long.
b. Equal.
c. 1 1/2 times as long.
d. Twice as long.

70. (444) What length of a piece of metal can be cut by setting the front gage of the squaring shears?

a. 24 inches.
b. 36 inches.
c. 48 inches.
d. 60 inches.

71. (444) When cutting slits and notches, what type cutter has more leverage and requires less effort?

a. Throatless shears.
b. Aviation snips.
c. Portable unishear.
d. Straight snips.

72. (445) To form a rectangular duct joint, use a

a. Pittsburg lock forming machine.
b. bar folder and slip roll forming machine.
c. box and pan break and turning machine.
d. bench plate and stakes.

73. (446) Center line can be determined from

a. the side and top of the duct.
b. a chalk line on the ceiling joints.
c. plan view and elevation view drawings.
d. detail views and elevation view drawings.

74. (447) Which one of the following is a key point about duct installati

a. Maintain a vertical and horizontal centerline.
b. Install the hangers before you install the flexible connection.
c. Mintain a vertical height of at least 20 inches.
d. Install the top braces first.

75. (448) Items placed on openings in a duct system are

a. registers, grilles, and diffusers.
b. diffusers, butterfly dampers, and grilles.
c. registers, grilles, and inspection plates.
d. butterfly, louvered and splitter dampers.

76. (448) Ease of installation of diffusers is accomplished when

a. the round duct ends are flush with the ceiling.
b. the round duct has a 2/8 inch flange turned out.
c. tabs have been installed on the duct.
d. extra long screws are supplied.

77. (449) Which one of the following best describes when an air conditioning duct system needs repair?

a. Insulation is removed or torn.
b. Fire has damaged the system.
c. Condensation and rust cause holes.
d. All of the above are true.

78. (449) If the backside of a duct repair is not accessible for bucking solid rivets, you should use

a. sheet metal screws.
b. spring nuts.
c. self-sticking patches.
d. overlaping, self-locking, patch.

79. (450) Wind will cause a stack or vent to draw if the opening of the stack or vent is located

a. even with or above the ridge of the roof.
b. even with or below the ridge of the roof.
c. where the wind can blow straight across it.
d. where the wind will not hit it straight on.

80. (450) The updraft of stacks and ventilators is affected by the

a. wind velocity alone.
b. outside air temperature.
c. velocity and direction of wind.
d. direction of the prevailing wind.

81. (451) Which one of the following best describes how double wall stack components are constructed?

a. The outer wall will not overheat.
b. An airspace prevents condensation.
c. The inner wall will resist corrosion.
d. All of the above.

82. (451) A storm collar is the part of a stack assembly that

a. prevents leakage around the top of a roof jack.
b. prevents rain from entering the vent or stack.
c. keeps the vent cap and wind ring in place.
d. keeps weather from entering through the hole in the roof.

83. (452) The first step to develop the pattern for a vent cap is to layout the

a. braces fro the top.
b. elevation view of the top.
c. ring for the weather cap.
d. collar for the base of the cap.

84. (452) Which one of the following best describes how the ceiling thimble is developed?

a. Spot weld the rings to the sleeves.
b. Spot weld the tabs to the sleeves.
c. Make two rings, two sleeves, and four tabs.
d. All of the above.

85. (453) When assembling a ceiling thimble what is used to attach the ring to the sleeve?

a. Solder.
b. Spot weld or rivet.
c. Grooved seam.
d. Sheet metal screws.

86. (454) The turbine (spin cap) ventilator pulls air from the building when

a. the wind blows across the vane and causes it to rotate.
b. there is a temperature difference in the inside and outside of the building.
c. the vane is rotated by an electric motor.
d. the damper is closed by hand.

87. (454) A main point to remember when installing a power ventilator is that

a. the damper must be left open.
b. effectiveness depends on the wind.
c. the automatic louver must work freely.
d. the damper should be installed at a 45° right angle.

END OF EXERCISE

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MAIL TO: ECI, GUNTER AFS AL 36118-5643

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 10 USC 8012. PRINCIPAL PURPOSE: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package, and used by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's inquiry. Failure to provide all information would result in slower action or inability to provide assistance to the student.

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11	Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 10 not yet received. Answer sheets submitted ______(date).	P	VOL 33-36
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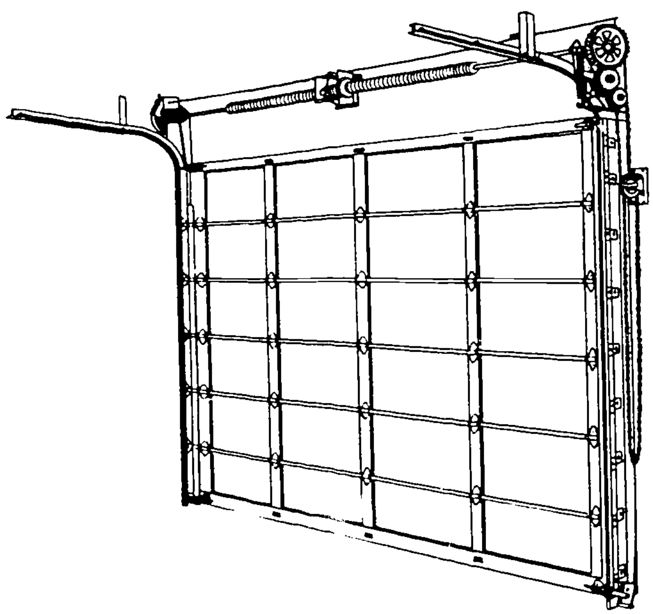
METAL FABRICATING SPECIALIST

(AFSC 55252)

Volume 4

Installed Equipment and Doors



CBG-101

Extension Course Institute
Air University

387

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THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

YOU HAVE NOW progressed to Volume 4 of CDC 55252. We would like to give you a "pat on the back" for satisfactory progress up to this point. We want to encourage you to continue with your fine effort. After this volume, you have only three more to complete. Then, you will be in a position to try for upgrading to the 5 skill level.

In this volume, we present information on installing, fabricating, and repairing such things as fixed utility equipment, awnings, canopies, metal roofs, and doors (overhead and sliding). With this volume, you will have received most of the technical knowledge needed to perform sheet metal work.

Code numbers appearing on figures are for preparing agency identification only.

Direct your questions or comments relating to the accuracy or currency of this volume to the course author: TTOXC, ATTN: MSgt Arnold D. Ringstad, Sheppard AFB TX 76311. If you need an immediate response, call the author, AUTOVON 736–2879 between 0800 and 1600 (CST), Monday through Friday. *(NOTE: Do not use the suggestion program to submit changes or corrections for this course.)*

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This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of September 1982.

Contents

NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Fixed Utility Equipment

IN THIS CHAPTER, we will discuss the fabrication, installation, and repair of indoor and outdoor fixed utility equipment. Indoor fixed utility equipment includes such items as exhaust hoods and serving line equipment. Outdoor fixed utility equipment includes such items as metal awnings and canopies.

Fabrication, installation, and repair of fixed utility equipment involves techniques you have already learned about in this course: pattern layout and cutting, notching, forming, assembly, and installation procedures. In this volume, you will learn how to apply some of these techniques to stainless steel, which is used in many items of indoor fixed utility equipment.

The fixed utility equipment discussed in this chapter is typical of what you will work with in your job, and the procedures to discussed will be similar to those you actually follow on the job. What you learn about these items will help you fabricate and install similar jobs more quickly and efficiently.

1-1. Hoods

Hoods are used to capture fumes and gases from cooking ranges, coffee urns, diswashing machines, and paint spray booths. The hood collects the air, which is carried away through a duct by exhaust fan suction.

600. Identify construction features of hoods, including horizontal dimensions.

[illegible] age of air pickup, the range hood [illegible] ches beyond the sides of the range [illegible] the front. Hoods are usually made [illegible]-gage stainless steel and have grease filters that can be removed for cleaning. The inside bottom edge of the hood has a flanged edge (lip) that acts as a grease collector or trap. One corner of this grease trap has a drain plug for draining any grease that collects. Figure 1-1 shows the location and shape of the grease trap. You will encounter hoods of various sizes and shapes; however, the fabrication and installation is similar to that for the one shown in figure 1-1.

Hoods are usually supported by adjustable hangers so that a corner can be lowered to allow the grease to drain from the plug. Hood hangers, like duct hangers, are fastened to the ceiling joists and are made of flat bar, rod, or chain. A turnbuckle or device with similar purpose is used for adjusting the height of the front corners of the hood.

Fabrication of hoods from stainless steel is similar to fabrication of other sheet metal components, except that stainless steel is a harder metal and its polished surface scratches easily. Some manufacturers apply an adhesive paper to the surface of stainless steel sheets for scratch protection. During layout and fabrication, pencil lines marked on the paper can be seen better than marks on the surface of the steel. For scratch protection, leave this paper on the metal until the component is assembled and installed.

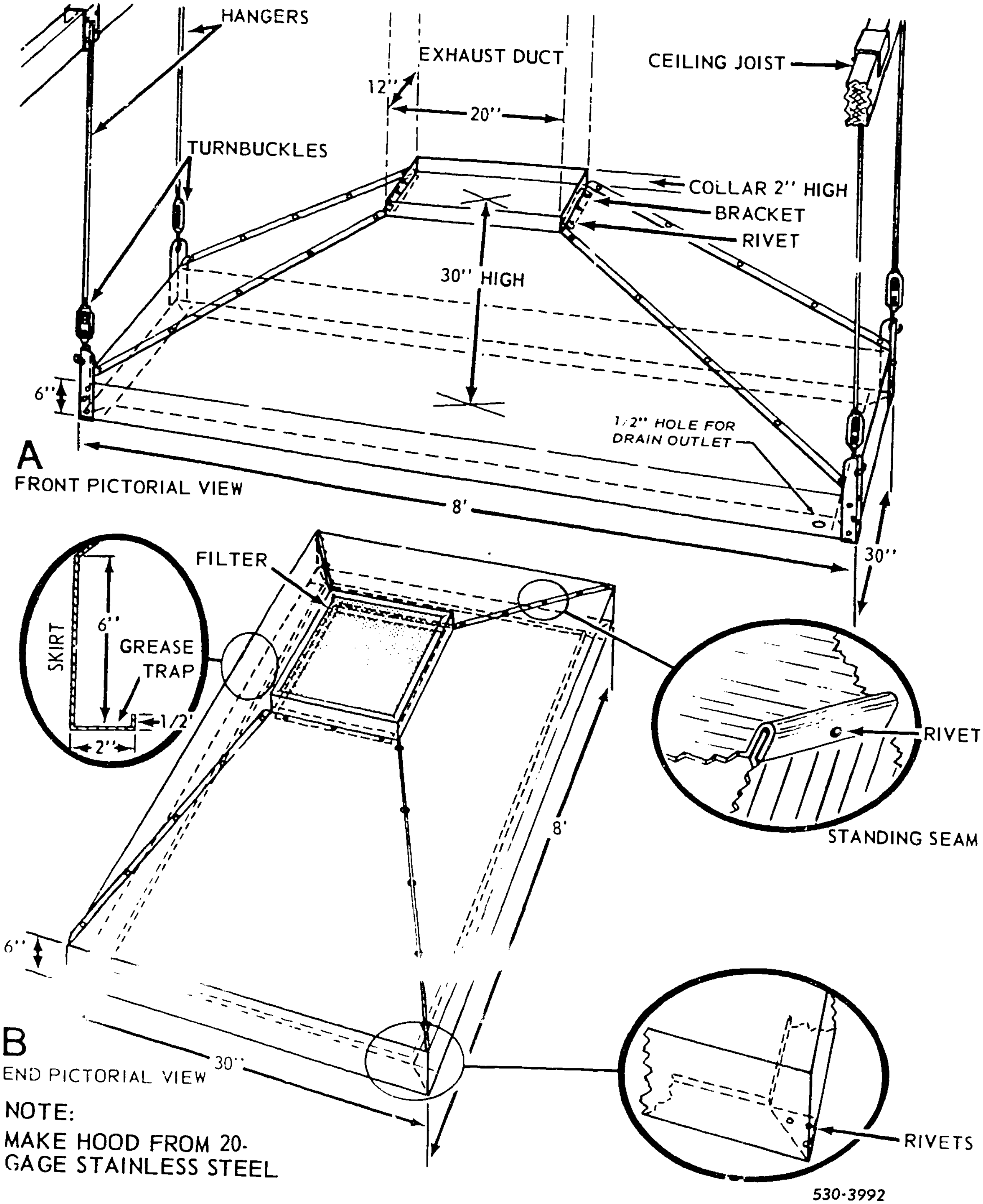
To fabricate a hood, you need to know the dimensions and shape. Figure 1-1 shows pictorial views and details of a hood that measures 8 feet long and 30 inches wide. It has a filter that fits inside the collar, and a drain plug in one corner of the grease trap. The collar at the top of the hood where the exhaust duct connects is 2"x 12"x 20". The corners of the grease trap and the standing seams are secured with Monel rivets.

Exercises (600):

1. How far should the hood extend beyond the sides and front of the range?

2. What type of metal are hoods usually made of?

3. How are the corners of the grease trap and standing seams secured?



NOTE:
MAKE HOOD FROM 20-
GAGE STAINLESS STEEL

Figure 1-1. Pictorial view of a hood.

601. List the steps for laying out a hood pattern, and state important aspects of hood layout.

Pattern Layout for a Hood. In figure 1-1, you can see that the hood is shaped somewhat like a transition. You should remember from (Volume 3 the triangulation method of layout that is used to dev[illegible]op patterns for transitions. A very similar method [illegible]d to lay out the pattern for [illegible] hood can be made in four pieces, as shown in figures 1-2 and 1-3. Notice that the front, back, and two sides will each be one piece.

A plan view of the transition is required so that certain points can be transferred to the true length chart. The height of the true length chart in figure 1-2 is 24 inches, which is the vertical distance from the 6-inch skirt to the collar. (The 6-inch skirt is an addition to the pattern and is not shown in figure 1-2.) To draw the plan view, draw (to scale) a rectangle 8 feet long and 30 inches wide. Draw the 12"x 20" outlet at the center. A good way to find the center is to locate the middle of each side of the 8"x 30"rectangle and draw lines F-E and 1-6. These lines cross at the center of the large rectangle. On line 1-6, mark off 6 inches (half the width of the small outlet rectangle) on each side of the center; on line F-E, mark 10 inches (half the length) on each side of the center. Then, draw the sides of the small rectangle through these points, as in figure 1-2. After the two rectangles are drawn and numbered as shown in figure 1-2, draw connecting lines between the letters and numbers.

The next step in developing the patterns is to find the true length of the lines between the rectangles of the plan view. Begin the true length chart with a 90° angle which has the vertical leg 24 inches high to represent the vertical height from the skirt to the collar. Use dividers (or trammel points) and measure the lengths of lines 1-2 and 6-5 on the plan view. These lines should be the same length. Transfer this distance (the length of line 1-2) to the base [illegible] of the [illegible] le[illegible]th cha[illegible], measuring [illegible] iden[illegible] as [illegible]

Draw [illegible] line [illegible]om point 1,6 on the baseline to the top of the 24-inch vertical line. Mark this top end point as 2,5, to identify the vertex point. The length of slant line 1,6 to 2,5 is the true length of the front and back pieces for the hood. Next, transfer the distance from 3 to E (or 4 to F) to the true length chart, draw the slant line, and label the bottom end 3,4 and the top end E,F. This slant line is the true length of the two side pieces of the hood.

Next, transfer the distance from point 2 to Point A to the true length chart, draw the slant line, and label the ends. This line is the same for 2-B, 5-C, and 5-D. It will be used later to develop the pattern for the front and back. Transfer line 3-B (or 4-A) to the true length chart, draw the slant line, and label it. On the true length chart, do not confuse 3-B, 4-A, on the left, with 3-E, 4-F, on the right. The last line to be transferred is 7-A, which is the true length of the edge of the pattern along the standing seams. All four corner lines should be the same length.

Patterns for the front and back. The true length chart is now complete enough to develop the patterns shown in figure 1-3. Since the patterns are id[illegible] except for bending instructions, only one pattern b[illegible] developed. Begin by drawing a straight line 8 [illegible] lon[illegible] letter one end A, D and the other end B, C. Notice how this line corresponds to lines AB and DC in the plan view of figure 1-2. Label the midpoint 1,6. The length from AD to 1,6 represents line A-1 on the plan view of figure 1-2. Then, set the dividers (or trammel points) to the length of line A-2 in the plan view. Transfer it to the pattern, with one end at point AD and the other end precisely above point 1,6. Draw a short arc above point 1,6. Keep the same setting, move the AD tip of divider to point BC. Swing another arc precisely above point 1,6. The point where these two arcs meet is point 2,5.

Next, transfer line 1-2 from the true length chart to the pattern; the top of this line should be at point 2,5. Connect points 1,6 and 2,5 with a dashed. This is the height (slant height) of the front and back pieces of the pattern. Draw a 20-inch line through point 2,5, parallel to line AD-BC. Transfer the length of line 2-8 from the plan view to the 20-inch line of the pattern. With one end at point 2,5, swing an arc on both sides of point 2,5. The arcs establish points 7,10, and 8,9, which are end points for the 20-inch sides of the collar. Next, transfer the length of line A-7 from the plan view to make lines A-7 and B-8 on the pattern. This completes the pattern, except for the additions and seam allowances.

The additions and seam allowances for the front and back pattern shown in figure 1-3 are made from information contained in the pictorial views of figure 1-1. Make the additions below the 8-foot line on the pattern, as follows: 6 inches for the skirt, 2 inches for the lip of the grease trap, ½ inch for the fla[illegible] grease trap, and 7/16 inch for the hem. At [illegible] the pattern, make a 2-inch addition for the col[illegible] ake a [illegible] inch allowance on each side for the 90 [illegible]lange portion of the standing seam. T[illegible] next step is to write the bend instructions for the [illegible]nes on the pattern. Notice that figure 1-3 has bending instructions for the back pattern, a statement that the bends for the front pattern are opposite.

Notches for the front and back pattern are somewhat different from those for other patterns discussed previously in this course. Notice in figure 1-3 that the 2-inch addition for the grease trap is notched at each end and that the same addition on the side pattern is not notched. The reason for this is that when the corners are joined, the 45° cut will be on the outside of the lap joint, and the mitered cut makes a more attractive corner. (Figure 1-1 shows how the finished corner looks and where the rivets are locat[illegible] Notice that the ½-inch flange addition and the 7/1[illegible]h hem allowance (in fig. 1-3) are notched at 90° so that they will make butt joints when the corners are joined. The 2-inch allowance for the collar has 90° notches. The

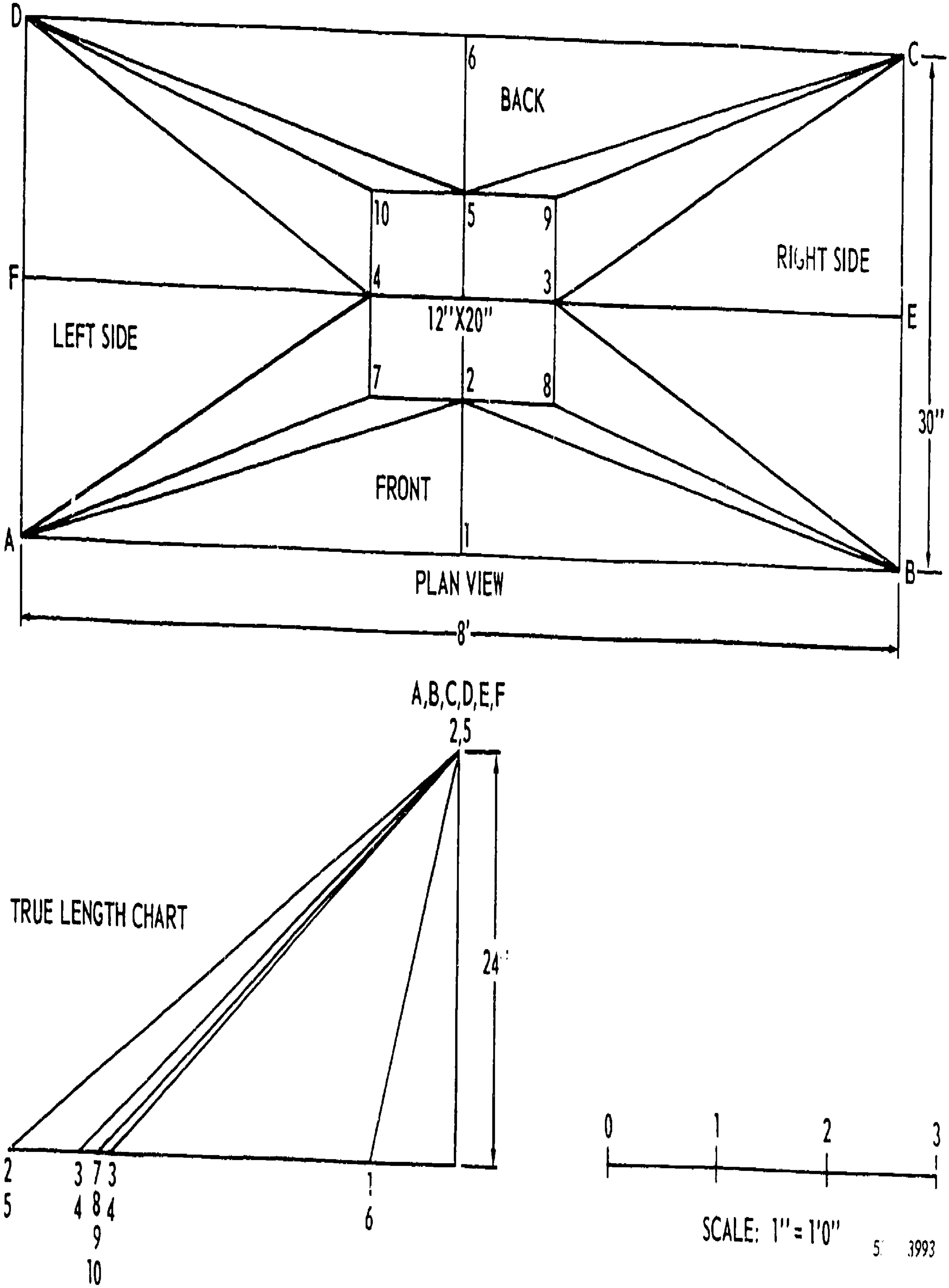


Figure 1-2. Plan view for developing patterns for a hood.

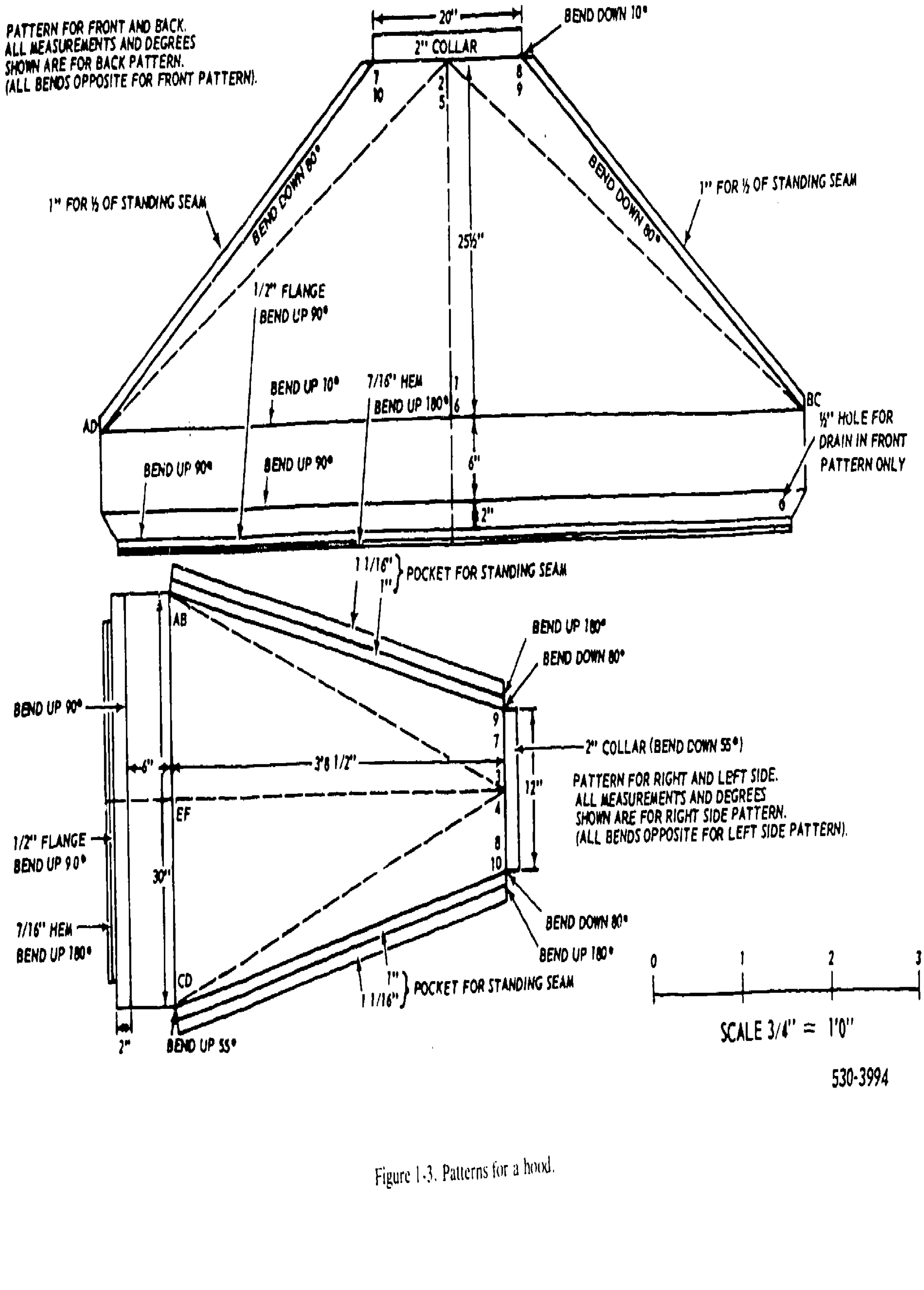


Figure 1-3. Patterns for a hood.

standing seam allowance on the front and back pattern is slant notched at each end.

Patterns for the sides. The pattern for the two sides of the hood is also developed from the true length chart of figure 1-2, using procedures similar to those used to make the front and back patterns. The completed pattern for the sides is shown in figure 1-3. It includes the dimensions, additions, seam allowances, bend direction, and notching instructions. The pattern illustrated is for the right side of the hood. Again, the pattern for the left side is identical except for the bends, which are opposite to those for the right side.

Exercises (601):

1. What view of a hood must you draw to develop the pattern for it?

2. What method of layout is used for making a hood?

3. The patterns for the sides of a hood are developed from ____________ ____________ ____________ ____________.

4. A 1-inch seam allowance is added for what part of a standing seam?

5. What instrument do you use to transfer lengths from the drawing of the hood to the pattern?

6. How is the standing seam allowance on the front and back notched?

602. Identify equipment and techniques used for cutting, notching, and forming hood patterns.

Cutting and Notching Patterns for a Hood. Cutting and notching the patterns for the hood shown in figure 1-3 requires squaring shears and straight snips. Use squaring shears to cut the outside edges of the side patterns and the front and back patterns, except for the edge of the standing seam. If you cut this edge seam with the squaring shears, you will clip the corners of the 2-inch collar, so use straight snips for this edge as well as for the notches on both patterns.

Forming the Patterns for a Hood. The bending instructions in figure 1-3 are for the back side and right side patterns shown. Notice that the bending instructions for the front side and left side patterns are opposite to the instructions written on the illustration. Starting with the *back pattern,* use the cornice brake to bend the standing seams 80°. Then, use a mallet and wood block to straighten about 2 inches of each seam near ends C and D. This is necessary so that the cornice brakes will not damage the metal when it is clamped to make the 10° end along line C-D. After this is done, make the 180° bend for the hem addition, the 90° bend for the 2-inch grease trap addition, and the 10° bends for the 6-inch skirt and 2-inch collar additions. After all of these bends have been made, use a mallet and wood block to reshape the ends of the standing seams which were temporarily straightened out. Make the *front pattern* just like you made the back pattern, except for reversing the direction of the bends and making a hole for the drain plug with a rotary punch.

You will need two forming machines to bend the patterns for the side pieces: the cornice brake and the box and pan brake. The bending instructions are shown on figure 1-3. To form the pattern for the right side, use the cornice brake to make the 180° and 80° bends for the pocket of the standing seams. It is not necessary to temporarily straighten the ends of the seam because the box and pan brake will be used to make the remaining bends. Arrange the fingers of the box and pan brake to make bends 30 inches long, and then make the following bends: 180° for the hem addition, 90° for the ½-inch flange addition, 90° for the 2-inch grease trap addition, and 55° for the 6-inch skirt addition, to make the 55° bend, you must turn the pattern over in the box and pan brake (along the outside end of the lower bending leaf), and bend it down with a mallet so that the standing seam will not be damaged. Arrange the fingers of the box and pan brake to make a bend 12 inches long; then, using the machine only, make the 55° bend for the 2-inch collar addition.

Exercises (602):

1. With which tool do you cut the edge of the standing seam, and why?

2. What do you do to the standing seam before making the 10° bend, and why?

3. What two forming machines do you use to make the side pieces?

603. Describe steps and materials for assembling and installing a hood.

Assembly of a Hood. Now that the pieces are cut, notched, and formed, the hood shown in figure 1-1 can be assembled. You can begin at any one of the four

corners and insert the grease trap of the side piece into the grease trap of the front (or back) piece. The 45° miter cut on the front (and back) piece should be on the outside of the lap seam. It is necessary to hold the side piece at an angle in order to insert the 1-inch flange into the pocket of the standing seam.

When the two pieces are joined and the corners of the skirt and collar are square, use a small C-clamp or vise grip pliers at each end of the standing seam to temporarily hold it together while you assemble the other pieces. Be sure to use cardboard or small blocks of wood to keep the clamps from scratching the metal. Continue this procedure until all four pieces of the hood are assembled. Inspect each seam and butt joint for proper fit, and when everything is satisfactory, install Monel rivets in each of the standing seams.

For good appearance and holding strength, locate the first three rivets as follows: one at the midpoint and one 2 inches from each end of the standing seam. Space the remaining rivets on 8- to 10-inch centers. After riveting, remove the clamps from standing seams.

The next part of the assembly procedure is to install Monel rivets at the corners of the grease trap. Make sure that the corners are square before you install the rivets. Carefully lay the hood on its front or back and use a carpenter's square. Install clamps at each corner to hold the corners until you install the rivets. You can doublecheck the squareness of the skirt corners by measuring the corners diagonally. The diagonals should be the same, if all corners are square. After you are certain that the hood is square, install Monel rivets in each of the four corners of the grease trap, as shown in figure 1-1. Solder the inside of the corner lap joint with 50/50 solder.

For the drain outlet, get a ½-inch stainless steel pipe coupling and have the welding shop solder it over the outlet opening with silver solder. (Silver solder is much stronger than regular solder.

The two brackets to hold the filter are each made of 11" x 11" stainless steel and are bent 35° along the 11-inch centerline. Fasten these brackets to the sides of the hood with three Monel rivets near the collar (see fig. 1-1). The filter rests on the ½ inch-edge of metal that extends into the opening, and is removed by raising one end until the other end clears the bracket.

The corners of the hoods are supported with hanger parts, such as those shown in figure 1-4. Notice that the parts include a corner connector, turnbuckle, rod, and joist connector. The corner connector is made of 16-gage steel, using the pattern shown in figure 1-4, B, and is made long enough to extend 4 inches above the skirt of the hood. Cut the straight sides with the squaring shears, cut the rounded end with throatless shears, punch the ½-inch hole with a rotary punch, and make the 90° bend with a cornice brake. Then, attach each corner connector to the hood with Monel rivets, as shown in view A of figure 1-4.

The remaining parts of the hood hanger, shown in figure 1-4, C, are made in the welding shop. You will thread one end of a ⅜ inch rod and weld the other end to a piece of 2-inch flat bar which is formed to fit over the ceiling joist. You will also thread a short piece of ⅜-inch rod at one end, heat the other end, and bend it to make a hook. The threads on each piece of ⅜-inch rod must fit the turnbuckle. The length of the rods is determined by the distance from the ceiling joists to the desired height of the hood.

Installation of a Hood. Before hanging a hood, such as that shown in figure 1-1, determine the location from the drawings or blueprints, then place the joist connectors (fig. 1-4) over the ceiling joists. With the hangers located so that the round rod hooks can be inserted into the corner connectors when the hood is raised into position, have three or more workers raise the hood and insert the hooks into the corner connectors. Level the hood by adjusting the turnbuckles; then slightly lower the drain corner and slightly raise the diagonally opposite corner so that the grease will drain when the plug is removed. Use wood screws to fasten each joist connector to the ceiling joists. The final steps of installation are to connect the exhaust duct, to remove the adhesive paper from the stainless steel, and to install the filter.

Exercises (603):

1. Where do you place the first three rivets in a standing seam?

2. How do you check the hood for squareness before you rivet the corners?

3. What materials are used to attach the corner lap joint and the drain outlet (pipe coupling), and why are they different?

4. Once the hood is installed, what adjustment do you make to the levelness, and why?

1-2. Serving Line Equipment

Most serving lines are installed by contractors when dining halls are built. The serving line counter shown in figure 1-5 is a typical piece of equipment used in dining halls. Special equipment is needed to work heavy-gag stainless steel and to polish the surfaces. Your job is, normally, to repair and replace components made of sheet metal.

604. List material used in serving line equipment.

The top of the serving line counter is made of 14-gage stainless (corrosion-resistant) steel, and is fastened to an angle iron or channel iron frame with

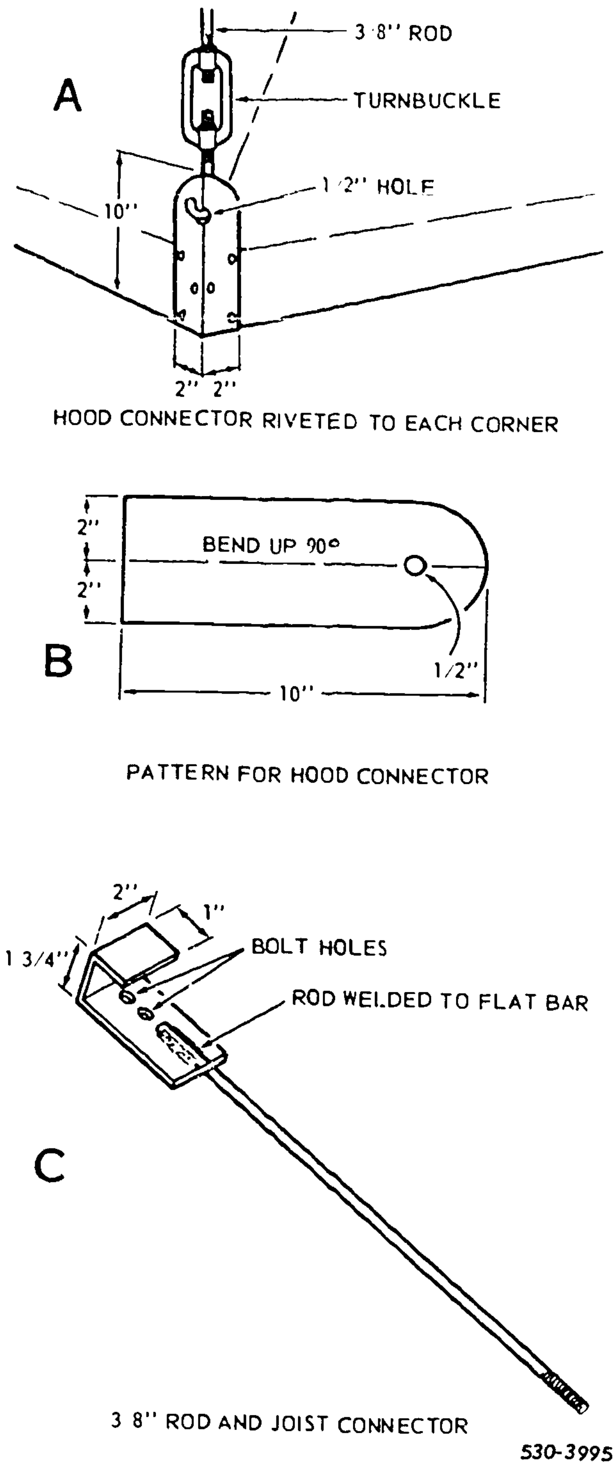


Figure 1-4. Hanger parts.

bolts that have been welded to the underside of the top.

The front and side panels are made of lighter gage metal than the top, usually 18-, 20-, or 22-gage. These panels are usually 4 feet wide (the width of a sheet), and are joined with butt joints covered with 14-gage stainless steel cap strips. The cap strips are usually 1½ inches to 2 inches wide, since the frame of the counter should have 1½- x 1½- inch angle iron vertical braces where the panels are joined. The cap strips are fastened to the panels and angle iron with corrosion-resistant steel bolts. In figure 1-6, you can see how a cap strip is used to cover a butt joint.

The three slide rails for trays shown in figure 1-5 are constructed of 1-inch stainless steel tubing. The rails are supported by brackets made from chromium-plated cast brass or stainless steel. The supporting brackets should not be spaced over 4 feet apart; they are fastened to the serving line with corrosion-resistant bolts.

The display shelf (over the cold pan), shown in figure 1-5, has three ¼-inch plate glass shelves that are bound on the edges with stainless steel. The frame uprights are made of 1-inch square or round stainless steel tubing. The shelves are usually 18 inches wide, and are as long as desired. The upright supports are spaced not more than 42 inches apart. Each shelf is supported with ⅝-inch square tubing welded to the uprights, and braced with a V-shaped corner clip. The corners have clips that are welded to hold the glass shelves in place.

The top of the protector shelf over the steamtable portion of the counter is usually made of stainless steel 16 inches high, 8 inches wide at the top, and 12 inches wide at the bottom. Thee front of the protector shelf is made of ¼ inch glass panels that are edged with stainless steel channel strips. The shelf is supported by chromiumplated braces. The fronts of the braces are slotted so that the panels of glass will fit into place; a cover plate with screws holds the glass panels securely. The protector shelf rests on the braces, and is fastened with bolts that have been welded to the bottom of the shelf. The bottoms of the braces are tapped so that they can be mounted with bolts through the counter top.

The legs of the counter are adjustable and are mounted to the counter frame. The legs are usually tubing or pipe. If they are stainless steel, the tubing is 16 gage and 1⅝ inches in diameter. If the legs are chromium-plated pipe, they are 1¼ inches in diameter. The legs are bolted or welded to the counter frame, depending upon the type being used, and are spaced not over 48 inches apart.

Exercises (604):

1. What material is used to make cap strips for a serving line counter?

2. What is used to construct slide rails for trays?

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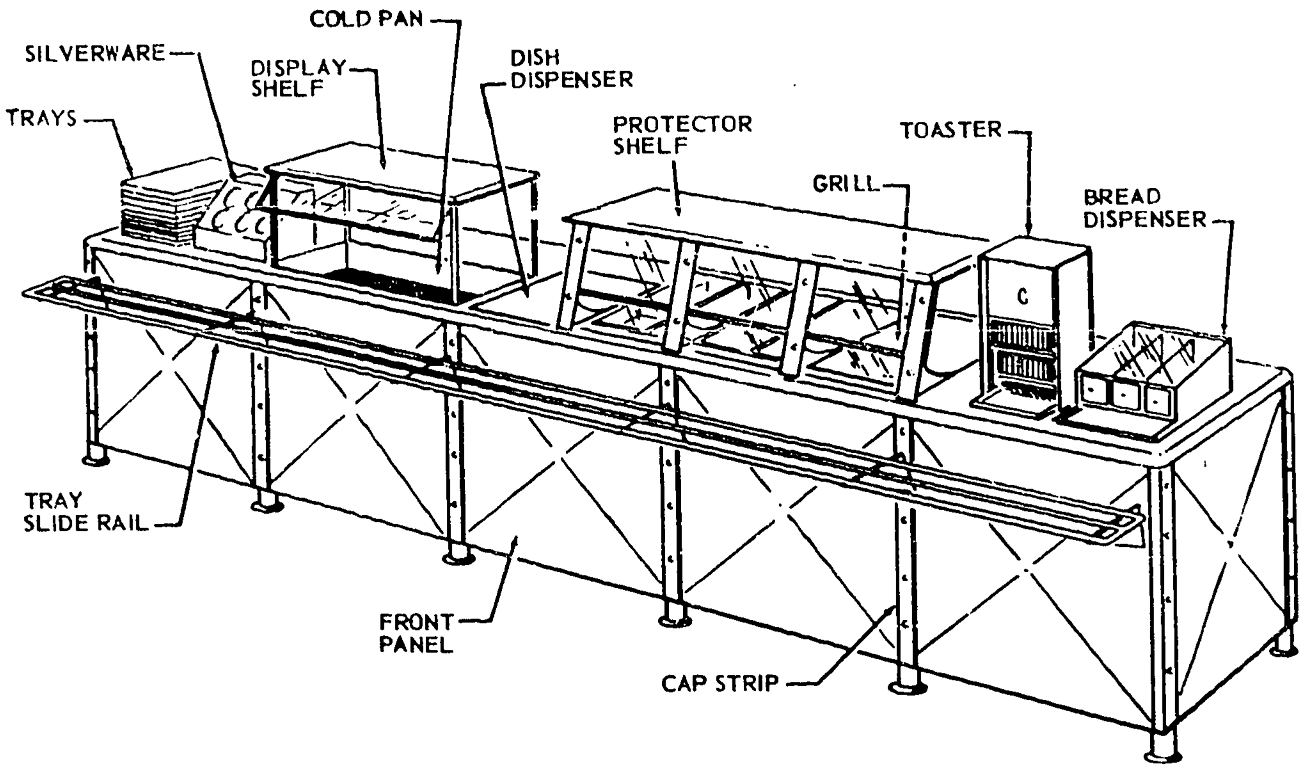

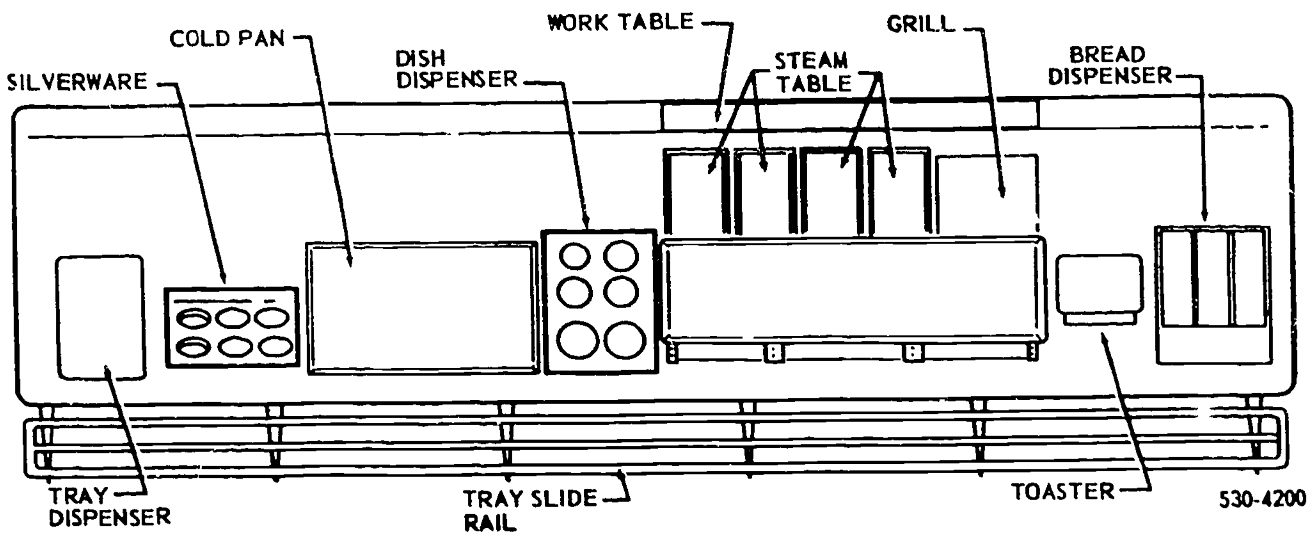

Figure 1-5. Serving line counter.

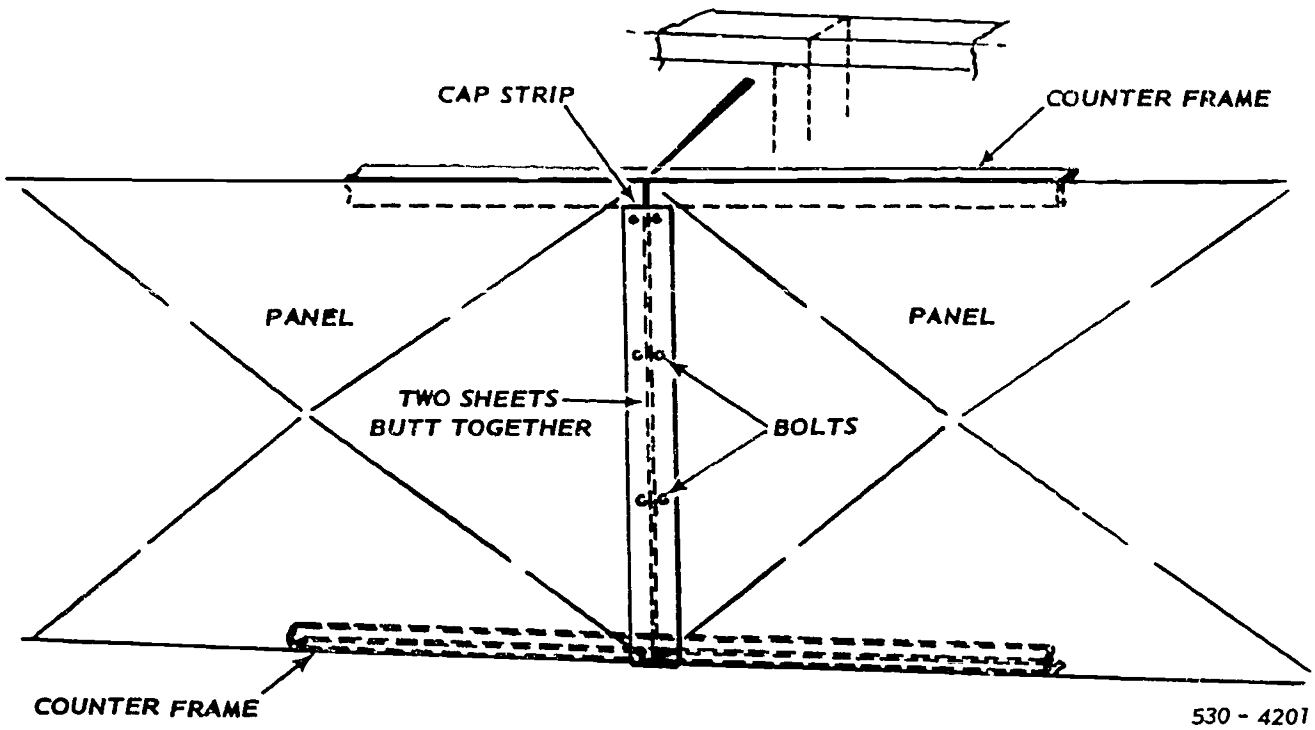

Figure 1-6. Stainless steel cap strip.

3. What gage and what diameter tubing is used for stainless steel legs on the serving line?

605. State the gage of stainless steel required to replace a panel, and differentiate between procedures for working mild steel and stainless steel.

Replacing a Stainless Steel Panel. Replacing stainless steel panels is one of the jobs you may be required to do. Therefore, suppose the right end panel of the counter shown in figure 1-5 needs replacing. The old panel should be removed and its measurements taken. To remove the panel, remove the corner cap strips and any screws that may be holding the panel to the counter frame. In this example, the panel to be repaired is 30 inches wide and 36 inches long, with a 1½-inch flange on the bottom to fit around the angle iron frame of the counter. Use the squaring shears to cut a piece of 20-gage stainless steel large enough to make the panel. After cutting the metal, use the cornice brake to make the cross brake bends and to make the flange. After cutting and forming the panel, you are ready to install it. Fit the panel into place, and reinstall the cap strips. Reinstall any other fasteners that are used to hold the panel in place.

Stainless steel is both tougher and more elastic than mild steel. Consequently, when cutting and working the stainless steel, you will notice that the machines require more force to operate than when working mild steel. When using the forming equipment in your shop, remember that the capacity ratings of cutting and forming machines are for mild steel. They do not apply to stainless steel. Refer to the technical manuals or manufacturers' handbooks for the capacity ratings for stainless steel. For *example*, shears designed to cut ¼-inch mild steel can only cut up to 3/16 inch of stainless steel without overloading the machine. When forming stainless steel, you will notice that there is more springback than from mild steel. This is because of the elasticity of stainless steel.

Exercises (605):

1. What gage of stainless steel is used to replace a panel on a serving line?

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2. What characteristic, different from mild steel, is noticable in stainless steel during the forming process?

3. When cutting and forming stainless steel, what difference, in procedure do you follow, compared with "mild" procedures?

606. Describe the repairing of a tray rail.

Repairing a Tray Rail. Repairing a tray rail of a serving line counter, such as that shown in figure 1-5, will usually consist of replacing screws that have worked loose where the rail is fastened to the bracket or where splices have been made. The ends of most rails have a chromium-plated end piece like the one shown in view A of figure 1-7. The hollow rails (tubing) slide over the recessed ends, and are secured with screws. The recess allows the rails to fit flush with the end piece, to make a nice fit. Because of the length of some serving lines and the lengths in which the rails are purchased, it is sometimes necessary to make splices. You can do this by welding and polishing or by the method shown in view B of figure 1-7.

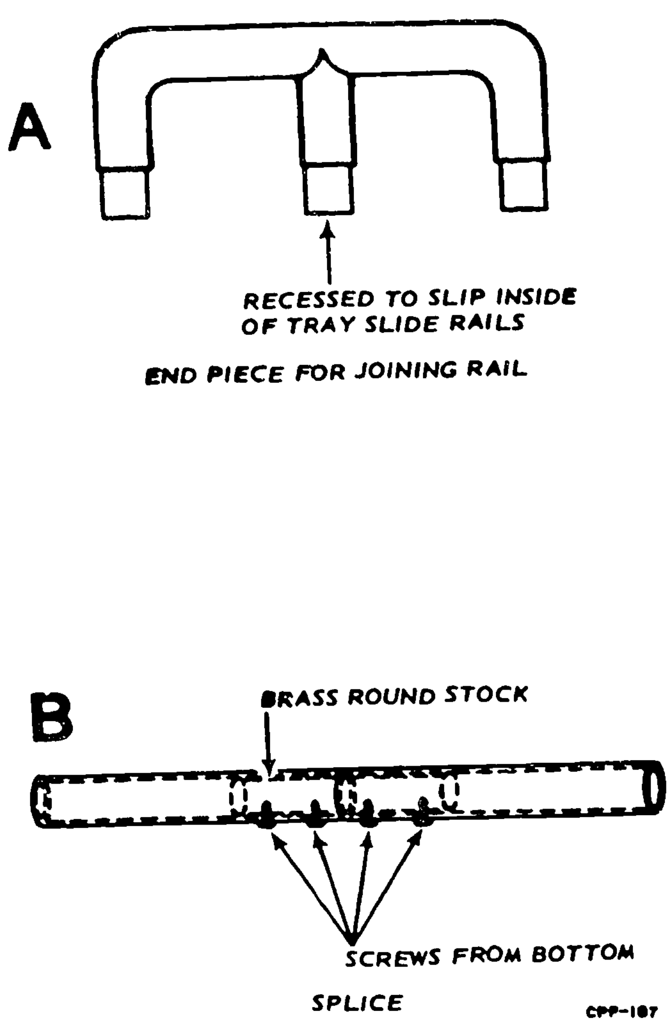

Figure 1-7. Repair of a tray slide rail.

If a tray rail becomes damaged, you can replace a section in several ways. Suppose that the outside rail in figure 1-5 is bent 6 feet from the right end, and requires replacement. Examination reveals that the ends are joined with a piece like the one shown in figure 1-7, A, and that the rail is spliced 10 feet from the right end, as shown in figure 1-7, B.

To make the repair, remove the end piece and all of the fasteners holding the rail to the braces. Remove the screws on the right side of the splice, and pull the 10--foot section loose. In this example, the 10-foot section will be replaced with a new one, but you have only a 5--foot section of new tubing. This meaans that you must use 5 feet of the old rail. Be sure to make a straight cut. If possible, use a bandsaw or power-operated hacksaw for the cut. Use a piece of brass round stock about 6 inches long (such as that shown in fig. 1-7) for the splice, so that it will cover enough area inside the tubing to make a strong splice. Drill and tap the holes in the bottom side of the tubing and round stock, fit the two 5-foot pieces together, and secure with 10-32 roundhead screws. When you return to the job, replace the 10-foot section and reinstall the end piece. Be sure to fasten the rail to the tray rail brackets.

Replacing a Tray Rail Bracket. Tray rail brackets that are chromium-plated should be replaced with new ones because welding will remove the chromium plating. However, if a bracket is made from stainless steel, you can make a repair, such as that shown in figure 1-8. Notice, in view A, how the rails are fastened to the bracket clips from the bottom with self-tapping sheet metal screws.

To fabricate the bracket, make patterns like the ones shown in views A and B of figure 1-8. Be sure to punch the holes before the bracket is formed. After bending the bracket through the centerline for the holes, weld the plate pattern to the bracket. This weld should be made from the inside. Make the clips, and weld them to the underside of the bracket just below each half-round space for the rails. Each clip should have holes to accommodate No 8 ½-inch sheet metal screws. After the bracket is fabricated, fit it to the rails, drill 7/16-inch holes in the counter, and fasten the bracket plate to the counter with ⅜-inch corrosion-resistant bolts. Then, secure the rails to the bracket with the self-tapping sheet metal screws.

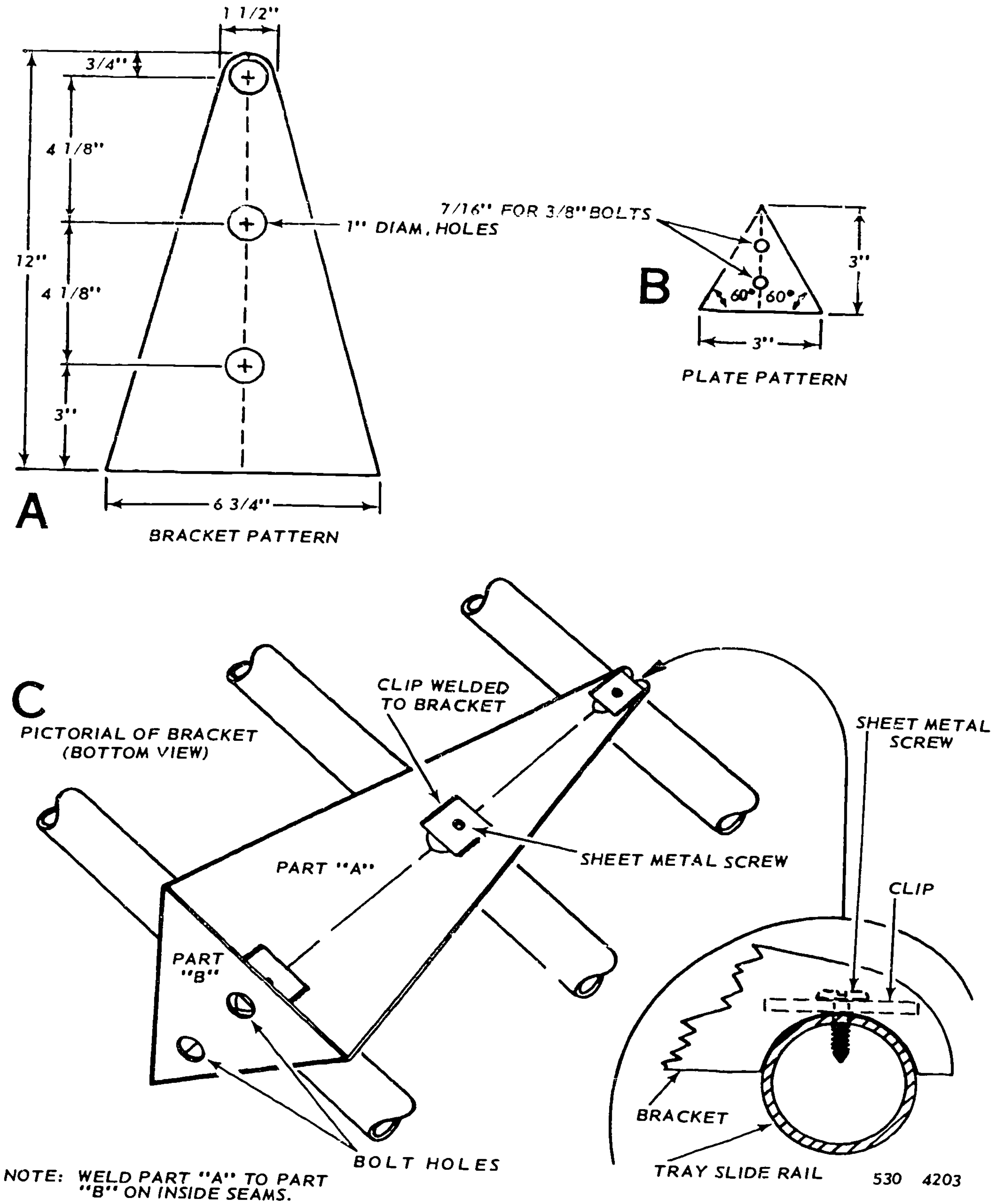

Figure 1-8. Support bracket for a tray slide rail.

Exercises (606):

1. Welding and polishing is one method used for splicing tray rails. Briefly describe the other method.

2. How are chromium-plated tray rail brackets "repaired," and why?

3. How is the bracket plate attached to the counter?

607. Describe the procedure for grinding a weld, list precautions to observe, and name material and equipment to use.

Repairing Broken Stainless Steel Welds. Most of your stainless steel work will be in food preparation areas. Some items needing repair most often are steamtables, sinks, steamcookers, serving lines, and counters. Welds will need repair. To repair a broken weld on stainless steel you must carefully prepare the joint. First, clean the surface of the metal; if the crack does not run the full length of the weld, stop drill each end of the crack to stop the break from moving further down the weld.
stop the break from moving further down the weld.

Welding stainless steel. Use a welding rod with the same metal composition as that being welded. Tack-weld the crack on each end and at about 2-inch intervals along the crack, and stagger the weld so that the metal surface will not become overheated and buckle. If the surface is overheated, the corrosion resistance of the stainless steel may become damaged, allowing the surface to corrode easily.

Grinding stainless steel welds. After the weld is completed and is cool, do the grinding, polishing, and buffing. For the grinding, use a portable grinder that has a handwheel similar to that of a bench grinder. Hold the grinder with both hands, one near the grinding wheel and the other at the rear handle. Do the first grinding rough cut of the weld with a wheel of 20 to 24 (medium coarse) grit, and do the second grinding with a wheel of 40 to 60 (medium fine) grit. Be sure to stop the grinding before the weld bead is flush with the surface, so that the polishing can be done. Before grinding, you can help keep the metal clean by applying adhesive paper on each side of the weld bead to protect the surface.

When using *portable grinders*, most inexperienced workers use too much pressure on the grinder. Do not bear down on the grinder. Use a light and even pressure, and move the grinding wheel smoothly along the weld. Allowing the wheel to remain in one spot too long causes the metal to overheat at that spot, and may cause the metal to buckle. If the temperature at the spot being ground reaches 400°F., the metal will become tinted (turn blue). Cool the area that is being ground. Use a wet cloth to avoid overheating of the metal.

It is good shop practice to grind stainless steel with a wheel that has not been used on metals; foreign metals on grinding wheels will contaminate the surface being ground. Keep the wheel dressed so that you won't have a tendency to cant (tilt) the wheel when grinding.

Polishing stainless steel welds. To start the polishing you need to select a grinding wheel with a grit that will remove all the pits and scratches caused by the earlier grinding operation. A medium fine grit is often used first; but in some cases, when the surface is not too rough you can begin with No. 100 fine grit. Keep polishing until the surface is uniform and blemish-free. When changing grit size, change the direction of grind also; this will help to eliminate the marks made by previous polishing. When starting to polish with very fine abrasive grits, you may want to use a lubricant, such as mutton tallow with stearic acid.

Buffing stainless steel. The buffing operation requires a buffing wheel that is flexible or soft near the outside edge. The wheel is made of layers of muslin sewn together. The surface of the metal should not be overheated when you are polishing or buffing. The first step in buffing usually requires a buffing compound. For the final step of buffing, sometimes called *coloring*, use a clean wheel and a green chrome oxide preparation to get a very high luster (reflecting quality).

When polishing and buffing stainless steel, you need to match the surrounding surface. The following guides will help you to obtain the desired finish:

- A No. 4 finish may be obtained by using No. 120 grit aluminum oxide applied on a soft wheel using a lubricant.
- A No. 6 (tampico) finish is obtained from a No. 4 finish by using a mixture of lubricating oil and powdered pumice (made into a paste) with a fine wire scratch wheel, followed with a tampico fiber wheel.
- A No. 7 finish can be obtained by buffing the surface with a very fine abrasive, such as white rouge, applied with a soft musline buffing wheel.

Exercises (607):

1. Briefly describe the general procedure for grinding a weld.

2. List at least two of the three precautions to observe in grinding a weld.

3. For fine polishing and buffing, what do you use in addition to a fine grit wheel or flexible buffing wheel?

Awnings and Canopies

IN THIS CHAPTER, we discuss the assembly, installation, and repair of awnings and canopies. These devices protect windows and doorways from the effects of weather and heat. They also help keep the interior of a building cool by shielding glass from direct sunlight.

The knowledge you gain from this chapter will help you do a good job on these exterior components. The examples discussed in this chapter are similar to the jobs you will be expected to do as a sheet metalworker.

2-1. Awnings

Metal awnings are usually installed over windows to keep sunlight out or to prevent weather damage to the screen or glass. It is not likely that you will make awnings, because they are usually purchased as factory-made assemblies. Your job usually consists of installation and repair. Awnings (fig. 2-1) are usually installed over windows, and are usually made of interlocking aluminum panels. The brace on an awning can be round tubing, square tubing, or angle iron. Braces are adaptable for different installations.

608. State materials and procedures used in awning installation and repair.

Assembly. Assemble awnings in accordance with the manufacturer's instructions. Normally, you start the assembly procedure at one end of the awning, where you lock the panels together. As you put the panels into place, fasten them to the frame with bolts and nuts. After the awning is completely assembled, you are ready to install it on a building.

Installation. To install the awning over a window, as shown in figure 2-1, first locate the center of the weatherstrip and the window (so that the awning will extend the same distance on each side of the window). Locate the holes for the screws by marking them while holding the strip in place, level with the window. After drilling the holes for the weatherstrip, apply calking compound to the back side of the weatherstrip and fasten the strip to the wall (with screws). Attach the awning to the weatherstrip (with nuts and bolts); then drill holes for the braces and fasten the braces to the wall (with screws).

If the awning is to be installed on a masonry wall, use a masonry drill to make holes for expandable sleeves. Fit the expandable sleeves into the holes to act as anchors for the screws so you can fasten the weatherstrip and brace to the wall. As before, the weatherstrip will need to be calked so that water won't run behind it.

Repair. Repair awnings by replacing panels or by patching Most repair will be required because of damage done by wind or hail. When an awning is damaged, inspect it to determine what repairs are necessary; sometimes you may need to completely replace it.

Suppose that the awning in figure 2-1 has been damaged upon inspection, you find that one brace and one end panel need replacing. Remove the awning and take it to the shop. To do this, remove the screws that anchor it to the wall. As the awning is being taken down, determine whether any screws will need to be replaced during reinstallation. Once the awning is at the shop, disassemble the parts that should be replaced and take the necessary measurements.

Lay out the pattern for the replacement panel, using the same type and gage of metal as the old panel, and then cut out the pattern with a suitable cutting machine. Since the panel has straight sides, the squaring shears will be suitable for the straight cuts. Straight snips can be used for notching the metal where notching is necessary.

Make the brace from tubing that is flattened and bent on the ends. To make a replacement, cut tubing to the desired length with a hand hacksaw, power horizontal bandsaw, or power hacksaw. Flatten the ends by placing the tubing on a solid surface such as an anvil and striking the tubing with a ballpeen hammer or tinner's riveting hammer. Turning the tubing over several times will enable you to do a good job of flattening the tubing. After flattening, drill holes in each end so that the brace can be fastened to the awning and wall, and attach the brace.

Reinstallation. Reinstallation of the awning requires fastening the weatherstrip and braces to the wall. Replace any fasteners that were damaged. Some of the holes may require larger screws or bolts to fasten the awning to the wall. Check the awning to see that it is level across the top and use a sealant (calking) behind the weatherstrip. Except for drilling holes, the reinstallation procedure is the same as the installation of a new awning.

Exercises (608):

1. Awning panels are assembled to the frame (before/during) installation.

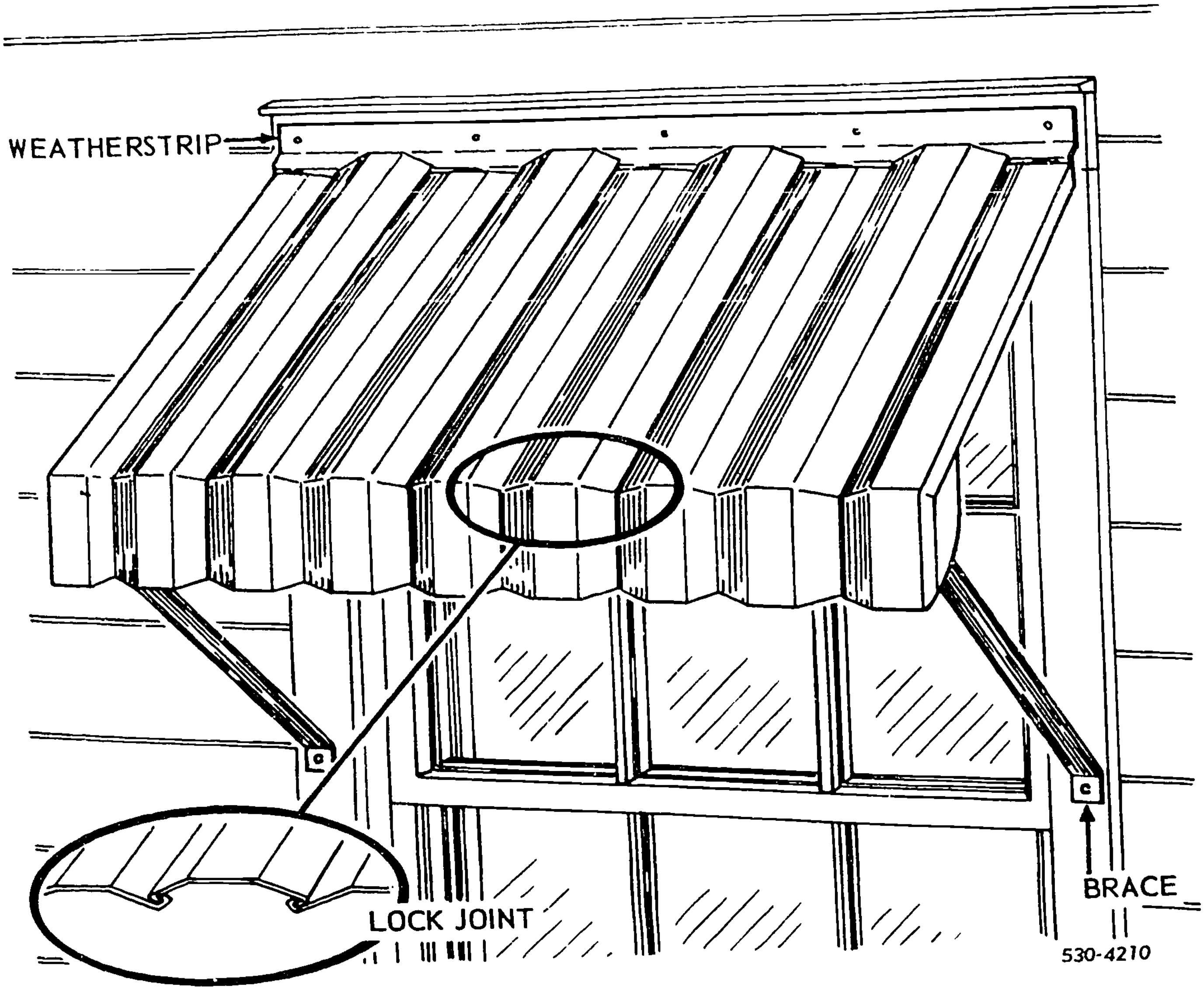

Figure 2-1. Metal awning over a window.

2. Awning panels are repaired with parts made from material of the same ____________ and ____________ as the original material.

3. What tool and what device(s) are used for installing an awning on a masonry wall?

4. What two procedures are needed to make a brace from a cut length of tubing?

2-2. Canopies

Metal canopies are similar to metal awnings but they are usually larger, and are installed over doors or entrance walks. Repair and fabrication procedures for canopies are similar to those for awnings.

609. Explain how to cut, notch, and form canopy parts.

Canopies are usually made of aluminum panels joined with standing seams or lap joints. Figure 2-2 shows a factory-made canopy installed over a door. It has standing seam roof panels with metal trim on the sides. It is supported by two corner posts made of 2-inch aluminum tubing at the front, and is fastened to the wall at the back. The canopy has a weatherstrip that extends 1 inch over the top panels to prevent water

from leaking between the walls and back of the canopy. A factory-made canopy is assembled and installed according to the instructions packed with the pieces.

Canopies can also be made in the shop. Suppose that you have a work order to make and install a canopy, such as that illustrated in figure 2-3. Notice that this canopy has a standing seam paneled roof, and hangers to support the front. The bottom of the canopy sides is perpendicular to the wall, and level; the panels have a 2-inch drop from the rear to the front. Making a canopy is like making other sheet metal items; it involves pattern layout, cutting, notching, forming, assembly, and installation.

Pattern Layout. The shape of the back trim is shown in the detail view at the left side in figure 2-3. Pattern layout for the canopy involves developing patterns like the ones shown in figure 2-4. The back trim pattern in view A is made 9 inches wide plus allowance for a ½-inch hem.

The two side patterns (view B of fig. 2-4) are develope so that the face of the trim will be 6 inches wide at the back and 4 inches wide at the front. Notice that each end has 1 inch for the corner lap seams. The bottom edge has an allowance for a ½-inch hem, and the top edge has an allowance for the pocket of a 1¼-inch standing seam.

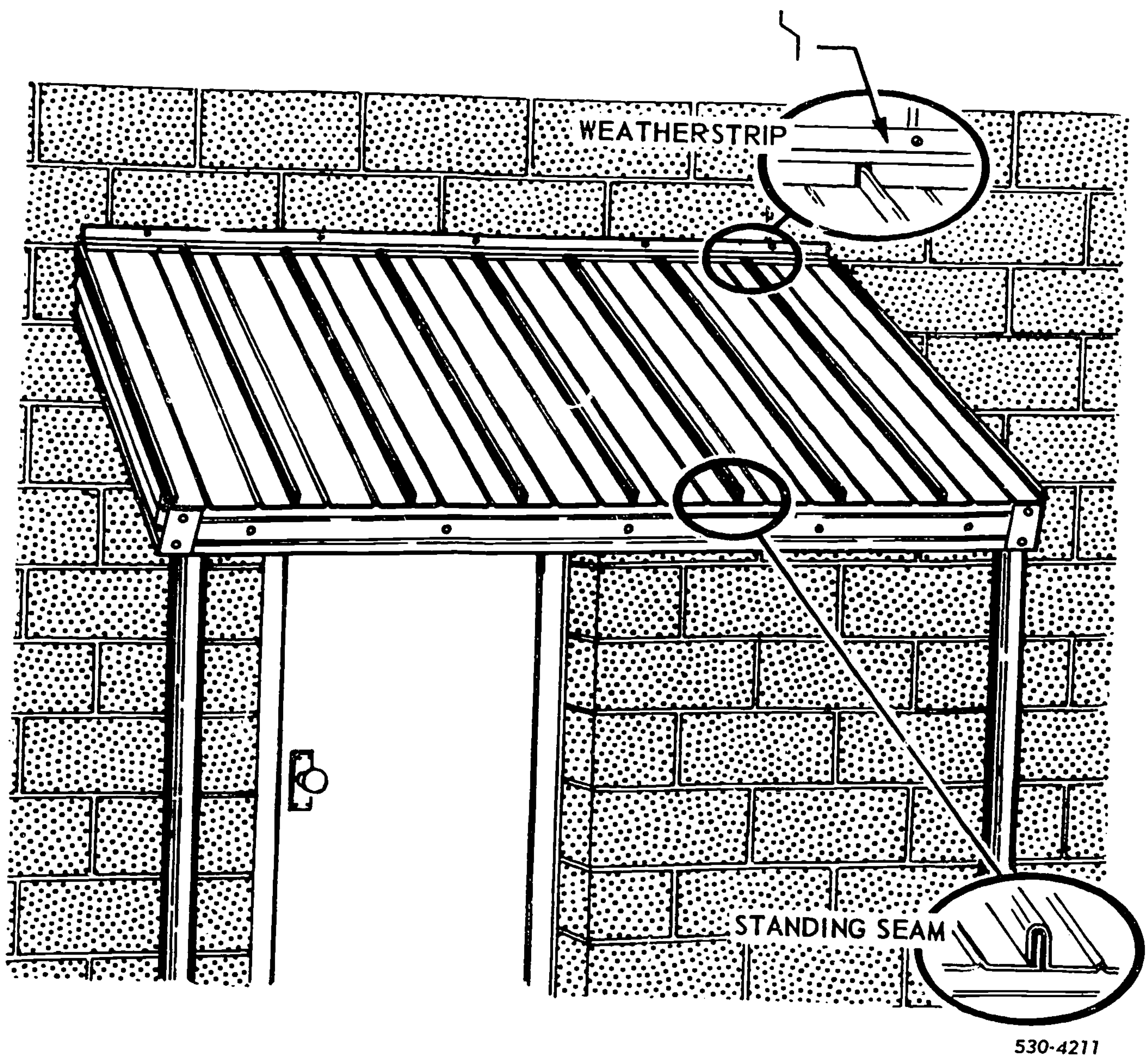

Figure 2-2. Metal canopy over a door.

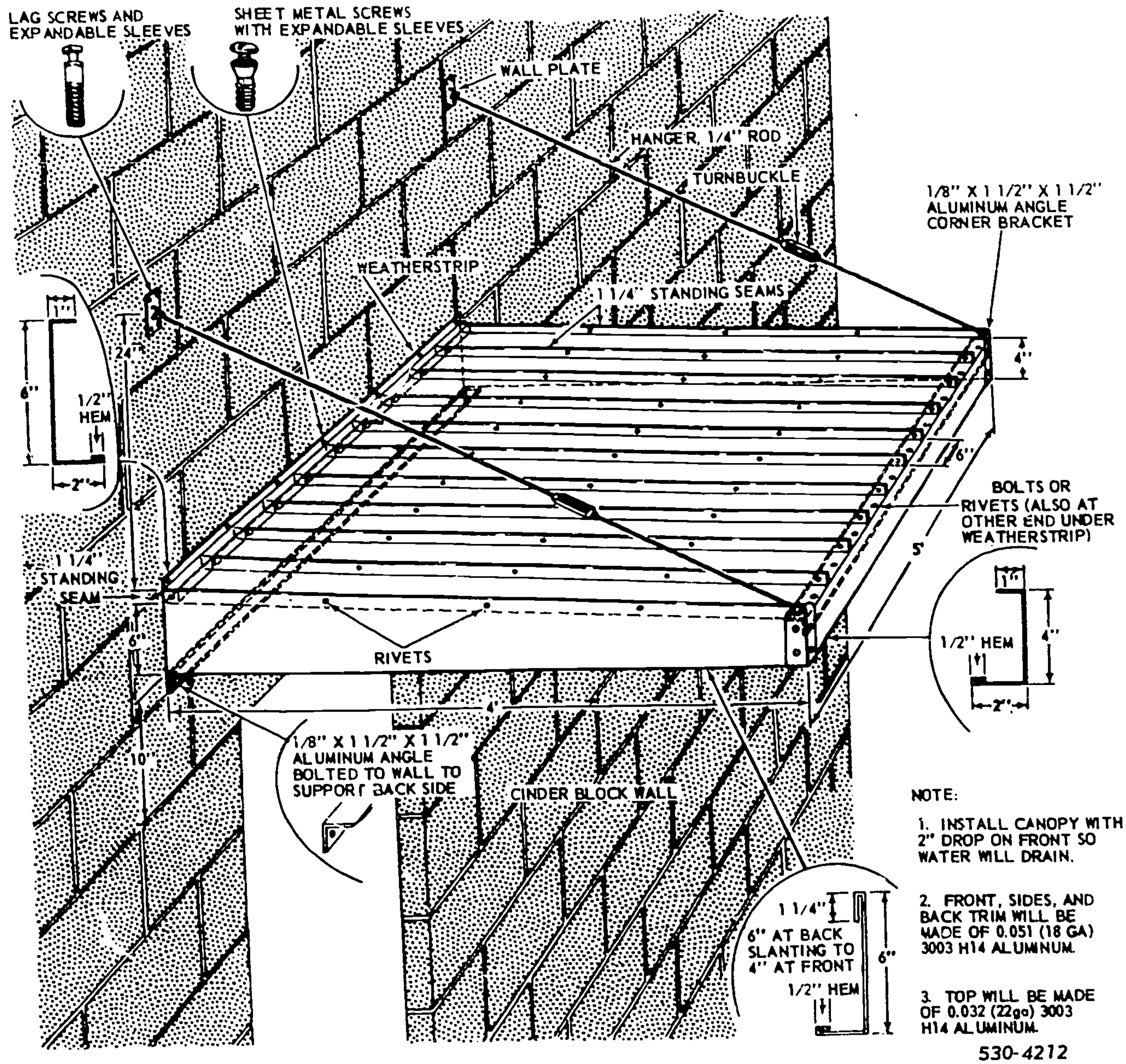

Figure 2-3. Metal canopy supported by hangers.

The front trim pattern shown in view C of figure 2-4 has a face 4 inches wide, and allowances for a ½-inch hem on the bottom edge and 1 inch on the top edge, for fastening to the top panels.

The pattern for the nine top panels in view D of figure 2-4 is 6 inches wide, plus allowances for the pocket of a 1¼-inch standing seam on one edge and the flange for a 1¼-inch standing seam on the other edge. Notice the instructions with the patterns.

The weatherstrip in view E of figure 2-4 is made into a Z-shape that measures 1" x 1" x 1¼," and is 5 feet long. The 1¼-inch allowance has slots ¼-inch wide and 1¼-inches long, cut at 6-inch intervals. The wall plate (view F of fig. 2-4) is 4 inches square and ¼ inch thick. It has an eye (a loop) to receive the hook-shaped end of the hanger rod. The eye is welded to the plate, and four 5/16-inch screw holes are drilled for ¼-inch screws. The corner brackets (G in fig. 2-4) are made of ⅛" x 1½" x 1½" angle iron, 5 inches long, with a ⅜-inch hole for the ¼-inch hanger rod.

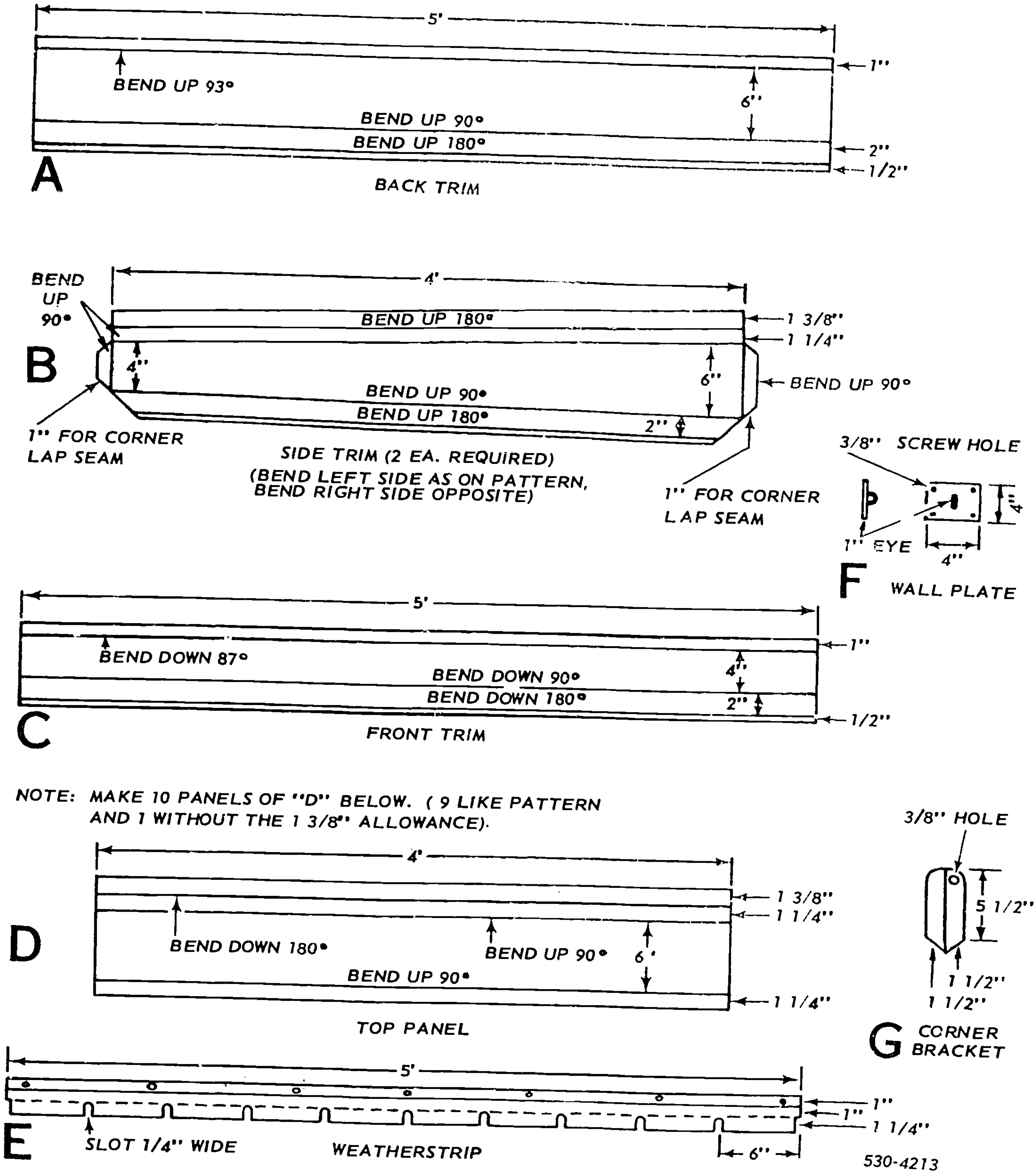

Figure 2-4. Patterns for a metal canopy supported by hangers.

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Cutting and Notching. You can cut and notch patterns A through D (fig. 2-4) on the squaring shears and with straight cut snips. Cut pattern E with the squaring shears, and notch it with straight snips; make the slots by using the rotary punch and the straight snips.

The corner brackets and wall plates (view G and F of fig. 2-4) are made in the shop. The straight cuts are made with the horizontal bandsaw, power hacksaw, or hand hacksaw The rounded end of the corner bracket is cut on the throatless shears, and is filed smooth; then the holes are drilled. The ⅜-inch hole should be drilled at least 1 ¼inches from the top edge. Remember to make two wall plates, and right and left corner brackets. The eye of the wall plate is made by welding a piece of ¼-inch rod (bent into a U-shape) to the plate. The eye should be approximately 1 inch in diameter.

Forming. Bend pieces A through E, for the canopy on the cornice brake, according to instructions on the patterns The only bends you make with a mallet are the 90° bends for the corner lap seams on the ends of the side pieces in B.

Exercises (609):

1. All but one of the top panels are cut and formed alike. What is the difference for the 10th panel? Why?

2. What tools and equipment are used to make the weatherstrip?

3. In forming the parts of a canopy, what bends are made with a mallet?

610. Name materials and procedures for the assembly, installation, and repair of canopies.

Assembly. The canopy shown in figure 2-3 is assembled by first connecting the standing seams of the top panels. You should have noted already that the 10th panel has two flanges instead of one flange and a pocket. When installing the top panels, install this 10th panel last (on the right side of the canopy, as viewed from the front). Next, position the front and back trim pieces, and rivet (or bolt) the panels as shown in the illustration. Drill rivet holes as needed, and use aluminum rivets or cadmium-plated bolts. The side pieces are slant notched on the 2-inch flange so that the corners of the assembled canopy will have a miter appearance like the corners of the hood discussed earlier in this text. When you have squared the front corners, install and rivet (or bolt) the corner braces. The last step of assembly is to install rivets at 12-inch intervals along the standing seams.

Installation. To install the canopy shown in figure 2-3, drill holes in the cinder block wall for the expandable anchor sleeves which hold the screws. The sleeves may be made of lead, plastic, or wood, and are sometimes called *anchor plugs* or shields. Inside the hole, the sleeve expands when the screw is inserted and tightened, making a secure anchor for the screw. In this example, the bottom of the canopy is installed 10 inches above the door. The canopy is bolted to a 5-foot aluminum angle piece (⅛" x 1½" x 1½") which is anchored to the wall with ¼-inch lag screws and expandable sleeves. Use the angle piece as a template, to locate the holes to be drilled. Use a masonry drill or star drill to make seven ½-inch holes. You can then securely fasten the angle piece to the wall with the lag screws side of the weatherstrip. Install the weatherstrip on the wall above the top of the angle piece so that the distance between the bottom of the slots in the weatherstrip and the top of the angle brace is about 7½ inches. This will allow the standing seams of the top panels to slide into the slots, and will allow the bottom of the back trim to rest on top of the angle piece.

Before raising the canopy, hook the hangers into the eyes of the wall brackets. The task of raising the canopy into position will probably require two or three workers, depending on the situation. If a scaffold is being used, the canopy can be placed on the scaffold and then positioned at the desired angles.

When the hangers are hooked, level the canopy by adjusting the turnbuckles. After leveling, drill holes through the aluminum angle piece and through the bottom edge of the back trim piece, and bolt the two pieces together.

Repair. Repair of canopies like the one in figure 2-3 is somewhat similar to the repair of awnings. Usually, the damage is caused by hail or wind. Suppose the fourth panel from the right side of the top (as viewed in the illustration) has a 1-inch hole in it. To make the repair, cut out around the damaged area, and cut out two patches of the same type and gage of metal as the awning. The patches should overlap 1 inch on all sides of the hole. One of the patches is for the top, and one is for underneath.

The thickness of the patches determines the size of rivets to use for the repair. Once they are determined, you can punch or drill one patch and use it as a template to punch the other patch. You will need a hand dolly, rivet set, Clecos, Cleco pliers (forceps), tinner's riveting hammer, portable electric drill, extension cord, twist drill, and aluminum rivets.

You must seal the top patch when you put it on the panel. Use zinc chromate tape or roll type calking; if the are not available, you can use calking compound from a tub and spread it with a putty knife.

To install the patch, apply the sealant on the top of the panel around the hole. Lay the top patch over the hole so that a 1-inch lap is obtained around the hole. Drill the holes, and install the bottom patch in alignment with the other holes. You can hold the patches in place with the Clecos while you drill the holes and install the rivets. After the rivets have been

installed, remove any excess sealant around the patch. This leaves a neat job.

For a second example of canopy repair, suppose the second panel from the right side of the canopy shown in figure 2-3 needs replacing. Remove the weatherstrip first. Next, drill out the rivets on both sides of the standing seams, and remove the screws on the second panel and the panels on each side of the second panel.

Once the screws are removed, slip the old panel out of the standing seams. Make a replacement panel like the one shown in view D of figure 2-4. Place the new panel into position and connect the standing seams. After the new panel is in place, drill the holes for fastening to the flanges of the back and front trip pieces. Replace the rivets that were drilled out of the standing seam. Since the weatherstrip has been removed, remove the old calking and apply new calking. Then position and refasten the weatherstrip to the wall.

Exercises (610):

1. When you are assembling a canopy, which top panel do you install last?

2. For installing a canopy, what is the sequence of step to secure and level the canopy?

3. What new material is needed to perform a top panel replacement (in addition to a new panel)?

Metal Roof Parts

IN THIS CHAPTER, we will discuss the fabrication, installation, and repair of roofing, flashing, gutters, and downspouts; these are available in different shapes and designs They may be made of galvanized iron, aluminum, or copper. Metal flashing is used with all types of roofing (metal, shingle, and asphalt) to weatherproof the joints, valleys, eaves, gables, and ridges. Gutters are installed under the eaves of buildings to collect rainwater from the roofs, and downspouts are the vertical pipes which carry the rainwater from the gutters to the ground.

The discussions include types of roofing, seams, and special tools; types of flashing, such as valley, fascia, gable, eave, ridge, and base; and components of gutters and downspouts.

Knowing the information in this chapter will help you to do better work when you are assigned jobs that involve roofing, flashing and downspouts. The examples discussed in this chapter are similar to the jobs you will be expected to do as a sheet metalworker.

3-1. Metal Roofing

Metal roofing is made of different kinds of metal, such as copper, aluminum, and galvanized iron. Let's briefly review some of the characteristics of metal that are important for roofing, flashing, gutters, and downspouts.

611. Name some metal roofing materials and their characteristics.

Copper, aluminum, and iron expand when they are exposed to heat. They contract when exposed to cold. An 8-foot sheet of copper will expand or contract as much as 9/64 inch, aluminum will expand or contract as much as 3/16 inch, and iron as much as 3/32 inch. Thus, you car see that seasonal effects have some bearing on the installation of metal roofs. For *example*, when you are installing metal roofs in cold weather, you will make provisions for considerable expansion but for very little contraction.

Briefly described, galvanic action is the reaction between dissimilar metals that produces an electric current; unfortunately, it also eats away one of the metals. Because of galvanic action that occurs when dissimi metals come in contact with one another, you should avoid joining different metals. If you must join them, use a layer of waterproof building paper, a layer of asphaltsaturated felt, or a coating of asphalt paint between the two metals.

Types of Metal Roofing Material. Copper, aluminum, and galvanized iron are the metals often used as roofing material to cover buildings. These types may be purchased in different shapes, such as those shown in figure 3-1. (Flat sheets are also used to cover roofs, but are not illustrated.)

Copper sheets. Copper sheets used in roof ng are usually 0.022 inch thick. Copper sheet thicknesses are designated by ounces per square foot; therefore, 0.022 inch thick is 16-ounce copper. Copper roofs are usually installed with grooved flat seams, batten seams, or standing seams with cleats fastened to the roof deck and formed into the seam. One advantage of a copper roof is that it lasts longer because of its resistance to corrosion. When new copper sheets are exposed to the atmosphere, a coating of oxide forms (it is called *patina*). It aids in making the surface resistant to further corrosion. Fasten copper with nails, screws, or bolts made of brass or bronze.

Aluminum sheets. Aluminum sheets used in roofing may be flat, corrugated, or double-rib. The corrugated and double-rib aluminum sheets are stronger than flat sheets or 5V-crimp, and are often used to cover roofs that do not have a solid deck underneath. The corrugated and doublerib sheets have other advantages over flat sheets in that they help to drain water from the roof, and the seams do not require soldering. Fasten aluminum with nails, screws, or bolts made of aluminum, cadmium-plated steel, or stainless steel.

Galvanized iron sheets. The galvanized sheets used on roofs may be flat, corrugated, or 5V-crimp. Galvanized sheet iron does not have as much resistance to corrosion as aluminum or copper, but it is very good for covering roofs. Two advantages that galvanized sheets have over aluminum and copper are lower cost and greater strength. Properly installed, galvanized metal roofs will render satisfactory service. They are often installed on sheds and warehouses. Fasten galvanized iron with nails, screws, or bolts, made of cadmium-plated steel.

Exercises (611):

1. What occurs when two dissimilar roofing metals are placed together?

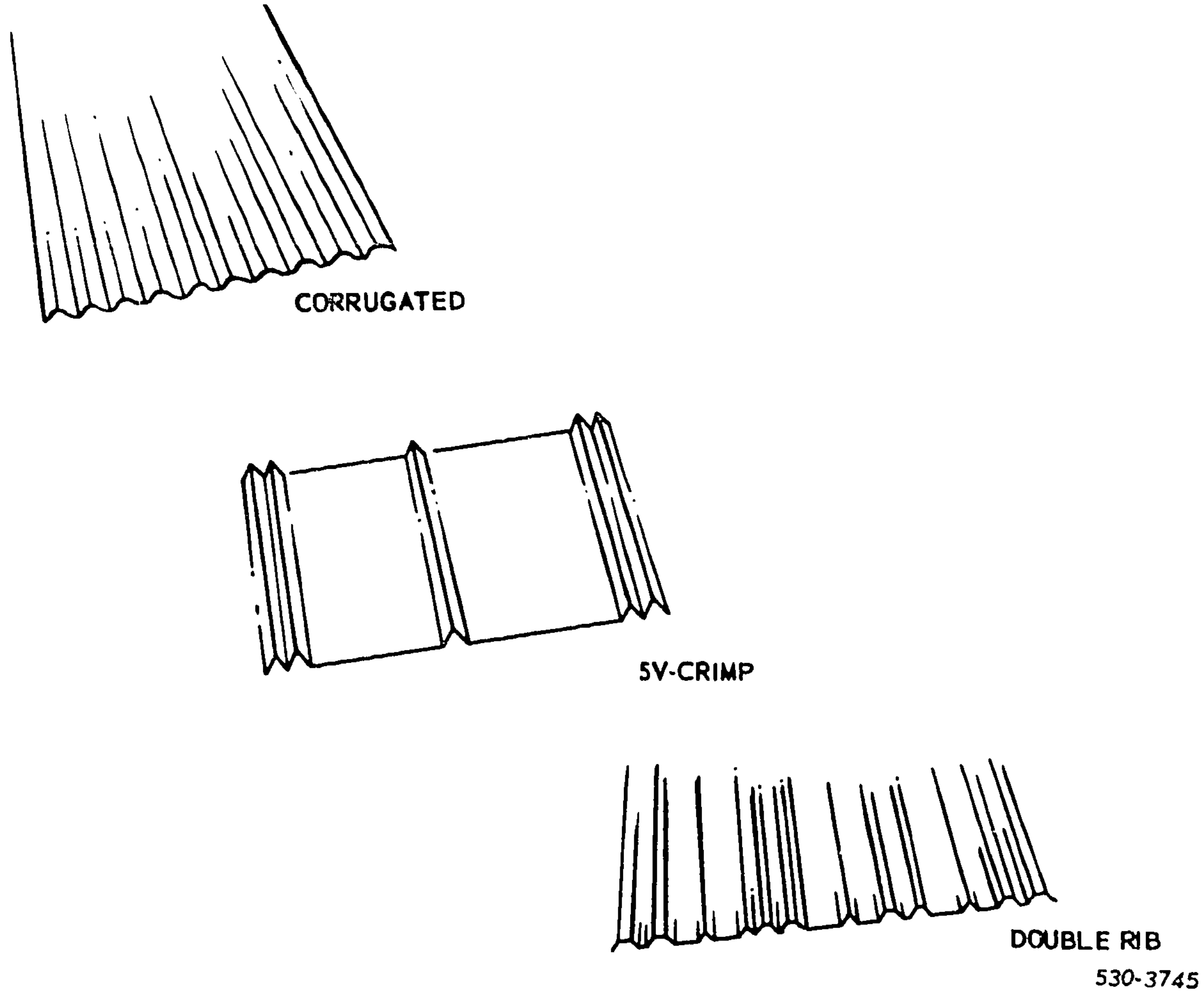


Figure 3-1. Shapes of metal roofing.

2. What three types of metals are commonly used for roofing, and which one should you NOT fasten with cadmium-plated steel nails?

3. What aids copper roofing in making the surface resistant to corrosion?

4. What are the advantages of galvanized sheets over copper or aluminum sheets?

612. State when roofing seams should not be used, state the difference between a standing seam and a roofing standing seam, and specify techniques for making seams used on metal roofs.

Seams Used with Metal Roofing. Seams used with metal roofing are similar to those used in other sheet metal fabrication; however, the way some of them are made and used will vary.

In figure 3-2, some of the names of parts of a roof are shown. Where two *ridges* join at an angle of less than 180°, a *valley* is formed. The slope of a roof is known as its *pitch*. Seams running parallel to the roof slope (pitch) are called *parallel seams*. The seams running across the slope are called *cross seams*. When cross seams are necessary to join the sheets (fig. 3-2), use a grooved seam. These grooved cross seams are seldom soldered, but if they are, make allowance for expansion and contraction at the eave or ridge.

Roofing standing seams. Roofing standing seams are generally used with flat sheets on pitched roofs. These seams are not soldered and, therefore, should not be used with a roof having a slope of less than 3 inches to the foot. A roof slope of 4 inches or more (to the foot) is desirable. Standing seams allow for expansion and contraction if you leave a 1/16-inch space (step B of fig. 3-3). Fasten the metal to the roof with cleats that are spaced 12 inches apart. Nail the cleat to the roof so that the upright part of the cleat is flush against the 90° flange of the preceding sheet. After nailing the cleat to the roof, bend the remaining flat part of the cleat over the nail heads. This prevents the heads from working through the top sheet that is to be installed next.

As in step B of figure 3-3, place the second sheet to be installed. It also has a flange turned up 90°, but, this flange extends above the flange on the first sheet. Bend this longer flange over the shorter flange to form the standing seam. In step C, you can see how this 90° bend is started. In step D, bend the metal to 180° to form the standing seam. In steps E and F, you can see how to bend the standing seam another 180° to complete the double seam.

Roofing grooved (flat) seams. The roofing grooved seam (flat seam) is adaptable for roofs that have very little pitch (less than 3-inch slope to the foot). This seam is normally used when installing 14" x 20" sheets. Fasten the sheets to the roof deck with cleats spaced 12 inches apart. Nail the cleats to the roof deck and then form them into the grooved seam. In figure 3-4, you can see how metal sheets are fastened to a roof with cleats. In figure 3-5, step A shows a small section of a metal roof panel with a cleat installed. To install the cleat, insert the bent end of the cleat into the pocket formed by the upturned flange of a roofing panel. After the cleat has been pulled tight and the panel is locked into the other roof panels, nail the cleat to the roof deck and turn the end back over the nailhead. This prevents the nail from backing out and causing damage to the roof. You will then install the next panel, which covers the cleat as shown in figure 3-5, step B.

Roofing lap seams. Roofing lap seams are used to install corrugated, 5V-crimp, or rib sheets, on a roof. The lap seams used in roofing are somewhat different from those in other fabrication because the seams are lapped more. When installing corrugated, rib, or 5V-crimp sheets, you must consistently use a definite number of sidelaps.

Notice that view A of figure 3-6 points out the crowns and valleys of a corrugated sheet. A sidelap of 1½-corrugations means that one crown and one valley are lapped In view B, you can see a 1½ corrugation-sidelap. In view C, there is a 2 corrugation sidelap (notice that two crowns and one valley are lapped). In view D, there is a single sidelap on V-crimp roofing sheets, and one crown is covered. In view E, there is a 2-corrugation sidelap where both crowns and one valley are covered. Sidelaps on corrugated sheets should nevver be less than 2 corrugations. Sidelaps for V-crimp and rib sheets should not be less than 1 corrugation.

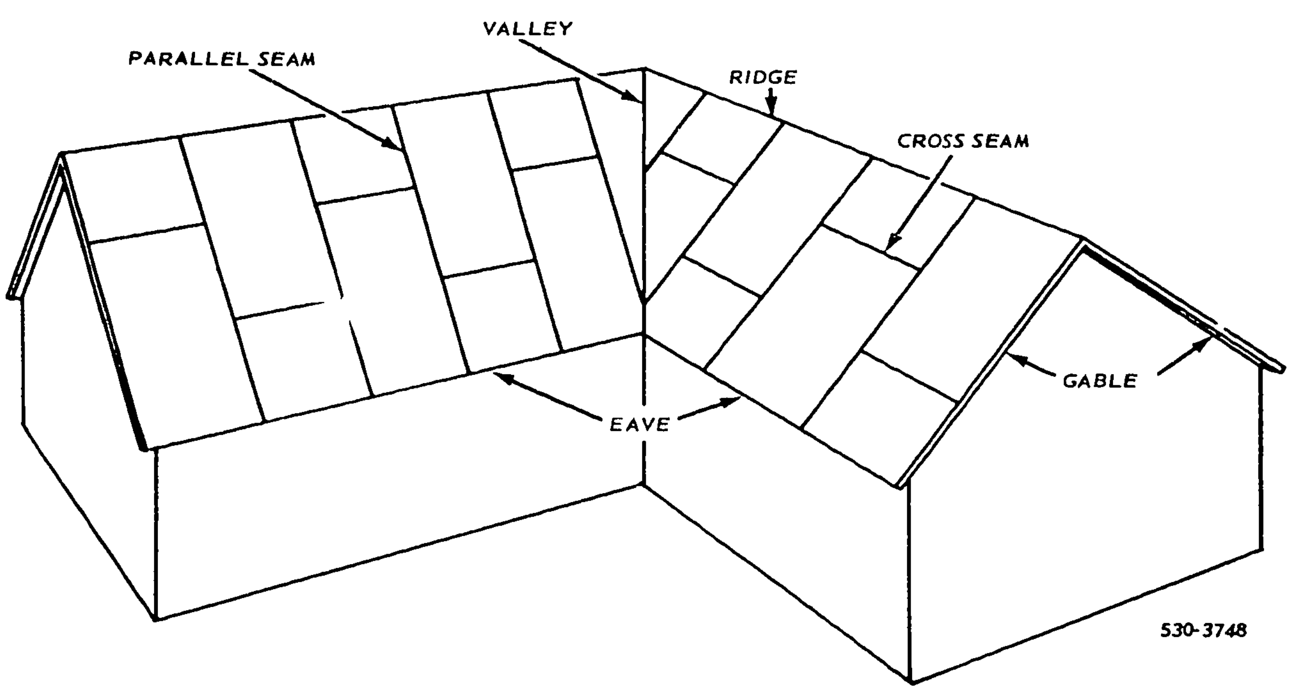


Figure 3-2. Parts of a roof.

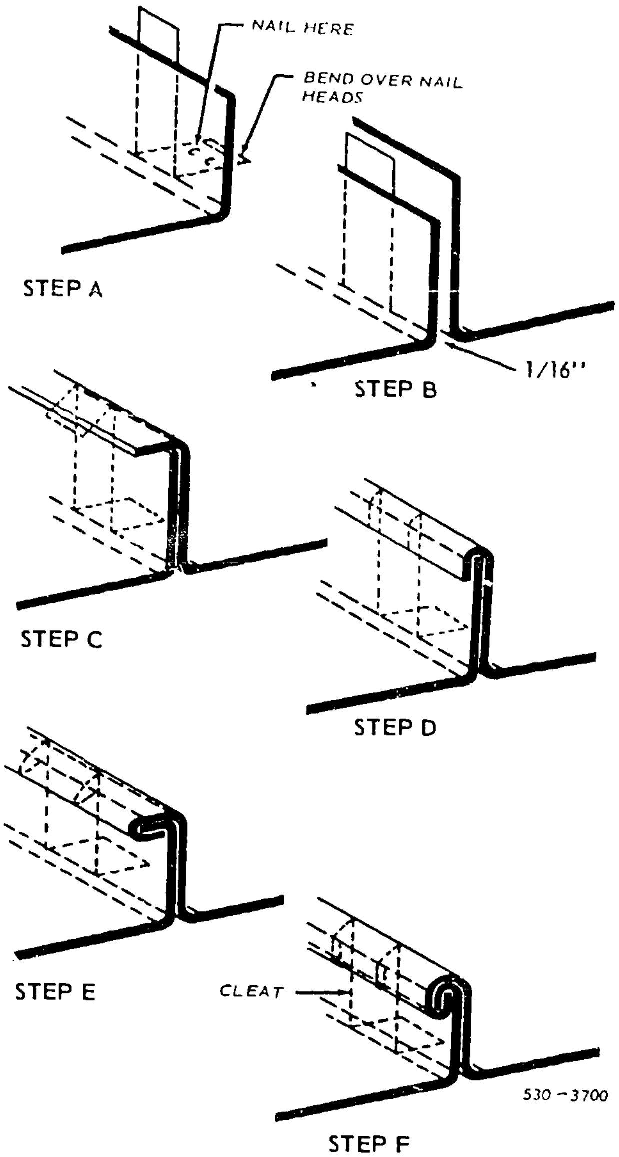


Figure 3-3. Roof standing seam.

Roofing batten seams. Roofing batten seams (see fig. 3-7) are formed over battens made of wood. (A batten is a strip of wood nailed to the deck of a roof.) Batten seams run parallel to the slope of the roof and allow the metal to expand and contract.

Cleats are used to fasten the roofing to the batten in somewhat the same way as the cleats used for standing and grooved (flat) seams. In step A of figure 3-7, you can see the cleats nailed to a batten. Step B shows the metal sheet formed 90° and placed along the right side of the batten. Step C shows how you form the metal along both sides of the batten and bend the tabs over one edge of each channel. Make a cap piece into a channel and place it over the batten, as shown in step D. Turn both edges 90° to make a single seam, as shown on the right side of step D. After this single seam is made, make another seam, as shown in step E.

Exercises (612):

1. Roofing standing seams should *not* be used on roofs that have less than ____________ slope to the ____________.

2. What is the main difference between a *standing seam* and a *roofing* standing seam?

3. How is a flat seam roof held to the roof deck, and what is used to seal the roof?

4. Name three types ("shapes") of roofing materials that are installed with the lap seam.

5. "Before making any roofing seam, you nail cleats to the roof deck". Why is that statement false?

613. Explain the use of special tools used on metal roofing.

Special Tools Used with Metal Roofing. Special tools used to form roofing seams may be classified into three types: roofing seamers, roofing tongs, and roofing folders. The availability of these tools in your sheet metal shop depends upon the organization of your maintenance and repair branch and upon local requirements. Some branches have a roofing crew which may work under the sheet metal shop and which should have the necessary roofing tools.

Roofing seamers. Roofing seamers look somewhat like the hand seamer discussed earlier in this course. View A in figure 3-8 shows a conventional seamer, which is used to turn edges on metal for making roofing seams. It is available in different sizes, turning seams from ½ inch to 2 inches wide. Conventional seamers are not adjustable and the correct size seamer is required for making seams. The adjustable seamer, shown in view B of figure 3-8, can be used to turn the edges for seams ¾ inch to 3 inches wide. The adjustment is made by loosening the wing nuts on each side of the blade.

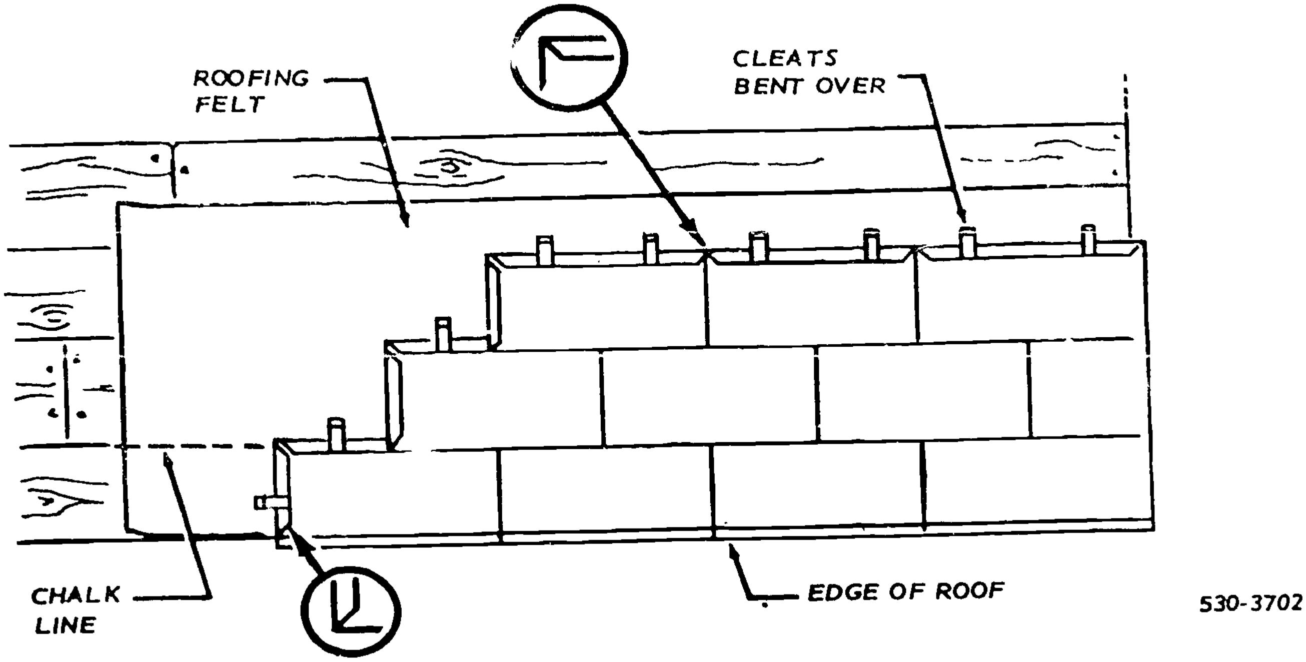


Figure 3-4. Metal roofing installed with cleats.

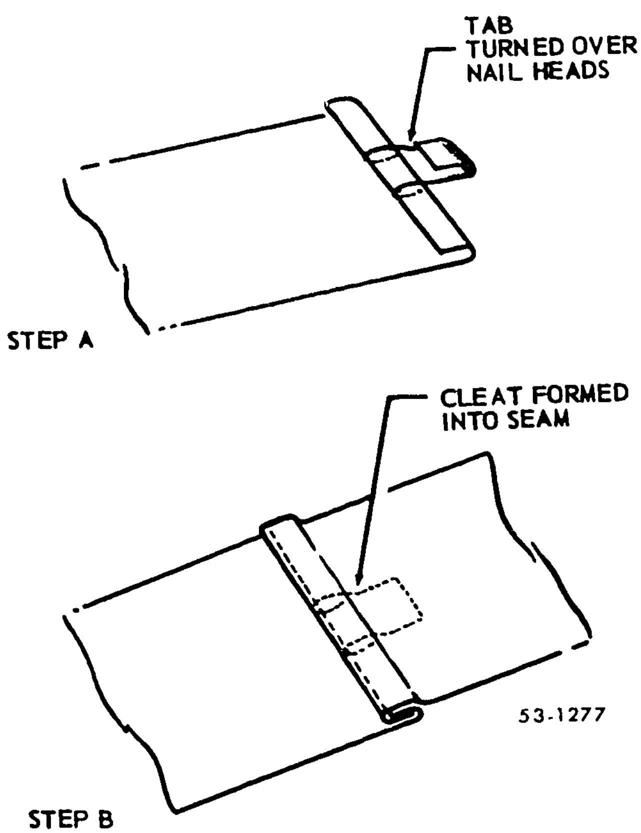


Figure 3-5. Installing a cleat in a grooved (flat) seam.

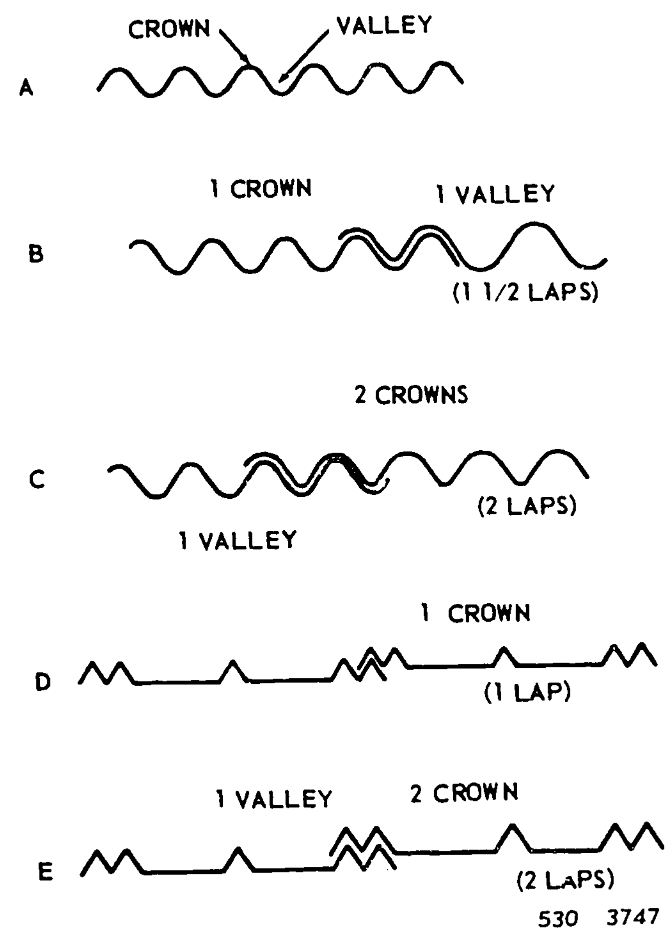


Figure 3-6. Sidelaps used with metal roofing.

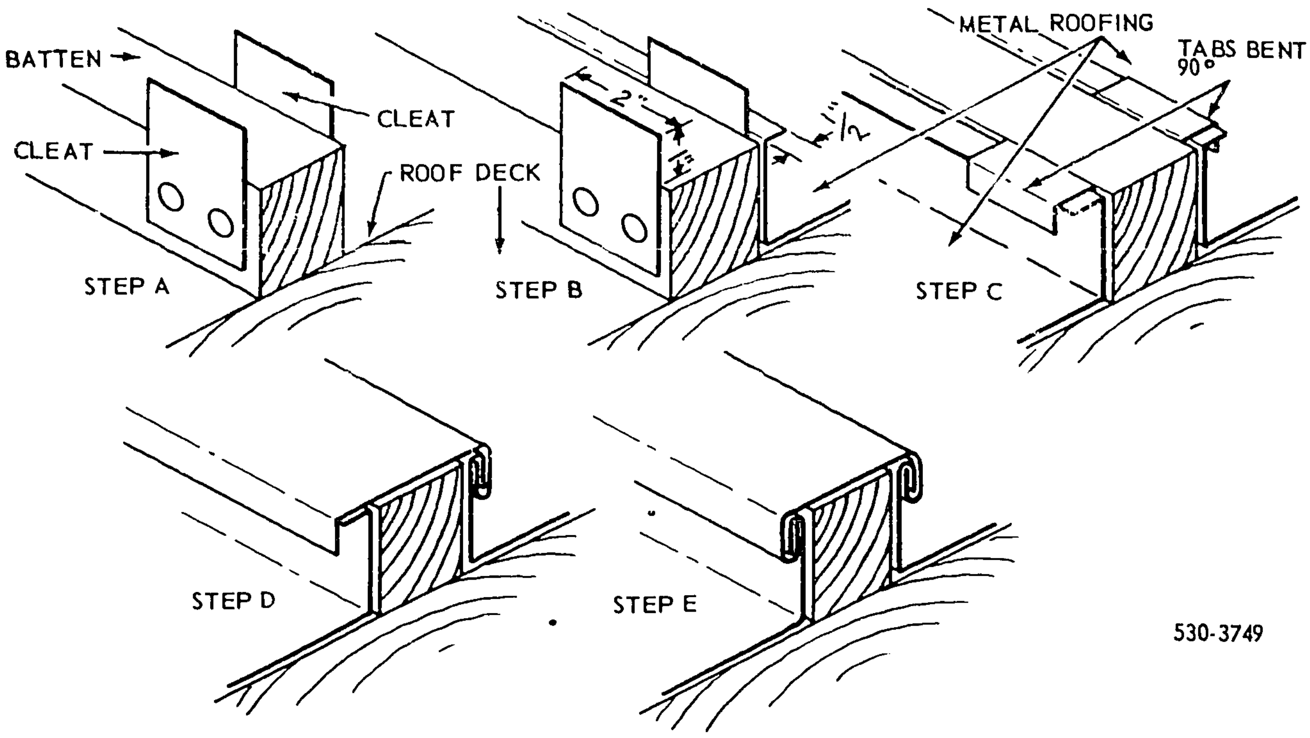


Figure 3-7. Making a batten seam.

The double seamer, shown in view C of figure 3-8, is used to make double seams from standing seams (see fig. 3-3). The bends are made with the folding jaws, and the edges are flattened with the squeezing jaws. These double seamers are available in two sizes. The common gage size is used to make ¾-inch standing seams. The double seamer folds the metal ¾ inch (or 1 inch) above the 90° flanges. The flanges, as shown in steps C and D, show that this bend is different from a standard standing seam because of the length of the material being bent.

The hand double seaming dolly, shown in view D of figure 3-8, acts as a backer when you're making a double seam on a standing seam. Place the seamer against the opposite side of the standing seam, and use a mallet to turn the edge. The double seamer in view C has a definite advantage over the one in view D because the seaming process can be done much faster with the dual-purpose tool.

Roofing tongs. Clamping tongs (fig. 3-9) are used to clamp seams to hold them in place. The ring on one handle can be slipped over the other handle to keep the jaws tight. This clamps the metal while you continue working. Use the squeezing tongs (fig. 3-9) to tighten seams. For *example*, they can be used to tighten the pocket of a standing seam before you make a double seam or grooved seam, if a double seamer is not available.

Roofing folders. Roofing folders, such as those (fig. 3-10) are used to turn edges for a grooved (flat seam roof. These folders operate somewhat like a bar folder. They have slots to prevent flattening of the edges that have already been turned. The common folder in view A is available in lengths of 14, 20, 28, and 30 inches. It turns an edge of 5/16 inch in thickness. The adjustable folder in view B has a gage that can be set to form 3/16- and 3/8-inch edges. Each of these folders has a bed, a bending leaf, and an operating handle. To form an edge, insert the metal into the folder and pull the handle forward, as if using a bar folder.

Exercises (613):

1. What are double seamers used for?

2. What tool do you use with the double seaming dolly?

3. Name the two types of roofing tongs, and explain the use of each.

4. What type of roofing seam is formed with a roofing solder?

614. State steps and procedures for installing metal roofs.

Installation of Metal Roofing. Installation of metal roofing involves the seams, tools, and fastening methods we have discussed in the preceding paragraphs. Now let's see how metal roofing is installed.

Installing a roof with lap seams. lap seams are used when roofing sheets are made of corrugated, V-crimp, or ribbed metal. Figure 3-11 shows a corrugated roof installed with lap seams. Endlaps are used so that the metal will lap over the top of the previous sheet in the direction of water flow. Sidelaps are made so that the metal will lap over in the direction of the prevailing wind.

To lay corrugated roofing, such as is shown in figure 3-11, start with sheet A. (NOTE: In this *example*, sheet A is used because it is downwind from the prevailing wind.) Position sheet A and fasten it to the purlins with the No. 14 x 1¾" self-tapping screws, except where it will join the laps of sheets B, C, and E. Lay sheet B over sheet A to make a 1½-corrugation sidel and fasten it to the purlins just as you did sheet A. Fasten the sidelap with No. 12 x ¾" self-tapping screws. Be very cautious when you are laying the sheets; stay on sheet A, and close to a purlin where the metal is rigid, and remember that the first row must not overlap the second row.

Next, lay sheet C so that you have an endlap of 6 inches. Fasten sheets A and C to the purlins with No. 14 x 1¾" self-tapping screws, except where sheet E is to overlap. Then, lay sheet D and fasten it to the purlins. Lay sheet E over sheet C to make a 1½-corrugation sidelap, and lay it over sheet B to make a 6-inch endlap. Continue this operation until you reach an expansion

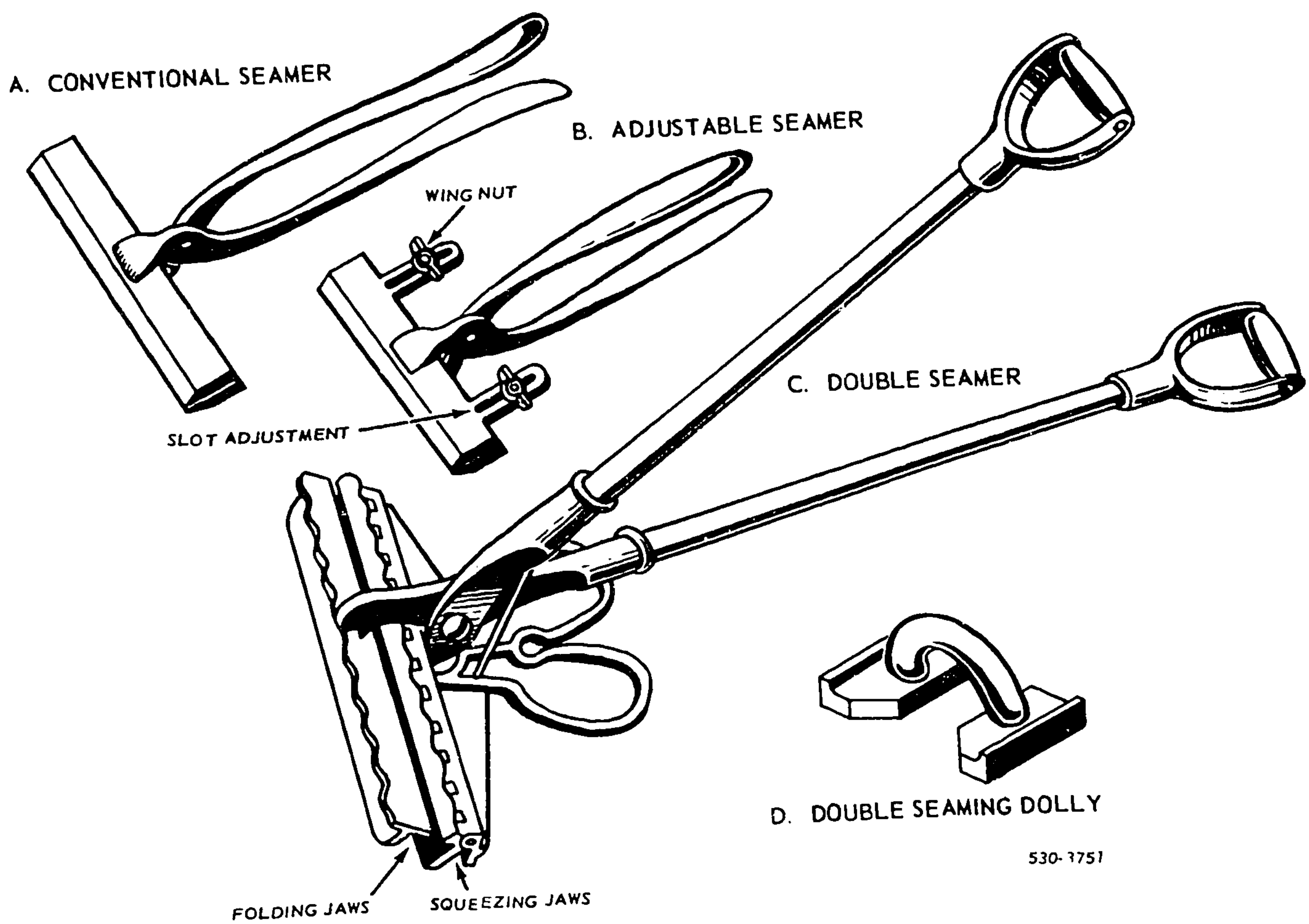


Figure 3-8. Roofing seamers and dolly.

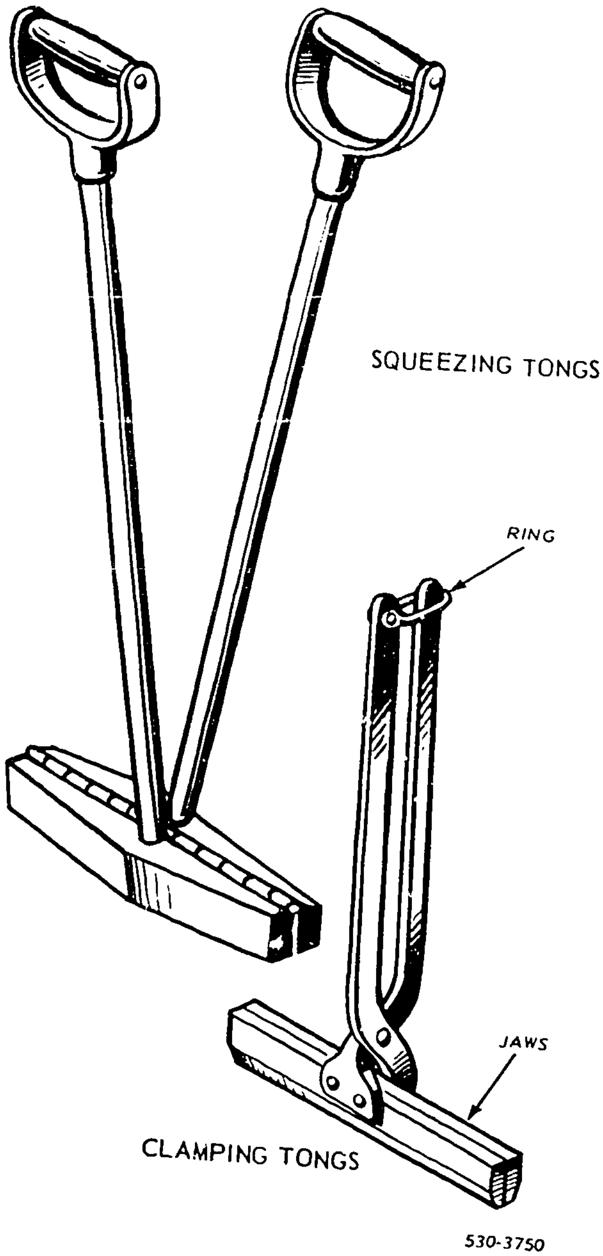


Figure 3-9. Roofing tongs.

joint. The installation procedure for V-crimp or ribbed sheet metal is the same as for corrugated sheet metal.

An expansion joint may be made like the one shown in view A for figure 3-12. This is an end view of an expansion joint which runs the full length of the roof slope. To install the expansion joint, fasten the flashing to the corrugated roofing with sheet metal screws spaced 12 inche apart. Use washers with the screws to prevent water seepage around the heads. After the flashing is fastened to the roofing sheets, install the cap over the flange. Notice that the cap has a slight pitch so that water will run off.

The flashing in view B of figure 3-12 is for the gable edge of a roof. This is also an end view of the flashing. Seam the gable flashing to the wall flashing, and fasten it to the roof with sheet metal screws. Install the flashing so that it overlaps in the direction of the roof slope. Notice the drip edge on the gable flashing where it overlaps the corrugated roofing. This drip edge allows the water to run into the valley of the corrugated metal and off the roof.

Ridge caps, illustrated in view C of figure 3-12, are used to seal the ridge of a roof. They are installed after the roof is laid. The ridge cap in view C-1 is shop made, and it extends over the ridge 7¼ inches. The cap shown in view C-2 is factory made and has a rolled edge on the top. The factory cap usually extends over the ridge about 7¼ inches on each side. Install both cap strips with sheet metal screws and a rubber closure strip. One edge of the closure strip is cut out for corrugations. Set this edge on the corrugated metal so that the cap strip will rest on the flat edge, opposite to the cutout. In view D of figure 3-12, you can see a cap that is installed with a closure strip. The sheet metal screws or bolts pass through the ridge cap and closure strip and into the corrugated initial roof.

Installing a roof with grooved (flat) seams. Grooved seams, sometimes called *flat seams*, are normally used on roofs that have a low pitch (½ inch to 3 inches). The

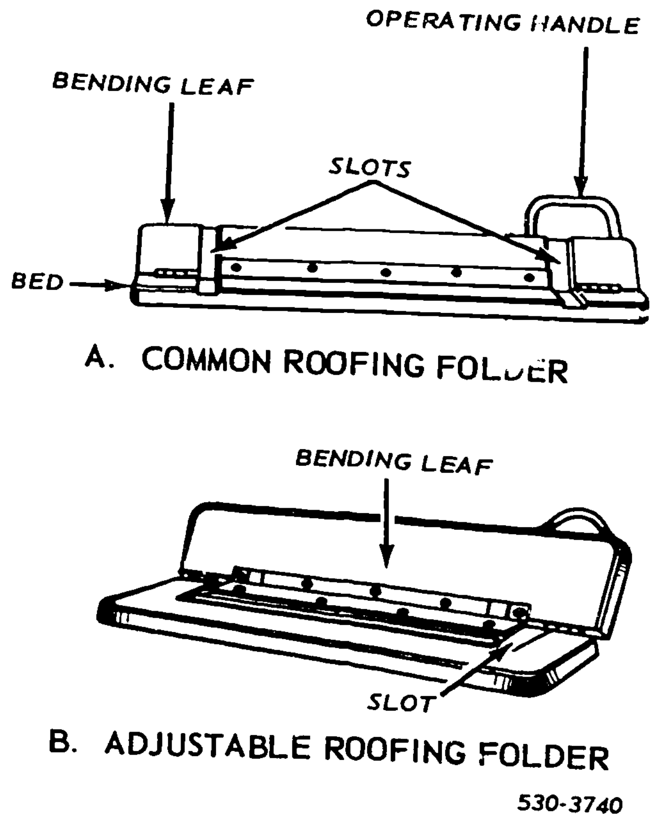


Figure 3-10. Roofing folders.

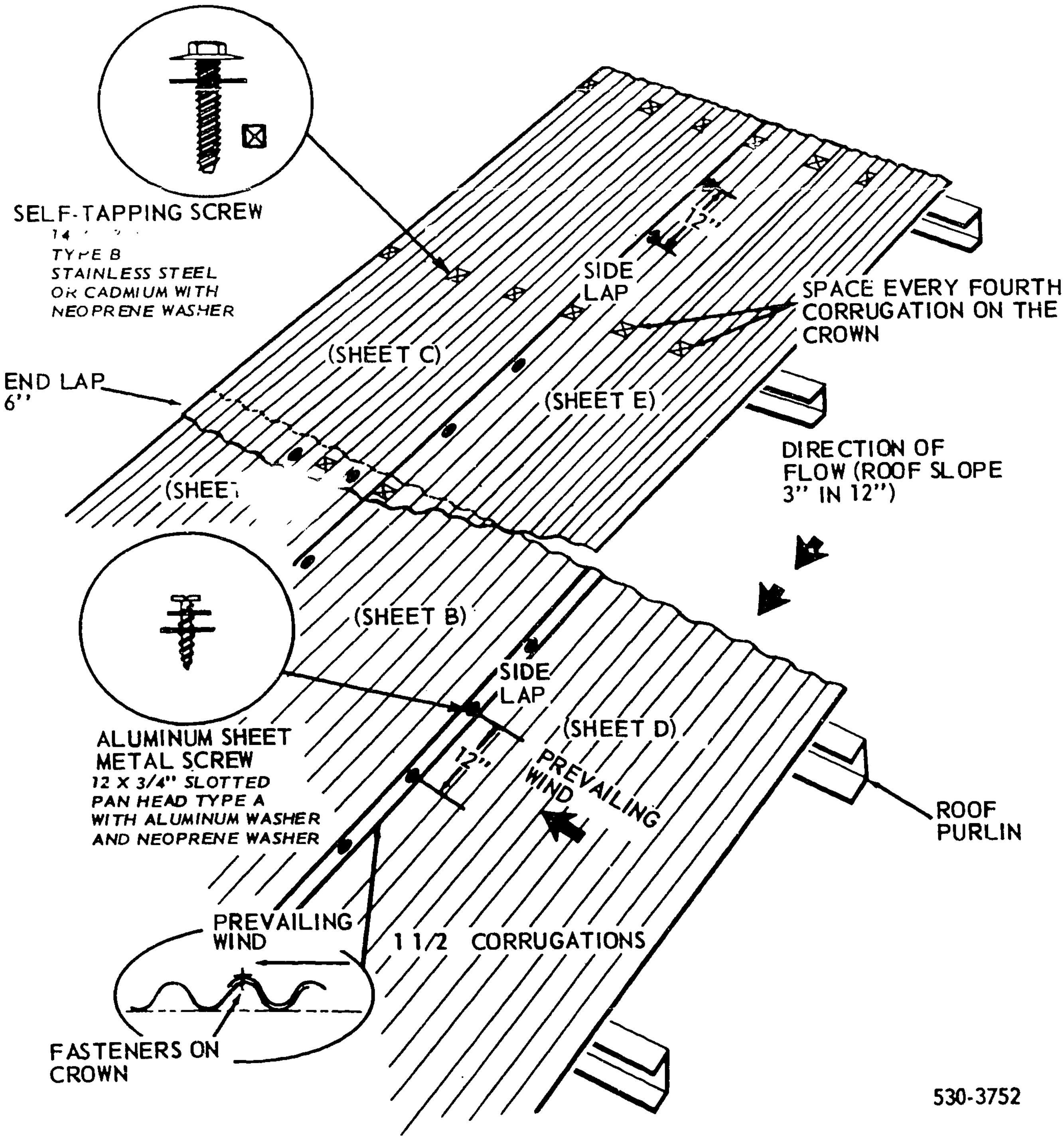


Figure 3-11. Installing a corrugated roof with lap seams.

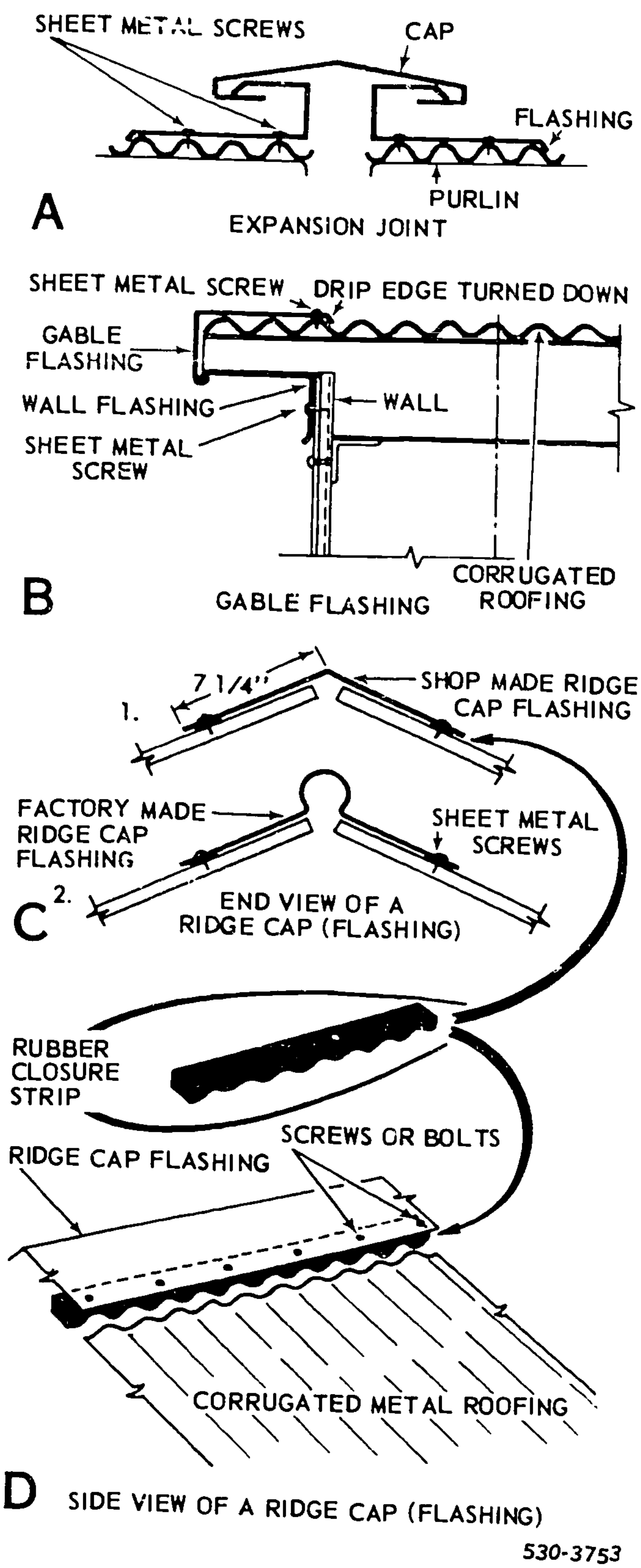


Figure 3-12. Installing roofing joints and sealers.

roof shown in figure 3-4 is installed with flat seams and cleats. When cutting and notching, make sure that you get a good notch; otherwise, a good solder joint will be hard to make. A good notch is shown in view A of figure 3-13. It looks like view B after the edges are turned. Notice that two edges are turned up and two are turned down. This allows the "down" edges to be hooked over the "up" edges, as shown in figure 3-4.

When laying a flat seam, nail the eave and gable strips as shown in views C and D of figure 3-13. Install the flashing for the eave with cleats and a continuous strip, as shown in view C. Do not nail the flashing to the roof deck. Notice that a ¾-inch pocket is turned over the strip. After the eave flashing is installed, insert the flat sheet into the pockets of the flashing with two edges turned down. View D shows the gable edge. Lap the sheet and grooved (flat) seam over the gable, and a ¾-inch pocket is turned When covered this way, the roof deck eaves and gables are sealed from moisture.

When the flat sheets are installed on a roof, as shown in figure 3-4, make sure that the cleats are spaced correctly and that the seams are well grooved. Flatten them with a mallet and set the grooves with a hand groover. Cover the entire roof to within 7¼ inches of the ridge (view E of fig. 3-13). The ridge cap can be cut and formed in the shop, with squaring shears and a cornice brake. Make the ridge cap in two halves: one half with the allowance for a standing seam pocket and the other half with a flange The other edges of both halves are turned down for a groove (flat) seam.

Fasten the roof cap to the roof deck with cleats. Insert the grooved (flat) seam edges of the ridge cap halves into the pockets of the roofing sheets, and flatten the seams. Using a double seamer, turn and flatten the pocket for the standing seam on the ridge in the same way as for the seam shown in figure 3-3. However, you must use a conventional seamer and a mallet to fold the seam completely over in (view E of fig.3-13).

All the seams on a grooved (flat) seam roof with less than a 3-inch slope are soldered, usually with 50/50 bar solder. You will need solder, flux, soldering coppers, and a firepoot. Carefully sweat the solder into the seams to insure a well- sealed joint.

Installing a roof with standing seams. Procedures for installing a roof with standing seams are shown in figure 3-14. View A shows that the deck is covered with roofing felt, and some of the sheets are installed with double lock standing seams like the seams shown back in figure 3-3.

In view B of figure 3-14, you can see how the eave flashing is installed to prevent leaks. The continuous eave strip in this example is formed into a Z-shape and nailed to the roof deck; it extends over the eave ¾ inch. Place the metal roofing on the deck so that a ¾-inch pocket can be formed over the ¾ inch of the eave strip that extends past the eave edge. Turn the ends of the standing seams 180° and flatten them, to prevent leaks.

Flashing for the gable edge is shown in view C of figure 3-14. Cut a strip as long as the entire length of

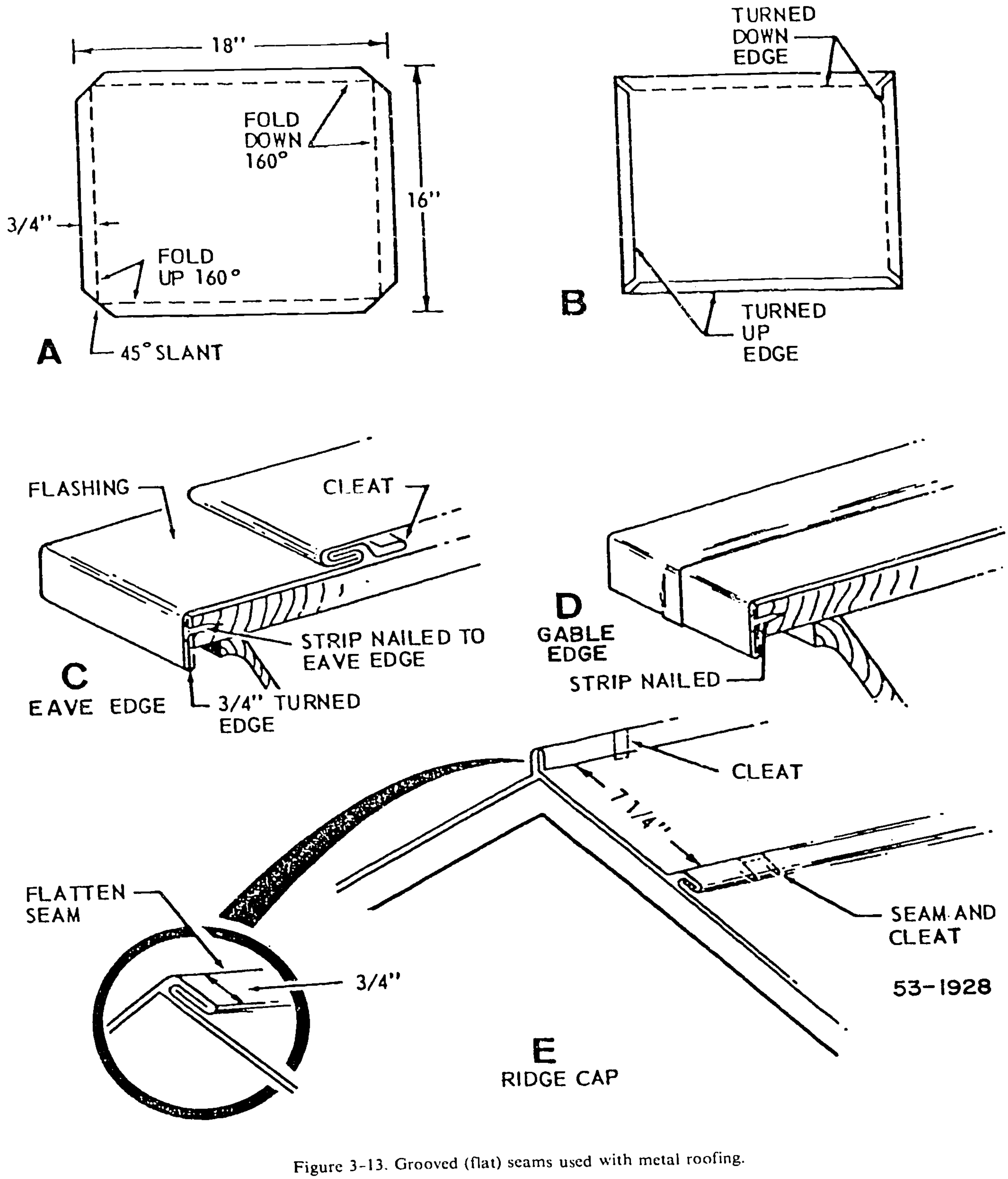


Figure 3-13. Grooved (flat) seams used with metal roofing.

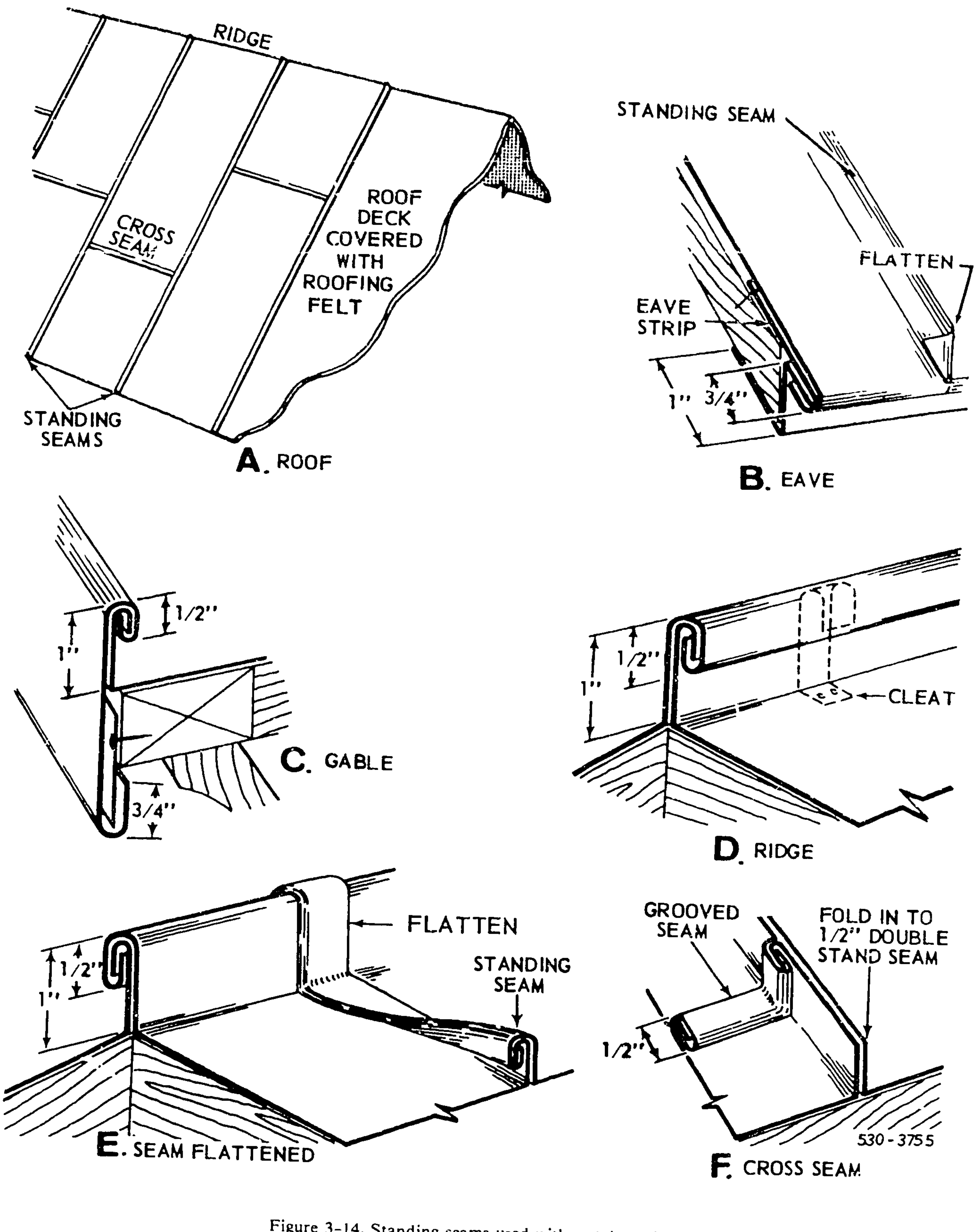


Figure 3-14. Standing seams used with metal roofing.

the gable. Nail it to the gable edge so that it extends ¼ inch below the bottom of the gable edge. Cut a piece of flashing wide enough to cover the thickness of the roof deck, and to form a ¼-inch pocket, a 1-inch standing seam, and a ½-inch double seam. Form the ¾-inch pocket with a cornice brake. Form the double seam with the double seamer when you install the flashing.

Cap the ridge (view D of fig. 3-14) by nailing cleats to the roof deck and forming them into the standing double seam. Where the standing seam which runs up the slope of the roof joins the standing seam on the ridge, flatten the seam on the slope and form it into the ridge seam, in view E of fig. 3-4).

Join the cross seams with ½-inch grooved seams, as shown in view F of figure 3-14, and seal the cross seams with solder. Be sure to seal the cross seam where it is formed into the double fold of the standing seam.

Installing a roof with batten seams. Install a roof with batten seams by putting the seams over the batten strips which are nailed to the roof deck. (To refresh your memory of how to make a batten seam, refer to fig. 3-7.) Figure 3-15 shows how the batten seams are sealed at the ridge, battern. Then, as in view B, turn a ½-inch edge so that you can turn the cap over the edge to form a pocket. After you turn the pocket on each side of the ridge cap, flattern it.

Make the gamble flashing, shown in view C, by turning a pocket on the batten that you can fasten to the strip which is nailed to the edge of the roof deck. Place the gable flashing on the edge of the roof, turn it 90° across the top of the batten, and seam it into the roofing that extends up the other side of the batten.

Seal the eave end of the batten seam as shown in views D, E, F, and G. First, make an end cap with ½-inch edges turned up 90° (view D). Second, extends the roofing 1 inch past the eave and make a ½-inch pocket (view E). Third, make a cap strip and extend it 1 inch past the eave, form a ½-inch pocket, and turn the seams (view F). Fourth, flatten the cap strip over the end of the batten (view G); this seals the eave end of the batten seam.

Exercises (614):

1. When installing lap seam corrugated roofing, which sheet do you install first?

2. When can you begin installing the second row of corrugated, V-crimp, or ribbed roofing?

3. Why is it necessary to make a good notch when you are cutting sheets for grooved seam roofing?

4. What holds the gable flashing of a standing seam metal roof to the roof deck?

5. What is the step in forming a batten seam roof that seals the end of the batten?

6. a. Where is a closure strip used?

   b. List the steps, in sequence for installing a closure strip.

615. Explain methods used to repair metal roofs, and list materials used.

Repair of Metal Roofing. Repair of metal roofing is seldom necessary if the roofing was properly installed; however, in some cases a seam may crack or the metal may break, thus necessitating repair.

Copper roofing. Copper roofing is usually installed with grooved (flat) seam, batten seams, or standing seams. Therefore, the most common cause of trouble is inadequate expansion joints. If cracks occur, install an expansion joint. Repair small holes and breaks in copper by solderin the hole or break. Clean the surface around the break with a wire brush or emery cloth, apply flux, and solder the spot. Repair large breaks by soldering a patch over the break.

Galvanized iron roofing. Galvanized iron roofing will not require very much repair if it is installed and maintained properly. Repairs to a galvanized iron roof are usually needed because of small breaks and holes, which you can repair by soldering. If a sheet has a large break, replace it.

Aluminum roofing. Aluminum roofing is repaired like galvanized iron roofs. Usually, the sheet which is damaged needs replacing; however, you can patch small holes and cracks.

If you make a patch, use the same type metal that was used on the original roof. Since roofs with steel purlins do not normally have decking, and the roofing can be reached from both sides, you can rivet a patch to the metal.

Exercises (615):

1. What is done to repair a hole or break in a grooved seam copper roof?

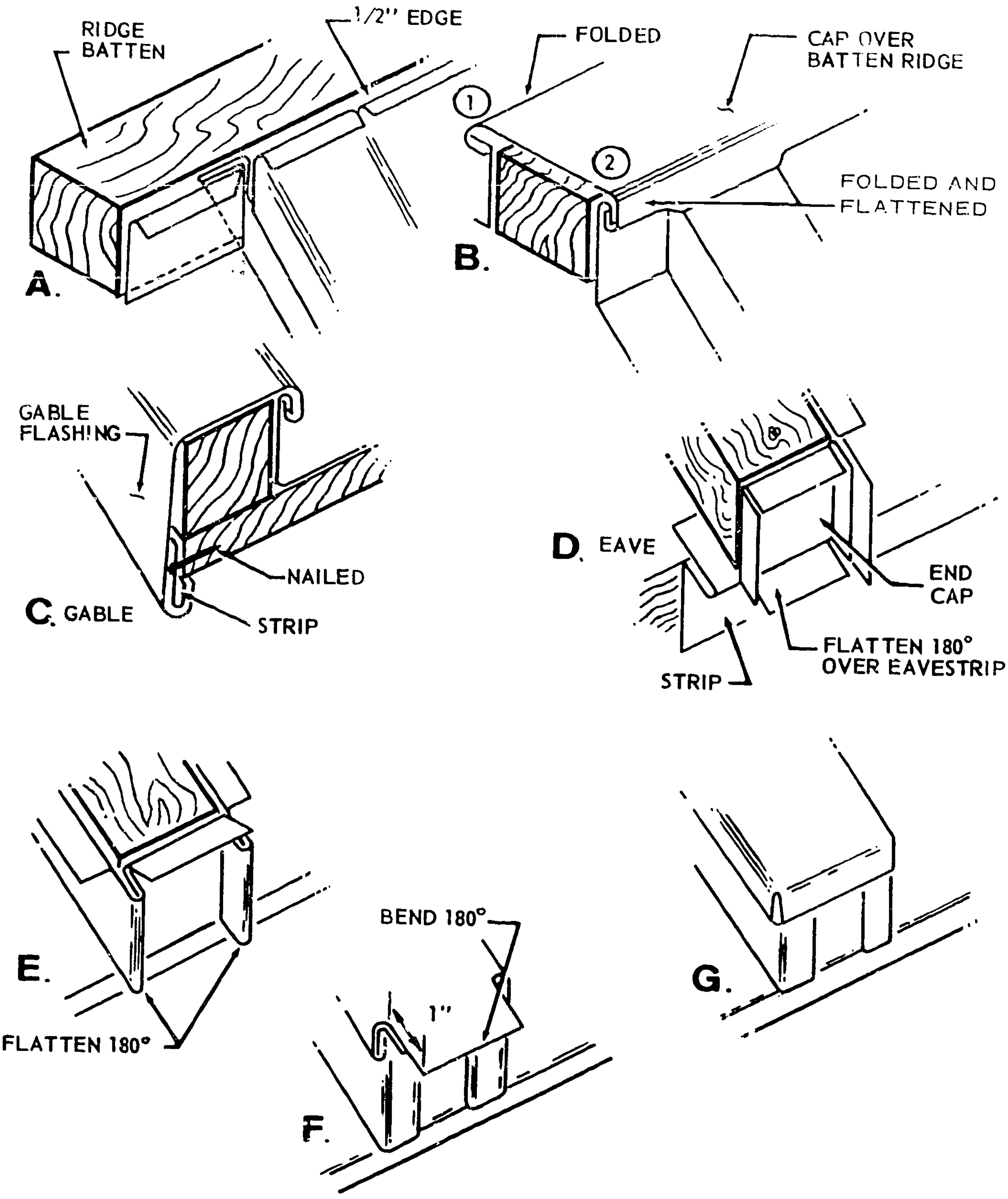


Figure 3-15. Details of a batten seam.

2. How is a large break in a galvanized roof repaired?

3. List the steps and materials used to prepare a copper roof section for repairing a crack.

4. List the steps to repair a 2-inch hole in an aluminum roof.

5. To repair most breaks and cracks in galvanized roofing, you should use ____________.

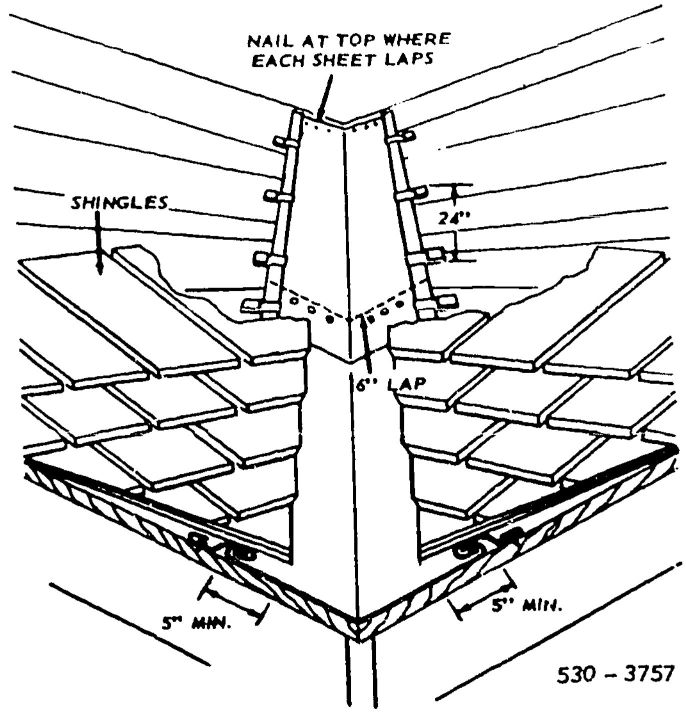


Figure 3-16. Valley flashing.

3-2. Flashing

Earlier in this course, we discussed the use of flash with stacks and ventilators. Flashing is also used with me roofing, shingle roofing, tar and gravel roofing, and built-up asphalt roofing, to weatherproof the joints and edges. Although, we have already mentioned flashing in the discussions about metal roofing, we should know more about the various types of flashing and how they are made, installed, and repaired.

616. Name various types of flashings, and tell where they are used.

Types of Flashing. Flashing consists of many types, such as valley, fascia, corner, gable, and ridge. When made of metal, flashing may be copper, aluminum, lead, or galvanized iron.

Valley flashing. Valley flashing, such as shown in figure 3-16, is used where two sloping roofs join. Valley flashing may be fastened to roof decks, sides of buildings, ridge and the edges of gables and eaves. Typical fasteners are cleats, nails, screws, or nuts and bolts. In some cases, flashing may be riveted. The type of fastening device is usually specified on the drawing.

For typical valley flashing on a sloping roof, the kind of metal used on the roof determines the kind of material used for the flashing and fasteners. Remember that dissimilar metals are not to be joined. If copper flashing is held by cleats, use copper or bronze nails to fasten the cleats to the roof deck. Lap the upper end of the valley flashing under the ridge cap, and lap the lower end over the eave.

Fascia and gravel guard flashing. The fascia and gravel guard flashing should not be over 8 feet long, and it should be wide enough to extend 4 inches under the roofing material. If the face of the fascia is over 5 inches wide, it should have a ½-inch V-crimp. Secure the bottom of th metal fascia flashing with a continuous strip nailed to the bottom of the fascia board. Space the nails at 6-inches, in the center. Form the bottom edge of the fascia flashing into a 1-inch pocket over the strip, and bend it 45° to form a drip edge.

Expansion joints should be used at intervals specified on the drawings. These expansion joints should allow for ¼ inch of expansion and contraction. The expansion joint should extend 4 inches over the roof, and cover the full width of the fascia flashing.

When the fascia flashing is spliced, the butt joint should be concealed with a cap strip. The cap strip should have the same shape as the fascia, and should lap the fascia 2 inches in each direction from the splice.

Gable flashing. Gable flashing is used to seal the edge of a roof at the gable. In view B of figure 3-12, the flashing is formed over the edge of the gable. Notice how a drip edge is turned on the top part of the flashing so that water will be discharged into the valley of the corrugated roof. The bottom edge is formed into a pocket to join the wall flashing. This completely seals the gable edge from moisture. In view D of figure 3-13, you can see how the gable flashing is fastened to the roof with a metal strip. The flashing is formed over the strip so that the flashing is fastened at the bottom.

Eave flashing. Eave flashing, such as that shown in view C of figure 3-13, is used to seal the eaves of roofs. Gable and eave flashings are used on most roofs, including asphalt shingle, built-up asphalt, tar and gravel, and metal. (The working drawings should specify how the eave flashing is to be made.)

Ridge flashing. An example of ridge flashing for roofs is shown in views C and D of figure 3-12. The metal ridge cap (flashing) is used on many types of roofs. To fasten this flashing on metal roofs, use sheet metal screws or bolts, as indicated in figure 3-12. On asphalt shingle roofs, you can fasten the flashing with nails; be sure to lap the ends at least 4 inches.

Exercises (616):

1. What is the name for the flashing placed around gravel covered roofs?

2. Name the flashing used to cover the uppermost part of a roof.

3. a. How may valley flashing be fastened to the roof or wall?

   b. What material is used for fastening copper flashing to a roof?

4. What type of flashing has a ½ inch or larger V-crimp, and how wide should this flashing be?

5. Which flashing is formed from part of the roofing and not from a separate piece?

6. Where is ridge flashing installed, and how much should it be lapped?

617. Identify steps in installing and repairing flashing.

Installation of Flashing. To install the fascia flashing, first install the tar stop. Install the bottom strip on the wood fascia. Next, install the expansion joint. Make sure the ¼-inch expansion allowance is made. Apply plastic roofing cement (mastic) in accordance with instructions on the working drawings. Install a length of fascia flashing (straight or corner pieces), starting with an expansion joint. Drill holes in the roof deck for No. 10 x 1⅜" wood screws, and install the screws.

The next part of the installation is to join the 8-foot joints of fascia. Fit the grooved seam pockets on the ends of the sheets, and the 1-inch pocket on the bottom edge. After the grooved seam is hooked, flatten it with a mallet and solder it. (The metal has already been tinned, so soldering will not be difficult.) To solder the seam, apply flux, and sweat-solder the seam with a heated copper. It will probably be necessary to apply some 50/50 bar solder to the seam, as you do the soldering. Sweat-solder the entire length of the seam, to insure that it won't leak. Copper requires a considerable amount of heat when it is soldered.

The remaining pieces of fascia flashing are installed as explained in the preceding paragraphs. Make sure that all the solder joints are made watertight and that roofing mastic is applied at each expansion joint.

Repairing of Flashing. Repair of flashing may involve the making of new flashing, or patching with solder or with plastic roofing cement. Copper flashing can usually be repaired by resoldering a seam or spot-soldering a hole in the flashing. To solder copper, clean the spot with a wire brush or emery cloth until the surface is bright. Apply the flux, and solder the hole with 50/50 bar solder. If a large hole in copper flashing needs repairing, clean the area to be soldered, apply a flux, tin the surface, make a patch from copper, and solder the patch over the hole.

Flashing made of galvanized iron is usually repaired by replacing the damaged metal. When replacement is required, removed the old flashing and make a new piece like the old one. When replacing the new piece, make sure that all joint are sealed with roofing cement.

Base flashing damage is usually caused by nails working loose, and the metal separating from the roof. If this occurs, apply roofing cement under the flashing, and renail the flashing to the roof. After renailing, apply a thin layer of roofing cement around the edge of the flashing.

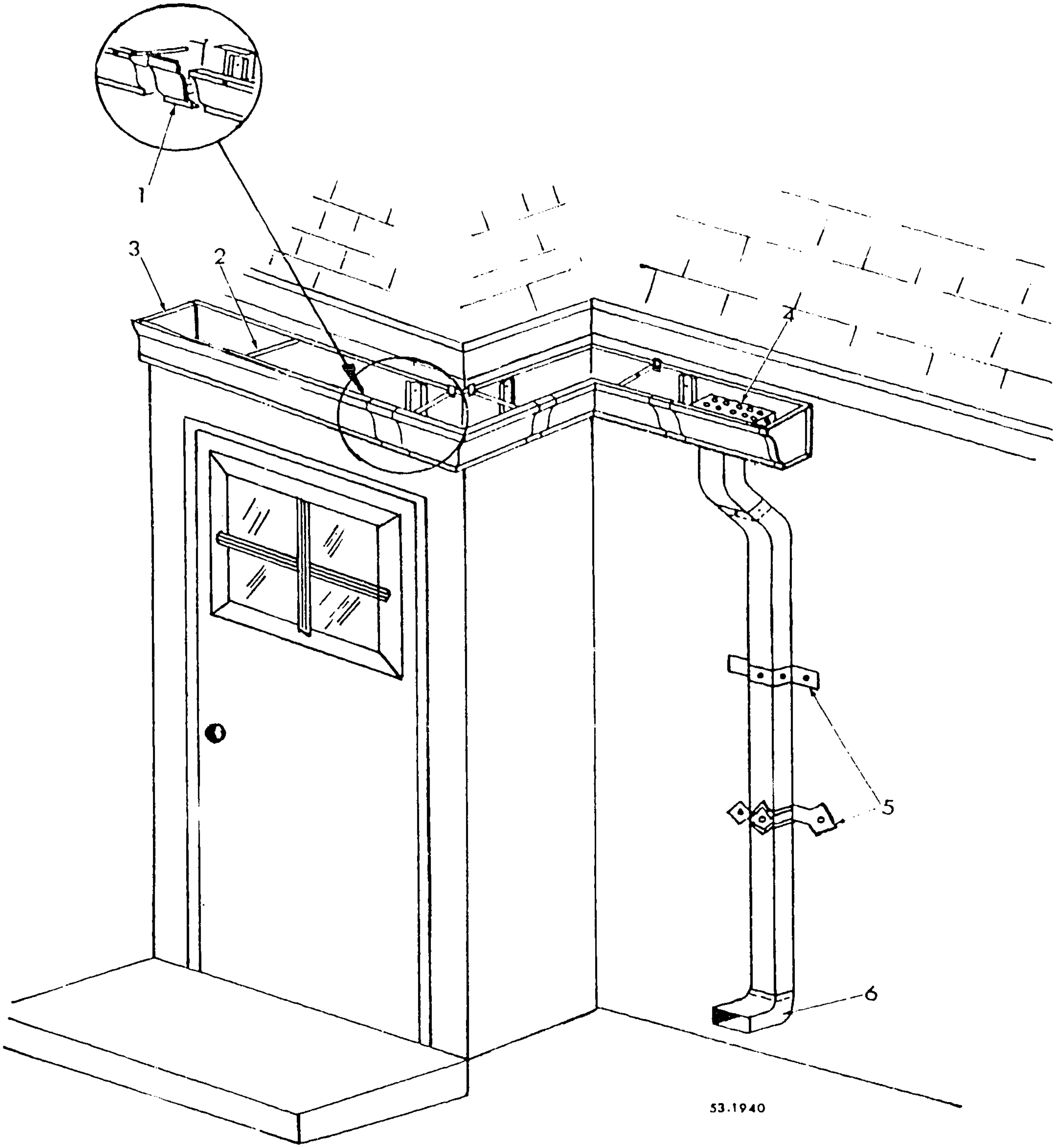
Most metal flashing will last for long periods of time if installed and maintained properly. You will find that most repairs are necessary because nails or other fasteners work loose.

Exercises (617):

1. What is the first item to be put in place when you are installing fascia flashing?

2. After you have joined the 8-foot joints of fascia, and the grooved seam has been hooked, what do you do next?

3. What are the first three steps in repairing a small hole in a flashing?



1. Slip joint
2. Ferrule and spike
3. End cap
4. Strainer
5. Handgear braces
6. 90° elbow

Figure 3 17. Gutter and downspout parts.

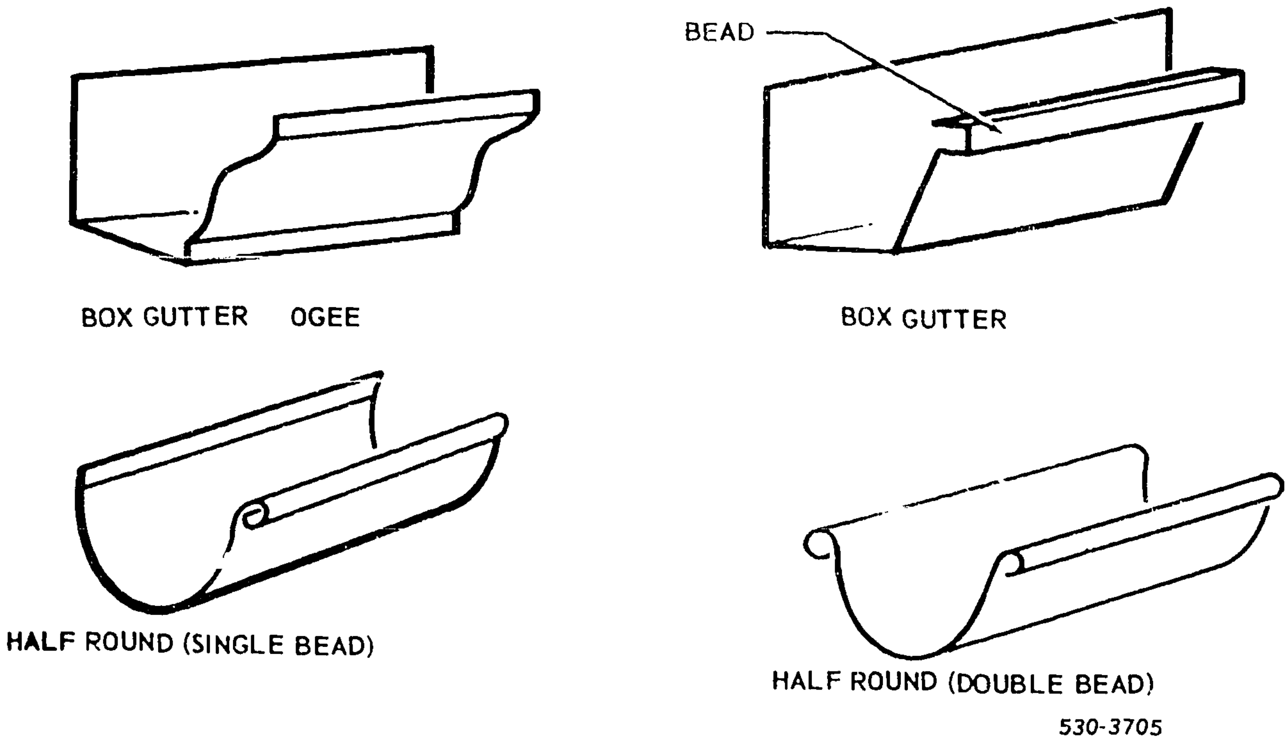


Figure 3-18. Gutter shapes.

3-3. Gutters and Downspouts

618. Identify gutter components with their purposes.

Gutters and downspouts are installed on buildings to handle the flow of water discharged from a roof. They may be made from galvanized iron, stainless steel, copper, or aluminum. Figure 3-17 shows the components of a gutter and downspout system which are installed on a building.

Gutter Shapes. Gutters are made in several different shapes (usually to the specification on the working drawings) to fit special needs. Figure 3-18 shows four basic shapes of gutters, from which many variations are possible. Box gutters are made in several shapes. The ogee box gutter is often used on buildings and can be purchased in standard sizes, such as 4-, 5-, 6-, and 7-inch widths and 10-foot lengths. The width is the distance across the top. The box gutter with a single bead is usually shop made, and the length is determined by the requirements of the job. Standard lengths of 10 feet and 20 feet are available on the local market. However, the maximum length that you can make is determined by the length of the cornice brake in your shop. Ten-foot joints are probably the maximum lengths that can be made in your shop. Half-round gutters, like the ones shown in figure 3-18, may have a single bead or a double bead on the edges. The beads add strength to the gutter and improve the appearance. Half-round gutters can also be purchased in standard sizes, such as 4-, 5-, 6-, and 7-inch widths and 10-foot lengths.

Gutter Components. Other components used with straight joints of gutter are parts such as slip joints, end caps, corner miters, hangar parts, strainers, and downspout drop outlets.

Slip joints. Slip joints are used to join straight sections and corner miters. They may be made of galvanized iron, stainless steel, copper, or aluminum. They may be purchased or made in the shop. The joint connection should match the size and shape of the gutter. When using slip joints to join gutters, use a nonhardening sealing cement. Slip joints (fig. 3-17) allow for expansion and contraction of the gutter when the temperature changes.

End caps. End caps are used as plugs at the ends of gutters. These caps are sometimes called *friction caps*, because the edges are folded into a pocket similar to the pocket of a standing seam. This pocket is on the right

end cap. On galvanized and copper gutters, the caps are soldered during installation. On aluminum gutters, the caps are sealed with a plastic cement compound during installation. End caps can be purchased, or made, to fit the gutter that is being installed.

Corner miters. Inside and outside corner miters are shown in figure 3-17. These miters can be purchased in standard sizes for box and half-rooound gutters. Purchased corner miters are usually 6 inches long on each side of the turn. They are joined to the gutter with slip joints, or they may be lapped, riveted, and sealed. If the joints are lapped, the lap should be in the direction of flow. The lap should be at least 1 inch in order to insure a strong joint.

Hangers. Hangers, (see figs. 3-17 and 3-19) are used to support and hang box gutters and half-round gutters. The hanger shown in view A of figure 3-19 acts as a hanger and as a brace. Two parts make up this hanger: the hanger and the fastener strap. Nail the hanger to the fascia board and into the rafter; then slip the gutter under the back lip of the hanger and fit it into place. Next, hook the slot in the fastener straps over the front lip on the hanger and snap it over the bead of the gutter, as shown in the illustration.

Ferrules and spikes (see view B of fig. 3-19) are used to hang gutters. The ferrule length is determined by the size of the gutter being installed, and the length of the spike is determined by the ferrule length. For *example*, a 4-inch ferrule should have a 7-inch spike because the spike should extend through the ferrule approximately 3 inches so that the spike will be held securely by the wood rafter. To install a ferrule and a spike, insert the ferrule between the gutter beads, and drive the spike through the outside gutter bead, the ferrule, the back side of the gutter, the fascia, and into the rafter. When a ferrule is installed, it should look like the one shown in view B of figure 3-19.

The hanger shown in view C of figure 3-19 is for a single-bead half-round gutter. Notice that it is made in two parts— the hanger and a half-circle brace—and is fastened with nails to the fascia board and the rafter. The hanger part has several vertical holes for height adjustment. The half-circle brace for single-bead half-round gutter can be used with several types of gutters, as shown in views C, D, and E. Notice that the hanger in view D is nailed under the shingles. This type of hanger is made for the pitch of the roof, so that the half-circle brace will hold the gutter level. The half-circle brace shown in view D is for a double-bead half-round gutter. It has a lip on the back of the brace. The hanger in view E is adjustable, and is used when the roof has a pitch and the hanger is being installed under the eave. View E shows how the hanger adjusted to the roof pitch.

Other hangers, such as the strap hanger in figure 3-17, may be used to hang gutters. Strap hangers may be shop made or purchased; they are nailed to the roof deck and bolted to the bead on the gutter. When this type of hanger is used, a brace is also used for additional strength.

Metal buildings. Gutters on metal buildings are supported from the roof. They must be situated well under the eave. These gutters are usually quite large, to carry off heavy rain water. In figure 3-20 is a cutaway view of the typical metal building gutter. If the building is insulated, the rubber closure strips must be in place. Special care must be exercised when you are removing or replacing this type of gutter, due to its large size.

Strainers. Strainers, (fig. 3-17) can be shop made or purchased. Install a strainer at each downspout drop to prevent the downspout from being clogged with leaves or trash. Make the strainer so that it can be easily removed for cleaning. The strainer shown in figure 3-17 is made so that it is wedged into the gutter.

Downspout drop outlets. Downspout drop outlets, like those shown in figure 3-17 and parts A and B of figure 3-21, are fastened to the flat bottom gutters. The round shape in view A of figure 3-21 can be used with square or round downspouting. The downspout outlet shown in view B is for square downspouting only. The oval downspout outlet shown in view C is for round and rectangular downspouting, and is used with half-round gutter only. All of the outlets taper so that the downspout pipe will fit over the outlet. When making a drop outlet in the shop, you should make it about ⅛inch smaller than the downspout so that the downspout will fit over the outlet. To fasten the downspout drop outlet to the bottom of a gutter, solder the flanges on the inside of galvanized gutters. For copper gutters, rivet the flange to the gutter and then solder it. On aluminum gutters, the flange can be soldered or riveted. Where the flange is riveted, use plastic cement.

Exercises (618):

1. A gutter having a round bottom and both edges tightly rolled is called a____________ ____________ gutter.

2. What type of sealant should be used for connecting gutter sections with a slip joint?

3. What item(s) can be used to hang ogee gutters?

4. What item is used to prevent the downspout from being clogged?

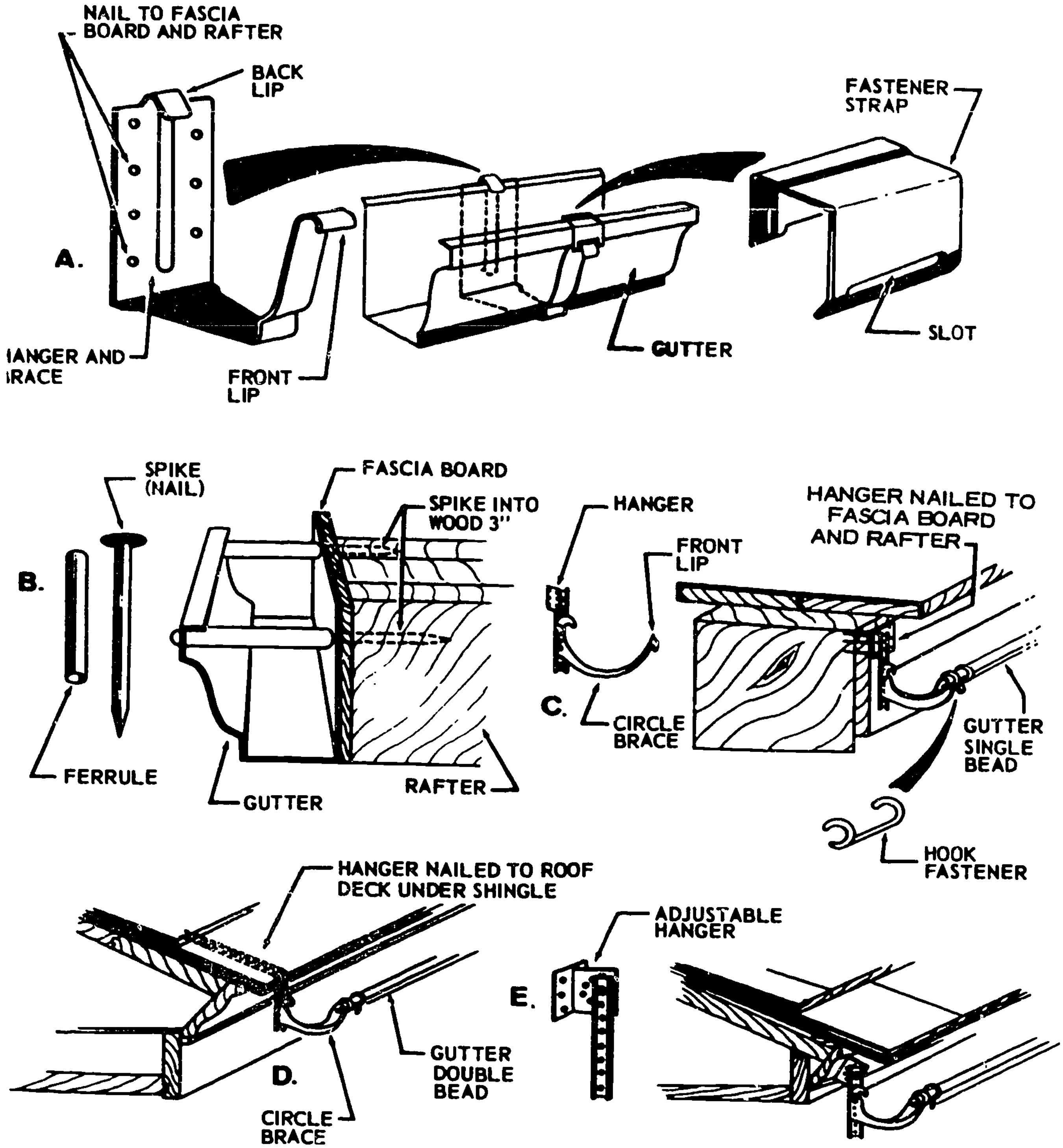


Figure 3-19. Gutter hangers and braces.

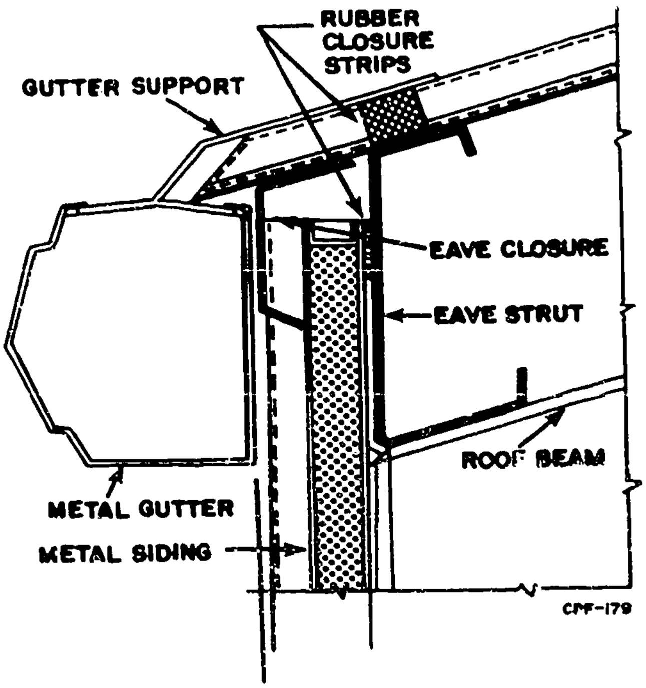


Figure 3-20. Gutter on metal building.

5. What is the difference between an ogee gutter and other box gutters?

6. What blocks the end of a gutter, and how is it held in place?

619. Identify downspout components and the purposes they serve.

Downspouts. Downspouts are used to route water from a gutter to the drainage system or to ground level. They are also called *conductor pipe* or *rainpipe.* Some downspouts can be purchased more cheaply than they can be made *unless* special equipment is not available in the sheet metal shop. However, it is possible to make square- or rectangular-shaped downspouts in most shops. Downspout shapes and sizes such as those shown in figure 3-22 are available. Plain and corrugated rectangular downspouts are usually 2″ x 3″ or 3″ x 4″; square corrugated downspouts are available in 2-, 3-, 4-, and 5-inch sizes; round corrugated downspouts are available in 2-, 3-, 4-, 5-, and 6-inch sizes; and plain round downspouts are available in 1½-, 2-, 3-, 4-, 5-, and 6-inch sizes. The standard length of these conductors is 10 feet.

Components. The material from which these downspouts are made depends on the material used for the gutter. This is why most downspout components are available in galvanized iron, stainless steel, copper, or aluminum. Corrugated downspouts are normally used in localities where the water may freeze in the conductor. The corrugations allow for expansion when water freezes. Under freezing conditions, plain downspouts may rupture because there is no provision for expansion of the pipe.

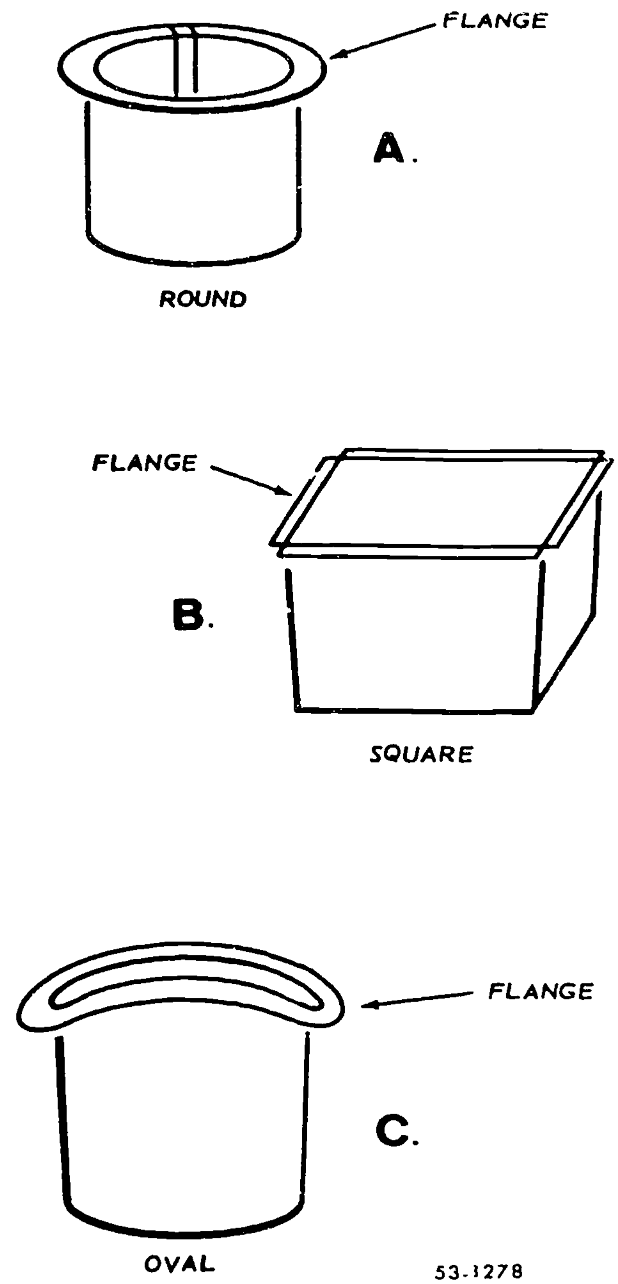


Figure 3-21. Downspout drop outlets.

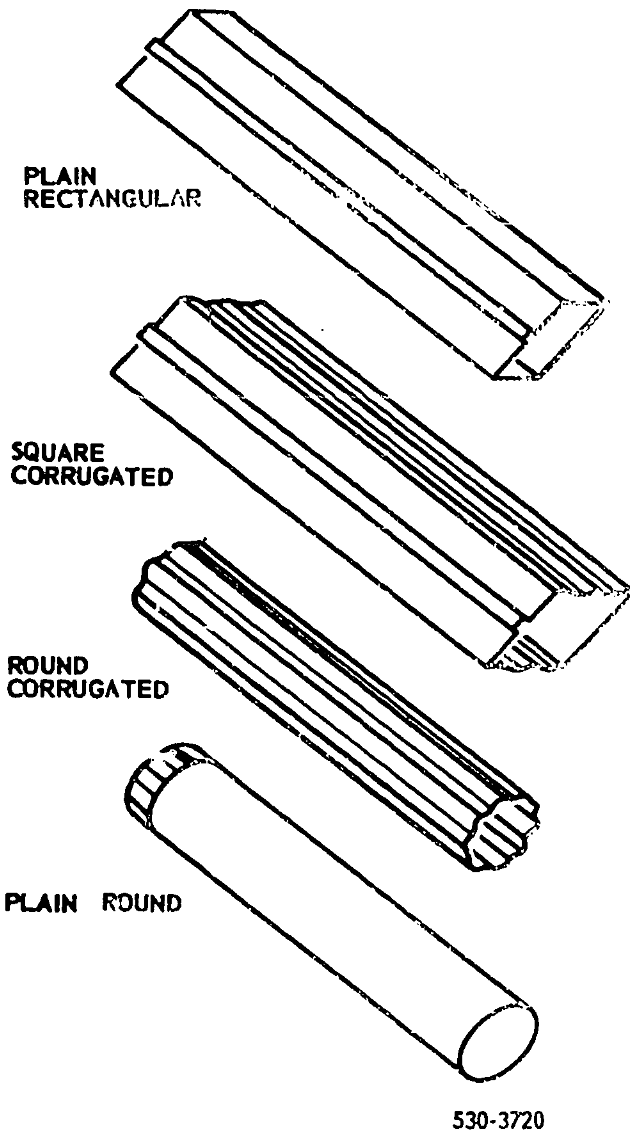


Figure 3-22. Downspouts.

Downspout components include straight joints, elbows, and hangers. The elbows are used to make offsets and turns for routing the downspout. Elbows are available in different angles, such as 30°, 45°, 60° and 90°. There are no sharp turns where the elbows are used. Sharp turns are avoided in order to get a smooth flow. The elbow at the bottom of the downspout is sometimes called a *shoe*; it turns the water away from the building. A concrete pad should be placed at this outlet to avoid washing soil away from the building.

Purpose. Strap hangers are used to support the conductor. They may be readymade, or they may be made in the shop from galvanized iron, stainless steel, copper, or aluminum. The straps are usually 2 to 4 inches wide, and long enough to fit around the downspout and make two flanges for fasten to the wall. The strap hangers are fastened to the wall with nails, sheet metal screws, or bolts, depending upon the material the wall is made of. If the wall siding is wood, use nails; if the siding is metal, use sheet metal screws; if the wall is masonry, use an anchor and bolt. Fasten the hangers to the conductor with sheet metal screws The spacing for the hangers should be specified on the working drawings. If it is not specified, a good rule to follow is two hangers for each 10-foot joint of downspout.

Exercises (619):

1. Conductor pipes are used to____________ ____________ ____________ ____________.

2. Corrugated downspouts are used in ____________ to provide expansion when water ____________

3. Downspouts are available in different materials so that ____________ ____________ .

4. A smooth water flow in a conductor is obtained by____________ .

5. A concrete pad is placed under the shoe to____________ ____________.

6. To secure a downspout to a brick wall, use ____________ ____________ ____________.

620. State procedures for installing gutters and downspouts.

Installation of Gutters and Downspouts. Install gutters and downspouts as specified on the working drawings. The following is a typical specification that you may find on a working drawing:

Gutters are to be installed with the high end opposite the downspout, so the water will flow to the downspout outlet. Hangers are to be installed not more than 30 inches apart on center. Expansion joints should be located at 40-foot intervals for 16-ounce copper, and at 48-foot intervals for 20-ounce (and thicker) copper. When the gutter is aluminum with a thickness of 0.032 inch, the expansion joint should be at 32-foot interval it should be at 40-foot intervals for aluminum which is 0.040 inch or thicker.

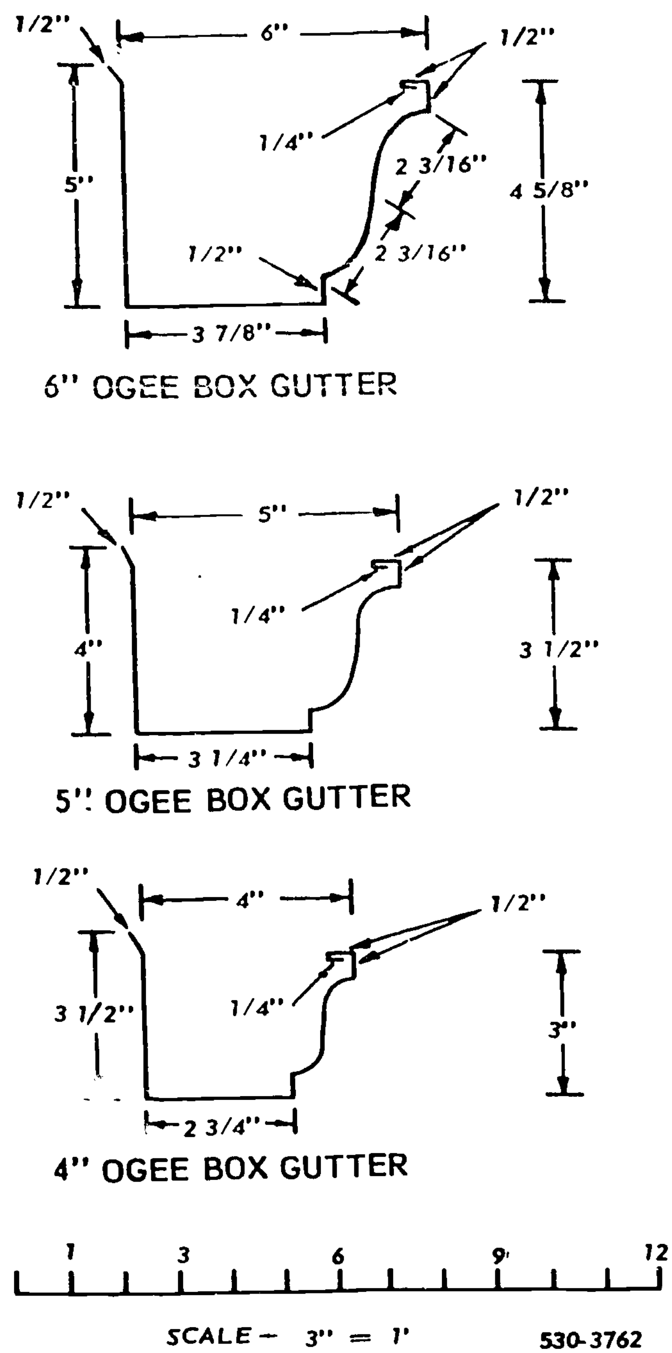


Figure 3-23. End views of ogee box gutters.

Specifications for the installation of downspouts may also require that slip joints telescope 1½ inches in the direction of flow. Fasten these joints with sheet metal screws and solder. The downspout should be plumb with the wall, but not against it; use straps to hold it away from the wall. Fasten the straps to the downspout with three screws and to the wall with two screws.

Gutter installation. To see how installation specifications are applied, let's go through a step-by-step description of a typical installation procedure. Suppose this gutter is to be installed over a building entrance that is 6 feet across the front, is 3 feet between corner miters, and extends 3 feet from the inside corner miter to the end. The gutter is galvanized iron, and was purchased readymade. The gutter is to be hung with hangers.

Start the installation by making a chalk line on the fascia board. Start the chalk line on the end opposite the downspout location. Hold the chalk line as close to the eave overhang as possible. On the other end, lower the chalk line ¼ inch so that the gutter will have enough drop to allow the water to flow toward the downspout. Pull the line straight out, and then release it to make a straight chalk mark. This is the chalk line for the 6-foot side of the front entrance shown in figure 3-23. Next, place one end of the chalk line on the ¼-inch mark at the outside corner, and stretch the line to the inside corner, lowering it ¼ inch more. Pull the string tight and make another chalk mark. Make the last chalk line, with another ¼-inch drop, from the inside corner to the end of the gutter where the downspout is located.

You can now install the hangers by nailing the first hanger about 3 inches from the high end of the gutter. Make sure that the top of the hanger is placed on the chalk line. Install the next hanger 3 inches from the outside corner. Since specifications require hangers on not more than 30-inch centers, install two hangers 22 inches apart between the end hangers. Next, install the hangers between the outside corner and the inside corner, 3 inches from the corners. The next hangers to be installed are between the inside corner and the outlet end of the gutter. One hanger is 3 inches from the inside corner, and one is about 2 inches from the gutter end. Don't place the end hangers too close to the end caps.

Installation of the inside corner miter is next. Place it in the hanger with the top edge on the back of the gutter under the lip on the hanger. Apply mastic (plastic cement) in the pockets of the two slip joints with a putty knife, and install the slip joints on each end of the inside corner miter. Install the outside corner miter the same way. Next, measure the distance from the bottom of the pockets on the two corner miters. This measurement should be close to 23 inches because the slip joints should have a ½-inch spacer. Cut a piece of the straight gutter to 23 inches, remove the outside corner miter, and slip the straight piece into the pocket at the inside corner miter. Now, reinstall the outside corner miter by slipping its joint pocket over the edge of the straight gutter piece. The snap locks can now be installed on the hangers to hold the gutter in position.

The front gutter can now be installed. First, measure from the pocket of the slip joint (at the outside corner miter) to the end of the building. This measurement should be close to 65 ½ inches. Cut the straight gutter piece to this length, and install the end cap (with solder) to this straight gutter; install the gutter by placing the back edge under the lip on the hangers and pressing down on the front of the gutter. Slide this straight

gutter into the outside corner slip joint, and install the snap locks on the hangers.

The last piece of gutter to install is the straight piece with the downspout drop outlet. Begin by cutting a piece of straight gutter 29 ½ inches long. Measure 6 inches from the outside edge for the center of the drop outlet. Cut a hole for the drop outlet, install the drop outlet (with the flange inside), and solder around the flange. With the outlet and the end cap soldered in place, the gutter is ready to install in the hangers. Do this by inserting the back edge of the gutter under the lip on the hangers, pushing down on the front, slipping the edge into the slip joint, and installing the snap locks. Check all slip joints to see that they are well sealed. Apply mastic where necessary.

Downspout installation. Now, let's see how this downspout is installed. Measure the distance from the bottom of the gutter (top of the drop outlet) to the ground. Assume that this measurement is 11 feet 6 inches, and that one 10-foot length of straight downspout and three elbows—one 90° and two 45°—are needed. A downspout assembly is shown in figure 3-17. (In this case, the assembled downspout is short enough to be held in place to check the fit.) Fasten the pieces together with sheet metal screws or blind rivets, and solder the joint connections. Position the assembled downspout with the upper elbow fitting over the gutter drip outlet, fasten with sheet metal screws, and install three strap hangers to support the downspout.

Exercises (620):

1. Where does the chalk line begin for the installation of a rain gutter?

2. What is used to seal a slip joint connection?

3. To complete the installation of a downspout, what steps should be taken?

4. At what interval do you place hangers for a gutter?

5. Before you install a corner miter on a building, what do you use to seal the item to the corner?

6. After the corners have been installed, what is the next stage.

7. How near to the end of a gutter do you put the drop outlet?

621. Tell how to make minor repairs to gutters and downspouts.

Minor Repairs of Gutters and Downspouts. Gutter and downspout repairs are usually minor repairs, such as resealing joints and refastening hangers. (Major repair includes the replacement of gutters and downspout components Before resealing joint connections with mastic, remove the old mastic so that the outside edges of the joint are clean. Apply new mastic with a putty knife or calking gun. To resolder seams, first clean the seams by heating the solder and wiping it with a clean dampened cloth, applying flux, and tinning the seam. After the seam is cleaned, solder it with a well-heated copper and bar solder. Small holes in gutters and downspouts can be easily repaired with solder, just like minor repairs on metal roofs. Larger holes, however, may require that a patch be made and installed. Hangers that have pulled loose may be refastened with sheet metal screws, nails, or bolts. If a hanger is missing, a new one should be made (to match the others).

When small holes are found in gutters or downspouts, carefully examine the damaged areas for evidence of corrosion (rust). To detect these areas, look for spots where the rust is showing. You should be able to see rust scales if a spot is bad. Pits will show in the metal where corrosion is beginning to take hold. On gutters that have been painted, corrosion can occur under the paint. In some cases, this may be only a bubble on the surface, and a small pin hole that reveals only a small area of corrosion. If the bubble is removed with a putty knife, a large area of rust may be exposed. The area should be thoroughly examined to determine how deeply the rust has penetrated. The strength of the metal can be tested by pressing against the corroded surface with the tip of the putty knife blade. If the metal gives way, replace the damaged metal.

Exercises (621):

1. How should a leaking slip joint be repaired?

2. What should you do if a hanger is missing?

3. How are minor (small) holes repaired?

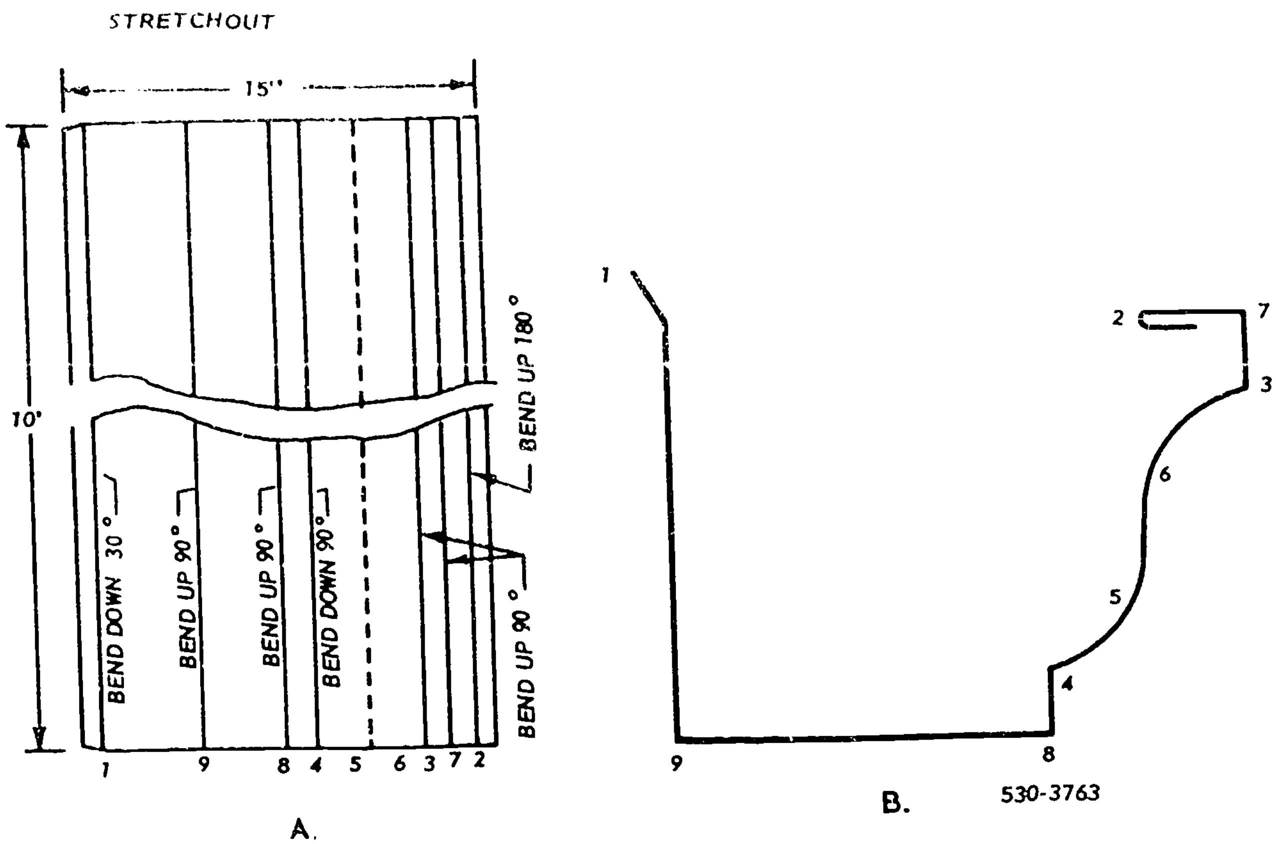


Figure 3-24. Pattern and shape for style K (ogee) gutter.

622. Identify steps used in the fabrication of replacement gutters and downspouts.

Replacement (Fabrication) of Gutters and Downspouts. To replace all or portions of gutters or downspouts, you must determine what is to be made and what material is to be used. Make a sketch of the gutter and downspouts (include dimensions and shape). After the sketch is made with all of the necessary measurements, you can return to the shop to begin fabrication of the replacement pieces.

Straight gutter. For this example, assume that you are to fabricate two 10-foot joints of 6-inch ogee box gutter like that shown in figure 3-23. A downspout drop outlet, 2 ⅜" x 2 ⅞" x 3" long, is to be made for a 2 ½" x 3" downspout. A 4L"x 10" sheet of galvanized iron will be enough metal to make the gutter and the downspout in this example. First, develop a pattern for the ogee gutter like the one shown in view A of figure 3-24. Since tne length of the sheet is 10 feet and the pattern is 10 feet, the 15-inch stretchout should be cut lengthwise from the sheet. Notice in view B of figure 3-24 that the bends are numbered and that they correspond to the numbers on the pattern. The bend lines should be prick-punched on the metal so that they can be easily seen from either side of the metal during the forming.

Cornicce brake. Before forming the pattern on the cornice brake, make sure that the machine is correctly set for bending 26-gage metal. Check the clamping pressure to see if it is tight enough for 26-gage metal, and to insure that the pressure is the same on each end of the brake. This pressure should be great enough to hold the metal firmly when bends are being made. Next, check the setback and bend allowance for the top leaf. Each end of the brake should have the same distance between the top nose bar and the bending leaf. Since sharp bends are to be made, this distance should be 1½ to 2 times the thickness of the metal. Make certain that the top leaf is adjusted correctly to make an even bend on each end of the brake.

With the pattern made and the cornice brake adjusted, you are ready to form the ogee box gutter. Make the bends in the order shown in figures 3-24 and 3-25. Place the meta in the brake and make the No.1

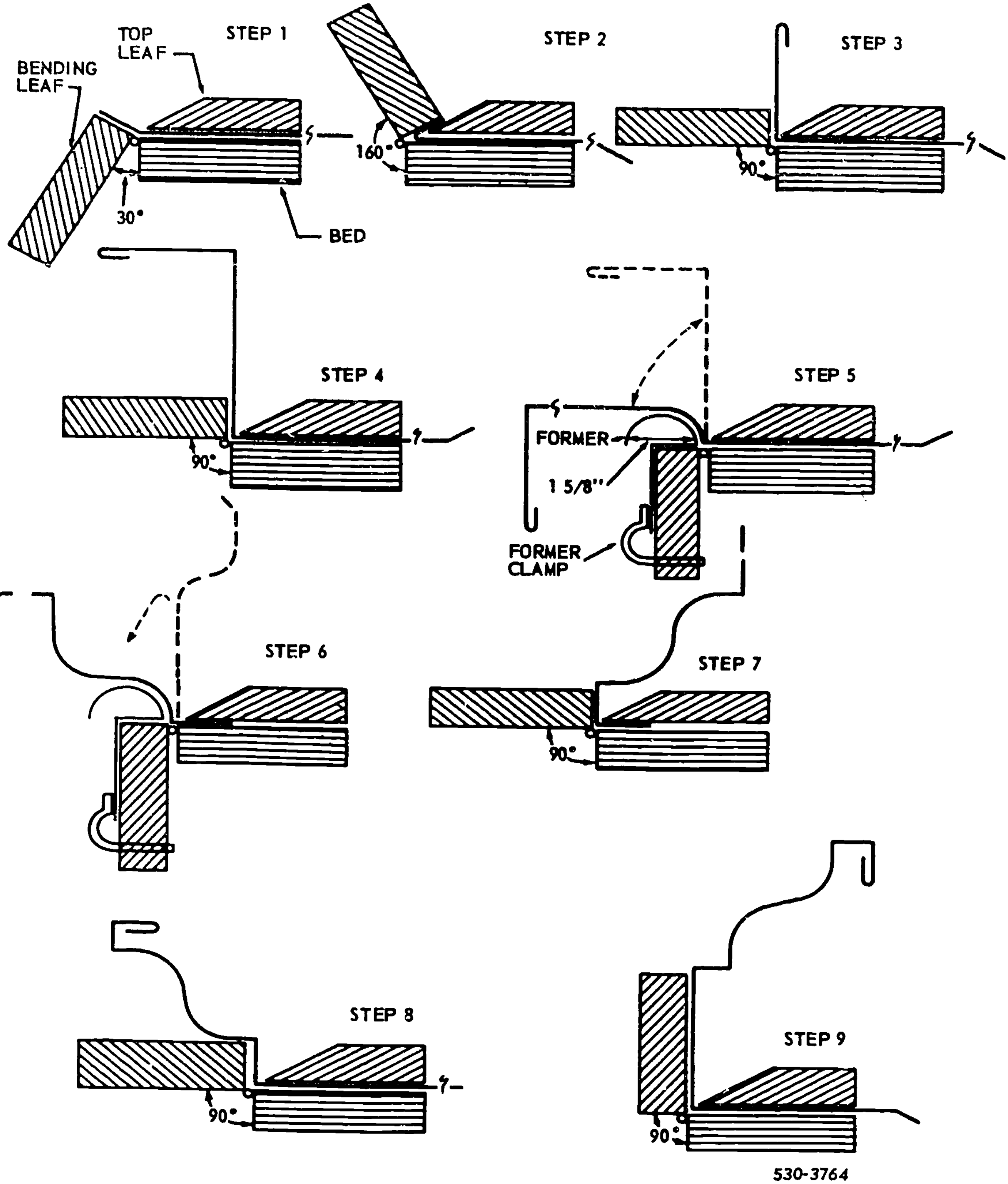


Figure 3-25. Forming ogee box gutter on the cornice brake.

bend 30. Turn the pattern around and make the No. 2 bend 160°. Remove the met from the brake, and flatten it to 180°. Make the No. 3 bend 90°, at the 1-inch mark on the same side of the sheet. Make the No. 4 bend by turning the metal over, and bending it 90°. Now, repeat each of these steps for the second pattern, because bend 5 will require that the ogee former be installed on the brake.

For bend 5 of figure 3-25, install the former by placing it on the bending leaf and installing the clamps. Use a mallet to set the clamps tightly, so that the former is held firmly to the bending leaf. To make bend NO. 5, insert the metal under the top leaf as far as the No. 4 bend. With the metal clamped in place, grasp the metal. Spread your hands about 24 inches apart, and pull the metal down until it is parallel with the bed, as shown for bend No. 5. Take the metal out of the brake, turn it over, clamp the 1-inch flange under the top leaf, and pull the metal down with your hands to make bend No. 6. Make these two bends (Nos. 5 and 6) on both pieces of metal, so that the former can be removed. Remove the former and continue with bends 7, 8, and 9. Make the No. 7 bend 90° as shown in figure 3-25. Turn the metal around and make the No. 8 bend 90°. Make the No. 9 bend 90°, to complete the forming of the first pattern. Make bends 7, 8, and 9 on the second pattern, to complete the forming of the second piece of gutter.

Exercises (622):

1. In replacing a damaged section of gutter, what do you do *before* you go to the shop?

2. How do you make the bend lines when you are forming a gutter replacement?

3. What is used to form the curved portion of an ogee gutter?

4. In making two lengths of gutter shaped as indicated in figure 3-25, what bends do you make after the second 90 bend, and why?

623. State materials and procedures involved in making and fitting replacement gutter and downspout components.

End caps. The remaining gutter components can now be fabricated. Start with the left and right end caps, and develop a pattern like the one shown in view A of figure 3-26. Make the seam allowances and notching instructions, as shown in the illustration. Using the cornice brake, form the ½-inch flanges on the three sides that are not notched. Start with the 3 ⅞-inch bottom flange. After the first bend is made, let the flange extend past the top leaf as the metal is clamped (to prevent damaging the flange Form the notched tabs on the ends of a conductor stake and a square stake. Using a tinner's riveting hammer, bend the tabs at the curved part of the pattern edge on the conductor stake; bend these at the straight parts of the edge on the square stake. Remember to bend one cap for the left end and one cap for the right end.

Drop outlet. The next component is a downspout drop outlet, such as that shown in view D of figure 3-26. Make the pattern (view C) with a ⅜-inch flange allowance across the top, and a ½-inch allowance for the 5/16-inch grooved seam. Form the grooved seam on the cornice brake or Pittsburgh lock forming machine. Notice that the seam will be on the back side when the outlet is installed. Next, bend the ⅜-inch flanges for all sides except the back, which should remain straight to fit agains the back of the gutter. Make these bends on the square stake by placing the bend line on the edge of the stake and striking the flange with a tinner's riveting hammer.

Fit the left end cap on one gutter joint, and fit the right end cap on the other joint. Fasten the bottom flange with two rivets, and the back flange with three rivets. Install a ⅜-inch No.6 sheet metal screw in the flange on the top edge of the bead, and solder the cap with 50/50 bar solder. Be sure to cover the rivets and screwhead, and sweat the solder into the lap seam. Next, install the drop outlet on the gutter piece with the left end cap. Locate the center of the drop outlet 6 inches from the left end, and cut a hole. Make a starter hole with a ½-inch cold chisel, and cut the rectangular shaped hole with aviation snips. Insert the drop outlet down through the opening, and rivet it into place. Solder around the flanges and rivet heads.

Slip joints. The next component to fabricate is a slip joint (see view D of fig. 3-27). The outside piece shown in view A has the same shape as the gutter shown in figure 3-24, but remember to measure the stretchout dimensions on the *outside* of the gutter. This outside piece of the slip joint is only 2 ½ inches wide. It is formed on the cornice brake like the long joints, except for the curved bends. Since the material is only 2½ inches wide, these bends can be made on the conductor stake by hand pressing. Make the inside piece of the slip joint (view B of fig. 3-27) by using the *inside* measurement of the gutter to make a stretchout pattern 2 ½ inches wide. Notice that this piece has neither the ½-inch flange nor the hem that piece A does. This piece can also be formed on the cornice brake and conductor stake. Make the ½-inch-wide spacer (view C) from 16-gage metal, to allow for the sealant and to give sufficient room for a slip joint. Form the spacer just like piece B. After you make the three pieces, assemble them by riveting or by spot welding.

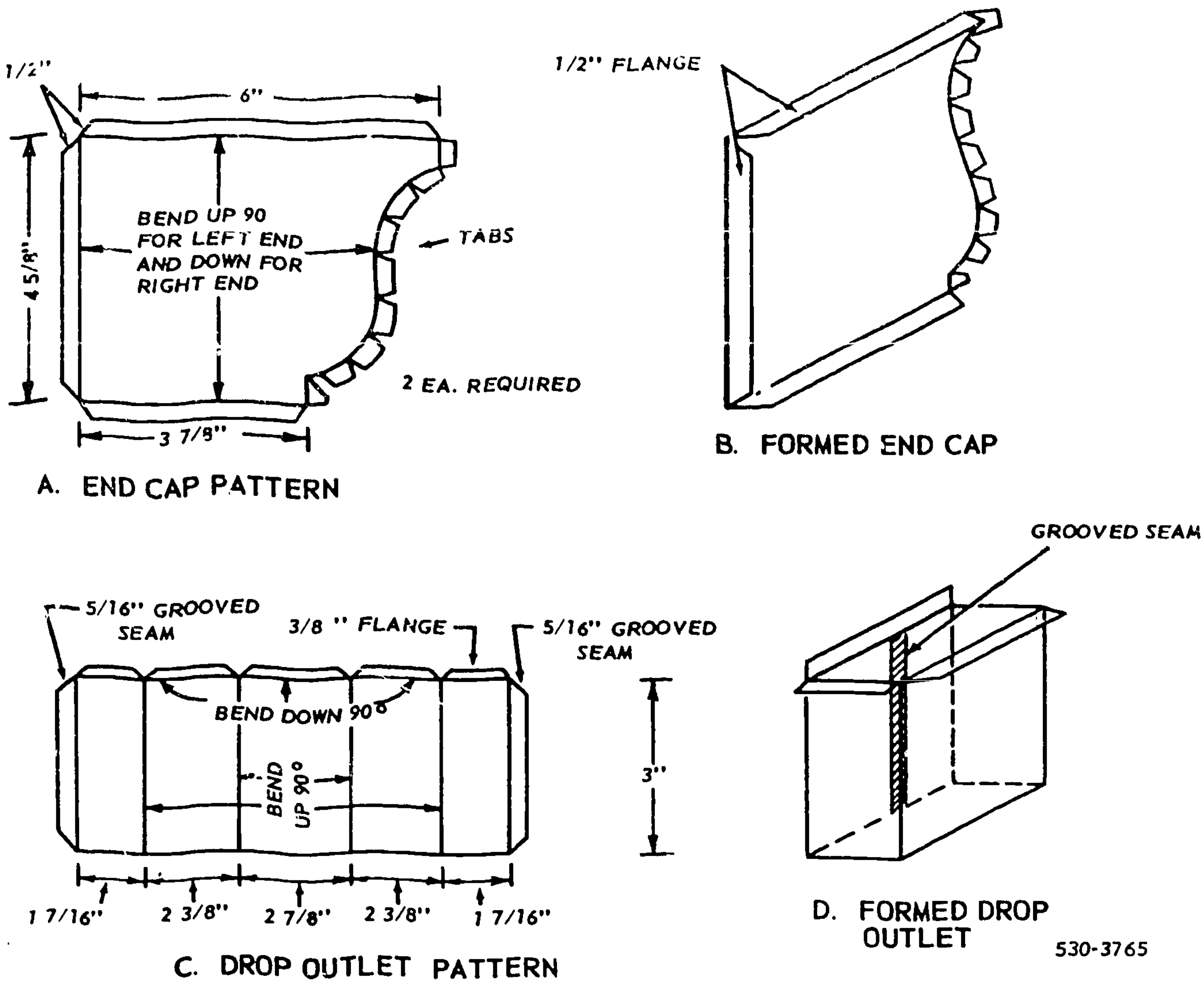


Figure 3-26. Patterns for gutter parts.

Corner miters. Corner miters can be made in a gutter at any point, where needed. In this *example*, we will make the outside and inside corner miters shown in figure 3-28. Notice the measurements: 6 feet from the end cap of piece 1 to the throat of the outside corner miter, 3 feet to the heel of the inside corner miter, and 3 feet to the end cap of piece 3. Begin with piece 1. Make a mark, on the back side, 6 feet from the end cap; then use the 90° side of a combination square to draw a line through the 6-foot mark on the back side. Next, place the 45° angle of the combination square against the back side, and draw a 45° line across the bottom of the gutter. Be sure that this angle for piece 1 is the same as shown in figure 3-28. After marking the 45° miter lines, make a ½-inch allowance on piece 1—for notches on the ogee side, and for flanges on the bottom and back sides. Piece 2 is made in a manner similar to that for piece 1, except that one end has a ½-inch allowance for the tabs and flanges. Be sure to make the miter angles as shown in figure 3-28. Piece 3 is 3 feet in length, and runs from the end cap to the heel of the inside corner miter. Notice that the 45° miter is plain. It does not have tabs or flanges.

Cut the miters, flanges, and tabs with straight snips and aviation snips. After cutting and notching pieces 1, 2, and 3, bend the back side flanges 90° with a hand seamer. The flange on piece 1 should fit inside piece 3. *Do not bend the bottom flanges.* Next, use common pliers to bend the tabs 90° in the same direction as the flanges. Fit the pieces together, with the flanges and tabs on the inside of the gutter; then rivet the flanges. Place a sheet metal screw in the top edge of the bends in

each corner (fig. 3-28). The last step is to solder the seams with 50/50 bar solder. Be sure to sweat the solder into the seams, and to cover the heads of the rivets and screws.

Straight downspouts. Straight downspouts (without corrugations) can be fabricated from patterns, such as the one shown in figure 3-29. This downspout is 2½" x 3", so the stretchout is 11 inches plus seam allowances. The downspout is jointed with a 5/16-inch grooved seam in the center of the 3-inch side; therefore, the ½-inch allowance is made (see view A). After developing two patterns like view A, cut the patterns on the squaring shears or gap squaring shears, and notch the ends of the seam allowances. Next, run the two sheets through the Pittsburg lock forming machine; then use the cornice brake to make the 90° bends in the 1, 2, 3, 4 order shown in view A.

Next, lock the seams and flatten them with a mallet. For a bucking bar, place a 6-foot piece of 2" x 2" x ¼" angle iron in a vise with the flat surface up. The metal should extend out of the vise at least 5 feet. Slip one of the downspout pieces over the angle iron, with the seam up. After flattening 5 feet of the seam, turn the downspout around and flatten the other 5 feet. Do this on both joints of downspout; then make three strap hangers from 16-gage sheet metal. They should look like the hanger shown in view D of figure 3-29. Cut three 11½" x 1¼" pieces of metal. Mark the metal as shown in view C, and punch the ⅛-inch holes with a Whitney hand punch or rotary punch. Next, bend the straps into the shape shown in view D.

Offset downspouts. The top joint of the downspout shown in view B of figure 3-30 is offset 8 inches from the inside of the drop outlet to the wall of the building; therefore, you need to make a 7½-inch offset. To do this, make a 45° elbow in two places on the downspout, as shown in view A. One 45° elbow is 6 inches from the end that connect to the drop outlet; the second 45° elbow is 11⅝ inches from the first elbow. Start the first 45° elbow by notching out a 22¼° angle on each side of the 6inch line. Make sure this first notch is on the seam side of the downspout. Make ⅜-inch allowances for the lap seam flanges so that they lap in the direction of water flow. On the opposite side of the downspout, make the center of the second notch 11⅝ inches from the center of the first notch. Cut out each notch by starting a hole with a ½-inch cold chisel; then cut the metal with aviation snips. Cut the seam with a hand hacksaw, to prevent damaging the blades of the snips. Notch both ends of the ⅜-inch lap seam allowances, and turn them in so that they will slip inside when the downspout is bent into position. The bending is easily done by hand. This changes the two notches to 45° elbows. The two elbows make the offset in the downspout. Install sheet metal screws through the sides with the lap seam flanges, and solder the seams and screwheads to prevent leaks.

Make the shoe shown in figure 3-30 by notching the metal on the side opposite the seam to make two 45° bends, as shown in view C. The notches have flanges, and are cut and assembled like the offset shown in view B, except that both notches are on the same side of the downspout.

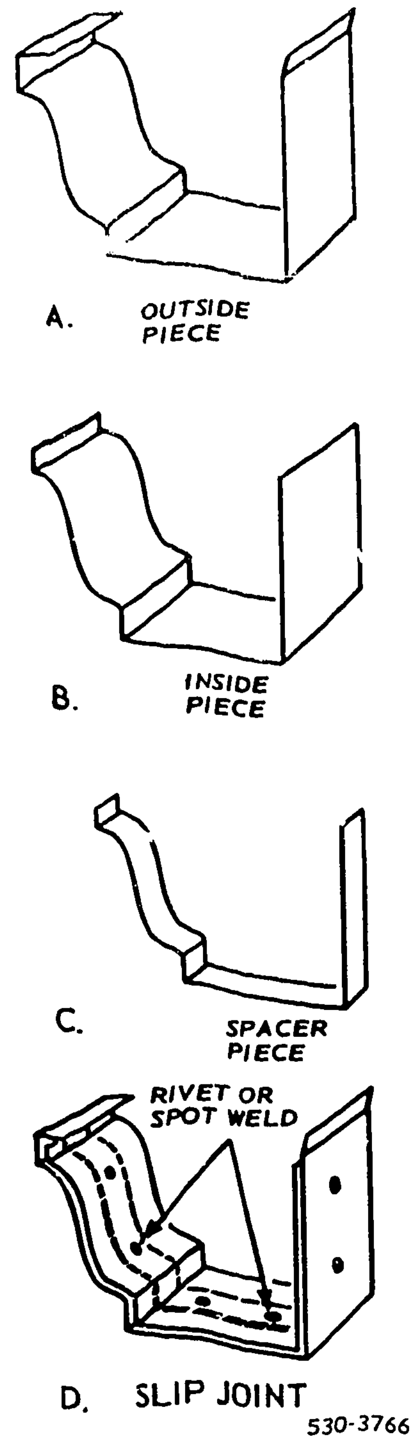


Figure 3-27. Pieces to fabricate a gutter slip joint.

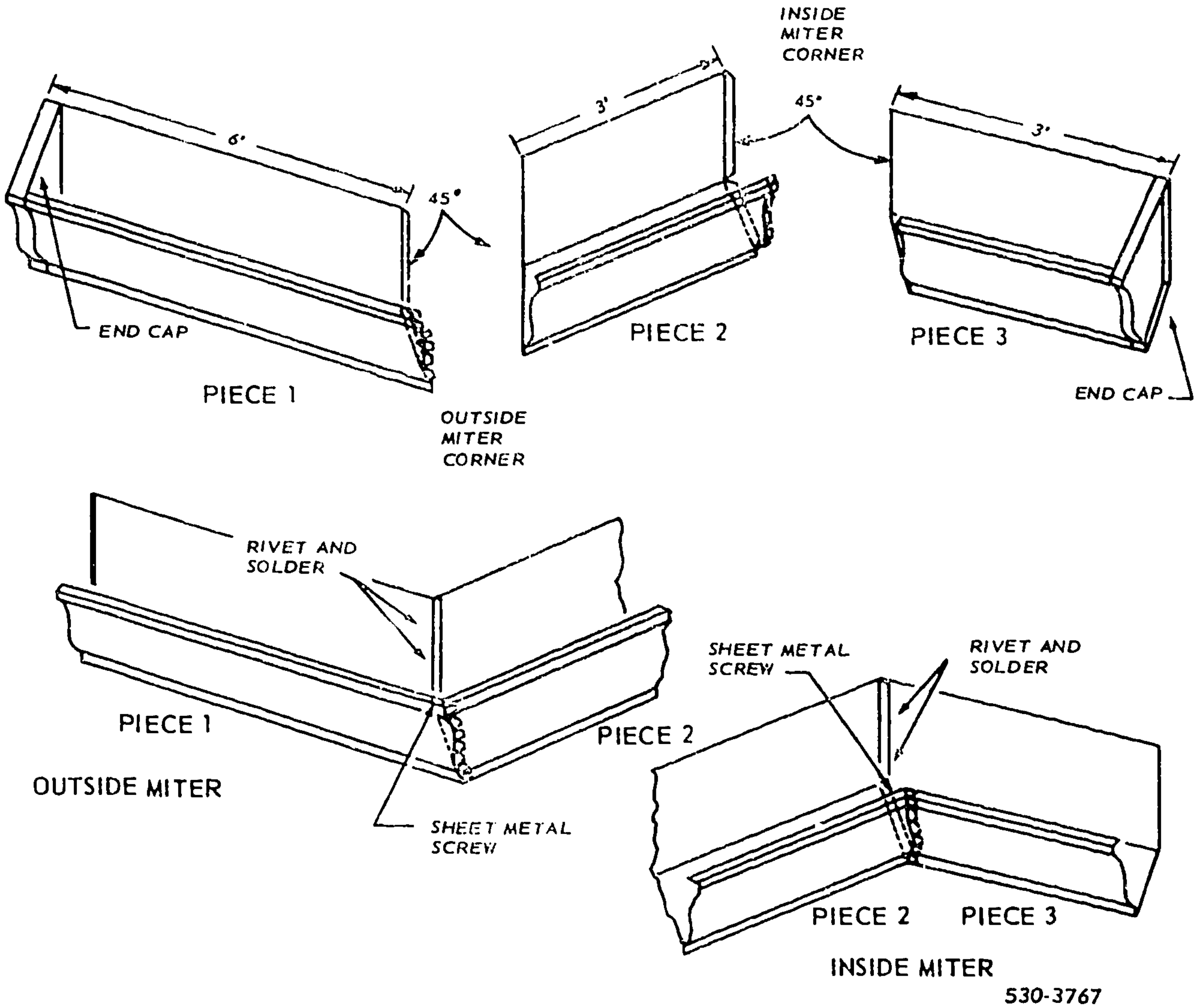


Figure 3-28. Making inside and outside gutter miters.

Exercises (623):

1. What fabrication step is performed on a drop outlet after the grooved seam is complete?

2. How many pieces are required to form and assemble a slip joint for a bar gutter?

3. When making a 90° miter joint in an ogee gutter, the flanges are formed to fit__________ the other piece.

4. When you are making replacement end caps for a gutter, remember that there must be both__________ __________.

5. When a drop outlet is properly installed, where is the seam?

6. Why don't you turn all four flanges 90° on the top of a drop outlet?

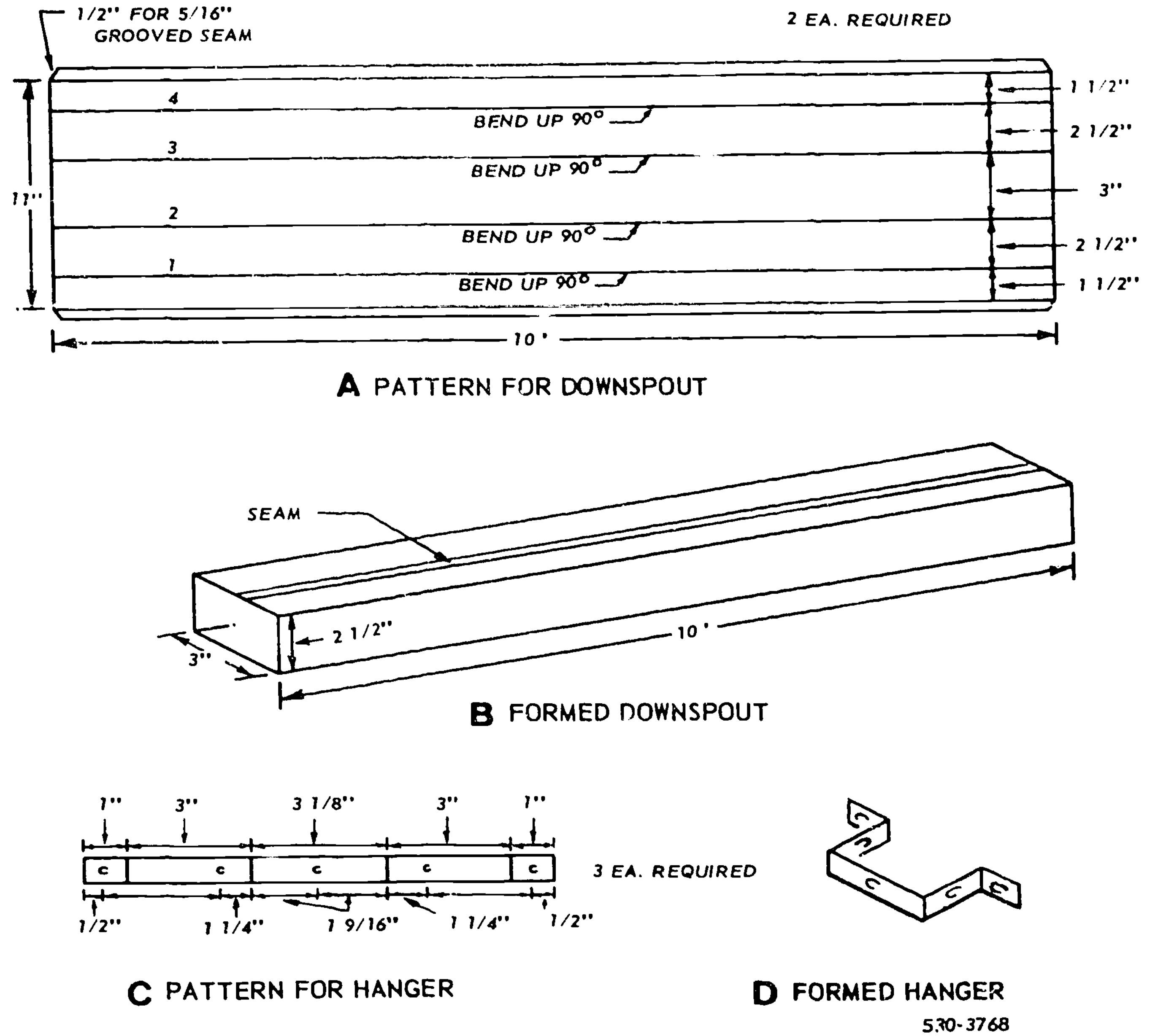


Figure 3 29. Making downspouts and hangers.

7. How are the ports of a slip joint held together?

8. You are making a 90° corner miter in an ogee gutter. How much seam allowance do you leave, and where?

9. When you are assembling a corner miter, where do you put the seam allowance?

10. What is used as a bucking bar for seaming a 10-foot section of leader?

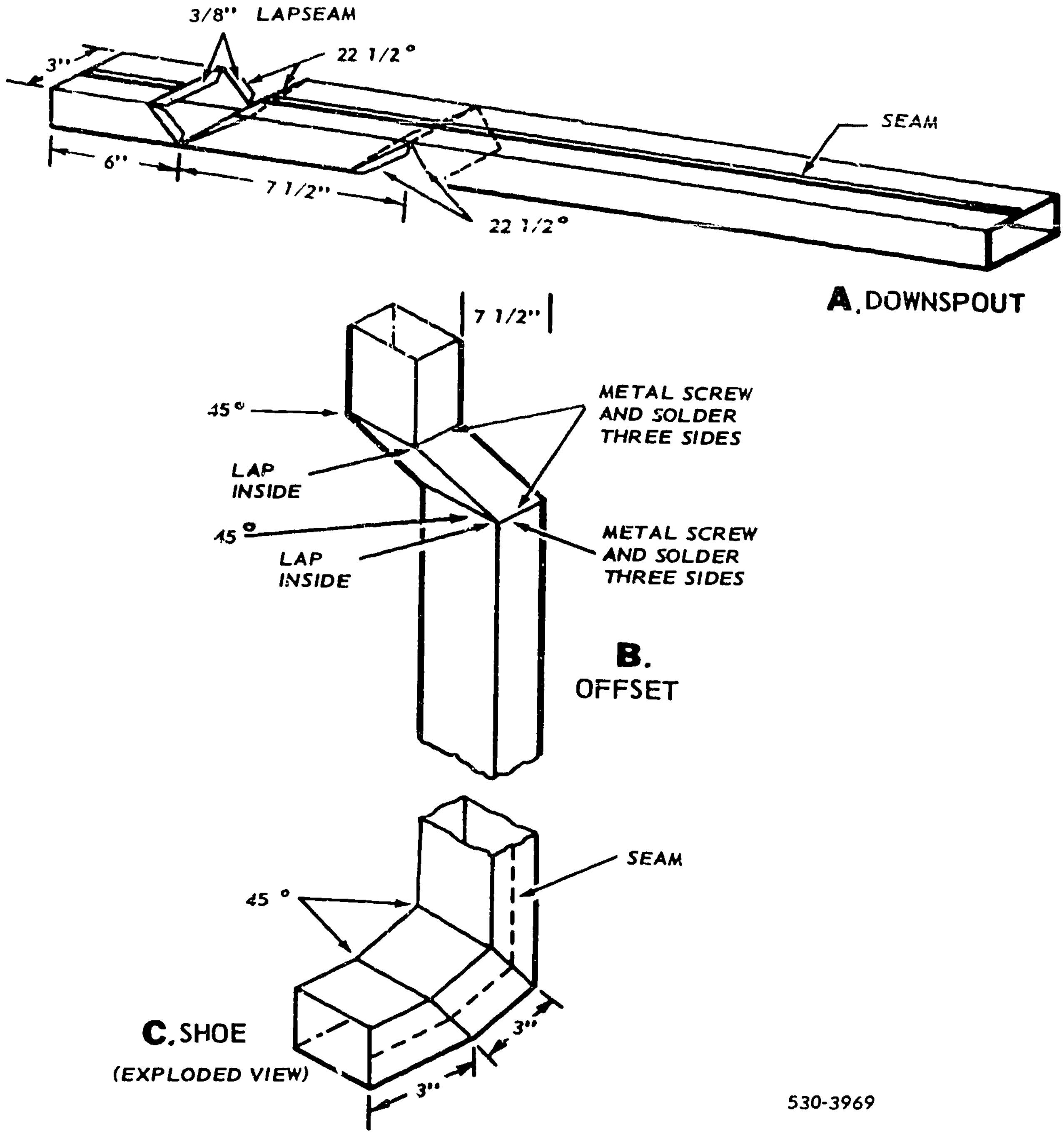


Figure 3-30. Making downspout offset and shoe.

11. In gutters and downspouts, what is a shoe, where does it fit, and how is it made?

624. Explain the installation of replacement gutters and downspouts.

Installation of Replacement Gutters and Downspouts. In this example, we are installing the replacement downspout and gutter which were fabricated, as described in previous paragraphs. Since the hangers for the gutter are still on the building, all we have to do to install the gutter is to place the gutter in the hangers and insert the snap locks. After the gutter is installed, pour some water into the high end to see if the water flows to the outlet on the low end. The drop should be enough to allow the water to flow out of the gutter. If it does not, reposition the hangers.

With the gutter in place, the next job is to install the replacement downspout. First, install the upper section (with the offset) over the drop outlet, and put sheet metal screws in the three outside surfaces of the downspout. Install the strap hanger just below the second offset. Next, measure from the bottom of the downspout to 3 inches above the ground level. This measurement, plus 1½ inches for a joint connection, is the length of the lower section of the downspout. Cut a small notch in each corner of the upper downspout, to make a slip joint.

After slipping the lower piece of downspout over the upper downspout, put sheet metal screws in three sides of the slip joint. Put one hanger just above the shoe, and put another halfway between the top and bottom hangers. This completes the fabrication and installation of gutter and downspout.

Exercises (624):

1. How and when do you test a newly installed gutter?

2. When you are replacing a downspout, how many hangers do you use?

Door and Gates

IN THIS CHAPTER we will discuss a few of the inspection, maintenance, and repair requirements on doors and gates. Because of the great variety of doors and gates in use Air Force wide, we will discuss only general maintenance and repair actions applicable to the majority of door styles. Because most of the maintenance on doors is well above ground level, we will first discuss the ladders and scaffolding that you will use on the job. Many components of large doors are very heavy, so it also is important that you understand the proper techniques for lifting heavy objects.

4-1. Ladders

It is important for you to know the right type of ladder for any job. The most common types of ladders that you will be using are the single ladder, extension ladder, and stepladder.

625. Match types of ladders with their descriptions and uses.

Single Ladder. A single ladder has two side rails from 8 to 26 feet long, with rungs (steps) placed each 12 inches. A quality ladder will support up to 500 pounds. The size of a ladder refers to its overall length. Single ladders that are not self-supporting should be equipped with nonskid bases (spikes or safety shoes). These nonslip bases must be securely bolted, riveted, or attached by equivalent construction to the side rails. You must place safety hooks at the tops of any ladders not equipped with nonskid feet. In addition, ladders must be lashed to nearby supports when necessary to insure stability. Nonslip tape or adhesive material should be affixed to metal ladder steps to insure sound footing.

Extension Ladder. The extension ladder consists of two or more sections. Each adjustable extension ladder must be equipped with nonslip bases and spring-loaded rung locks with metal shackles. Pulleys and ropes must be provided for adjusting ladder length. The sections must overlap at least 3 feet for a 36-foot extension, 4 feet for a 45-foot extension, and 5 feet for any extension over 45 feet. You must not use any ladder extended beyond 60 feet.

Stepladders. All stepladders are self-supporting. Use such ladders only on flat surfaces to insure solid footing. When the ladder is open, the steps m , be horizontal, and all stepladders must have a locking device to keep them open.

Exercises (625):

1. Match the type of ladder in column B with the phrases in column A.

Column A	*Column B*
____ (1) Use to climb a scaffold 30 feet high.	a. Single ladder.
____ (2) Use where there is no wall for support.	b. Stepladder.
____ (3) Use to get onto a roof of a building 14 feet high.	c. Extension ladder.
____ (4) From 8 to 26 feet long.	
____ (5) Equipped with nonslip bases and spring-loaded rung locks with metal shackles.	

626. Distinguish between proper and improper ladder raising techniques.

Straight Ladder. Erect a straight ladder by placing the base of the ladder (wide end) against the foundation of the structure. Raise the top and walk under the ladder toward the bottom end, grasping and raising the ladder rung by rung as you proceed. When the ladder is perpendicular, pull the bottom out from the building to a distance of one-quarter of its length, as shown in figure 4-1. If you must get on top of the building or on a scaffold, the ladder must extend at least 36 inches beyond that surface, as shown in figure 4-2.

Extension Ladder. Erect extension ladders in the collapsed position in the same manner as the straight ladder. After the ladder is against the structure, use the ropes to extend the sections until the ladder is long enough.

Exercises (626):

1. Indicate each statement reflecting a good ladder raising technique.

____ a. The base of a 16-foot ladder extends 3 feet from the foundation of a building.
____ b. The top of a 10-foot ladder extends 36 inches above the roof.
____ c. Extend an extension ladder on the ground before raising it.
____ d. Spread a stepladder until the legs lock in position.
____ e. Place the bottom of a straight ladder against a foundation to raise it.

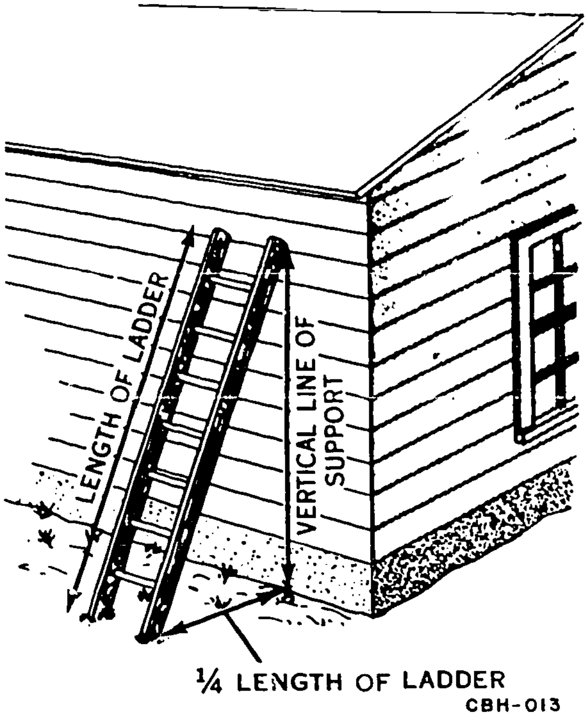


Figure 4–1. Placing a short ladder.

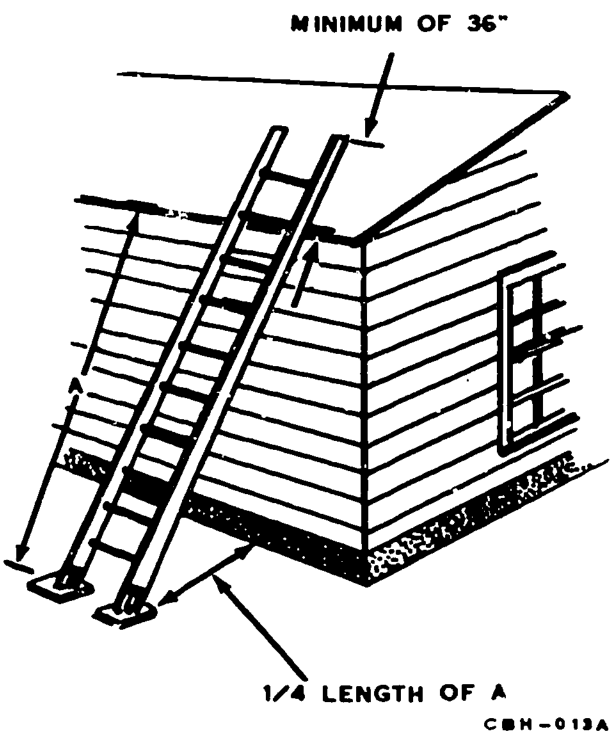


Figure 4–2. Placing a long ladder.

627. Identify safety precautions to observe when you use a ladder.

Ladder Safety. Observe these safety precautions when you use a ladder:

a. Always inspect a ladder before using it.

b. Before climbing a ladder, be sure that both rails rest on solid footing.

c. Equip the ladder side rails with safety shoes. This is especially necessary when you use the ladder on surfaces that would permit it to slip.

d. Never use stepladders as substitutes for workstands.

e. As you ascend or descend, face the ladder and hold on to each side rail.

f. When the security of a ladder is endangered by other activities, rope off the area around it, fasten it securely, and assign a helper to steady the bottom.

g. When you use a ladder in front of a door, lock the door or block it off and route people to another exit.

h. Never leave a ladder unattended for any length of time while it is erected—take it down and lay it on the ground.

i. When you work from a ladder, stand no higher than the third rung from the top and do not try to reach beyond a normal arm's length.

j. If you need help to do the work, have your helper get another ladder—don't allow anyone on the ladder with you.

k. Never climb a ladder while using both hands to hold material; you must use at least one hand to climb or descend a ladder.

l. Never place either the top or the bottom of a ladder against unstable material.

m. Before climbing a stepladder, be sure it is fully open and locked, and that all four legs are on a solid footing.

n. Do not leave tools on the top of a stepladder unless it is equipped with a special holder.

o. Never use metal ladders where they might come in contact with electric current.

p. Get help when erecting long, heavy ladders.

Exercises (627):

1. Match the following situations in column B with the safety requirements in column A.

Column A	*Column B*
____ (1) Safety shoes.	a. Climbing a ladder.
____ (2) Do not stand on the top steps.	b. Working from an extension ladder.
____ (3) Rope off the area.	c. Before climbing a stepladder.
____ (4) Do not use near electrical apparatus.	d. Using a stepladder.
____ (5) Stand no higher than third rung from top.	e. Be sure ladder rails are equipped with these before climbing.
____ (6) Face the ladder and use both side rails.	f. Using metal ladder.
____ (7) Be sure locking device is locked.	g. Ladder placed in area of other activities.

628. State the proper care and handling of ladders.

Care of Ladders. Inspect ladders for defects and discard a ladder if any defect has developed. Carry a ladder over your shoulder with the front end elevated. Do not drop it or

allow it to fall, because the impact will weaken it. Store the ladder horizontally on three hangers to prevent sagging. Do not store a ladder near heat or exposed to the weather.

Exercises (628):

1. Indicate each true statement.

____ a. Carry a ladder with the front elevated.
____ b. Use two hangers to support a stored ladder.
____ c. You can store a ladder on an exterior wall.
____ d. Never drag a ladder.
____ e. Inspect a ladder for defects before using it.
____ f. You can store a ladder leaning against a wall.

4-2. Scaffolds

You must do part of your work from a scaffold. Serious accidents have been caused by workers using scaffolds that were erected or used improperly. A scaffold erected improperly not only endangers the workers using it but right become a serious danger to people who work near it.

There are many types of scaffolds—some made of wood and some of metal. The scaffolds you will use include scaffold horses, sectional steel scaffolds, and aluminum stairway scaffolds.

629. Identify scaffolds with their advantages and limitations.

Types of Scaffolds. A pair of scaffold horses with scaffold boards placed across them make a useful scaffold (fig. 4-3). It is erected quickly and can be moved easily as the work progresses, but its height is limited to the height of the horses. Always use two boards, at least 1½ inches thick and 9½ inches wide (2 x 10s). You can use an extension plank, as shown in figure 4-4, in place of the scaffold boards.

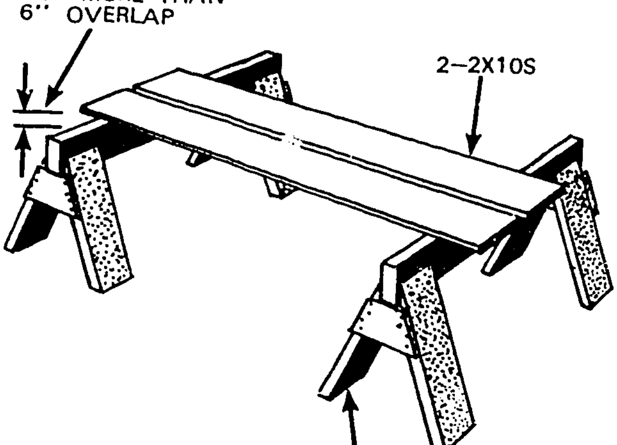


Figure 4–3. Scaffold horse.

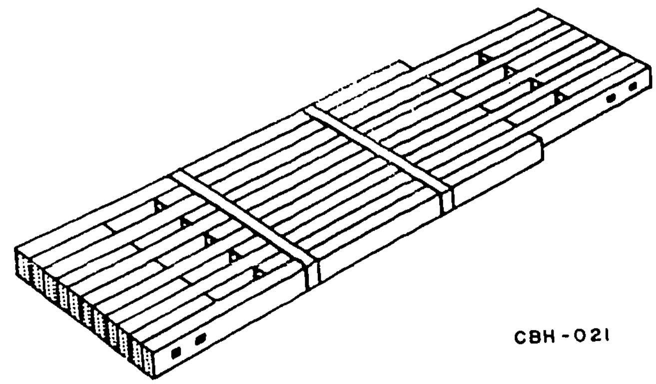


Figure 4–4. Extension plank.

The sectional steel scaffold is strong and assembled easily. It will hold heavy loads. The most popular scaffold is the aluminum stairway scaffold. The sections of this type of scaffold unfold. You can erect this scaffold quickly and easily, but it is limited to lighter loads than those possible with the sectional steel scaffold.

Exercises (629):

1. Match the descriptive phrases in column A with the types of scaffolds listed in column B. The items in column B may be used once, more than once, or not at all.

Column A	*Column B*
____ (1) Is limited in height.	a. Aluminum stairway scaffold.
____ (2) Fast to assemble.	b. Scaffold horse.
____ (3) Used to hold heavy loads.	c. Sectional steel scaffold.

630. Given hypothetical situations that might occur in erecting scaffolds, decide which ones are appropriate.

Erecting Scaffolds. A scaffold using scaffold horses is the easiest scaffold to erect. Place the horses on even footing and lay two scaffold boards (2 x 10s or larger) or an extension plank on top of them. The scaffold is ready to use.

Sectional steel scaffold. First set the footing plates on firm, even ground or on a board to support the weight of the scaffold. Then insert a leveling jack into each footing plate and install two panels into the leveling jacks (fig. 4-5). Have helpers steady the panels while you attach X-type pivoted braces, as shown in figure 4-6. Now you have one basic unit. Add more units until the scaffold is as long and as tall as you need. Figure 4-7 shows an erected scaffold. The upright legs of the scaffold are held securely by couplings. Spring-loaded pins in the coupling automatically lock the sections together.

Sectional steel scaffolding can be constructed as high as required, but scaffolding over three sections high must be secured to the structure. One way to do this is shown in figure 4-8. The top section always must have a guardrail and a toeboard. The guardrail prevents workers from

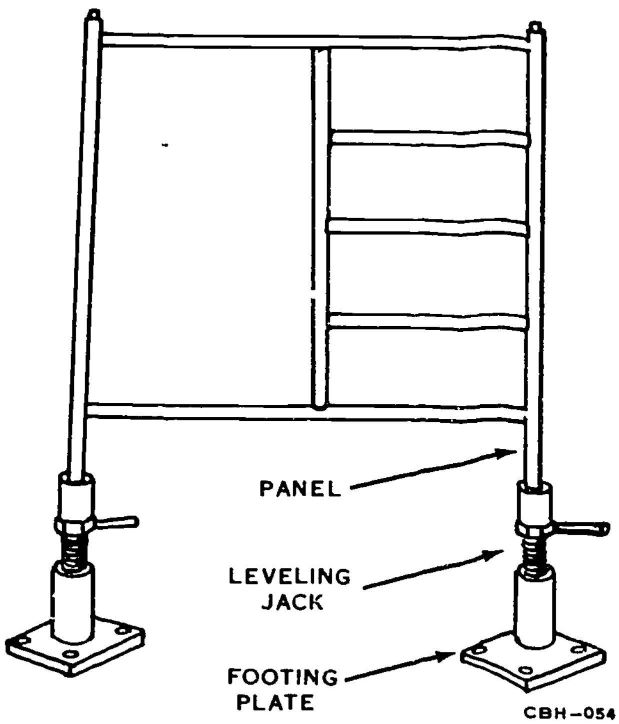


Figure 4-5. Installing leveling jacks.

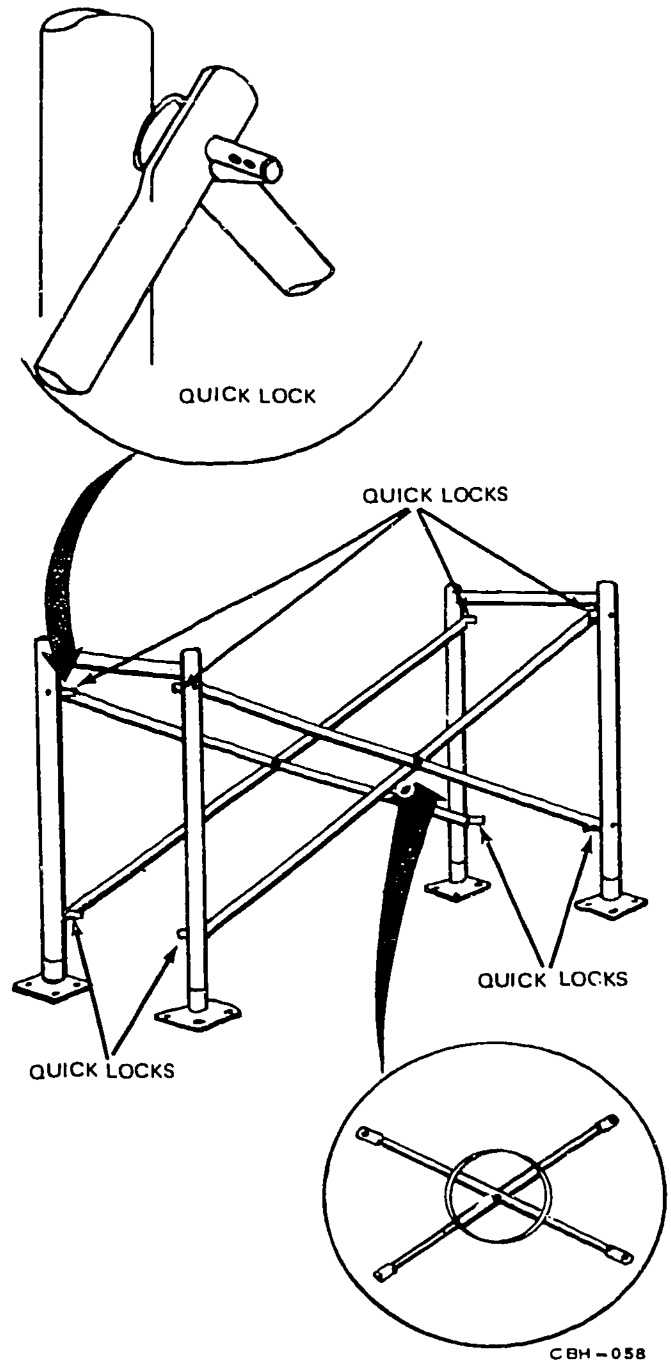


Figure 4-6. Installing braces.

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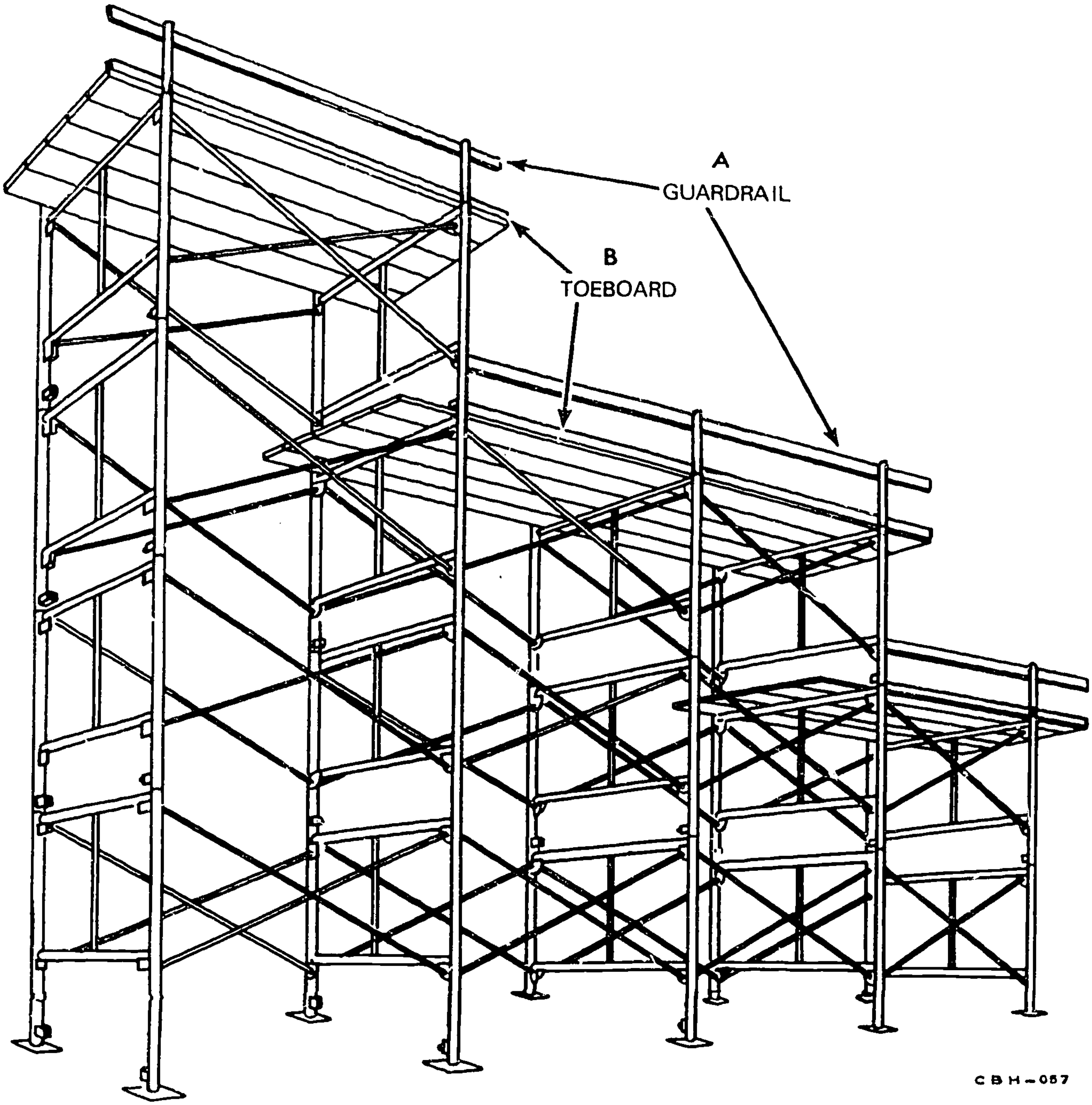

Figure 4–7. An erected scaffold.

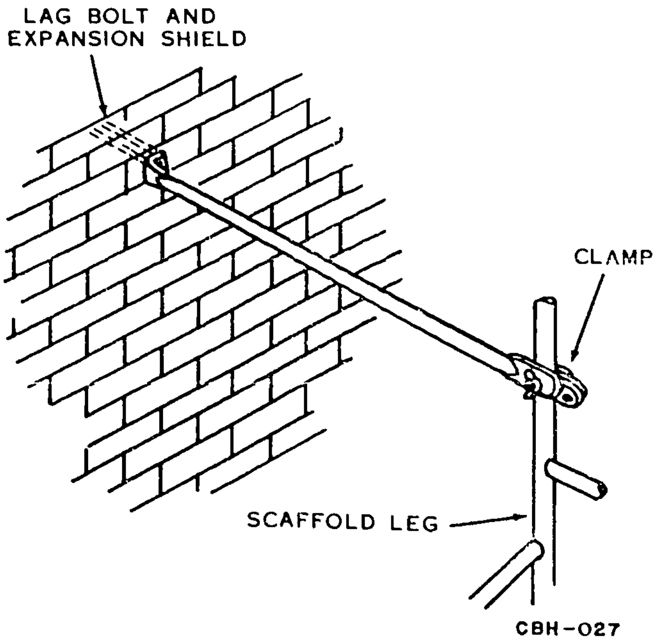

Figure 4-8. Building tie-in.

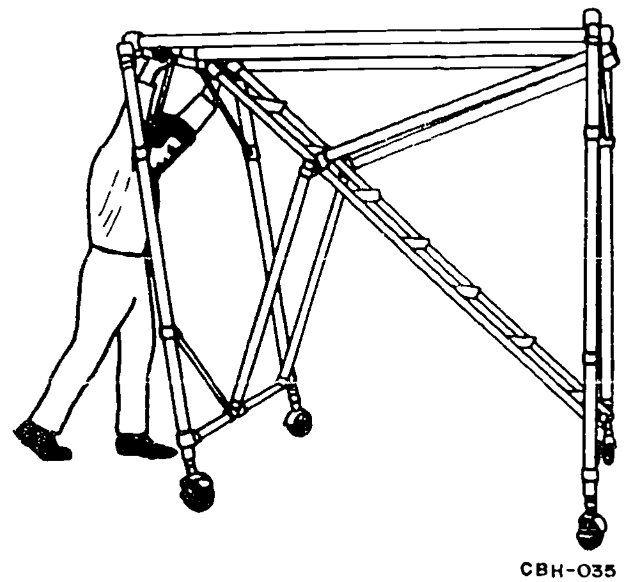

Figure 4-9. Unfolding aluminum scaffold sections.

falling, and the toeboard keeps tools and materials from falling on the workers below.

If the scaffold is to be used on a solid floor and moved frequently, you can replace the footing plates with locking casters. The height of this rolling tower must not exceed four times the smallest base dimensions, and it must be equipped with a toeboard and a guardrail above the working platform.

Aluminum Stairway Scaffold. Aluminum stairway scaffolds consist of three basic sections that unfold and lock together. The base sections is shown in figure 4-9. In storage it folds in on itself in a Z pattern. This section contains the wheels which are adjustable up and down to allow for leveling on uneven work surfaces (fig. 4-10). When the sections are unfolded, be sure that the braces are in locked (fig. 4-11). The other sections unfold in the same manner and fit together as shown in figure 4-12. Interlock clips lock the sections together to prevent separation during use (fig. 4-13).

Exercises (630):

1. Indicate each satisfactory scaffolding procedure.

____ a. You place all four legs of a scaffold horse on even ground.

____ b. You substitute a 2 x 6 for extension plank.

____ c. You adjust the height of a sectional steel scaffold with the pivot braces.

____ d. Couplings secure upright legs of the sectional steel scaffold.

____ e. A sectional steel scaffold four sections high secured to the building.

____ f. A rolling tower with four swivel casters.

____ g. The first section of an aluminum stairway scaffold being erected with the stair treads facing up.

____ h. Spring-actuated latches of an aluminum stairway scaffold unlocked.

____ i. Lock caster brakes before attempting to climb aluminum stairway scaffold.

____ j. Sections of an aluminum stairway scaffold fastened together with an interlock clip.

631. Rate hypothetical scaffold erection procedures as safe or unsafe.

Scaffold Safety. Although scaffold horses are not very high from the ground, there always is some possibility of danger. Here are several precautions that you can take to prevent serious injury to yourself or others. Always inspect the scaffold horses for split members, loose knots, and bad nailings. Set the scaffold horses on firm, even footing for each leg. Test scaffold boards by jumping on them. Never use a scaffold board that is under 1½ x 9 1/2 inches (2 x 10). Place the boards close together on the horses, and do not overload the scaffolds.

Sectional steel scaffold. The sectional steel scaffold is the safest type, because it will hold such heavy loads. Still, there are safety precautions to observe when you work from the sectional steel scaffold. Inspect all scaffolds before using—never use any equipment that is damaged or deteriorated in any way. Keep all equipment in good repair. Avoid using rusted equipment. You can never be sure how strong it is. Inspect erected scaffolds regularly to be sure they are maintained in safe condition.

Support scaffold posts adequately, and use base plates. Use leveling jacks instead of blocking to adjust to uneven grade conditions. Plumb and level all scaffolds as the erection proceeds. Do not force braces to fit—level the scaffold until a proper fit can be made easily. Fasten all braces securely, and never climb across them.

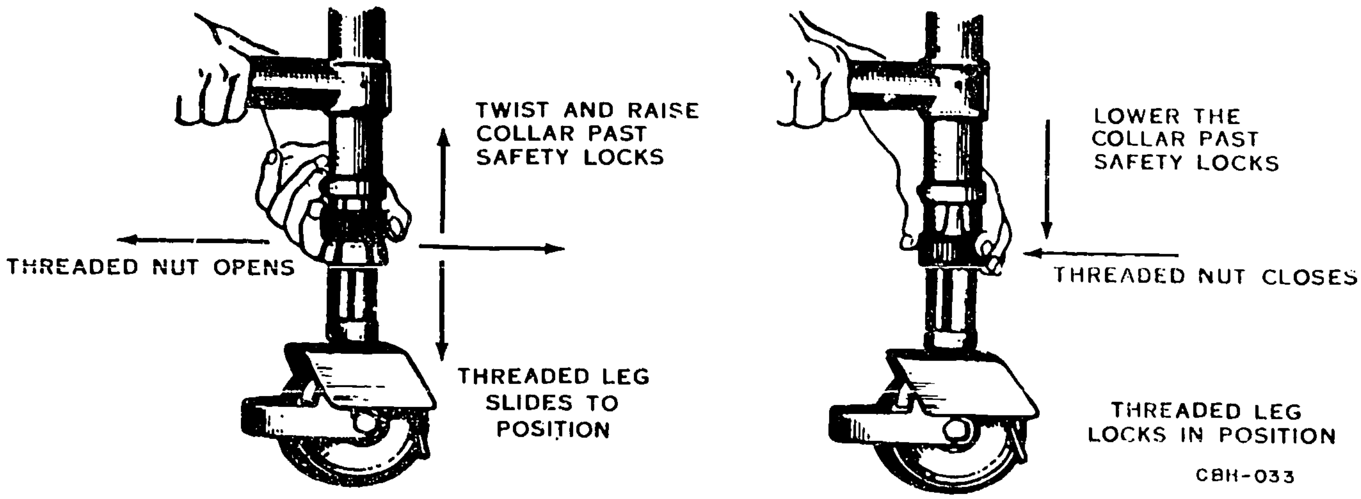

Figure 4–10. Leveling aluminum scaffolds.

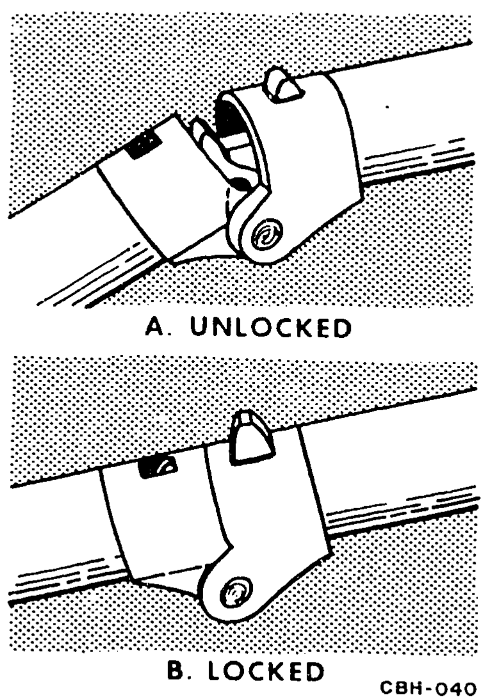

Figure 4–11. Locking latches.

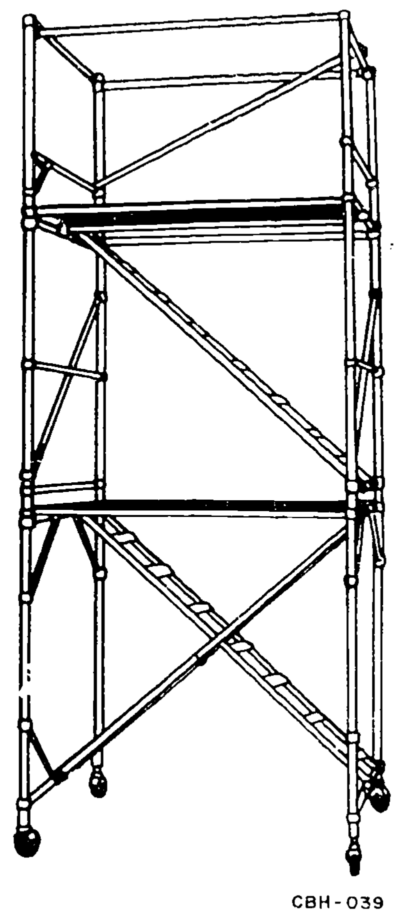

Figure 4–12. Aluminum stairway scaffold.

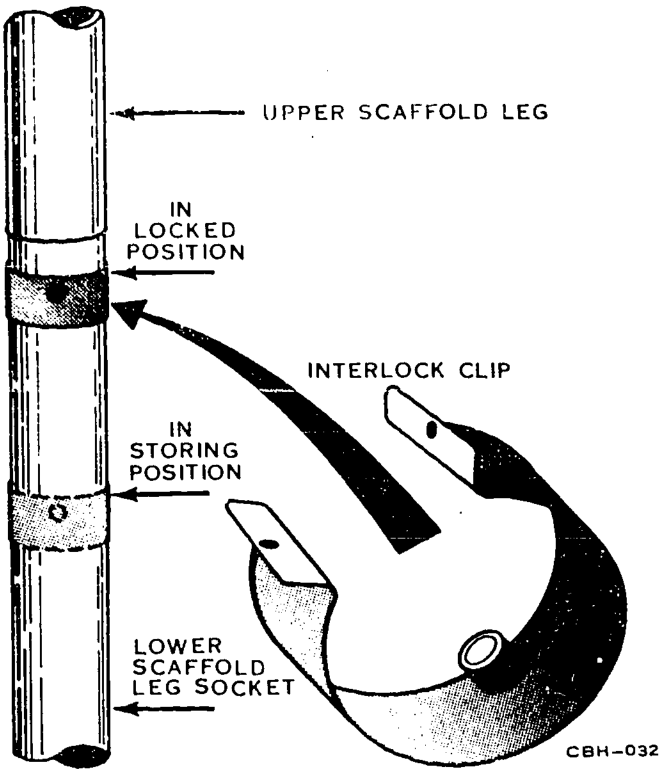

Figure 4–13. Interlock clip.

On wall scaffolds, place and maintain tie-ins securely between the structure and the scaffold at least every 30 feet of length and each three sections in height. Equip all planked or staged areas with proper guardrails and toeboards.

Do not erect metal scaffolds near powerlines, and don't use ladders or makeshift devices on top of scaffolds to increase the height. Don't overload the scaffolds, and be sure you use only lumber that is inspected and graded properly as scaffold plank. Planking must have at least 12 inches of overlap and extend 6 inches beyond the center of the support (or be cleated at both ends to prevent their sliding off supports). Do not allow unsupported ends of plank to extend an unsafe distance beyond their supports. Secure the planks to the scaffold when necessary.

Never ride rolling scaffolds, and remove all material and equipment from the platform before moving the scaffold. Apply the caster brakes whenever the scaffold is not being moved. Casters with plain stems must be attached to the panel or adjustment screw by pins or other suitable means. Do not try to move a rolling scaffold without sufficient help. Watch out for holes in the floor and for overhead obstructions. Do not extend adjusting screws on rolling scaffolds more than 12 inches. Always consider the likelihood of overturning before you decide to use brackets on rolling scaffolds. The working platform height of a rolling scaffold must not exceed four times the smallest base dimension unless the scaffold is guyed or otherwise stabilized.

Aluminum stairway scaffold. Apply all caster brakes before climbing the scaffold. As it is with any other scaffold, never move the scaffold when anyone (or any material) is on it. Be sure the scaffold is level at all times. When you adjust a leg, be sure to push the locking collar completely over the expanding nut and below the safety locks. Never adjust the legs when anyone is on the scaffold. Don't try to "stretch" the platform height with the adjustable legs. When additional height is required, add more scaffold sections. Save the leg adjustment for leveling the scaffold. Do not lean a ladder against a stairway scaffold or place a ladder on the platform of a scaffold. Never push or lean against the wall or ceiling when you are on a scaffold, unless the scaffold is tied securely to the building.

Make sure all locking hooks are firmly in position. These hooks are at each end of the separate horizontal and diagonal braces and at the lower end of stairways. Before using a scaffold with folding braces, be sure that the latches of all locking hinges are locked. Always install a safety railing and toeboard when a platform is to be used at heights of 4 feet or over. If the platform height is going to exceed three times the minimum base dimension, tie the scaffold to the building. Do not climb or stand on diag[illegible]l braces. Work only while standing on one of the plat[illegible]. Never use a scaffold of any type near live electric [illegible]pparatus or near machinery that is in operation.

The columns of each scaffold section have interlock clips positioned in the lower area of a pair of holes at the upper ends. As an upper section is inserted, the interlock clips of the section below are moved to the upper section bushings, interlocking the two sections. Never erect a scaffold without interlocking the sections in this manner. If the interlock clips are damaged or lost, replace them immediately. Never work from stairways; they are for personnel to walk up and down between platforms. Stairways are designed to take the weight of a 200-pound person. They are not designed to take excessive loads or abuse. Never climb up the outside of a stairway scaffold. Always use the stairway for access. The platform of the stairway scaffold always must be located on the floor braces by four locating pins. Outdoors, or wherever the scaffold is exposed to wind or updrafts, the platform must be tied down and the scaffold secured to the building. The platform of the stairway scaffold is designed to carry a maximum distributed load of 750 pounds. Do not exceed this 750-pound load. When you bridge between scaffolds with planks or ladder stages, place the ends of such planks or stages on the scaffold platform across both floor braces.

When erecting or taking down an upper section of the scaffold, stand in the center of the platform below and keep a firm hold on the section.

Exercises (631):

1. Indicate each safe situation.

____ a. Raising the height of a platform with the leveling jacks.
____ b. Cross braces with the locking devices locked.
____ c. Climbing scaffold cross braces to reach the platform.

____ d. A 2 x 8 scaffold board.
____ e. Ladder placed on a scaffold.
____ f. Aluminum stairway scaffold tied to the wall of a building.
____ g. Columns of aluminum stairway scaffold locked with an interlock clip.
____ h. Working from the stairway of an aluminum stairway scaffold.
____ i. Platform of aluminum stairway scaffold located on the floor braces by locating pins.

632. Differentiate between safe and unsafe lifting situations and sequence lifting steps in the correct order.

Lifting Heavy or Cumbersome Loads. The *Ground Accident Prevention Handbook*, AFR 127–101, states that physical differences make it impracticable to set up lifting limits for workers. In your career field, there may be times when heavy materials must be moved. For example, a 200-pound drilling machine may have to be lifted and placed onto a pickup truck. Don't be like the airman who carried two 94-pound sacks of cement from a truck to the mixer. He was showing off. This time, however, he ended up with a hernia, a reprimand, lost time, and an unfavorable mark against the unit.

Use commonsense when it comes to moving objects. If it is too heavy or cumbersome to lift, get a friend to help you. If you decide you can lift a heavy load, use the proper lifting method to do it.

When you must lift a heavy or bulky object from the floor, USE YOUR LEGS—NOT YOUR BACK. If you are not mindful of this advice, you can hurt your back. An injured back often is difficult to heal and can keep you from taking part in many work and athletic activities. If you take the following precautions in lifting, you can greatly reduce the likelyhood of injury.

(1) Consider the size, weight, and shape of the object to be carried. Do not lift more than you can handle comfortably. If necessary, get help.

(2) Set your feet solidly, with one foot sightly ahead of the other for increased stability. Place them far enough apart to give good balance.

(3) Get as close to the load as possible. Crouch by bending your legs about 90° at the knees. Do not squat by sitting on your legs. It takes about twice as much effort to get up from a squat as from a crouch.

(4) Keep your back as straight as possible. It need not be vertical, but it should not be arched. Bend at the hips, not the middle of the back.

(5) Grip the object firmly. Maintain the grip while lifting and carrying.

(6) Straighten your legs to lift the object and at the same time, bring your back to a vertical position.

(7) Never carry a load that you cannot see over or around. Make sure the path of travel is clear. Setting an object down requires just the reverse procedures.

Exercises (632):

1. Arrange the following steps for lifting a heavy load in the proper sequence.

____ a. Keep your back straight.
____ b. Crouch.
____ c. Check weight and size.
____ d. Plant your feet well apart.
____ e. Lift slowly by pushing with your legs.

4-3. Personnel Doors

It is safe to say there are more personnel doors on base than any other type. Because these doors are opened and closed many times a day, they break down frequently. The majority of the problems you will encounter will involve the hinges and "fit" of the door. Occasionally a door will be damaged beyond repair, and it will be necessary for you to order a replacement door and temporarily secure the damaged door.

633. Differentiate between various door swings.

Door Identification. When replacing or ordering components for swinging doors, you must be able to accurately determine the swing (or hand) of a door according to a specific, widely accepted method or standard. Various manufacturers determine door swing in different ways. The method you should use, however, is widely accepted and used by engineers both in and out of the military. The four types of door swing you should be familiar with are shown in figure 4-14.

You always face the *outside* of the door to determine its swing (or hand). The outside is the street side of an entrance door or the corridor side of a room door.

Left hand. A left-hand door has the hinges on the left and opens inward (away from you).

Right hand. A right-hand door has the hinges on the right and opens inward (away from you).

Left-hand reverse. The left-hand-reverse door has the hinges on the left and opens outward (towards you).

Right-hand-reverse. The right-hand-reverse door has the hinges on the right and opens outward (towards you) as you face it from the outside.

Exercises (633):

1. What is the swing of a door that has the hinges on the left and swings inward (away from you) as you face it from the outside?

2. How can you identify a right-and-reverse door?

3. Where must you stand to determine the swing of a door?

634. Explain common problems and repair methods for personnel doors.

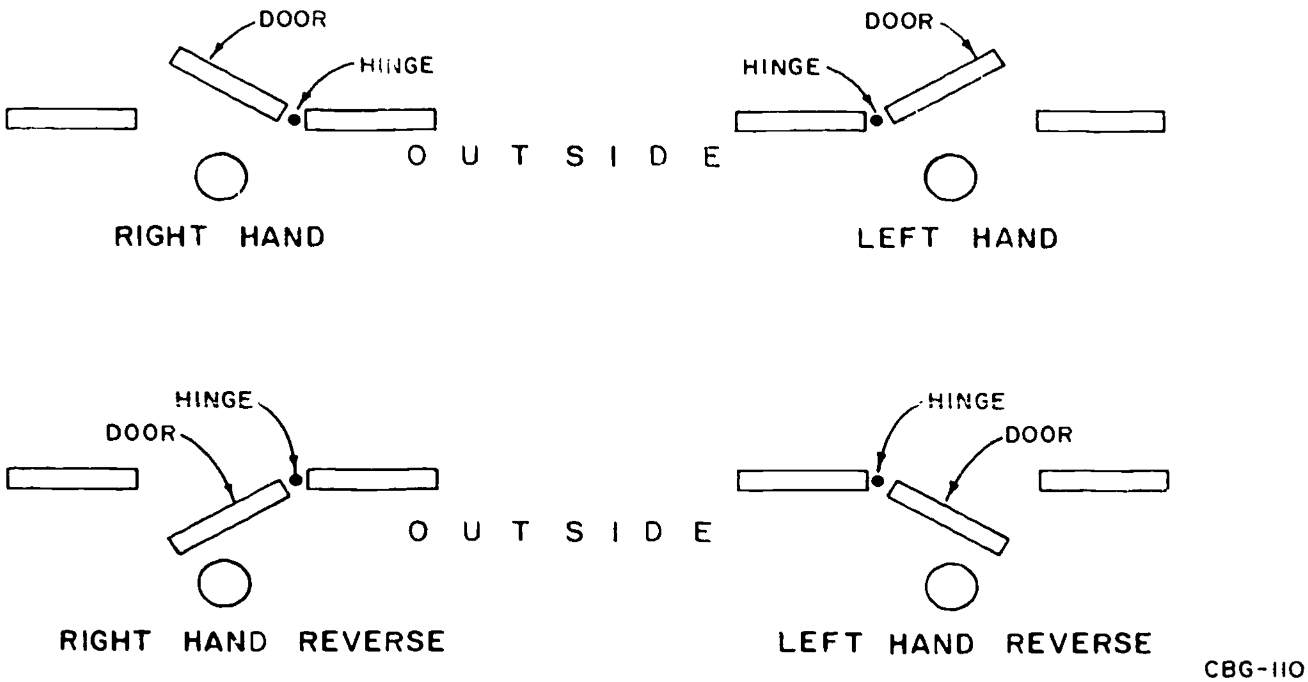

Figure 4–14. Door hand.

Maintenance and Repair of Personnel Doors. Personnel doors require very little maintenance when installed properly. The main problems you will encounter will involve the door hinges, which, in turn, affect the fit of the door into it's casing. Typically, hinges are secured with machine screws to hinge reinforcement plates as shown in figure 4-15 on both the door and casing. Over a period of time these screws may work loose, or the spot welds securing the plate to the door or casing break. A broken door closer may allow the door to be opened violently by the wind, which can break these plates or screws. A door that is not hung properly can cause the hinge to bind and cause enough pressure to damage the plates or screws. A hinge-bound door is difficult to close, and springs open. Occasionally the hinge reinforcement plate is not mounted flush with the inside of the jams or becomes twisted, which causes excess pressure on hinge components.

Before you may any repairs to the door, you should first determine what caused the damage. It will not help to replace a hinge only to ruin it because the hinge plate is twisted. Usually by visually checking door alignment and operation, you will be able to determine the problem. Check the gap between the door and its casing to see if this may indicate a problem. If the door fits tighter at one end than it does at the other, perhaps a hinge is bent or sprung. If the door tends to spring open, check the hinges for binding or the mounting plates to see if they are misaligned or damaged.

If a hinge plate is twisted in its mount, you may be able to straighten it with the use of a simple shop-made tool as shown in figure 4-16. By fastening the old hinge part of the tool to the reinforcement plate with the correct size screw, you can pry it in the direction needed to straighten it.

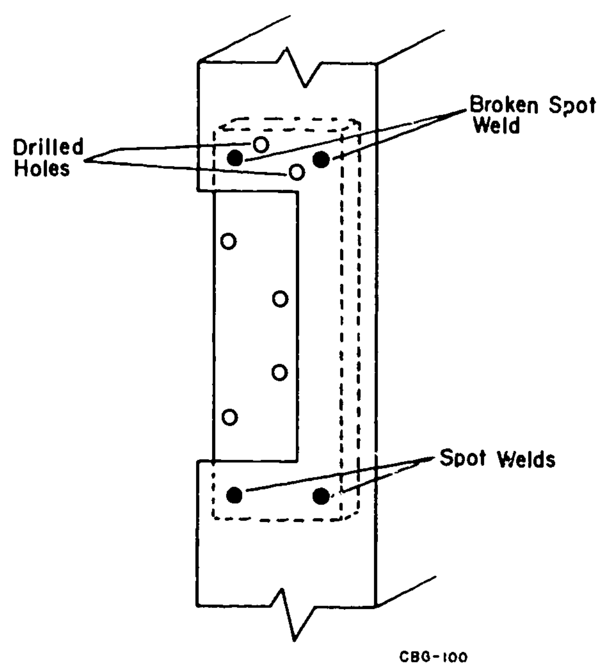

Figure 4–15. Hinge reinforcement plate.

If the spot welds holding the plate in position are broken, you must reweld it. Because the hinge mounts into the recessed area, the best way to repair it is to drill holes in the casing as shown in figure 4-15 and reweld through these holes. The welds may then be ground flush, and the hinges re-installed. The tool used to straighten the hinges may be

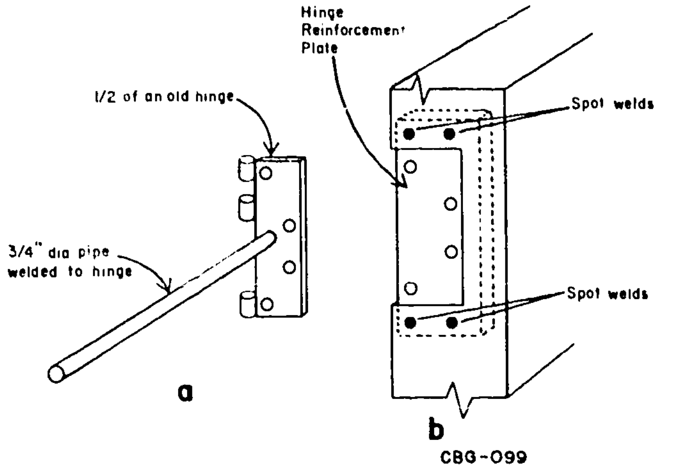

Figure 4–16. Hinge alignment tool.

used at this point to hold the hinge plate in position for welding.

If the screws have been stripped or pulled loose you will have to cut new threads into the plate with a tap (fig. 4-17). Taps are made of carbon or high-speed steel and heat treated. They are very hard and brittle and must be handled carefully. These taps are made in three different styles; taper, plug, and bottom for each size. The long taper tap allows easier starting of a tapped hole, but cannot cut threads to the bottom of a hole that does not go completely through an object. The plug tap has less starting taper and will cut threads deeper into a blind hole (one that does not go all the way through). The bottom tap is used to cut threads all the way to the bottom of a blind hole.

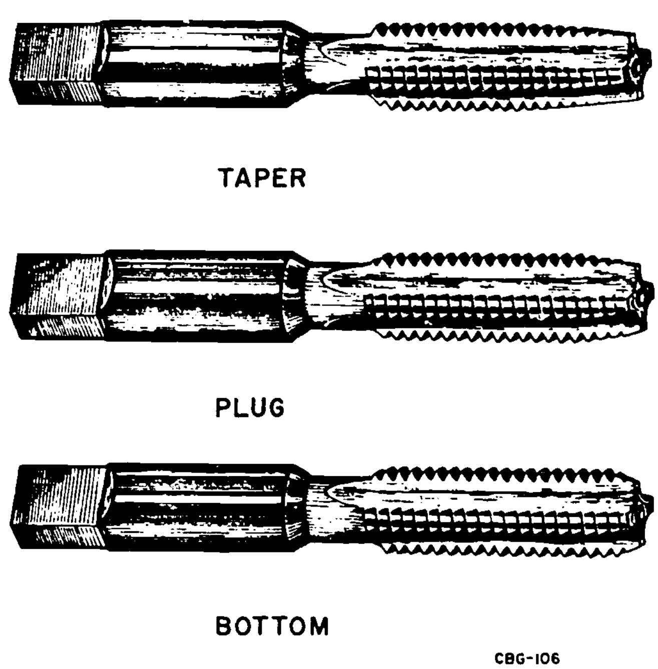

Figure 4–17. Taps.

Before cutting the threads, drill a hole of the correct dimension. For example a 1/4–20 thread size requires a #7 tap drill size. The chart in figure 4-18 shows the tap drill sizes for the most common screw sizes. A special tool to turn the tap is the tap wrench shown in figure 4-19.

Some things to remember when cutting new threads are:

(1) Use the correct size tap drill.

(2) Use a cutting oil to lubricate the tap.

(3) Be sure the tap is started and fed squarely into the hole.

(4) Remove chips frequently as you cut. Turn the tap 1/4 turn ahead and then back to break the chips.

(5) Do not force the cut.

Other problems usually involve the structural integrity of the door itself. Usually the various panels and braces that are used to construct the door are spot welded together. When the welds break, the door becomes very flexible rather than rigid and will not fit properly into the door casing. The method of repair will depend on many things; door construction, type of break or damage, availability of repair materials, etc. And you will have to decide on a job by job basis as to the best repair method to use.

Exercises (634):

1. What should you do before you begin to repair a swinging door?

2. How do you repair broken spot welds?

3. What might indicate a hinge-bound door?

4. Which of the three tap styles is the easiest to start and why?

5. When wouldn't you use a starting tap and why?

6. What tap drill size should be used for a 5/16–18 thread size? (Refer to chart in fig. 4-18)?

4-4. Rollup and Overhead Doors

Rollup and overhead doors are used extensively on Air Force bases throughout the world. They receive a lot of use and abuse and require many hours of maintenance and repair work to keep them operational.

TAP DRILL SIZES

SIZE	THREADS PER INCH	TAP DRILL SIZE	DECIMAL EQUIVALENT
4	40	43	.0890
	48	42	.0935
6	32	36	.1065
	40	33	.1130
8	32	29	.1360
	36	29	.1360
10	24	25	.1495
	32	21	.1590
12	24	16	.1770
	28	14	.1820
1/4	20	7	.2010
	28	3	.2130
5/16	18	F	.2570
	24	I	.2720
3/8	16	5/16	.3125
	24	Q	.3320
7/16	14	U	.3680
	20	25/64	.3906
1/2	13	27/64	.4219
	20	29/64	.4531
9/16	12	31/64	.4844
	18	33/64	.5156
5/8	11	17/32	.5312
	18	37/64	.5781
3/4	10	21/32	.6562
	16	11/16	.6875
7/8	9	49/64	.7656
	14	13/16	.8125
1	8	7/8	.8750
	14	15/16	.9375

CBG-107

Figure 4–18. Tap drill sizes.

CBG-104

Figure 4–19. Tap wrench.

634. Differentiate between rollup and overhead door types.

Rollup doors. There are many different designs and manufacturers of rollup doors; however, they all are basically similar. A rollup door has a curtain that rolls up around a tube or shaft as it is opened. This tube usually contains torsion springs which act as a counterbalance and assist in raising the door (see fig. 4-20).

The various components of the door will vary in their design; however, their function will remain the same. The slats that make up the curtain will be of different shapes as shown in figure 4-21, depending on the manufacturer of the door. This is important to remember when ordering new slats.

There is also a variety of mechanisms used to turn the shaft to raise the door. Typically a chain operated gear reduction assembly like the one shown in figure 4-22 will be used. There are many variations of this assembly. Some use direct gearing rather than chains, some are power driven, and some use a number of gear reductions to aid in raising the door.

All these doors use a shaft with torsion springs to counter balance the weight of the door. The number and size of springs vary depending on the type and size of door. If two or more springs are used, they are wound differently and are not interchangeable from side to side on the shaft or in the drum. When replacing these springs, always ensure you have the one which winds in the correct direction. Usually the spring has a stamp and some other method of identification that shows if it is left or right. If you interchange these, they will not assist in opening the door.

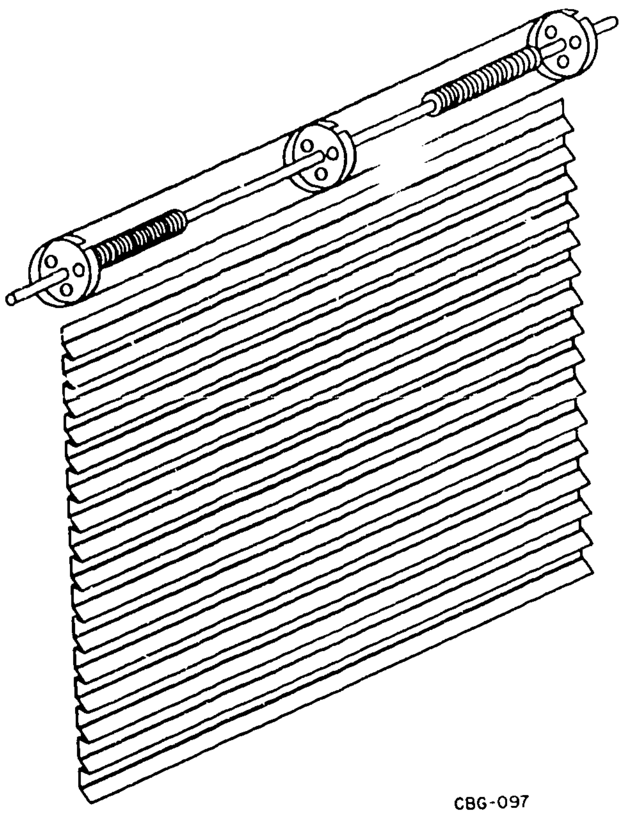

Figure 4–20. Rollup door.

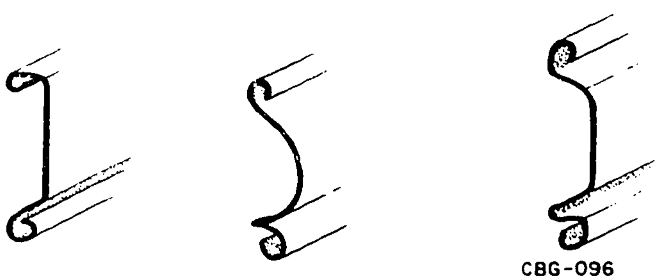

Figure 4–21. Door slat shapes (typical).

The spring or the mount will break if the spring is wound in the wrong direction.

Overhead Doors. The overhead doors differ from the rollup doors in that they usually are made up of large panels that ride on rollers in a track that moves them from a vertical to an overhead horizontal position as shown in figure 4-23. These doors have a shaft similar to the rollup doors, including the torsion springs and gear assemblies. The difference in the lifting mechanism lies in the cable drum (or spool) and cable that attach to the bottom of the door as shown in figure 4-24.

The track for these doors is offset from the wall to give it clearance from the wall and allow it to open and close easily (fig. 4-25). To compensate for this offset the hinges are different between each panel to make the door fit tight to the frame when it is closed (fig. 4-26). One variation of this door rises straight up the wall and does not change to a horizontal position when open. This type sometimes is found in hangers. The lifting mechanisms are the same as those found on the other types.

Exercises (635):

1. Which type of door has slats that make up a curtain?

2. How does the lifting mechanism of an overhead door differ from a rollup door?

636. Explain common maintenance and repair actions on rollup and overhead doors.

Maintenance. Proper, regular maintenance of rollup and overhead doors is necessary for trouble-free operation. There are a number of items you should look for during regularly scheduled maintenance.

Rollup doors. On roll up doors check for gear alignment, ease of operation, curtain alignment, adequate lubrication, excessive wear of components, and any broken or damaged components.

To check gear or sprocket alignment, lay a straight edge across the face of both gears or sprockets as shown in figure 4-27. The straight edge must contact the full face of both sprockets for proper alignment. If the sprockets are not aligned properly, adjust them by loosening the sprocket set screw, moving the sprocket into alignment and retightening the screw.

In addition to proper alignment, you also should ensure that all set screws are tight, the slack in chains is not excessive, all keys are installed as needed, and that the chain and guides are lubricated properly.

To check curtain alignment, look at the spacing on the sides between the curtain and the track. By raising the curtain up about 6 inches, you can observe the clearance between it and the floor end to end which will indicate if the curtain is aligned properly. If the curtain is not plumb you must realign it. To correct a misaligned curtain, rotate the barrel rings on the barrel to bring the door into proper alignment.

Once the alignment is correct, operate the door through a full cycle. This may indicate problems that are not obvious visually. Any sticking or jerking usually indicates a lack of lubrication. The guides should be lubricated with a paste wax or silicone spray. These lubricants will provide smooth operation without attracting dirt and debris.

Most repairs on rollup doors involve the curtain, which is easily damaged. Most curtains have interlocking slats which can be removed and replaced without dissassembling the entire door. Usually you can remove the slats from the curtain by separating them from their end locks, prying

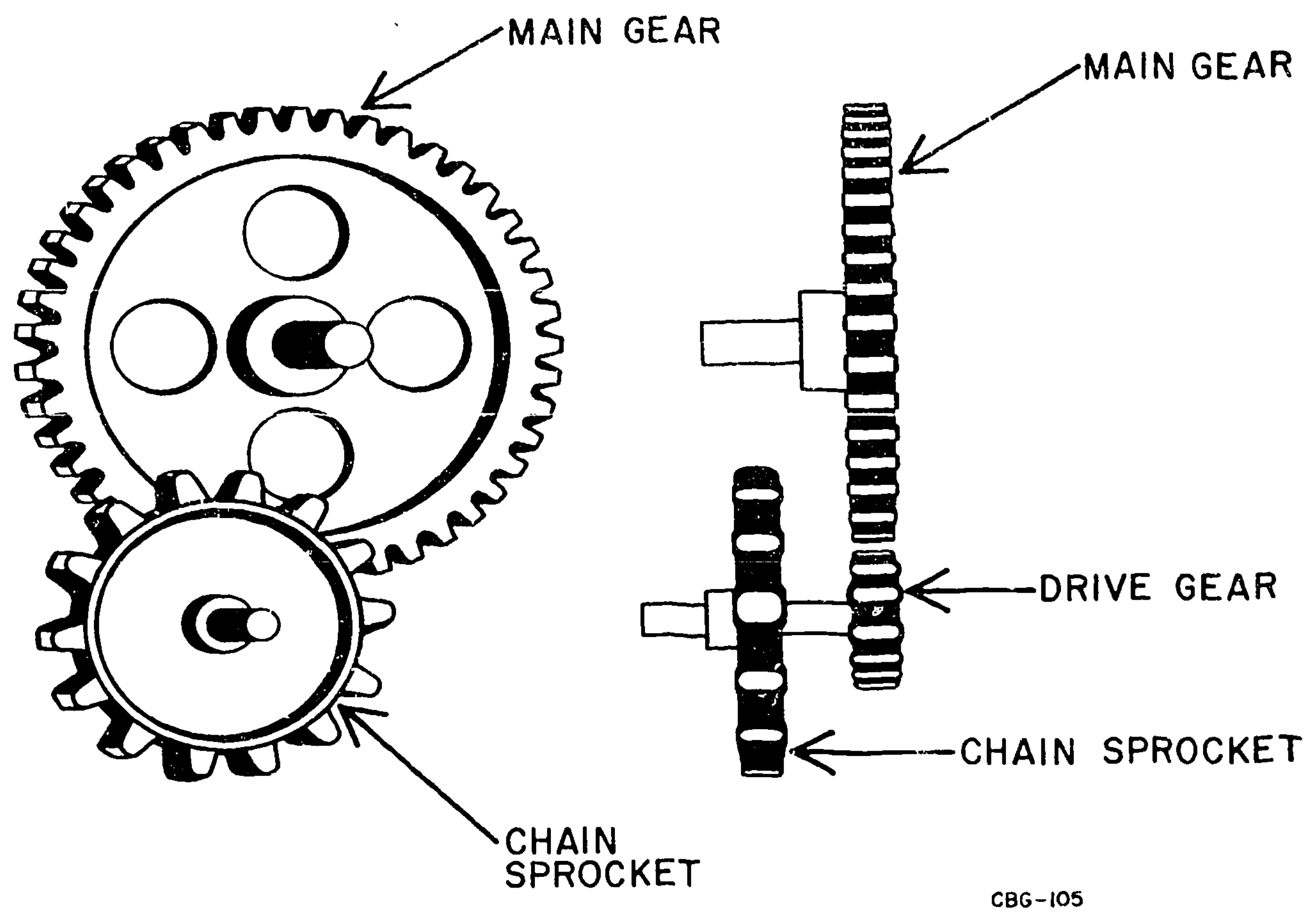

Figure 4–22. Typical drive mechanism.

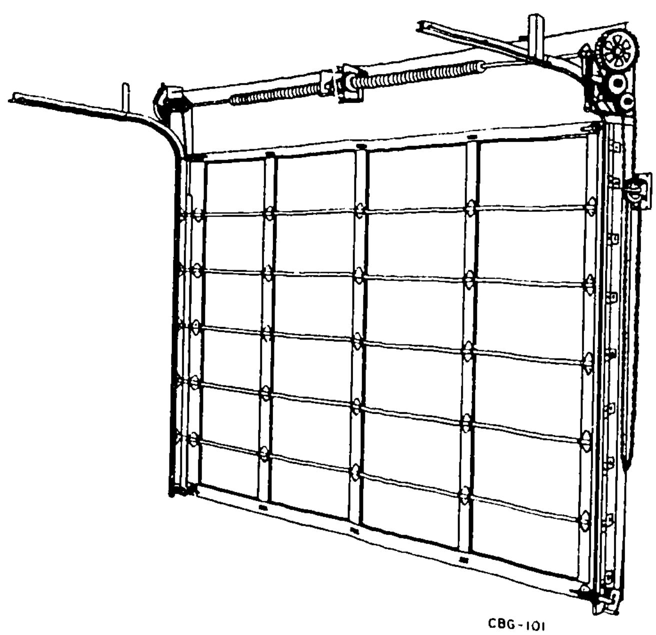

Figure 4–23. Overhead door.

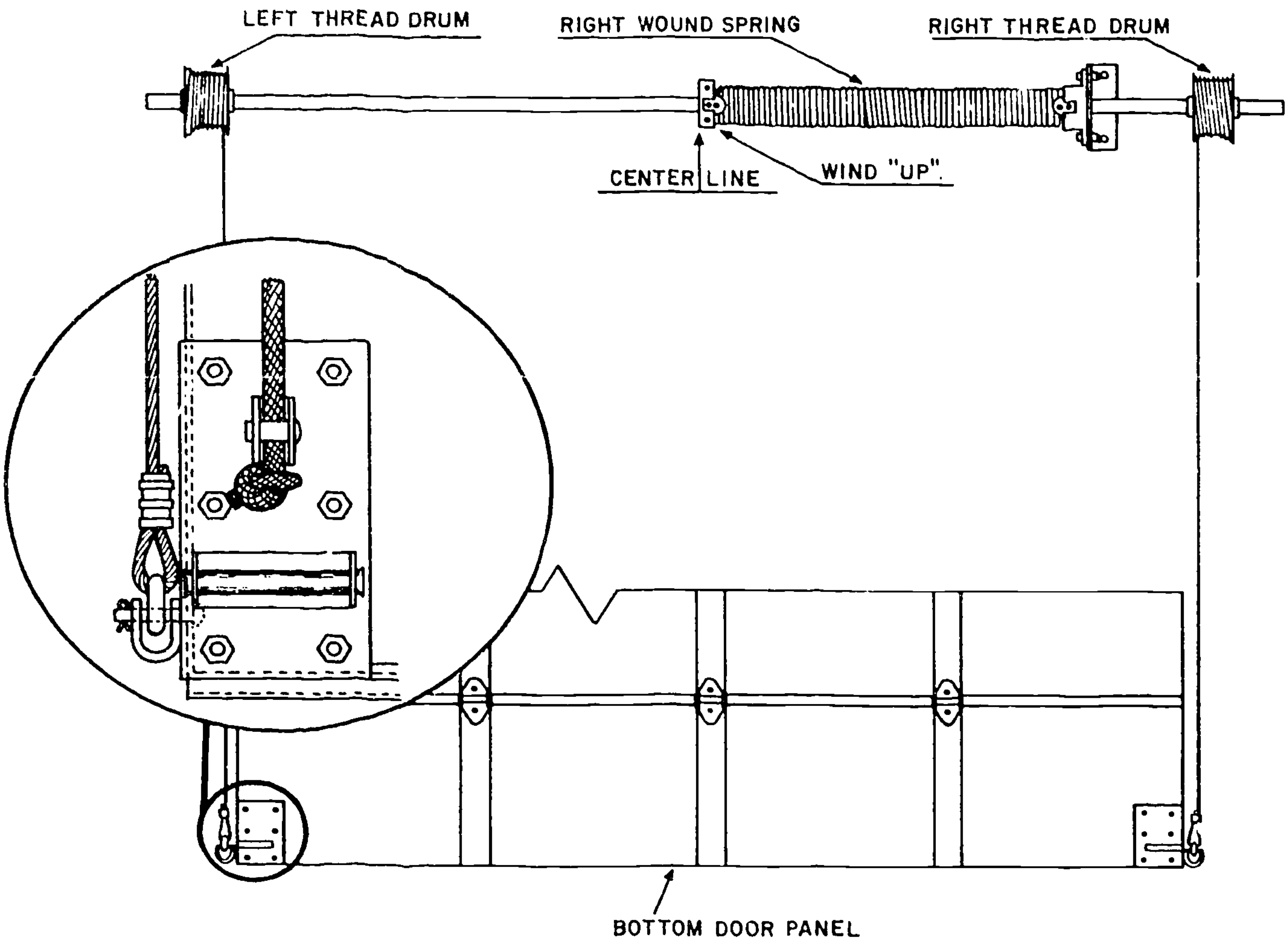

Figure 4–24. Overhead door counterbalance.

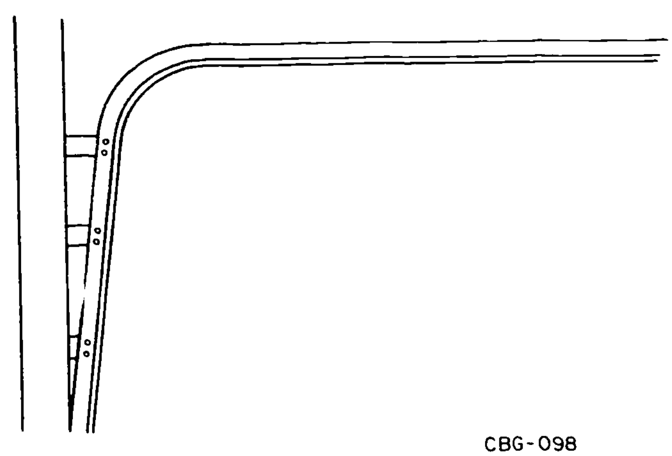

Figure 4–25. Track offset (typical).

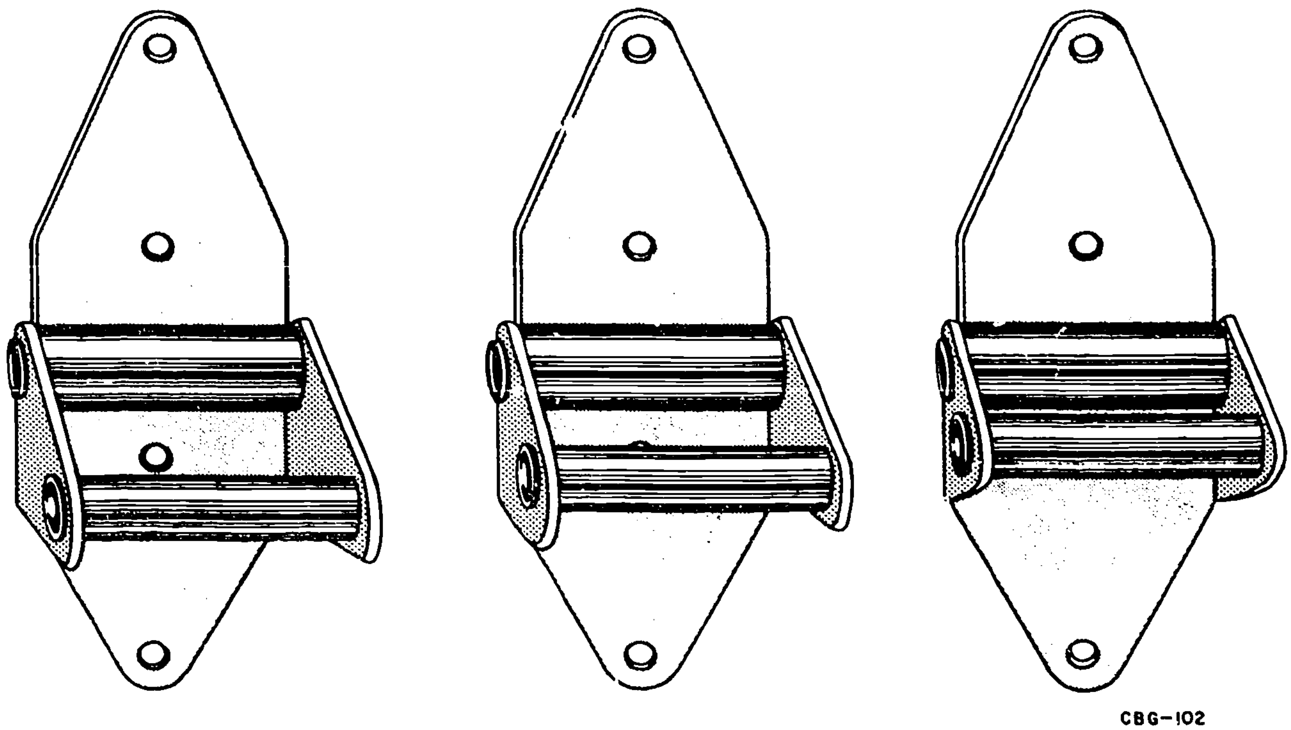

Figure 4–26. Overhead door hinges.

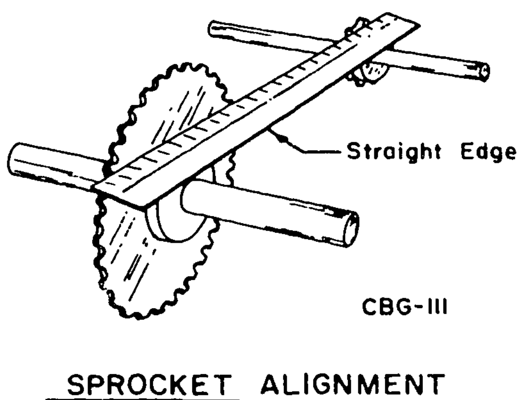

Figure 4–27. Sprocket alignment.

them clear of the guide, and sliding them out. Replacement is just the opposite, slide the new slat(s) in and lock them to the end locks. Specific instructions on replacement of slats will be found in the manufacturers manual and should be used for this operation.

Overhead doors. Many of the maintenance and repair actions taken on rollup doors apply to overhead doors also, because the components are essentially the same. Although the track the door rides in is designed differently, it still requires lubrication for free, smooth movement of the door. Use parafin wax or silicone lubricant here to avoid collecting dirt, etc. Lubricate the rollers with a few drops of machine oil.

To check door alignment, you must check it in the open and closed positions. First, check to see if the door is centered in the track by checking the space on each side of the door between it and the track. This space should be even the full length of the door. If it is not, either the door is hung improperly or the track is mounted wrong. With the door in the full down position, check the space at the bottom of the door. This space should be even (if the floor is known to be flat) for the full width of the door. Overhead and vertical doors commonly need adjustment to square them in their track. They become misaligned for several reasons.. The cable may not be wound correctly on the drum (caused by abuse in unwinching the drum too far). The cable drum may have slipped on the shaft, or the centerline coupler may have slipped. Check this first! Why? On most doors there are two springs; and the center coupler ties them together. If one side of the door binds or hits something, then all the torque of the spring on that side passes through the coupler. After a few times, something will give.

To correct a door that is high on one side, first inspect the cable, then the set screws on the cable drum. To correct the lopsided door, loosen the coupling bolts. Use the hand chain to level the doors, then retighten the coupling bolts. Test the door in operation. To level doors with one solid shaft, you must adjust the cable drum.

To adjust the level of an overhead door you may have to raise or lower one side of the door. Each type of door requires its own technique to accomplish this.

If you remember back in figure 4-24, the cable has a nonadjustable eye at the lower end. This adjustment is at the top. Before you start undoing things, remember that

there is a lot of tension on the torsion shaft assembly, so you should secure the drum before you loosen the set screws.

To adjust doors at the grooved cable drum, slightly raise the low side of the door and secure the torsion shaft. Loosen the set screws, and rotate the drum until the cable is tight. Then, tighten the set screws. Raise the door 2 or 3 feet. Now close it, and recheck the alignment.

Doors that have two springs and a split shaft can be aligned easily. To do this, loosen the coupling bolts and slightly raise the door until it is level, or parallel with the floor. Then retighten the coupling bolts. You need not worry too much about tension, since you are not making any break in the tension line (door, cable drum shaft to spring). Be very careful when you must remove the coupling bolts. This sometimes is necessary to allow enough adjustment between two shafts. When all the bolts are removed, you must support the shaft ends—holding them in place until the coupling bolts are replaced.

Once a door is level, you must adjust the torsion springs for proper lift. First, draw a horizontal tension on the torsion springs is to draw a horizontal line on the spring from plug to plug with a piece of chalk. As the spring is wound, the number of spirals shown by the chalk will indicate the number of turns on the spring. The number of turns needed will depend on the height and weight of the door.

Consult the manufacturer's installation procedures for the number of turns required for your particular door. Wind up the springs with an extension rod that fits snugly into the spring plugs. Then secure the spring with the set screws in the plug. Some of the shafts may have a flat side to assure a good tight fit. When the shaft has more than one torsion spring, each should be wound by the same amount. As the spring is wound, the outside gets smaller and the spring gets longer. If the spring, when wound, is shorter and fatter, it is wound in the wrong direction and will not function. Test the door for balance. If the door is heavy to lift, and hangs before it is completely up, wind the springs tighter. On the other hand, the tension is too great when the door has a tendency to jump off the floor, and when it rises rapidly. All these adjustments must be checked with the door sitting on the floor.

A correctly adjusted door should snap into the head assembly (up position), and barely tend to lift off the floor (down position). It also will fall through the midrange of its travel. Wind the tension wheel in the direction that would tend to raise the door. Adjust the tension wheel one notch at a time. After proper tension is applied, install a pin in the tension wheel to lock it in position. This adjustment is the same on both overhead and rollup doors.

Alignment of an overhead door also should be checked in the full open position. If the tracks are not parallel and aligned properly, the door could fall out of the track when opened. Check to see if clearance between the door and track are equal and not excessive. Ensure the doorstop is in place and functional.

Occasionally a hinge may break or become worn enough to require replacement. Remember that the hinges are designed for specific panels on the door and cannot be interchanged. Consult the proper manufacturers manual for correct parts replacement.

Exercises (636):

1. What method is used to check alignment of sprockets or gears?

2. What should be used to lubricate guide tracks and why?

3. How can you correct a misaligned curtain on a rollup door?

4. Why would you draw a line across a torsion spring with chalk?

5. How can you tell if an overhead doors torsion springs are adjusted to the correct tension?

4-5. Hangar Doors

There are many types of hangar doors: overlap sliding, folding, cable connected, interlocking, individual, and overhead folding. We will discuss some problems that are related to all hangar doors, since there are often three or four types on each base.

637. Identify maintenance actions for hangar doors.

Sliding Hangar Doors. Hanger doors are large sections of steel beams, sheets, and other materials, assembled in such a way as to be able to be moved out of the way. Moving parts cause problems. They need oil and grease, which collect dust, dirt, and sand. These doors can weigh up to 68 tons, and can cover areas 40 feet high and 25 to 30 feet wide. Most doors roll on tracks mounted in concrete.

When you inspect a hangar door, some things to watch for are: general appearance, excessive grease, shiny areas, operating instructions posted near the switch, and a list of authorized operators.

Many doors are set up with brake systems or locks (drop pin 1 inch in diameter). These items must be checked for functional operation, and they also must be listed on the operating instructions.

Every now and then, a door will get off the track. Your job is to put it back on. This can be done with a long steel bar and small pieces of wood. On large doors, you will need a hydraulic jack with a sidemount attachment and a large steel bar.

Check for the reason the door comes off the track. It could be caused by rocks on the track, the door hitting a

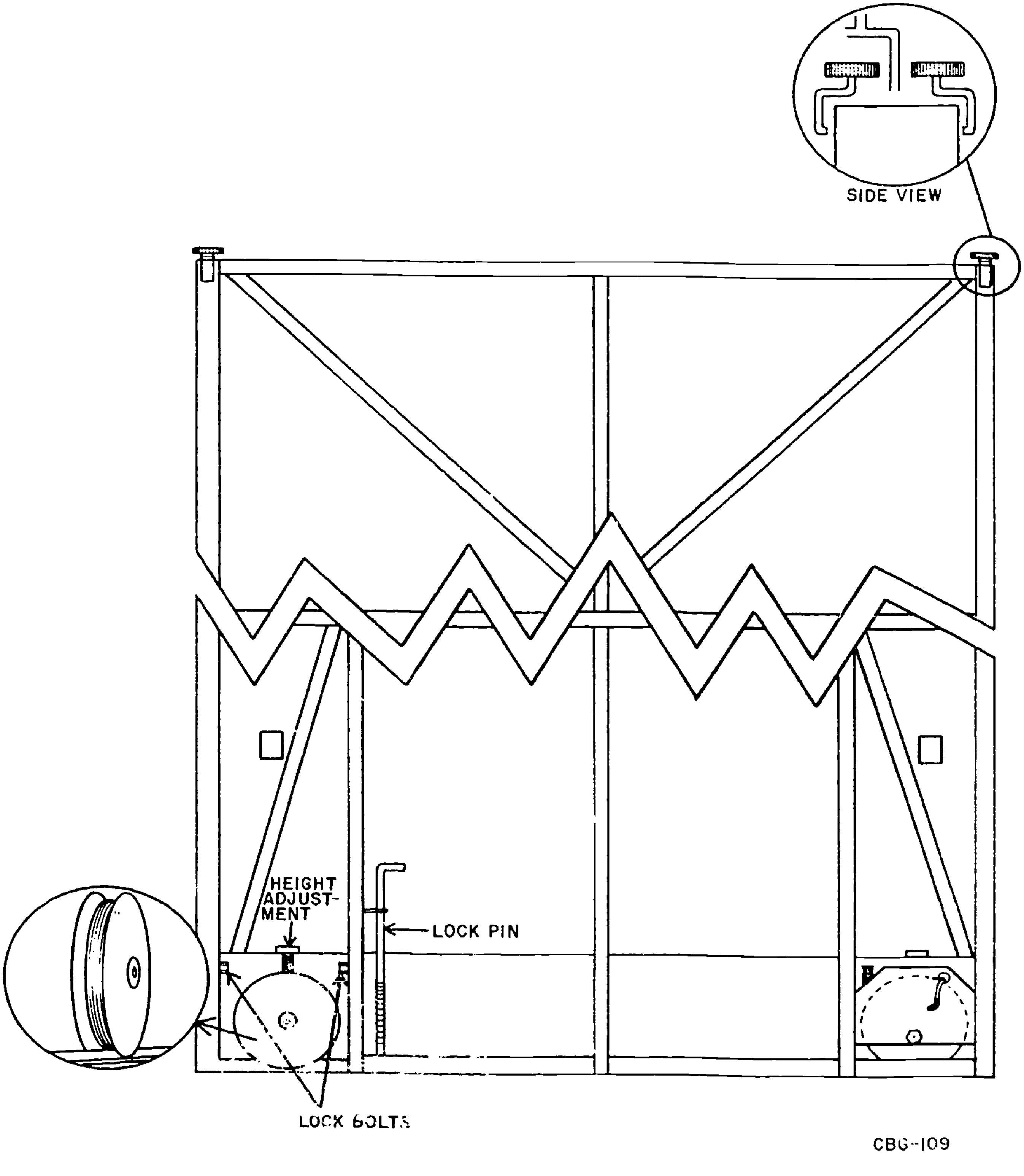

Figure 4–28. Hanger door adjustments.

stop too hard, or the door being pushed by powered equipment.

Door alignment. The door must stand straight (plumb). A door that is out of plumb can be corrected by adjusting the wheels up or down. Each door has its own design of wheel adjustment. Look it over. Check for lock bolts, and check the adjusting nut. Check the floor clearance at each wheel, from the bottom of the door to the floor. The doors must stand straight so that they will trip the limit switch just as they close to a snug fit (fig. 4-28).

The limit switches on most hangar doors are mounted at the top of the door. Limit switches are tripped by arms, ramps, posts, springs, or any of a number of devices. After you plumb a door, always check for any effect on the limit switch caused by closing the door. If the door closes too tightly and the power unit continues to run; or, if the door stops before it closes, you will have to adjust it to the proper position.

The greatest aid in keeping hangar doors operating properly is a thorough RIPE maintenance program in which systems are checked, lubricated, and maintained on a regular schedule.

Exercises (637):

1. How do you adjust a hanger door to plumb?

2. After a door has been plumbed, what should you check?

3. Why do the lubricants used on hanger doors cause problems?

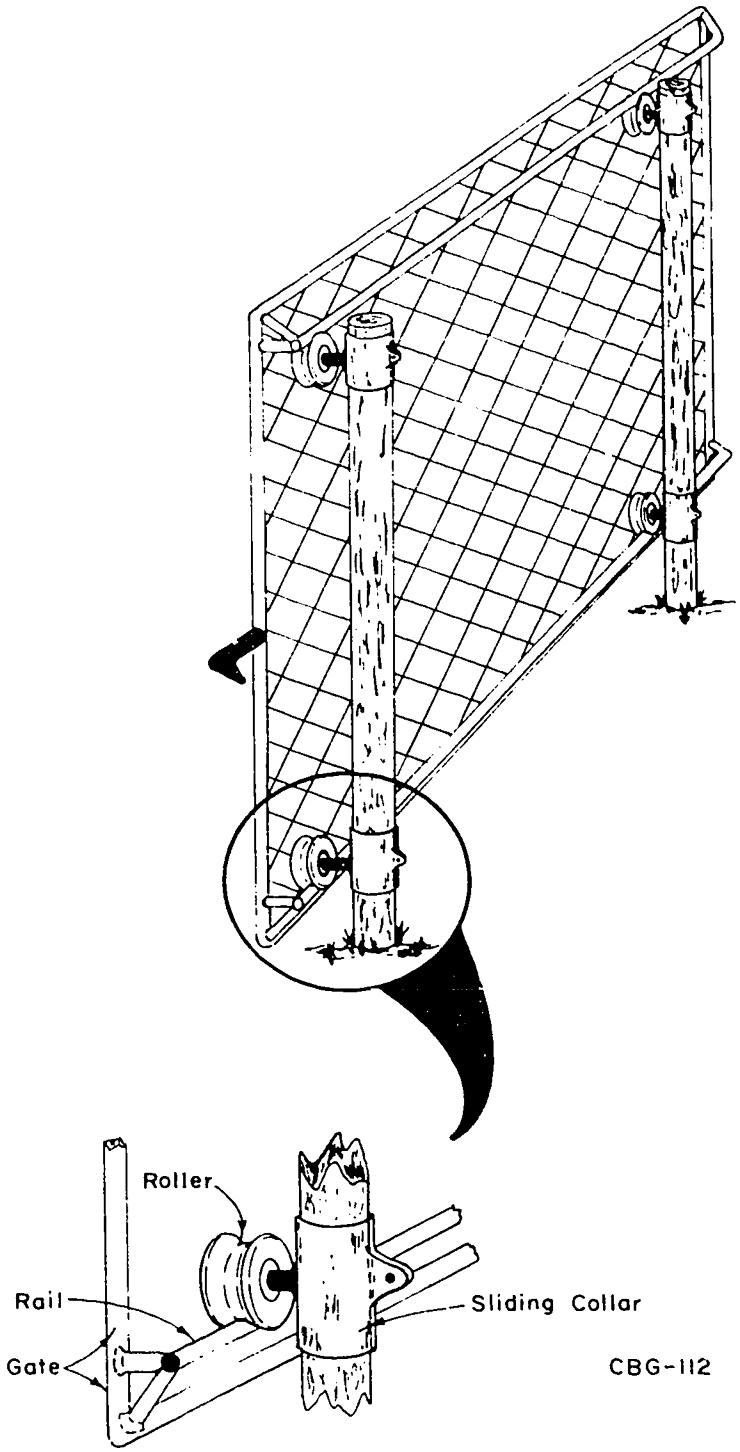

Figure 4-29. Typical rolling gate.

4-6. Gates

Rolling gates are used on almost every Air Force base in the world. They may be at an outside supply storage area, around a secure building or area, or maybe even within a warehouse. They may be of several different designs. Usually they are of local manufacture, so, although they are similar, they are not identical from base to base. To provide trouble-free operation, these gates must be maintained regularly. This will consist of lubricating and adjusting the rollers and guides on the gate and gate posts.

638. Cite adjustments and lubrication requirements of rolling gates.

Gate Design. The most common rolling gate design is shown in figure 4-29. Notice that the entire gate rides above the surface of the ground on four rollers attached to the gateposts. The gate itself usually is constructed of a welded pipe frame covered with chain link fence fabric. The rollers are mounted on axles with either bushings or bearings with

the axle welded to a collar that can be adjusted to different heights on the post (fig. 4-29). The gate may be operated or powered manually. The latch mechanism may be operated manually or have an electromagnet-operated latch within a secure box of some type.

Maintenance and repair. The most common problem with these gates involves the rollers. If they are not lubricated and adjusted regularly, the bushing and/or bearings will wear out rapidly. Usually there is a grease fitting (zerk) in the axle shaft or on the roller hub which facilitates lubricating the roller. The position of the rollers supports the gate and prevents its being removed. Only one set of rollers (top or bottom) supports the gate, while the other set guides and secures the gate in position. Another variation would be to have the upper and lower gate rails both on the inside of the rollers. Then only the lower set would support the gate while the upper set would guide and secure it. The rollers are adjusted on the gateposts by loosening the bolt in the collar, sliding the assembly into the required position, and retightening the bolt. The rollers should not be adjusted tight enough to cause drag or stress nor loose enough to allow the gate to come off the rollers. You also must be careful to align the latch properly when the gate is closed.

Power units. The power unit on a mechanical gate is similar to that of the overhead door. The principle is the same. A power unit (operator) turns a shaft and sprocket, which moves a roller chain. The gate is attached to the roller chain and moves on tracks. As with the overhead door operator, dust and dirt collect on the roller chain and cause many problems. This dust and dirt must be removed during regular maintenance.

Exercises (638):

1. Why are the upper and lower rollers installed either on the inside or the outside of the rails?

2. What items should be checked during inspection of a gate system?

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

600 – 1. 6 inches on side and 12 inches in front.
600 – 2. 20-gage stainless steel.
600 – 3. Monel rivets.

601 – 1. Plan view.
601 – 2. Triangulation method.
601 – 3. The true length chart.
601 – 4. The 1-inch 90° bend portion.
601 – 5. Dividers or trammel points.
601 – 6. Slant notched at each end.

602 – 1. Squaring shears and straight snips, so you won't clip the 2-inch collar.
602 – 2. Straighten about 2 inches of each seam end, so the cornice brake won't damage the metal when you clamp it.
602 – 3. Cornice brake and box and pan brake.

603 – 1. One 2 inches from each end of standing seam and one in the center.
603 – 2. Measure distances between diagonally opposite corner to make sure they are equal.
603 – 3. 50/50 solder for the corner lap joint, but silver solder for the outlet; silver solder is stronger.
603 – 4. Use turnbuckles to lower the drain outlet so that grease will drain out properly.

604 – 1. 14-gage stainless steel.
604 – 2. 1-inch stainless steel tubing.
604 – 3. 16 gage and 1 inches in diameter.

605 – 1. 20 gage.
605 – 2. Stainless steel is stronger, requiring more force to bend, and it has more springback.
605 – 3. Use shears and forming equipment with a larger capacity than you would use for the same gage of mild steel.

606 – 1. Make straight (butt) cuts, insert a piece of brass round stock about 6 inches long, drill and tap hole in the bottom side, and attach the pieces with roundhead screws.
606 – 2. Use new brackets, because welding removes the chromium plate.
606 – 3. With a 3/8-inch corrosion-resistant bolt.

607 – 1. Do the rough cut with a medium coarse grit, do the second cut with a medium fine grit, and stop grinding before the bead is flush.
607 – 2. Use a wheel that hasn't been used on other metals; apply adhesive paper to protect the surface; avoid overheating the surface. (Any two of these is a good answer.)
607 – 3. Use 120 grit aluminum oxide applied with a soft wheel, using a lubricant.

CHAPTER 2

608 – 1. Before.
608 – 2. Material of the same type and thickness as the original material.
608 – 3. A masonry drill and expandable sleeves (anchors).
608 – 4. Shaping (flattening and bending) the ends and drill holes in them.

609 – 1. It has seam allowance for two standing seam flanges because the side trim has the pocket portion of the standing seam.
609 – 2. Punch press, straight snips, and cornice brake.
609 – 3. The corner lap seams on the ends of the side pieces.

610 – 1. The top panel installed last is the one with two flanges and no standing seam pocket.
610 – 2. First attach the hanger, position the canopy on the wall angle and level it, then drill holes and bolt to wall angle.
610 – 3. Rivets or bolts and caulking compound.

CHAPTER 3

611 – 1. Galvanic action.
611 – 2. Copper, aluminum, and galvanized iron. Don't use steel nails with copper.
611 – 3. A coating of oxide (patina) that forms when copper is exposed to the air and weather.
611 – 4. Lower cost and strength.

612 – 1. Less than a 3-inch slope to the foot.
612 – 2. The roofing standing seam is a double seam.
612 – 3. Grooved (flat) seamed roofs are held in place with cleats and the seams are soldered.
612 – 4. Corrugated, rib, or 5 V-crimp.
612 – 5. Because, for a batten seam you nail the cleats to the batten strip.

613 – 1. Double seamers are used to make double seams out of standing seams.
613 – 2. Mallet.
613 – 3. Clamping tongs hold seams in place while you work; squeezing tongs are used to tighten seams.
613 – 4. Grooved or flat.

614 – 1. The first sheet installed is the lower sheet in the direction of the prevailing wind.
614 – 2. After the first row has progressed far enough that it will not overlap any of the second row.
614 – 3. So that a good solder joint can be made easily.
614 – 4. A metal strip the full length of the gable is nailed to the roof deck and extends 3/4 inch past the bottom edge of the gable.
614 – 5. The cap is flattened over the end of the batten.
614 – 6. a. Under the ridge flashing.
b. Lay the roof, place the closure strip, place the ridge cap, fasten with screws through the cap-closure strip and into the roof.

615 – 1. Solder the hole or break.
615 – 2. By replacing the sheet with the break.
615 – 3. Clean with wire brush or emery cloth and apply flux.
615 – 4. Make a patch from like material; use roofing cement and blind rivets to fasten the patch in place.
615 – 5. Solder, usually 50/50.

616 – 1. Fascia and gravel guard flashing.
616 – 2. Ridge flashing.
616 – 3. a. With bolts, screws, rivets, nails, or cleats.
b. Always use the same kind of material as the flashing.

616 – 4. Fascia and gravel guard flashing, and it should be wide enough to extend under the roofing material 4 inches and cover the entire fascia.
616 – 5. Gable flashing.
616 – 6. On the ridge of a roof; it should be lapped at least 4 inches.

617 – 1. Tar stop.
617 – 2. Piece A of an expansion joint.
617 – 3. (a) Clean the area, (b) apply flux, and (c) apply 50/50 solder.

618 – 1. Half-round double-bead gutter.
618 – 2. Nonhardening type.
618 – 3. Ferrules and spikes.
618 – 4. Strainer.
618 – 5. On the front, the ogee gutter has a slow S-shape.
618 – 6. End cap, held in place by friction, solder, or plastic cement.

619 – 1. Route water from the gutter to the drainage system.
619 – 2. Cold areas; freezes.
619 – 3. They will match the gutters.
619 – 4. Avoiding sharp turns.
619 – 5. Prevent washing the soil away.
619 – 6. An anchor bolt and strap hanger.

620 – 1. Opposite the downspout and as close to the eave overhang as possible.
620 – 2. Mastic (plastic cement).
620 – 3. Secure the downspout in place by placing sheet metal screws through the hanger into the downspout.
620 – 4. Not over 30 inches apart.
620 – 5. Slip joints are installed with mastic.
620 – 6. Measure the distance between the pockets of the slip joints.
620 – 7. 6 inches.

621 – 1. Remove all of the old mastic and reseal with new mastic.
621 – 2. Replace it with a like hanger.
621 – 3. Clean the area around the hole and solder.

622 – 1. Sketch the gutter, including dimensions and shape, and determine what material to use.
622 – 2. Prick-punch the bend lines.
622 – 3. Cornice brake with a former.
622 – 4. Make the first four bends on the second gutter; then you can make all the curve bends when you put the former in.

623 – 1. The 3/8-inch flanges on three sides of the drop outlet are bent out 90° with a stake and mallet.
623 – 2. Three.
623 – 3. Inside.
623 – 4. Left and right ends.
623 – 5. In the back.
623 – 6. The one at the back remains straight to fit the back of the gutter.
623 – 7. With rivets or spot weld.
623 – 8. 1/2 inch, on only one piece.
623 – 9. Inside.
623 – 10. A 6-foot section of 2" x 2" x 1/4" angle iron.
623 – 11. An item placed at the bottom of a leader to turn water out away from the building. It is made by making two 45° miters.

624 – 1. Test the new gutter with water to insure that the water will flow out. Make the test before you install any other components.
624 – 2. Three.

CHAPTER 4

625 – 1. (1) c.
(2) b.
(3) a.
(4) a.
(5) c.

626 – 1. b, d, e.

627 – 1. (1) e.
(2) d.
(3) g.
(4) f.
(5) b.
(6) a.
(7) d.

628 – 1. a, d, e.

629 – 1. (1) b.
(2) a.
(3) c.

630 – 1. a, d, e, f, g, i, j.

631 – 1. b, f, g, i.

632 – 1. c, d, b, a, e.

633 – 1. Left hand.
633 – 2. It has the hinges on the right and swings out (toward you) as you face it from the outside.
633 – 3. On the outside.

634 – 1. Determine the cause of the damage.
634 – 2. By drilling through the casing and plug welding the hinge plate in place.
634 – 3. Difficult to close and springs open.
634 – 4. Taper, because of the long tapered section at the starting end which helps center and guide the tap into the hole.
634 – 5. In a blind hole because threads will not be cut the full depth of the hole.
634 – 6. F.

635 – 1. Rollup.
635 – 2. The shaft has cables and cable drums. The cables attach to the bottom panel and wind around the cable drum as the door is raised.

636 – 1. Place a straight edge across the face of the sprockets. The straight edge must contact the full face of both gears for proper alignment.
636 – 2. Parafin wax or silicone, because these lubricants do not attract dirt as other lubricants do.
636 – 3. Adjust the cable drums to level the door.
636 – 4. To obtain an accurate count of the number of revolutions the spring has been wound.
636 – 5. It should fall through the midrange of its travel and barely tend to lift off the floor. When opened it should snap into the head assembly.

637 – 1. By adjusting the wheels you can raise or lower each end of the door independently.
637 – 2. Limit switch operation.
637 – 3. Because they attract dust, dirt and sand.

638 – 1. To support the gate and prevent its being removed easily.
638 – 2. Proper lubrication, roller positioning, and broken or worn components.

AUGAFS, AL (860967) 600

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AU GAFS, ALA. (830348) 1500

S T O P -   1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

55252 04 22
INSTALLED EQUIPMENT AND DOORS

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet .
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover your answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you have to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If mandatorily enrolled student, process questions or comments through your unit trainer or OJT supervisor. If voluntarily enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the Learning Objective Number where the answer to that item can be located. When answering the items on the VRE, refer to the Learning Objectives indicated by these Numbers. The VRE results will be sent to you on a postcard which will list the actual VRE items you missed. Go to the VRE booklet and locate the Learning Objective Numbers for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the best answer to each question.

1. (600) For good coverage of an air pickup, range hoods should extend how many inches beyond the front and sides of a range?

   a. 12" in front and 6" on the sides.
   b. 9" in front and 4" on the sides.
   c. 6" in front and 3" on the sides.
   d. 3" in front and 2" on the sides.

2. (600) What is used to secure the corners of the grease trap and the standing seams of a stainless steel hood?

   a. Blind rivets.
   b. Monel rivets.
   c. 4 lb tinner's rivets.
   d. Stainless steel rivets.

3. (601) When laying out a hood pattern, a plan view of the transition is required so that certain points can be transferred.

   a. to the elevation view.
   b. to the true length chart.
   c. from the elevation view.
   d. from the pictorial view.

4. (602) What equipment is used to bend the patterns for the side pieces of a hood?

   a. The cornice brake and the box and pan brake.
   b. The setting down machine and the box and pan brake.
   c. The Pittsburg lock forming machine and cornice brake.
   d. Each of the above.

5. (603) When assembling a hood designed with standing seams, why are the rivets placed 8 to 10 inches apart?

   a. To maintain uniformity.
   b. To reinforce the welded seams.
   c. Only for appearance since the seams are welded.
   d. For good appearance and holding power.

6. (603) What are the last two steps to be taken in the installation of a range hood?

   a. Recheck for leveling and install the filter.
   b. Remove the adhesive paper and install the filter.
   c. Install the filter and seal with adhesive paper.
   d. Install the filter and remove the temporary exhaust duct.

7. (604) On a serving line, the cap strip is used to cover

a. the display shelf.
b. the edge of the top.
c. the hinges of the doors.
d. the butt joints.

8. (604) What material is used to construct the three side rails for trays on a serving line?

a. 1" diameter stainless steel tubing.
b. 1 1/8" diameter steel pipe.
c. 2" diameter stainless steel pipe.
d. 2 1/2" diameter stainless steel tubing.

9. (605) What are the first steps to be taken when replacing a panel of a serving line?

a. Repair and weld the old panel and replace.
b. Order a replacement and install.
c. Cut to size and form the new panel.
d. Replace with correct size panel but do not use fasteners.

10. (605) In forming stainless steel panels for a serving line you should remember that stainless steel as opposed to mild steel

a. will crack easily.
b. has a great spring back.
c. will not bend sharply.
d. has good forming qualities.

11. (606) What steps are required to repair a tray slide rail that has a clean break 12" from a support bracket?

a. Remove the end piece and broken section and then install a brass splice.
b. Remove the end piece and broken section and then replace with a new section.
c. Remove the broken section and weld it; then replace the repaired section.
d. Repair it in place by placing a brass sleeve over it.

12. (607) When repairing a cracked weld in stainless steel, what must be done to prevent the crack from getting longer?

a. Weld from center to the ends of the crack.
b. Weld from each end of the crack toward the center.
c. The weld of the crack must be ground flush with the surface.
d. Stop drill each end of the crack before welding.

13. (608) An awning is installed over a window so that it will

a. extend 14 inches over the window.
b. extend 12 inches over the window.
c. extend 6 inches over the window.
d. extend the same distance over each side of the window.

14. (608) When repairing or replacing panels of an awning it is necessary to

a. completely disassemble all the parts.
b. replace panels rather than patch.
c. replace with the same type and gage of metal used in the old panel.
d. use a heavier material for the replace parts.

15. (609) Canopies are usually made of aluminum panels joined together with

a. post locks.
b. standing seams.
c. double lock seams.
d. Pittsburg lock seams.

16. (610) When assembling a canopy with standing seams, what procedure is followed to secure the panels together?

a. Install a cap strip and crimp the seams.
b. Place a bolt or screw at each 10 to 12 inch interval.
c. Place a rivet every 12 inches along the seams.
d. Lock the seams by bending the top edges over each other.

17. (610) When installing a patch of like material on a canopy, you should use

a. a sealant between the patch and panel.
b. rivets made of a material compatible to the panel.
c. Clecos to hold the patch in place while other holes are being drilled.
d. all of the above.

18. (611) A patina forms on which of the following roofing materials?

a. Aluminum.
b. Copper.
c. Ternplate.
d. Galvanized iron.

19. (61) Which of the following roofing materials is available in flat, corrugated, or double-rib sheets?

a. Aluminum.
b. Ternplate.
c. Copper.
d. Galvanized iron.

20. (612) Which of the following roofing seams are secured to the roof deck with cleats?

a. Grooved, lap, and batten.
b. Lap, batten, and standing.
c. Standing, grooved, and lap.
d. Batten, standing, and grooved.

21. (613) The double-seamer is a roofing tool used to make

a. lap seams.
b. grooved seams.
c. batten seam joints.
d. double seams from standing seams.

22. (613) Which of the following is used to turn the edges from a grooved (flat) seam roof?

a. A bar folder.
b. A cornice brake.
c. A roofing folder.
d. None of the above.

23. (614) When you install metal roofing with lap seams, the direction of the sidelap will be determined by the

a. pitch of the roof.
b. number of crowns in the seam.
c. water runoff.
d. direction fo the prevailing wind.

24. (614) On flat seam metal roofing, you should make proper notches so that

a. the cleats will fit into the seams.
b. the seams can be set with ease.
c. a good solder joint can be obtained.
d. the seams can be joined evenly.

25. (615) The steps in sequence to repair a small hole on a flat seam copper roof are:

a. Clean the surface with an emery cloth, apply flux, and solder.
b. Apply flux, clean with a hot iron, and solder.
c. Clean the surface with a scraper, apply flux, and solder.
d. Clean the surface with an emery cloth and apply a plastic roofing cement.

26. (616) What type of flashing would you use where two sloping roofs join?

a. Base.
b. Gable.
c. Valley.
d. A gravel guard.

27. (617) When installing a fascia flashing, you should solder

a. the grooved seam.
b. the expansion joint parts.
c. all the nail heads.
d. all of the above.

28. (617) Flashing made of galvanized iron is usually repaired by

a. attaching aluminum patches.
b. replacing the damaged metal.
c. soldering the edges of the damaged area.
d. covering the damaged area with cement.

29. (618) Which of the following is used to join straight gutter sections and corner miters?

a. Slip joints.
b. Soldered joints.
c. Lock joints.
d. Lap joints.

30. (618) Ferrules are used to hang gutters. Which of the following determines the length of a ferrule?

a. The size of gutter being installed.
b. The height of the gutter.
c. The number of downspouts.
d. The length of the spikes you use.

31. (618) What is the purpose of strainers in a gutter system?

a. To keep the gutter from being clogged.
b. To prevent clogging the downspout.
c. To keep birds from nesting in the gutter.
d. To prevent the downspout from freezing.

32. (619) Downspouts can be purchased ready for installation. The standard length of such downspouts is

a. 7 feet.
b. 8 feet.
c. 10 feet.
d. 12 feet.

33. (619) In a gutter system, downspout elbows are used to

a. make offsets and turns.
b. only to create shoes.
c. join two or more downspouts.
d. make offsets and reduce the downspout size.

34. (620) While installing a new gutter, what is used to seal the slip joint?

a. Solder.
b. Mastic.
c. A duct sealant.
d. A calking compound.

35. (621) A small hole in a gutter can be repaired by

a. soldering the hole.
b. installing a metal screw in the hole.
c. forcing mastic into the hole.
d. covering the hole with a pressure sensitive tape.

36. (622) Before making a sharp bend in a gutter on a cornice brake, you should adjust the

a. bend stop to 90 degrees.
b. back stop for uniform bends.
c. bend stop for the proper radius.
d. setback to 1 1/2 to 2 times the thickness of the metal.

37. (623) The lap seam flanges of the offset downspouts are placed

a. inside in the direction of water flow.
b. inside against the direction of water flow.
c. outside in the direction of water flow.
d. outside against the direction of water flow.

38. (623) To make a downspout shoe, both notches should be cut

a. in the direction of water flow.
b. on each side of the downspout.
c. on the back side of the downspout.
d. on the front side of the downspout.

39. (624) After you have replaced a section of gutter, you should

a. pour water in the gutter to check the drainage.
b. fill with water to check for hanger strength.
c. raise the hangers to ensure they are securely attached.
d. check the level with a chalk string.

40. (625) What precaution must you take when using a single ladder without a non-skid base?

a. Apply non-slip tape to the base of the ladder.
b. Tie the ladder base rigidly to the building with a hemp rope.
c. Place safety hooks at the top of the ladder.
d. Affix a non-slip tape to each rung of the ladder.

41. (626) How far should the base of a 28 foot straight ladder be from the foundation of a building?

a. 2 feet.
b. 3 feet.
c. 5 feet.
d. 7 feet.

42. (627) Which of the following statements regarding ladder safety is incorrect?

a. Face the ladder when ascending or descending.
b. Lock or secure the doors obstructed by your ladder.
c. Stand no higher than the second rung from the top.
d. Never leave a ladder unattended for any length of time.

43. (628) How should a ladder be carried?

a. At arm's length over your head.
b. Vertically, with your arms through the rungs.
c. No higher than waist level to avoid any back strain.
d. Over the shoulder, with the front end being elevated.

44. (628) How should a ladder be stored?

a. Outdoors and hung at a diagonal angle.
b. Vertically from three hangers.
c. Horizontally from three hangers.
d. In a hot area and hung vertically.

45. (629) What is the minimum number of boards that should be used to form a platform on a scaffold?

a. 1.
b. 2.
c. 3.
d. 4.

46. (630) The top section of steel scaffolding must always have

a. a guardrail.
b. a toe board.
c. a guardrail and toe board.
d. footing plates and leveling jacks.

47. (630) How can a sectional steel scaffold on a solid floor be prevented from moving?

a. By lockin the V-braces.
b. Through the use of locking casters.
c. With locking levers on the leg adjustments.
d. By tying both the top and bottom sections together with a nylon cord.

48. (631) Which of the following is <u>not</u> a precaution which should be taken prior to using a scaffold horse?

a. Provide adequate support for the base plates.
b. Set the horses on a firm, even footing.
c. Place boards close together.
d. Jump on scaffold boards.

49. (631) What is the maximum distributed load permitted on the platform of a stairway scaffold?

a. 250 pounds per crew member and equipment.
b. 250 pounds per crew member, less equipment.
c. 750 pounds total crew and equipment weight.
d. 1000 pounds total crew and equipment weight.

50. (632) When lifting a heavy, small, object, what should your starting position be?

a. The squatting position.
b. The kneeling position.
c. The crouching position.
d. The straddling position.

51. (633) Which of the following describes a left hand door?

a. It swings away from you as you face it from the inside, with the hinges being on the right.
b. It swings toward you as you face it from inside with the hinges being on the left.
c. It swings toward you as you face it from the outside and the hinges are on the left.
d. It swings away from you as you face it from the outside and the hinges are on the left.

52. (634) Which of the following indicates a hinge-bound door?

a. It is difficult to open and it binds in the jamb.
b. It is difficult to close and it springs open.
c. There is excessive space at the top of the jamb.
d. There is excessive space at the striker plate and it will not stay open.

53. (634) Which tap should be used to cut threads to the bottom of a blind hole?

a. Starting.
b. Taper.
c. Plug.
d. Bottom.

54. (635) How are rollup doors counterbalanced?

a. Extension springs on cables are attached to the bottom of the door.
b. Extension springs are used on the central shaft.
c. Torsion springs are used on the control shaft or in the tube.
d. Torsion springs are attached to cables that reach to the bottom of the door.

55. (635) Why are the hinges different between each panel of an overhead door?

a. To give clearance at the top of the door.
b. To give clearance at the bottom of the door.
c. To compensate for the offset track at the top.
d. To compensate for the offset track at the bottom.

56. (636) What should be used to check the gear on sprocket alignment?

a. A plumb bob.
b. A straight edge.
c. A tape measure.
d. Dividers.

57. (637) When a hanger door repeatedly comes off track, what steps should you take?

a. Put the door back on the track and identify the cause.
b. Put the door back on the track and adjust the brakes.
c. Put the door back on the track and adjust the limit switches.
d. Adjust the wheel gears and put the door back on the track.

58. (638) The most common problem with rolling gates involves the

a. sliding collars.
b. rollers.
c. rails.
d. gates.

END OF EXERCISE

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STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY 10 USC 8012 and EO 9397. PRINCIPAL PURPOSES: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package. It is utilized by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's need. Failure to provide all information would result in slower action or inability to provide assistance to the student.

SECTION I: CORRECTED OR LATEST ENROLLMENT DATA *(Mail to: ECI, Gunter AFS AL 36118)*

1. THIS REQUEST CONCERNS COURSE (1-6)	2. TODAY'S DATE	3. ENROLLMENT DATE	4. AUTOVON NUMBER

5. SOCIAL SECURITY NUMBER (7-15)	6. GRADE/RANK	7. NAME (First initial, second initial, last name) (17) (18) (19-32)
– –		

8. ADDRESS *(OJT Enrollees -- Address of unit training office with zip code. All others -- current mailing address with zip code.)*	(33-53) (54-75)

9. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE	10. TEST CONTROL OFFICE ZIP CODE/SHRED (33-39)

SECTION II: REQUEST FOR MATERIALS, RECORDS, OR SERVICE

(Place an 'X' through number in box to left of service requested)

		FOR ECI USE ONLY	
1	Request address change as indicated in Section I.	16	
2	Request Test Control Office change as indicated in Section I.		33
3	Request name change/correction (Provide Old or Incorrect data)	G	
4	Request Grade/Rank change/correction.	K	Vol 33-35 GR 36-38
5	Correct SSAN. (List incorrect SSAN here) (Correct SSAN should be shown in Section I) ______		33-34 35-40
6	Extend course completion date. (Justify in REMARKS)	M	33-38
7	Request enrollment cancellation.	N	
8	Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 Originals were: ☐ Not received ☐ Lost ☐ Misused	P	Vol 33-35 TC 36-37
9	Send course materials. (Specify in REMARKS) ☐ Not received ☐ Lost ☐ Damaged		33-34 Volume 35-37
10	Course exam not yet received. Final VRE submitted for grading on ______ (date).	Q	00
11	Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 not yet received. Answer sheet(s) submitted ______ (date).	38 1	39-42
12	Results for CE not yet received. Answer sheet submitted to ECI on ______ (date).	2	39-42
13	Previous inquiry (☐ ECI Fm 17, ☐ Ltr, ☐ Msg) sent to ECI on ______ (date).	3	39-42
14	Give instructional assistance as requested on reverse.	16	
15	Other (Explain fully in REMARKS)		

REMARKS *(Continue on Reverse)*

OJT STUDENTS must have their OJT Administrator certify this request. ALL OTHER STUDENTS may certify their own requests.	I certify that the information on this form is accurate and that this request cannot be answered at this station. *(Signature)*

ECI FORM 17, OCT 82 (PREVIOUS EDITIONS MAY BE USED)

SECTION III REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of subject matter should be forwarded directly to preparing agency. For an immediate response to these questions, call or write the course author directly, using the AUTOVON number or address in the preface of each volume. All other inquiries concerning the course should be forwarded to ECI.

VRE Item Questioned:

Course No ______

Volume No ______

VRE Form No ______

VRE Item No ______

Answer You Chose ______ (Letter)

Has VRE Answer Sheet been submitted for grading?

[ ] Yes [ ] No

REFERENCE

(Textual reference for the answer I chose can be found as shown below)

In Volume No ______

On Page No ______

In [ ] left [ ] right column

Lines ______ Through ______

MY QUESTION IS:

REMARKS

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. Course workbooks have a Form 17 printed on the last page.

55252 05 8301

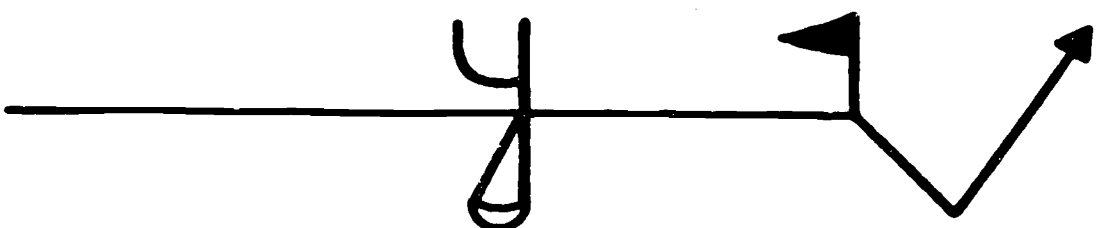
CDC 55252

METAL FABRICATING SPECIALIST

(AFSC 55252)

Volume 5

Oxyacetylene Welding



TI-101

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Air University

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EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE STATION, ALABAMA

Preface

VOLUME 5 of CDC 55252, *Metal Fabricating Specialist*, is designed to provide you with a knowledge of oxyacetylene welding. Take a little time to study the table of contents page and to leaf through the pages of each chapter and look at some of the objectives. This give you an idea of the scope of this volume and an insight into the organization of the material.

Directed your questions or comments relating to the accuracy or currency of this volume to the course author: Tech Tng Cen/TTOXC, ATTN: MSgt Arnold D. Ringstad, Sheppard AFB TX 76311. If you need an immediate response, call the author, AUTOVON 736-2879, between 0800 and 1600 (CST), Monday through Friday. *(NOTE: Do not use the suggestion program to submit changes or corrections for this course.)*

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to a Successful Course, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If this agent can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 15 hours (5 points).

Material in this volume is technically accurate, adequate, and current as of November 1982.

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Contents

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NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see whether your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Oxyacetylene Welding Equipment

OXYACETYLENE welding includes several processes in which metal parts are joined together. In this volume, we will discuss some of these processes. However, before we can discuss the various oxyacetylene operations, you should acquaint yourself with the equipment you will be required to use and its operation.

In this chapter, we will discuss assembling the equipment, testing the equipment for leaks, troubleshooting equipment malfunctions, operating the equipment, closing down the equipment, and disassembling the equipment.

In the first four volumes of this CDC, we made reference to sheet metal in our discussion both of working and equipment, mainly because that portion of the work deals with thin metal sheets. Now we are starting in to the hands-on portion dealing with heavy metal—that is, metal too heavy to form in the brake or Pittsburg machine.

Earlier you learned how metals are refined and alloyed. Now we will discuss ways of using heat to connect metal pieces along with some of the equipment used. Since the world knows and identifies people in this trade (welders), we will use the terms welder, welding machine, welding equipment, and so forth.

1-1. Oxyacetylene Welding Equipment

A welder (metal fabricating specialist) must know the correct procedure for setting up and operating both station and portable oxyacetylene welding equipment. Air Force shops make extensive use of both types of equipment.

800. Differentiate between stationary and portable welding outfits.

Stationary and Portable Welding Outfits. Stationary and portable welding equipment are basically the same. Stationary oxyacetylene welding equipment is installed when welding operations are conducted in a fixed location. This arrangement is most effective for production line work. Oxygen and acetylene are supplied to the welding are from a number of cylinders manifolded or connected together and equipped with master regulators to control the pressure and flow of the gases (see fig. 1-1). The gases are then supplied to the welding area through pipelines equipped with station outlets, as shown in figure 1-2.

The stationary oxyacetylene welding equipment (fig. 1-2) consists of single-stage acetylene and oxygen regulators attached to the gas distribution pipelines, a welding torch with a set of tips, 12½ to 15 feet of acetylene and oxygen hose, and fittings for attaching the hose to the regulators and torch. You will need a torch wrench, safety flint igniter, and welding goggles.

The portable welding outfit, (see fig. 1-3, consists of a cart, a fire extinguisher, oxygen and acetylene gas cylinders, oxygen and acetylene pressure regulators complete with gages and connections, two lengths of hose with adapter connections for the regulators and torch, a torch wrench, a safety flint igniter, and welding goggle. If you damage any part of the basic equipment, the whole outfit will be out of commission until the damaged part is replaced or repaired.

Both the stationary and portable outfits are assemble in much the same manner. We will discuss assembly procedure after we talk about the uses of the parts of an oxyacetylene outfit.

Exercises (800):

1. How does the gas supply for stationary and portable welding outfits vary?

2. The use of the stationary outfit is confined to what area within the shop?

3. How long must a whole welding outfit be out of commission if you damage just one part of it?

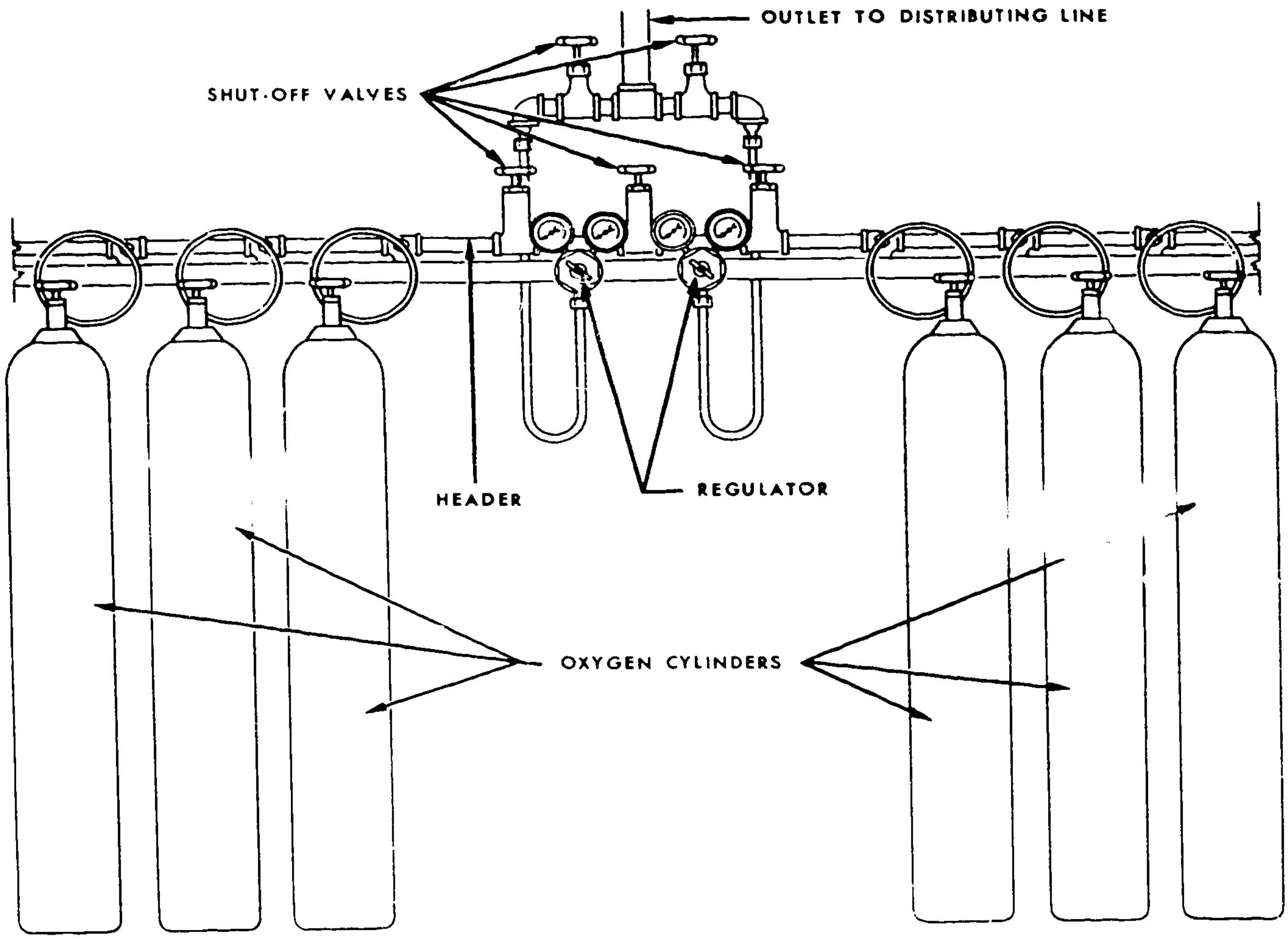

Figure 1-1. Oxygen manifold.

801. Specify the uses of the various parts of the oxyacetylene outfit.

Cylinders. The acetylene cylinder is designed to store acetylene under pressure up 250 pounds per square inch (psi). The cylinder is made of welded or brazed steel and is filled with acetone to 40 percent of its liquid volume. This allows space for expansion as the acetone absorbs the acetylene to stabilize it under pressure.

The cylinder is equipped with a cylinder valve and a protective cap. As a safety factor, the valve has left-hand threads to prevent an improper connection. Another safety factor is the safety plugs for releasing the gas if the cylinder is overheated. These plugs melt between 212° F. and 220° F. and are small enough to keep the gas from burning back into the cylinder. All acetylene cylinders are yellow and must be stored upright to prevent the escape of the acetone.

The oxygen cylinder is made of seamless steel and contains oxygen at a pressure of up to 2,000 psi. The container is green and is equipped with a safety cap to protect the valve. The valve has a bursting disc for releasing pressure increase caused by heat. It is right-hand-threaded to prevent its being confused with the acetylene connections. The great amount of pressure in an oxygen cylinder makes it a potential missile if the valve is broke off or the tank is pierced.

Storing cylinders. Both oxygen and acetylene cylinders are stored in accordance with Air Force regulations. Here are a few rules to follow for storing cylinders:

a. Keep oxygen cylinders away from oil and grease. Mixture of oxygen under pressure with oil or grease may cause an explosion.

b. Do not drop cylinders or handle them roughly.

c. Store cylinders in a cool, dry, well ventilated building.

d. Store oxygen and acetylene cylinders in an upright *secured* position and separated from each other whether they are full or empty.

e. When the cylinders are exhausted, replace the safe cap and mark the cylinder with the letters "MT."

Regulators. The regulators, or reducing valves, are mechanical devices that reduce the high pressure of the gases as they flow from the cylinders. Single-stage regulators reduce the pressure of the gases from cylinder pressure to working pressure in one step (stage). Two-stage regulators (fig. 1-4) do it in two steps.

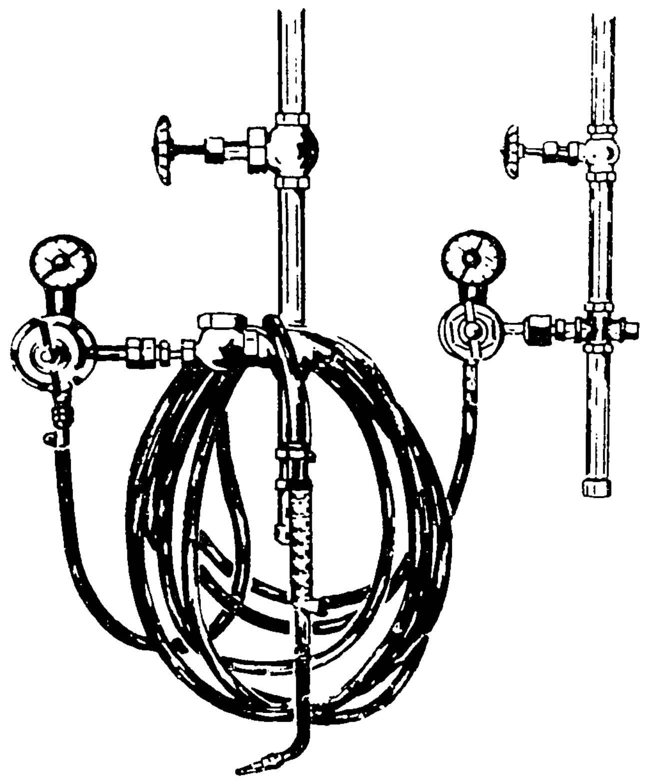

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Figure 1-2. Stationary equipment.

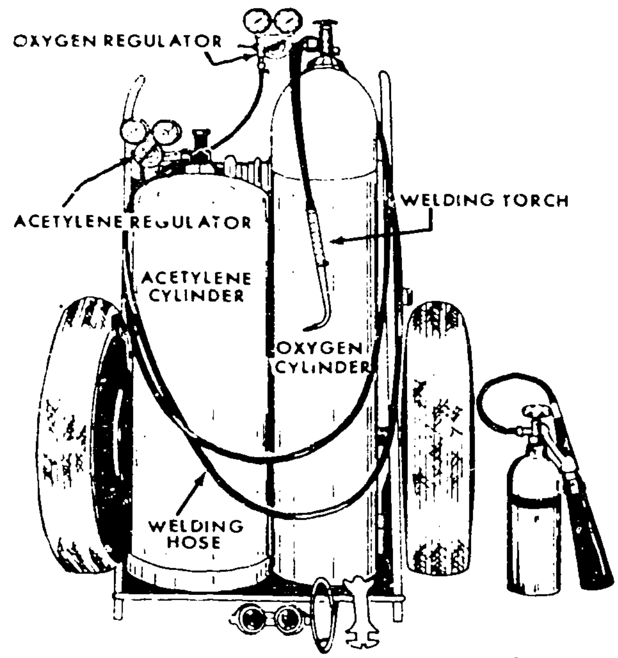

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Figure 1-3. Portable equipmment.

Hoses. Hoses take the gases at working pressure from the regulators to the torch needle valves. The oxygen hose is always green or black. and the acetylene hose is always red or maroon.

Oxyacetylene Torch. Figure 1-5 is a cutaway illustration of an oxyacetylene torch. The gases flow from the hoses through the open needle valves and through their respective tubes to the mixing head. The gases combine in the mixing head and flow forward through the tip to produce a flame.

Torch Tip. The torch tip mixes the gases and directs their flow so that the flame can be controlled.

Torch Wrenches. Torch wrenches are designed for use with an oxyacetylene outfit, and the slot or hole is of the correct size to tighten all connections.

Safety Equipment. The welding goggles, flashback arrester, and fire extinguisher are all safety equipment used with the oxyacetylene outfit. This equipment is designed to protect the operator from injury and to prevent damage to property.

Exercises (801):

1. Which regulator reduces cylinder pressure directly to working pressure?

2. What are red hoses used for?

3. List the safety equipment used with an oxyacetylene outfit.

4. Where do the gases combine in the oxyacetylene outfit?

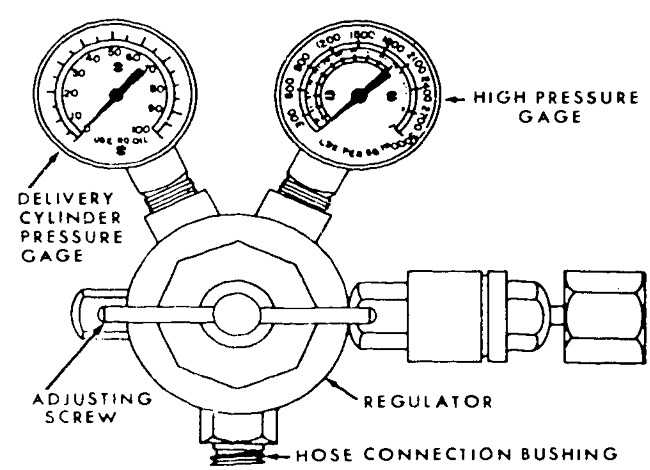

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Figure 1-4. Regulator.

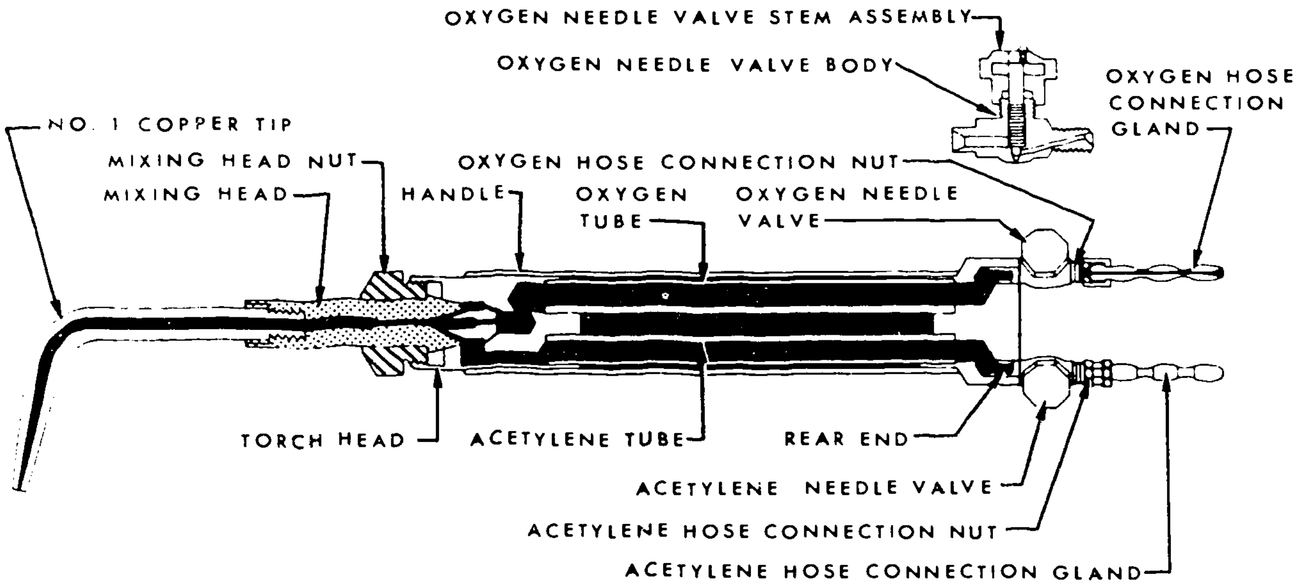

Figure 1-5. Oxyacetylene torch.

5. Describe the significant feature of the torch wrench.

6. Why should you store acetylene cylinders vertically?

7. What must be done to a cylinder after it has been emptied and removed from the manifold?

8. Why must you handle oxygen cylinders carefully?

9. How is acetylene stored under pressure in cylinders?

802. Identify important procedures in assembling oxyacetylene welding equipment.

Assembling Portable Equipment. To assemble portable equipment, place the acetylene and oxygen cylinders on the cart, secure them, and remove the cylinder valve protective caps. Open (crack) each cylinder valve slightly for an instant to blow out any dirt lodged in the outlet nipple (see fig. 1-6). Attach the two-stage regulators to their respective cylinders and tighten the union nut with the torch wrench, as shown in figure 1-7.

Attach the red acetylene hose to the acetylene regulator outlet (left-hand threads). Attach the green oxygen hose to the oxygen regulator outlet (right-hand threads). Screw the nuts tightly with the torch wrench, as shown in figure 1-8. Release the regulator-adjusting screws by turning them counterclockwise until they are loose. Open both the acetylene and the oxygen cylinder valves slowly one-fourth to one-half turn; then turn the oxygen valve to full open. (*Do not* open the acetylene

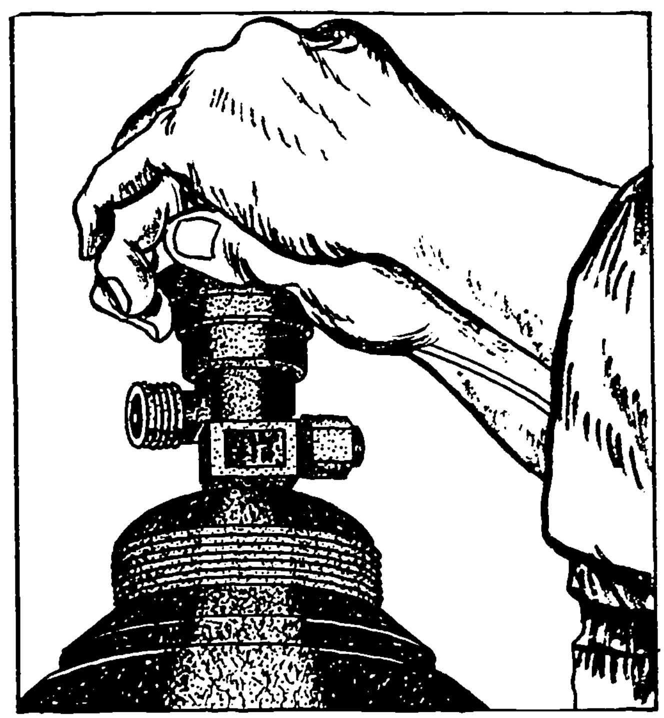

Figure 1-6. Cracking a valve.

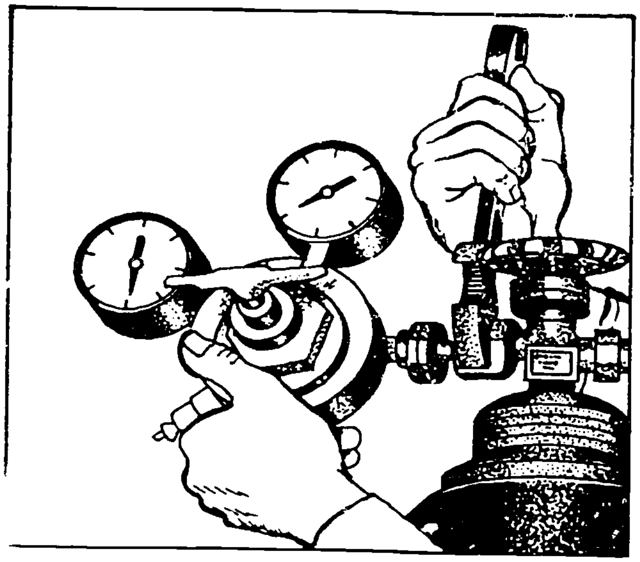

Figure 1-7. Tightening the union nut.

valve more than one-half turn.) Never open cylinder valves before you release the regulator adjusting screws (fig. 1-9). Read the high-pressure gages to check the pressure of each cylinder. Open each regulator by turning the adjusting screw clockwise. Blow out the hoses one at a time, shown in figure 1-10. After blowing out the hoses, release the adjusting screws. Connect the hoses to the torch: the red hose to the gland marked "AC" with left-hand threads, and the green hose to the gland marked "OX" with right-hand threads. Refer to figure 1-11.

Select the torch tip and attach it to the torch. Tighten the tip moderately. Now the outfit is totally assembled and ready for operation.

Assembling Stationary Equipment. The stationary equipment is connected in the same way as the portable equipment with the exception of the regulators. Single-stag regulators are used for a stationary outfit because the cylinder pressure has already been reduced to line pressure After connecting these regulators to

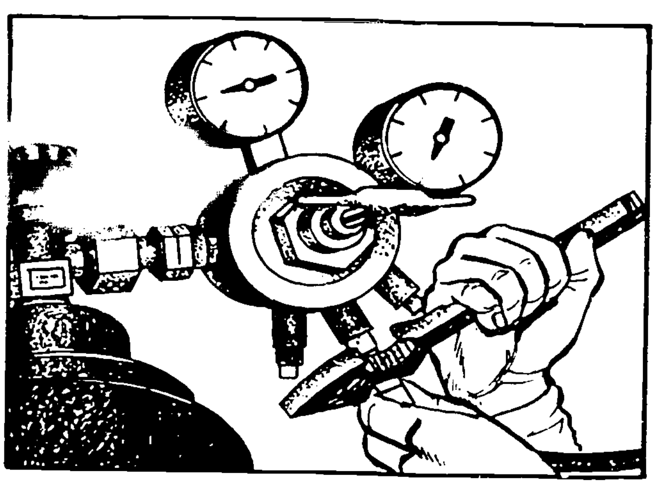

Figure 1-8. Attaching the hose.

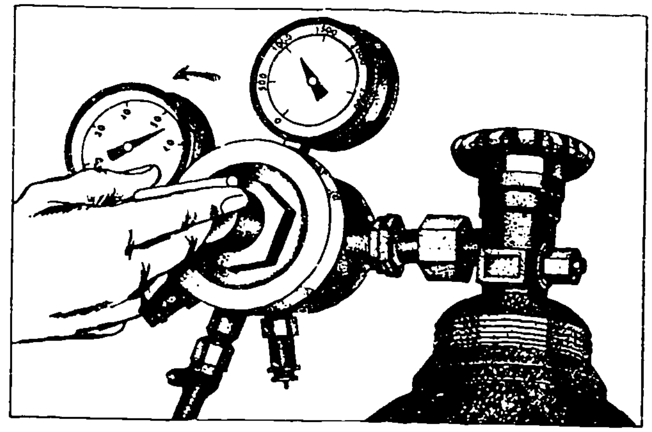

Figure 1-9. Releasing the regulator.

their respective gas supply pipes at the welding station, follow the same sequence to assemble the remainder of the equipment. NOTE: All acetylene connections are left-handed threads, and all oxygen connections are right-handed threads. This helps to prevent wrong connections.

Exercises (802):

1. Why should cylinder valves be cracked before regulators are connected?

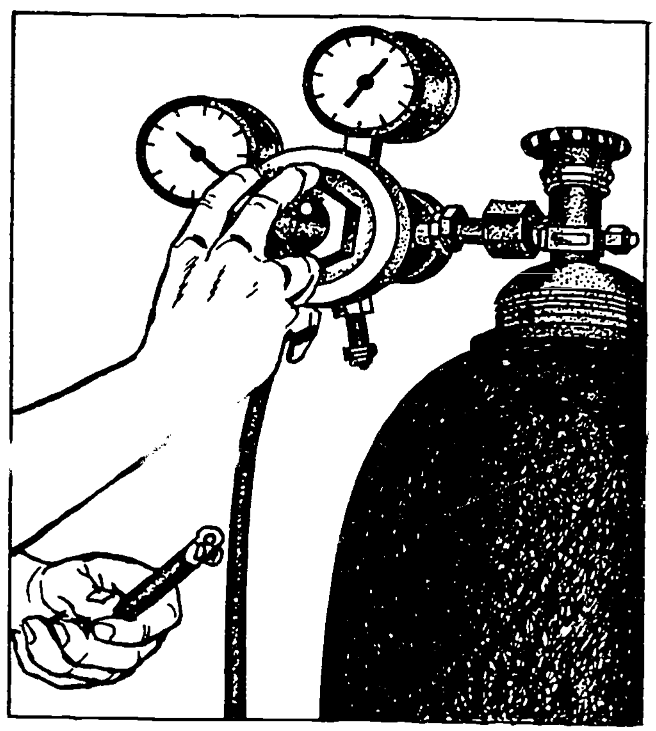

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Figure 1-10. Blowing out a hose.

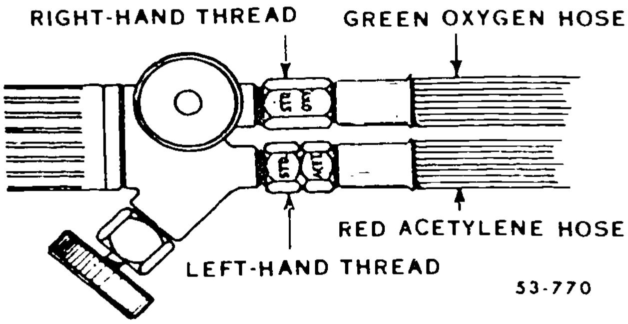


Figure 1-11. Connecting the hose and torch.

2. How much is each cylinder valve opened?

3. What tool is used to tighten all connections in assembling outfits?

4. What is the safety feature that prevents wrong connections of acetylene hoses and oxygen hoses?

803. Specify procedures for lighting the oxyacetylene torch and adjusting the flame.

Before you can operate the oxyacetylene welding equipment, you must adjust the regulators for the working pressure of the gases. To do this, first open the torch acetylene valve and adjust the regulator for the required pressure; then close the torch acetylene valve. Adjust the oxygen working pressure in the same way. Now you are ready to light the torch.

Lighting the Torch. To light the welding torch, first open only the acetylene valve. Strike the flint igniter in of the tip, keeping your hand at one side, as shown in figure 1-12. Hold the torch so that the flame is directed away from the cylinders or manifold, the hose, any flammable material, and yourself. The pure acetylene flame is long and bushy and has a yellowish color. Since the oxygen valve is closed at this point, the acetylene burns in combination with the oxygen in the air. This is not sufficient to burn the acetylene completely, and th ... y, producing ... ot fine unbu ... rbon. The pure acetylene flame is unsuitable ... lding.

When you open the oxygen valve, the flame shortens and the mixed gases burn in contact with the tip face. The flame changes to a bluish-white and forms a bright inner cone surrounded by an outer envelope. The inner cone develop the high temperature needed for welding. The outer envelope contains varying amounts of incandescent carbon soot, depending upon the proportion of oxygen to acetylene. To adjust the torch for a neutral flame, open the torch oxygen valve slowly until the feather at the end of the central cone disappears. Three distinct flames can be obtained with the oxyacetylene welding outfit: neutral, reducing or carburizing, and oxidizing.

Exercises (803):

1. Which valve do you open first?

2. How should you hold the torch?

3. How should you hold the igniter?

4. What result do you want to achieve when you open the second valve?

5. Where are the welding temperatures developed in the flame?

804. Distinguish among the three types of oxyacetylene welding flames.

Neutral Flame. There are two clearly defined cones in a neutral flame. The inner cone is luminous and bluish-white. Around this cone is a colorless area surrounded by a large flame envelope or sheath, which is faintly luminous and has a light bluish tint, as shown in figure 1-13. The neutral flame is produced by a mixture of approximately 1 volume of oxygen and 1 volume of acetylene supplied from the torch. The temperature at the tip of the inner cone is approximately 5850° F.

Reducing or Carburizing Flame. The reducing or carburizing flame, figure 1-14, is produced by slightly less than 1 volume of acetylene. To obtain this flame, you first adjust the welding flame to neutral and then open the acetylene torch valve slightly to produce a white streamer or "feather" of acetylene at the end of the inner cone. Y... can recognize the reducing or ... the presence of three distinct

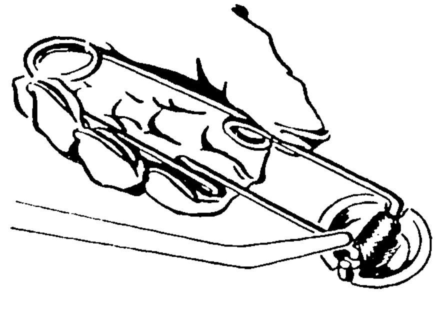


Figure 1 12. Lighting the torch.

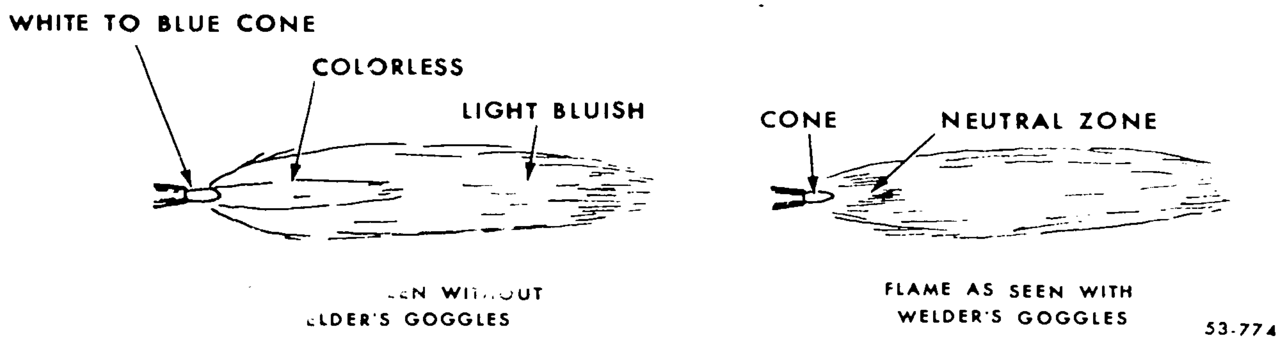


Figure 1-13. Neutral flame.

flame cones: the clearly defined, intense white, central cone; a white feather or intermediate reducing cone indicating the amount of excess acetylene, and the light orange to bluish outer flame envelope. The flame has a temperature of approximately 5700° F. at the tip of the central cone.

Oxidizing Flame. The oxidizing flame, figuure 1-15, is produced by slightly more than 1 volume of oxygen mixed with 1 volume of acetylene. To obtain this type of flame, adjust the torch first to give a neutral flame. Increase the flow of oxygen by opening the oxygen torch valve. This flame can be recognized by the short, pointed central cone, a white or colorless middle cone, and a somewhat shorter outer flame envelope. There is a distinct hissing sound. This flame has a temperature of approximately 6300° F.

Exercises (804):

1. Compare the gas volume of a neutral flame to that of an oxidizing flame.

2. Give the type and temperature of the hottest welding flame.

3. The central white feather of a carburizing flame is produced by ____________.

4. How can you recognize the reducing flame?

805. Give reasons for some regular and emergency close-down procedures for welding equipment.

Stationary Outfit. To close down a stationary welding outfit, close the torch acetylene valve and then the torch oxygen valve. Turn off the line valves. Open the torch acetylene valve until the regulator gage shows no pressure; then close this valve. Open the torch oxygen valve until the regulator gage shows no pressure; then close this valve. Shut off the regulator by turning the adjusting screw counterclockwise (fig. 1-16 These actions relieve the pressure on the regulator diaphragm. Next, hang up the hose and torch, being careful to avoid kinking the hose.

Portable Outfit. When you are closing down a portable welding outfit, close the torch ac[illegible] first and then the torch oxygen val[illegible] both cylinder va[illegible]es. Open the torch valves [illegible] a time (acetylene first) and bleed the regulators. [illegible]lose the torch valves. Turn the reg[illegible]tor-adjusting screws counterclockwise to relieve the pressure on the

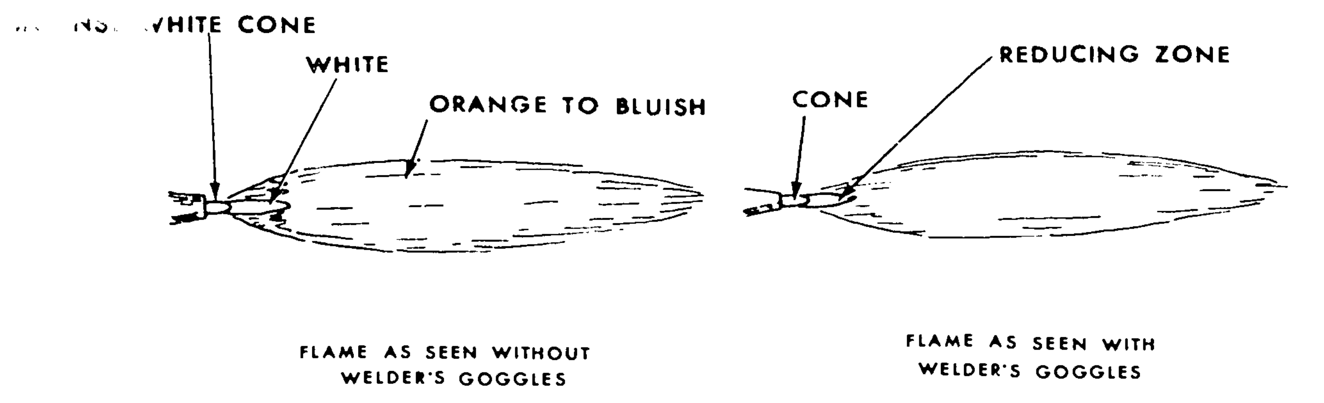


Figure 1-14. Carburizing flame.

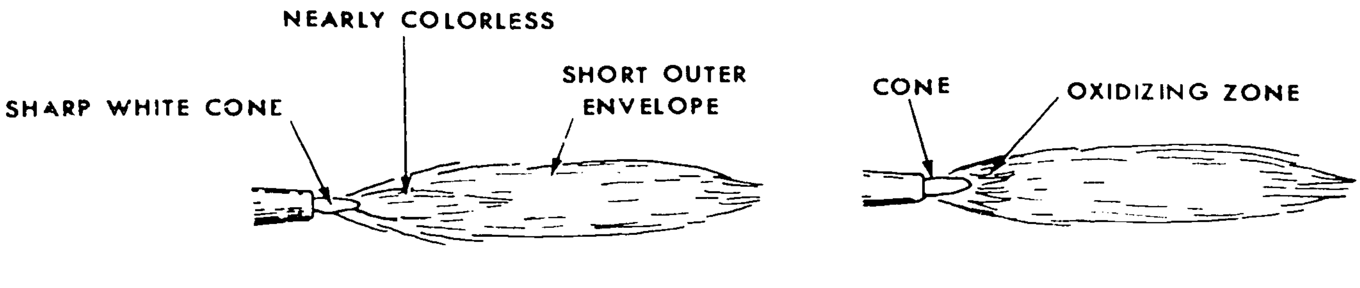


Figure 1-15. Oxidizing flame.

diaphragm. Hang the torch and hose up properly to prevent kinking the hose or damaging the torch Be careful not to damage the tip by letting it hit the cylinder or cart.

Emergency Closing Down. If you must close down because of an emergency, ALWAYS shut off the acetylene torch valve FIRST, then the acetylene *cylinder valve*. The emergency shutdown of equipment may be necessary because of a flashback. A flashback is the burning of gas inside the torch and is indicated by a high pitched whistle. It can burn all the way back to the cylinder if it is not stopped. If the flashback reaches the cylinder, the cylinder may explode. It is always dangerous and the farther back it burns, the more the equipment is damaged. A flashback must not be confused with a backfire. A backfire is merely the popping of the torch caused by a dirty tip, a tip size that is too small, the tip held too close to the work, or too little gas pressure.

Exercises (805):

1. Why should the acetylene torch valve be shut off immediately when a flashback is discovered?

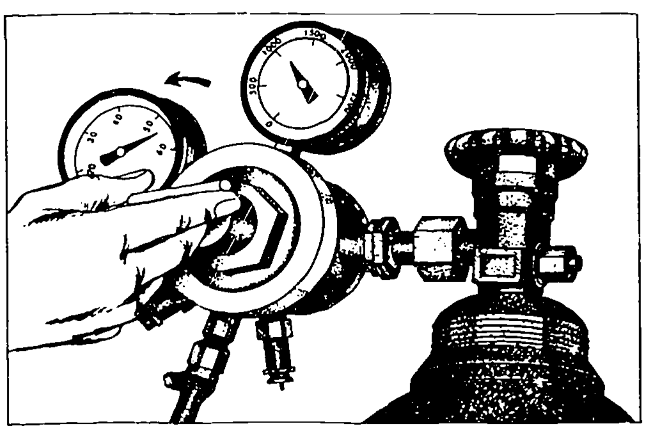


Figure 1-16. Releasing regulator pressure.

2. Why are regulator-adjusting screws released when the equipment is closed down?

3. When you are bleeding regulators, which valve must you always open and shut first?

4. What is a flashback? What noise characterizes a flashback?

806. Point out significant steps in the disassembly of welding equipment.

When it is necessary to disassemble a welding outfit, use a procedure that is the exact opposite of assembly. Use the following checklist to disassemble a welding outfit:

(1) Be sure the gas supply is shut off.
(2) Bleed the regulators.
(3) Remove the torch tip.
(4) Disconnect the hoses from the torch.
(5) Disconnect the hoses from the regulators.
(6) Disconnect the regulator from the cylinder or manifold line.
(7) Replace the cylinder valve safety cap or line protective nuts.

When you are disassembling an outfit, use the torch wrench to prevent rounding the corners on the connecting nuts. Also handle the tips, torches, and regulators careful to prevent damage.

Exercises (806):

1. What is the first thing to do in disassembling a welding outfit?

2. After disconnecting the regulator from the cylinder, you must ____________

807. Specify the procedure for testing welding apparatus for gas leaks.

Before any welding outfit is put into use, it should be throughly checked for gas leaks. The testing of the apparatus is a very simple but important task. It can be done with a container of soapy water, a small paint brush or acid brush, and a bucket of clear water.

After the apparatus has been assembled and adjusted to a working pressure, test all the connections with the soapy water and the brush. Wherever bubbles form, there is a leak. The connections that should be checked are shown in figure 1-17. Test all the hoses (K) by submerging them in a bucket of clear water. A leak will be indicated by a string of bubbles.

Exercises (807):

1. What equipment do you use for testing a welding outfit for leaks?

2. How can you find a leak in welding equipment?

53-777

A. Oxygen cylinder valve packing nut.
B. Oxygen cylinder regulator connection.
C. Oxygen regulator hose connection.
D. Oxygen hose torch connection.
E. Torch oxygen needle valve nut:
F. Acetylene cylinder valve packing nut.
G. Acetylene cylinder regulator connection.
H. Acetylene regulator hose connection.
I. Acetylene hose torch connection.
J. Torch acetylene needle valve nut.
K. Hoses.

Figure 1-17. Checkpoints for leaks.

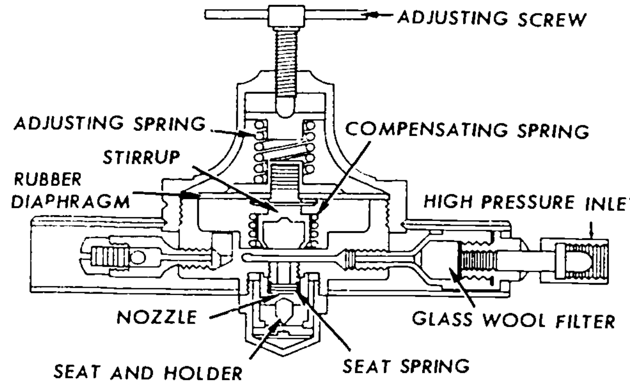


Figure 1-18. Cutaway of a pressure regulator.

3. How many connections should you test?

4. How do you test the hoses?

808. State procedures for stopping leaks in welding equipment.

Leaking Regulators. The primary problem with regulators is gas leakage between the regulator seat and the nozzle (see fig. 1-18). You can detect it by observing a gradual pressure rise on the working pressure gage after the cylinder or manifold valve is opened. This is known as a "creeping regulator" and is caused by worn or cracked seats or by dirt particles lodged between the seat and the nozzle. A leaking regulator should be replaced by a good one and sent out for repair.

Gages. Problems with a gage are usually caused by a leaking or broken bourdon tube, indicated by fluctuating gage pressure or gas leaking from the gage case. This defect develops when you fail to release the adjusting screw fully before opening the cylinder valve. A leaking gage tube can be repaired by soldering. More extensive repairs should not be attempted without the special equipment required.

Torches. The primary causes of torch trouble are leaks in the mixing head seat, leaking needle valves, and clogged torch tubes. When the gas continues to flow after the valve is closed, you know the needle valve is leaking. This condition is caused by a worn or bent valve stem, a damaged valve seat, or loose packing around the needle valve. A leak in the mixing head seat allows the gases to escape, and, unless you correct the trouble immediately, flashback is the dangerous result.

You can repair needle valve leaks around the seat by tightening the packing gland nut. If the leak is in the seat, remove the needle valve with a wrench and clean it (fig. 1-19). If it is worn or pitted, replace it with a new one. If the valve seat is scored, pitted, or otherwise damaged, the torch should be returned to the manufacturer for repair.

53-780

Figure 1-19. Cleaning a needle valve.

Leaking mixing head seats should be removed and cleaned. If the seats are damaged, the torch should be returned to the manufacturer for repair.

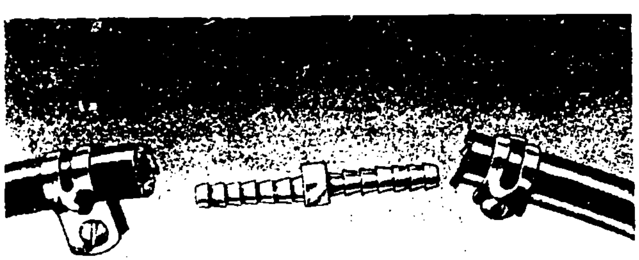
Clean clogged torch tubes by removing the hoses and mixing head and by blowing out each tube with 20 to 30 pounds of oxygen pressure.

Hoses. Check the welding hose at regular intervals for leaks, worn spots, and loose connections. You can find leaks in the hose by immersing it in clean water under pressure. Since worn or leaking hoses are dangerous and wasteful, they should be repaired or replaced immediately.

Repair leaks in the hose by removing the damaged section and inserting a hose splice, as illustrated in figure 1-20.

Note: Do not (by way of shortcut or for other reasons) put a piece of copper tubing in place of brass hose splice. Why? When copper and acetylene are placed together, they form copper acetylide, an unstable compound that will disassociate violently (EXPLODE) at the slightest shock. In short, do not use copper with acetylene.

Repair hoses leaking at the regulator or torch connect by cutting off 1 or 2 inches of hose and replacing the connections.



53-781

Figure 1-20. Hose splice and clamps.

Exercises (808):

1. You can detect a creeping regulator by observing ____________.

2. Defective bourdon tubes are indicated by ____________ or ____________.

3. You should ____________ a cracked needle valve.

4. Pitted valve seats should be repaired by the ____________.

809. Give reasons for specific procedures in the repair of welding and cutting torch tips.

Welding and cutting torch tips cannot function properly if they are dirty or improperly cared for. There are two major malfunctions of both welding and cutting tips: accumulating dirt and leaking gas.

Dirty Tips. Tips require frequent cleaning because small particles of metal and oxide collect on the tip and in the orifice. Use a soft wire or drill-type tip cleaner to clean the tip. The tip cleaner should be approximately one size smaller than the tip orifice to prevent enlarging the orifice during cleaning. There are two correct ways of using a tip cleaner. One method is to remove the tip from the torch and insert the cleaner from the threaded end, as shown in figure 1-21. The other method is to open the oxygen valve and insert the tip cleaner, as shown in figure 1-22. Whichever method you use, you must always use a straight back-and-forth motion to prevent enlarging the orifice. If a tip orifice becomes scored, out-of-round, or enlarged, the tip should be replaced. Remember that too much cleaning will eventually enlarge the orifice anyway.

Slag accumulation (fig. 1-23) is a greater problem on cutting tips than on welding tips. To remove slag from

Figure 1-21 Cleaning a tip from inside.

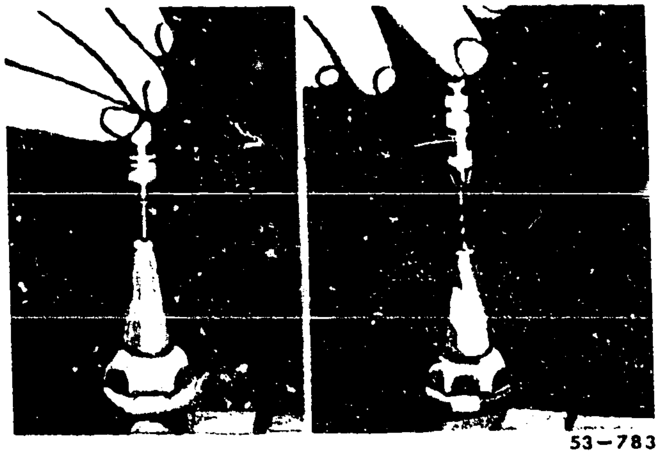


Figure 1-22. Cleaning a tip on the torch.

cloth placed on a file, as shown in figure 1-24. Open the oxygen valve to blow out the slag and dirt when you have loosened it. When you use this method, be very careful not to remove too much of the tip. If you do this, you will enlarge all the orifices because of their original taper.

In addition to cleaning the slag from the tip face, you must remove the slag from the tipsides. Dressing the tip (fig. 1-25) removes the slag from the sides. A sharp edge must be maintained at the meeting of the face and sides to prevent distorting the flame. Distorting welding and cutting tips causes uneven preheating and creates problems in making a weld or cut.

Gas Leakage. Gas leakage around a tip usually indicates a nick or flat spot in the tip seat. If this is the case, the tip should be discarded. Always check for bad torch seats as well. Gas leakage around the tip is very dangerous because it can cause a flashback. Correct it immediately.

Exercises (809):

1. If a number 1 tip is smaller than a number 2, which tip cleaner should you use to clean a number 2 tip? Why?

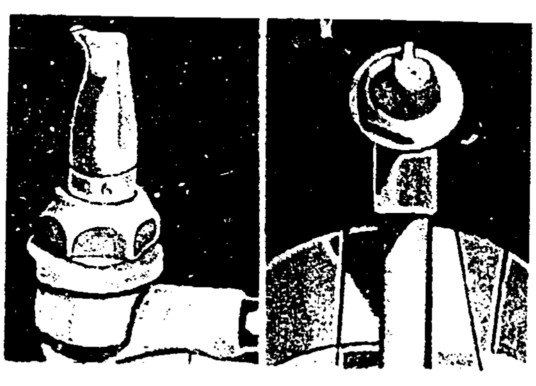


Figure 1-23. Slag on a tip.

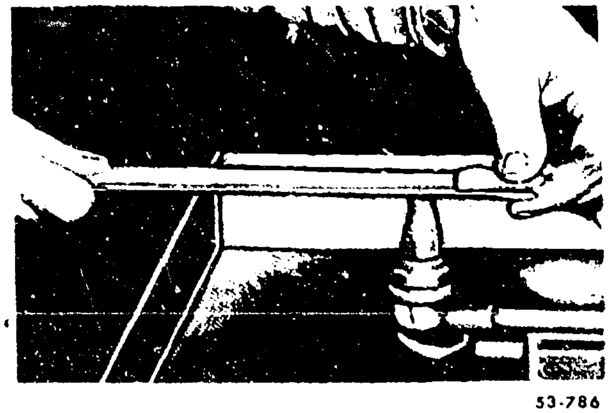


Figure 1-24. Cleaning the tip face.

2. Why should you use a straight back-and-forth movement when cleaning a tip?

3. Can a tip be ruined by too much cleaning? Why?

4. What must you do if you notice gas leakage around the tip? Why?

5. When you are dressing the tip, why must you maintain a sharp edge where the face and sides of the tip meet?

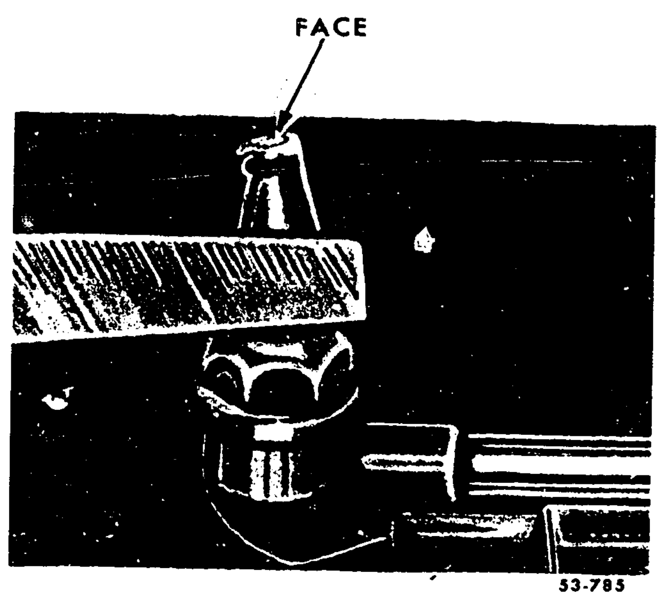


Figure 1-25. Dressing a tip.

Welding Carbon Steel and Heat- and Corrosion-Resistant Ferrous Alloys

WELDING PROCEDURES and qualifications in today's nuclear and space age involve more than just meeting ductility and strength requirements and the tensile tests prescribed by existing standards and codes. Other factors that must be considered are operating temperatures and pressure ranges which have greatly increased. In order to meet the more critical service requirements and conditions today, new metals and alloys are being produced. To join these metals and alloys properly, new welding methods are being developed and present methods are being improved.

Although there are new methods of welding, such as ultrasonic welding, electron beam welding, resistance welding and inert gas welding, you will find that oxyacetylene welding is still done. In some respects, the oxyacetylene welding of heat- and corrosion-resistant ferrous alloys (stainless steels) is a continuation of welding carbon steels. There are many similarities in the two processes. In this chapter, we will discuss these similarities, along with certain differences. However, first you must know a little something about the metal you are going to work with.

2-1. Types and Uses of Carbon Steel

The weldability of a carbon steel depends to a great extent upon its carbon content which varies from 0.04 to 1.70 percent. In general, weldability becomes poorer as the carbon content increases because of the hardening effect of carbon. In high carbon steels, a hard, brittle zone forms in the fusion area, caused by the rapid cooling of the molten metal.

810. List the types of carbon steel and give some of their properties.

Low Carbon Steels. These are normally steels that contain up to 0.30 percent carbon. They are soft and ductile and can be rolled, punched, sheared, and worked, either hot or cold. They are easy to weld by any method, and they harden very little when cooled suddenly from a high temperature. Low carbon steels are widely used in industry because they are easy to work, relatively low in cost, and obtainable in bar, sheet, and tubular form. Low carbon steels are used for aircraft parts that do not require high strength. They are used extensively for ground installation parts, such as jigs, stands and structures. These steels are also commonly used in stamp drawing, and case-hardening applications.

Medium Carbon Steels. These are nonalloy steels with a carbon content ranging from 0.30 to 0.45 percent. Because they have enough carbon, their mechanical properties can be improved by heat treating. You can weld medium-carbon steels satisfactorily by several methods, but you must control the flame and heat more carefully than for the low-carbon steels. During welding the weld zone hardens if it is cooled rapidly, and it must be stress-relieved after welding. These steels are used for general machinery and forging applications in which strength and hardness are required. The steels can be obtained in bar sheet, and tubular form.

High Carbon Steels. These nonalloy steels contain 0.45 to 0.90 percent carbon. They are more difficult to weld than the low and medium carbon steels because of their high carbon content and the heat treatment needed to develop special mechanical properties. The heat of the welding changes these properties in the vicinity of the welded joint Heat treatment after welding is, therefore, necessary to restore the original properties of the welded parts. You should stress-relieve these steels by heating them uniformly to a temperature between 1,200° F. and 1,450° F. and cooling them slowly. High carbon steels are used for drills, taps, dies, springs, and other hand and machine tools that are heat treated for high strength and wear resistance. These steels are available in bar, sheet, and wire forms in either the annealed or normalized condition.

High Carbon Tool Steels. These nonalloy steels have a carbon content ranging from 0.60 to 1.70. They are used to manufacture tools and other similar parts that require a high degree of hardness to maintain a sharp cutting edge. They are very difficult to weld because of their high carbon content.

Exercises (810):

1. List the various types of carbon steel.

2. Carbon steel with a carbon content of 0.40 percent is ____________ ______________ __________

3. The weldability of high carbon tool steel is impaired because of its ______________________

4. If you had to weld a spring, what should you do after completing the weld?

2-2. Principles of Welding

When steel is heated, it goes through a soft or plastic range between the solid and liquid states. Steel doesn't become fluid until it reaches a temperature between 2,450° F and 2,750° F. The composition of the metal determines the temperature at which its fluidity occurs. The temperature range is important when you weld various metals. Knowing the range allows you to control the weld. Also, selecting the correct torch tip and welding or filler rod aids in weld control.

811. State what to look for when selecting torch tip and filler rod.

Torch Tip Selection. Selecting the proper tip size depends upon the thickness of the metal and rate at which the heat is conducted and radiated in it. If you select a tip that is too large, the metal will overheat and excessive scaling and loss of elements from the metal will occur, producing a weak weld. In light metals, overheating often results in the burning of holes, excessive penetration, and large globules of metal protruding on the opposite side of the weld. If the tip is too small, the flame volume is too small to obtain proper fusion. Adhesion occurs between the base metal and the filler rod and produces only a physical bond. A chemical bond, the actual mixing of the metals to form a solid mass, must occur to produce a sound weld. If you do not have the torch manufacturer's table giving the approximate sizes of the tip for welding different thicknesses of material, you can select the approximate size of the tip by gaging the tip orifice and referring to a table, such as the one shown in figure 2-1. Oxygen and acetylene pressures are approximately the same in an equal pressure type of torch.

Filler Rod. The type of filler rod for the job depends upon the type of metal you are welding. In fusion welding, the filler rod is usually of the same composition as the base metal. For welding low carbon steels, use a copper-coated, low carbon rod. The size of the filler rod depends upon the thickness of the metal you are welding. Welding rods are available in a diameter of 1/16 inch and larger. Figure 2-2 compares filler rod diameter and metal thickness.

Exercises (811):

1. What are the factors that govern tip size selection?

METAL THICKNESS	TIP SIZE NO. (Airco)	ACETYLENE PRESSURE
1/64" to 1/32"	0	1
1/32" to 1/16"	1	1
1/16" to 1/8"	2	2
1/8" to 3/16"	3	3
3/16" to 1/4"	4	3
1/4" to 3/8"	5	3.5

CP-37

Figure 2-1. Tip sizes and pressure.

2. Describe what happens if you use a tip that is too large.

3. What determines the type and size of filler rods?

812. State the methods used for oxyacetylene welding.

The two methods used in oxyacetylene welding are the forehand method and the backhand method.

Welding Forehand. To make satisfactory bead welds on the surface of a plate in flat position welding, the flame motion, tip angle, and position of the welding flame above the molten puddle should be carefully maintained. Adjust the welding torch to give the proper type of flame for the metal you are welding. Make narrow bead welds by raising and lowering welding flame with a slight circular motion while progress in a forward direction. Hold the tip of the torch at an angle of 45°-60° to the plate surface and point the flame in the direction of welding at all times, as shown in figure 23. To increase the depth of fusion, either increase the angle between the tip and the plate surface or decrease the welding speed. The size of the puddle should not be too large or will cause the flame to burn through the plate. A properly made bead weld, without filler rod, should be slightly depressed below the upper surface of the plate, and a ridge should form on the underside to indicate full penetration.

Bead welds made on the surface of a plate with a welding rod are shown in figure 2-4. In making this weld, heat the surface of the metal to bring a small portion of the metal up to the melting temperature. Then insert the welding rod into the puddle and melt

METAL THICKNESS	FILLER ROD
1/16" TO 1/8"	1/16" TO 3/32"
1/8" TO 1/4"	1/8"
3/8" TO 1/2"	3/16"
1/2" AND UP	1/4"

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Figure 2-2. Filler rod size.

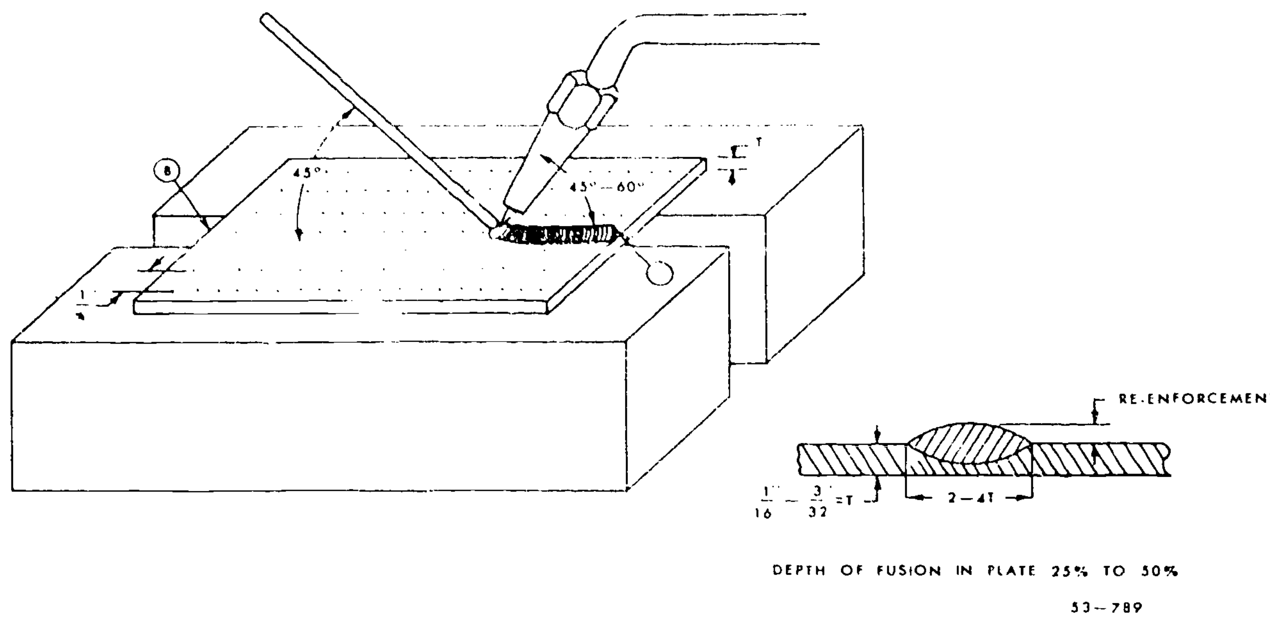

Figure 2-3. Welding beads.

both the base metal and rod together. Move the torch from side to side slightly to obtain good fusion. By varying the welding speed and the amount of metal deposited from the welding rod, you can control the size of the welding bead to any desired limit.

Welding Backhand. In this newer method of welding, the welding tip precedes the rod in the direction in which the weld is being made, and the flame is pointed back at the molten puddle and the completed weld. Hold the end of the rod between the flame and the molten puddle and keep the welding tip at an angle of approximately 60° to the plates. Positioning the welding rod and tip requires less transverse motion than in forehand welding.

If you use a straight welding rod, rotate the rod so that the end rolls from side to side in the puddle and melt off evenly. If you use a bent rod, move the rod and the tip toward and away from each other to simulate a rapid bellows action. In a welding operation in which you are making a large weld deposit, move the end of the rod in full circles in the molten puddle. Move the torch to and fro across the weld while you advance slowly and uniformly in the direction of the welding.

Use backhand welding mainly for welding heavy sections because it permits forming narrower V's at the joint. A 60° included angle of bevel is sufficient for a good joint weld In general, less weld rod is used in welding by this method than by forehand welding.

You can compare the forehand and backhand methods by referring to figures 2-4 and 2-5.

Exercises (812):

1. Describe the movements in forehand welding.

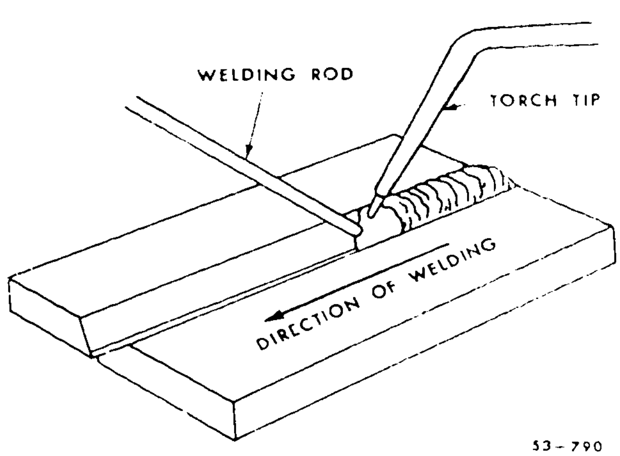

Figure 2-4. Forehand welding.

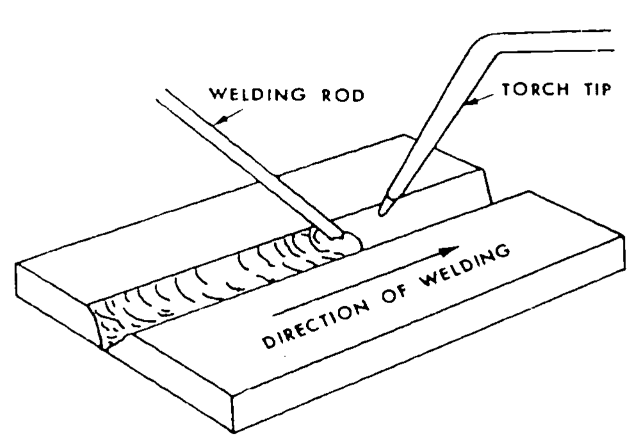

Figure 2-5. Backhand welding.

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2. In forehand welding, how should you hold the torch?

3. Why is the backhand method considered slightly easier than the forehand method?

4. How do you control the size of the weld bead?

2-3. Welding Positions

All welding can be classified according to the position of the metal or its joint edges.

813. Name the four welding positions and differentiate among them.

There are four general positions: flat, horizontal, vertical, and overhead. To make satisfactory welds in positions other than flat, a knowledge of the factors that permit you to control the weld metal in various positions is essential. Because of the effect of gravity, the molten weld metal in the puddle always tends to seek a lower level. This tendency is restrained by the following forces: (1) the cohesion of the molten pool, (2) the support provided by the base metal and solidified weld metal, (3) the pressure of the flame on the molten metal, (4) the manipulation of the filler rod and the chilling effect of the filler rod upon the molten pool, and (5) surface tension.

The most important force that tends to counteract the force of gravity is the cohesion of the molten metal, which permits a certain amount of molten metal to remain in the molten pool without running or falling. Cohesion is affected by the amount of heat applied.

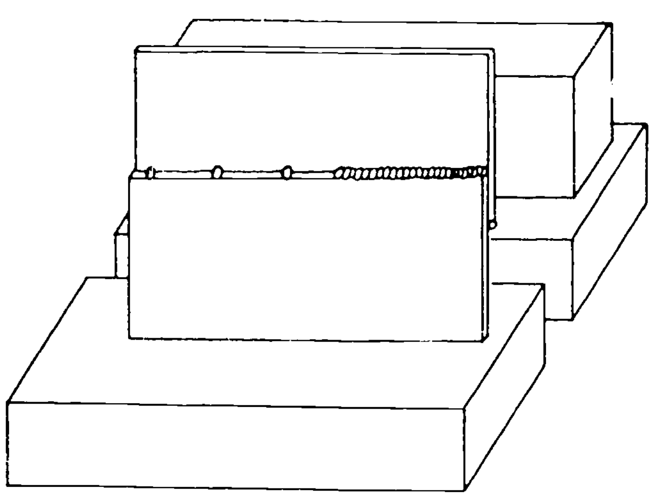

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Figure 2-6. Horizontal lap joint.

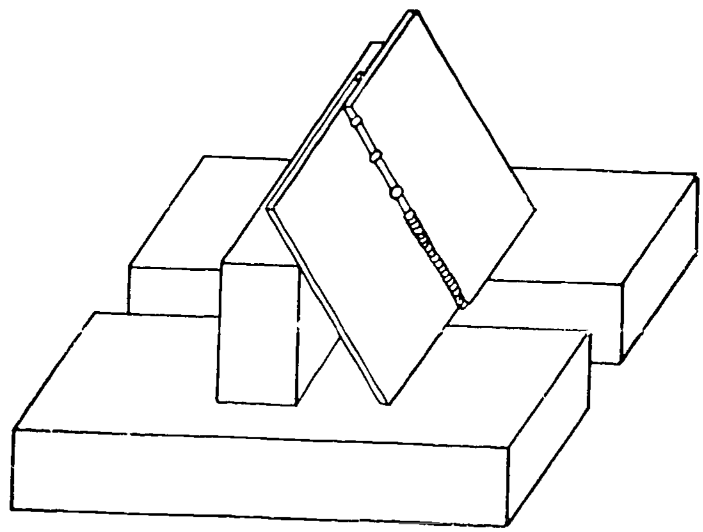

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Figure 2-7. Vertical lap joint.

More heat than necessary increases the fluidity of the molten metal, giving it a greater tendency to run or fall.

Flat Position. When a weld is made with the parts flat on the table, or inclined at an angle less than 45°, the filler metal is deposited from the upper side of the joint and the face of the weld is approximately horizontal. This is flat position welding.

Horizontal Position. When you weld joints with the joint edges horizontal, as illustrated in figure 2-6, the tip should be held at an angle of 45° to the plate surface and inclined slightly in the vertical plane to direct the flame upward. The slight inclination of the tip keeps the molten metal from sagging to the lower edge of the weld. Move the tip slightly from side to side to deposit the metal uniformly along the joint. Add the filler rod to the upper edge of the molten pool to permit an even distribution of weld metal.

Vertical Position. When you are welding with the parts inclined at an angle greater than 45° and the seam is running vertically, as illustrated in figures 2-7 and 2-8, you produce a vertical weld. During vertical welding, gravity causes the molten metal to run down and produce a highly crowned bead. To control the flow of the molten metal, hold the flame below the welding rod and point it upward at an angle of 45° to the plate. Removing the flame momentarily when the molten metal tends to sag will aid in producing a weld of proper contour. The solidified weld metal just below the molten pool acts as a ledge that provides support.

Overhead Position. The overhead position is probably the most difficult of all welding positions. Metal deposited in the overhead position tends to drop or build up in the center of the molten pool, causing the bead to have a high crown. In this case, where there is no supporting ledge of solidified weld metal to provide partial support, the pool carried must be relatively small so that gravity does not exceed the forces of cohesion and flame pressure. Manipulate the filler rod and let its chilling effect keep the pool of metal small.

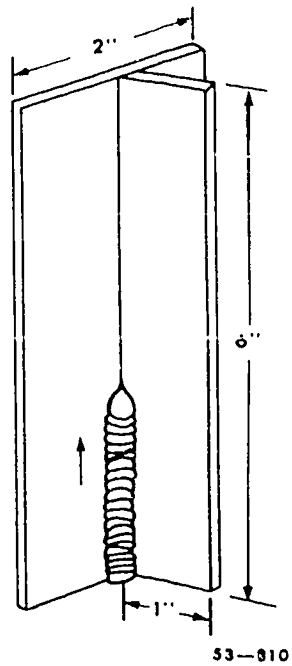


Figure 2-8. Vertical tee joint.

Form the bead by slowly moving the rod from side to side so that the molten metal cannot collect at one spot and run off. The filler rod metal chills the pool of molten metal to a plastic state, and it solidifies quickly to form the weld bead. If the molten pool becomes too large, remove the flame from the pool for an instant to allow the weld metal to solidify before resuming.

Exercises (813):

1. Name the four welding positions.

2. What effect must you overcome when you are welding a vertical tee joint?

3. Describe the vertical position

4. Describe the horizontal position.

2-4. Weld symbols

In an earlier volume in this CDC, we discussed symbols used for duct systems. In this section, we will discuss welding symbols (road signs to good welds) used on blue prints. This would be an ideal place for you to review the section on sheet metal layout. Do you remember how to make a of the pattern layouts, views, lines, etc? Pattern development is used in all phases of fabrication and repair.

814. Interpret welding symbols used on blueprints.

The welding symbols on blueprints provide complete and concise information for the guidance of welders. Figure 2-9 shows a welding symbol and the standard location of the elements of welding information. The reference line of the welding symbol

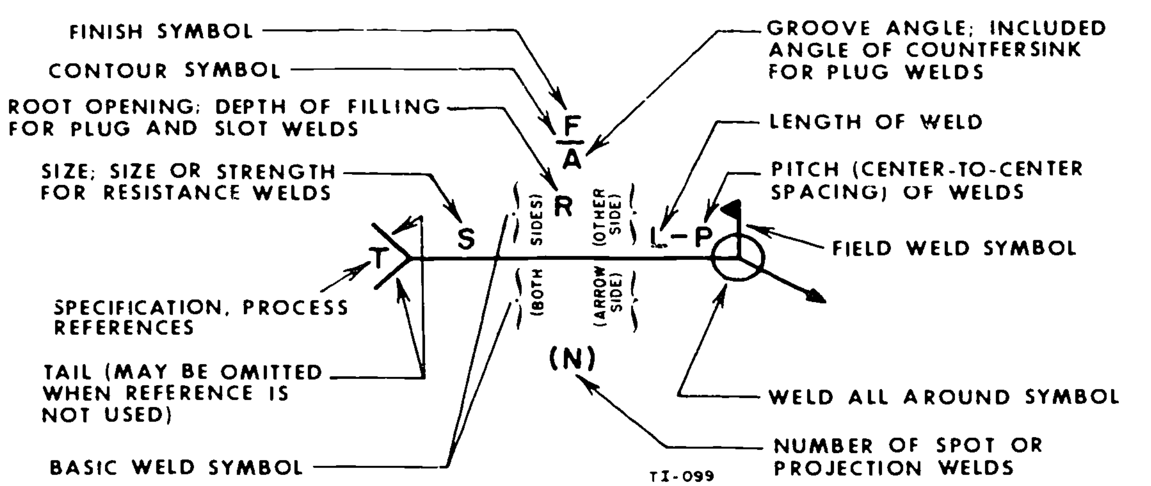


Figure 2-9. Welding symbol.

designates the welding process to be used, its location, dimensions, extent, contour, and other supplementary information. If necessary, a tail is attached to the reference line and used to provide specific notations. If such notations are not required, the tail is omitted.

There is a distinction between the terms "weld symbol" and "welding symbol." The weld symbol is the symbol (as in fig. 2-10, details A and B) that indicates the desired type of weld. The assembled welding symbol contains the following elements: reference line, arrow, basic weld symbol, dimension and other data, supplementary symbols, tail, and the specification process, or other reference.

The basic weld symbol means the welding process to be used in a metal-joining operation, such as whether the weld is to be localized or "all around," or whether it must be a shop or field weld. It also indicates the contour of the weld. These basic weld symbols may be summarized as follows:

a. Arc and gas weld symbols are those signifying bead, fillet, plug or slot, square, V, bevel, U, and J welds, as illustrated in figure 2-10, detail A.

b. Resistance weld symbols are those signifying spot, projection, seam, flash, and upset welds, as illustrated in figure 2-10, detail B.

c. Since brazing, forge, thermit, induction, and flow weldments do not have specific weld symbols, the tail of the welding symbol designates which of these welding processes is used, together with the specifications, procedures, and other supplementary information needed for making the weld. The codes for these notations in the welding symbol are usually established according to their uses.

d. Supplementary symbols designate requirements that are common in many welding processes and include symbols fo weld-all-around, field weld, and flush and convex contour welds, as illustrated in figure 2-10, detail C.

Welds on the arrow side of the joint are indicated by the weld symbol on the side of the reference line toward the reader, as in figure 2-11, detail A. Welds on the other side of the joint are indicated by the weld symbol on the side of the reference line away from the reader, as in figure 2-11, detail B. Welds on both sides of the joint are indicated by the weld symbols on both sides of the reference line, as in figure 2-11, detail C.

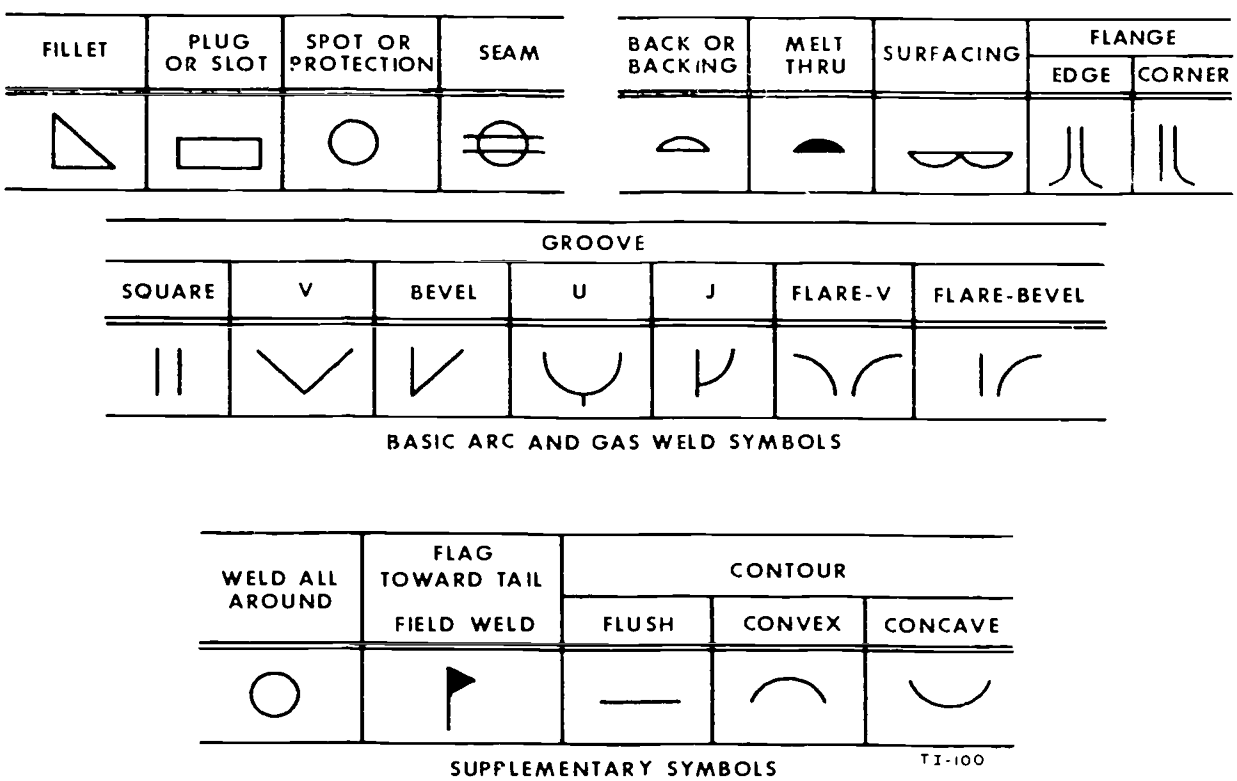


Figure 2-10. Basic weld symbols.

The symbols for spot, seam, flash, and upset welds have no arrow side or "side" significance in themselves, although supplementary symbols used with these symbols may have. For example, the flush-contour symbol shown in figure 2-10 is used with the spot and seam symbols in figure 2-11 to show that the exposed surface of one member of the joint is to be flush. Spot-, seam-, flash-, or upset-weld symbols are centered on the reference line as in figure 2-11, detail D. If more than one type of weld is to be used on a joint, the symbol for each weld is shown as indicated for the types of welds that are illustrated in figure 2-11, detail E.

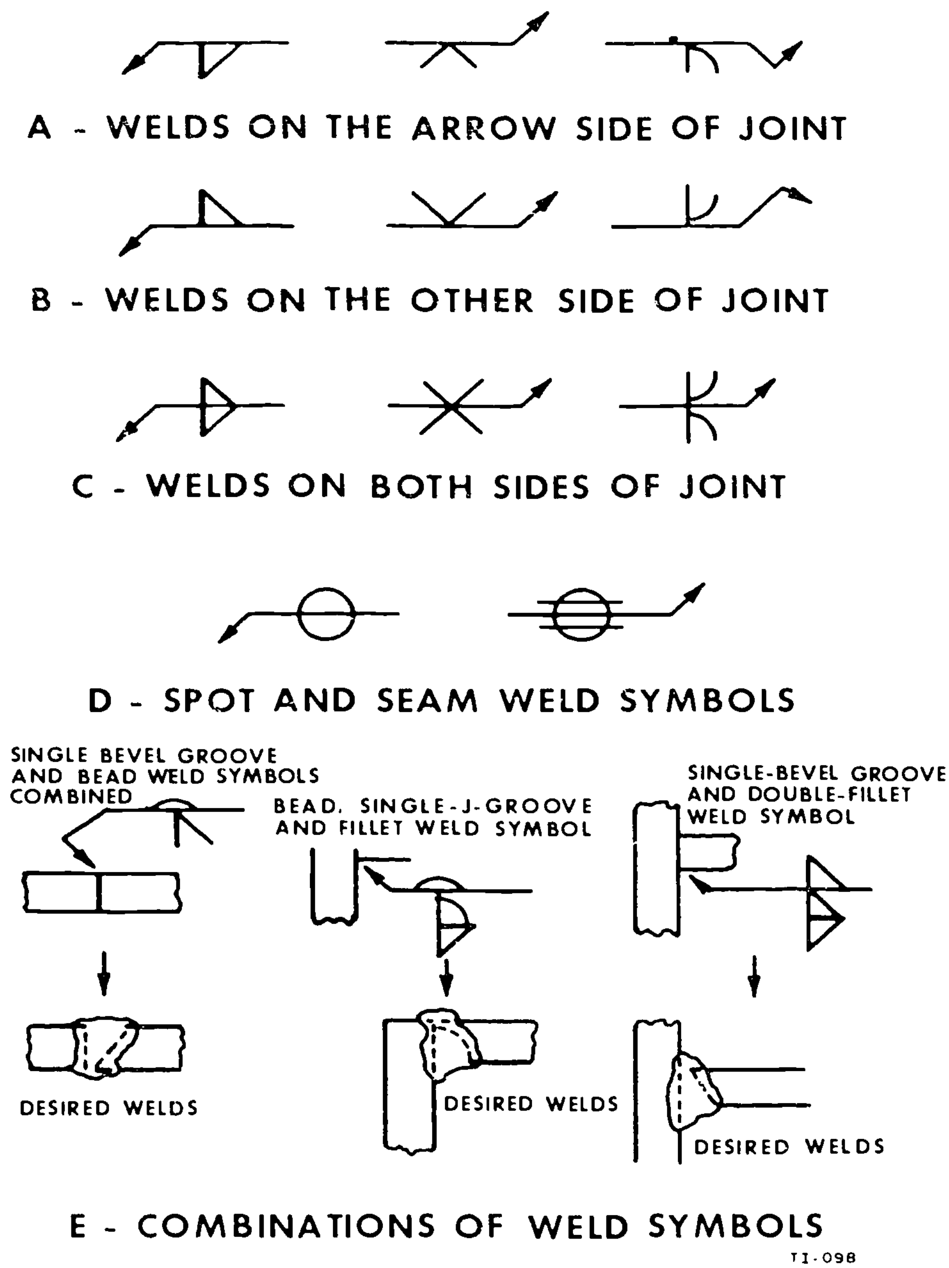


Figure 2-11. Symbols indicating type and location of welds.

Exercises (814):

1. What type of weld is symbolized by two parallel vertical lines?

2. The welds for the arrow side of the joint are indicated ________

3. A right triangle is the symbol for what type of weld?

2-5. Welding Joints

The properties of a welding joint depend partly upon the correct preparation of the edges. You must remove all mill scale, rust, oxides, and other impurities from the joint edges and surfaces. If you don't, these impurities will be included in the weld. Prepare the edges to fuse completely without excessive melting. The edge preparation and type of joint you use must keep the heat loss, which radiates into the base metal from the weld, to a minimum. A properly prepared joint will keep the expansion of heating and the contraction of cooling within allowable limits.

The preparation of the edges and the type of joint are governed by the form, thickness, and type of metal, the load that the weld must support, and the available means for preparation. Some of the most common types of edge preparation are shown in figure 2-12. We will discuss preparation, welding techniques, and weld specifications in the following objective segments, covering the five basic types of welded joints: lap, butt, tee, corner, and edge.

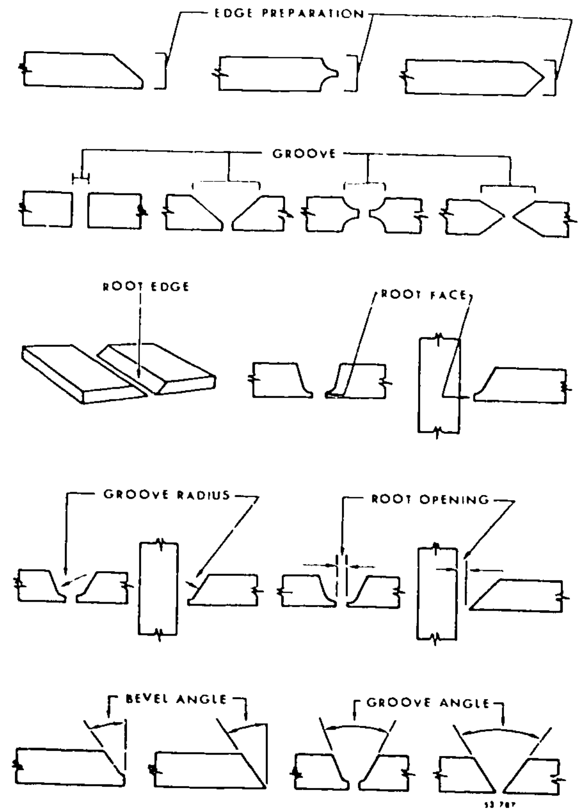


Figure 2-12. Edge preparation.

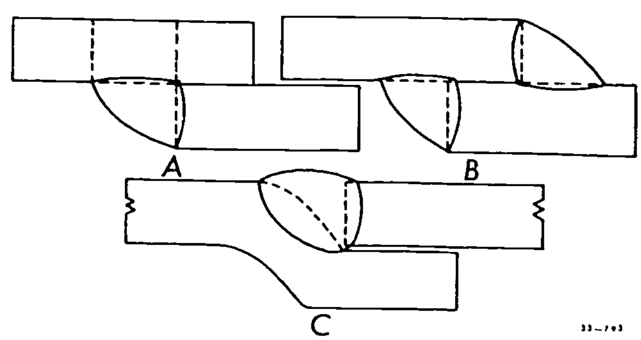
815. List and compare the three types of lap joints.

A lap joint is made by placing the edge of one sheet over the edge of another sheet and welding the edge of the first sheet to the surface of the other. Lap joints are used extensively in constructing equipment made from plate and sheet metal. In general, the lap joint is not the strongest type of joint, but certain types of lap joints develop the full strength of the base metal under tensile pull. The fillet weld is used when making lap joints. The different types of lap joints, single-fillet, double-fillet and joggled, are shown in figure 2-13.

Single-Fillet Lap Joint. The single-fillet lap joint requires no machining of the joint edges. You use this join when the design of the part does not permit welding from both sides. The single-fillet lap joint in figure 2-13, detail A, does not develop full base metal strength, but it is stronger than a butt weld when it is used for some purposes. When tubing or frames overlap or telescope together, the lap joint is preferred to the butt joint. If loading is not too severe, this joint is suitable for welding metals of all thicknesses. However, with fatigue or impact loads, stress concentrates at the edge of the weld. Under tension, the plates will pull out of line, causing the root to bend.

Double-Fillet Lap Joint. The double-fillet lap joint in figure 2-13, detail B, can withstand much more severe load conditions than the single-fillet lap joint. When properly made, this joint develops the full strength of the base metal.

Joggled Lap Joint. When you want to use a lap joint and the metal surfaces must be kept on the same plane, use joggled lap joint shown in figure 2-13, detail C. This joint gives a more uniform distribution of load stresses than the single-or double-fillet lap joint.



A. Single-fillet
B. Double-fillet
C. Joggled

2-13. Types of lap joints.

Exercises (815):

1. List the three types of lap joints.

2. Which lap joint is the best to use when the work will be under stress?

3. What type of weld is used when making lap joints?

4. Which lap joint is welded from both sides?

816. State the specifications for welding lap joints.

To understand the specifications and techniques for lap joints, you must understand weld nomenclature.

Weld Nomenclature. The meanings of the terms for a lap joint, shown in figure 2-14, are as follows:

a. The *fusion zone* is the area of weld metal that has penetrated beyond the surface of the base metal.

b. The *root* is the portion of the weld metal that is deposited at the bottom of the joint.

c. The *leg* is the dimension of the weld extending on each side of the root of the joint.

d. The *face* is the outer surface of the weld reinforcement.

e. The *toes* of the weld are the edges of the weld face.

f. *Penetration* is the distance from the original surface of the base metal to the point at which fusion ceases.

g. The *throat* is the distance through the center of the weld from the root to the face.

Weld Specifications. Weld specifications, illustrated in figure 2-15, are the requirements for completing a sound weld. All the specifications are based on the thickness (T) of the base metal. However, when you make welds on metals of unequal thickness, the specifications are based on the lighter gage metal. The specifications for the lap joint in figure 2-15 are:

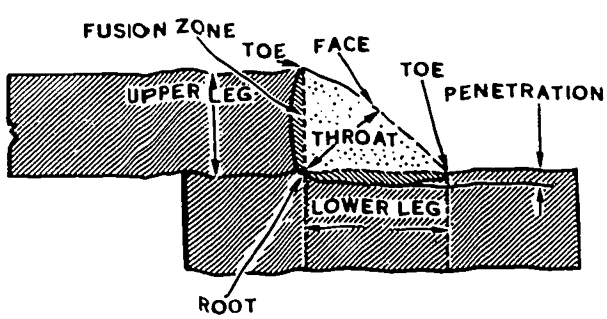


Figure 2-14. Lap weld nomenclature.

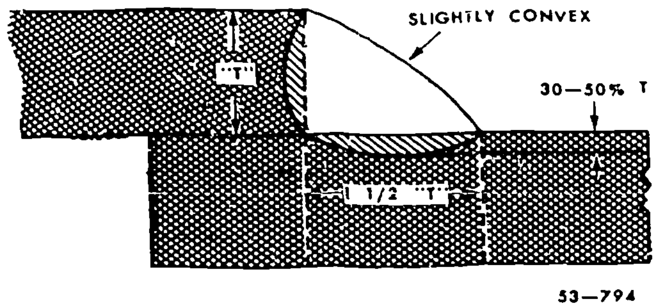


Figure 2-15. Lap weld specifications.

a. The *upper leg* should equal the thickness (T) of the base metal; the lower leg should equal 1½ time T.

b. The *face* should be slightly convex in shape.

c. *Penetration* for metals ⅛ inch or less in thicknes should be 30 to 50 percent of the metal thickness. For heavier gages, the minimum penetration should be 1/16 inch.

d. *The throat* thickness should equal the thickness of the base metal.

Welding Techniques. When you join metal thicknesses of ⅛ inch or less, overlap the sheets from four to six times the metal thickness. Tack weld the joint at intervals of approximately 1½ inches, as shown in figure 2-16. Before welding, preheat the edges of the sheet by directing the flame above and below the joint edges. This raises the temperature of the metal to a point that produces fusion into the root of the joint.

Hold the torch approximately 60° from horizontal to direct most of the heat upon the bottom sheet, and point the flame in the direction of travel. When the edges are heated to the molten state, the center of the molten pool should be in line with the unmelted upper edge of the joint This procedure permits a greater amount of the base metal to be melted into the molten pool, thus requiring less filler rod and assuring adequate fusion into the upper sheet. To prevent possible undercutting at the upper edge of the joint and overlapping on the lower plate, you should add the filler rod to the upper edge of the molten pool. You can determine the speed of travel by the size of the molten pool at the joint edges. Figure 2-16 shows dimensions, weld metal form, and penetration. You can use the following weld characteristics to determine incorrect techniques in making lap welds:

a. A concave weld face means that too large a welding tip was used and not enough filler rod was added to the weld. Excess penetration and undercutting at the toes of the weld are the results.

b. A weld face that is excessively convex is caused by the use of insufficient welding heat and the addition of an excessive amount of filler rod. Overlap and lack of penetration result.

c. Undercutting and overlapping occur when the flame is directed improperly. Undercutting occurs on the overheat edge, and overlapping occurs on the insufficiently heated edge. This same condition can

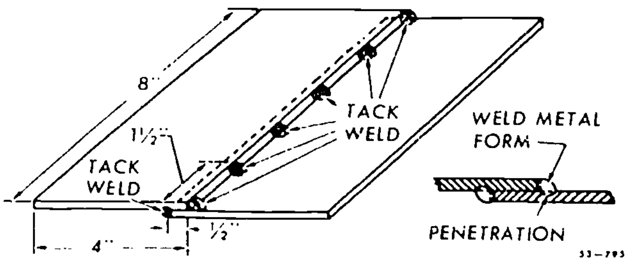


Figure 2-16. Lap joint setup.

result from the improper addition of filler rod into the molten pool.

d. Narrow and wide welds are caused by improper welding travel along the joint edges. If the welding speed is too fast, the weld will be narrow. If the welding speed too slow, the molten pool will increase in size and the weld will be wide. Slow travel usually causes excessive penetration, and rapid travel causes inadequate penetration.

Exercises (816):

1. When you are welding lap joints of ½ inch thick metal what is the penetration range in inches?

2. The shape of the face of a lap weld should be __________

3. What are the specifications for the legs of a single-fillet lap joint?

4. The distance from the point where the fusion ceases to the original surface of the base metal is known as __________.

817. State how to set up and weld butt joints.

You can use a butt joint to join the edges of two pieces of metal when their surfaces are in approximately the same plane. A properly made butt joint develops the full strength of the base metal, and it is satisfactory for all types of loads. Regardless of the metal's thickness, penetration through the base metal must be 100 percent, and fusion into the side walls must be at least 1/16 inch. To be able to weld butt joints, you must know the sections of a welded joint, illustrated in figure 2-17. For maximum strength, definite specifications for reinforcement, penetration, and shape of face have been established. Proper fusion and a uniform bead are necessary, as indicated in figure 2-18.

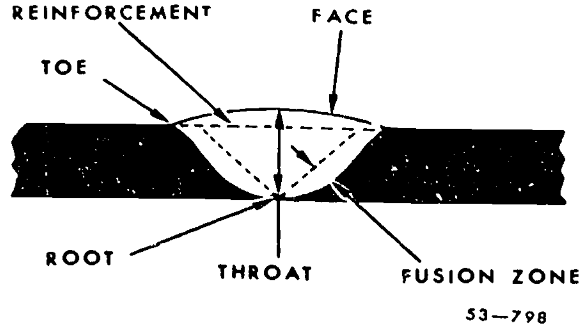


Figure 2-17. Butt joint nomenclature.

Joint Preparation. You can weld plain butt joints on metal up to 1/8 inch thick without any special edge preparation, such as the beveling of heavier gage metals. Several types of edge preparations for butt joints on heavy gage metals are shown in figure 2-19. You can prepare these edges by flame cutting, shearing, machining, chipping, or grinding. Plate thicknesses of 3/8 to 1/2 inch can be welded, using the single V-joint or single U-joint type, as shown in detail A and detail C of figure 2-19. For welding heavy sections, the single U-groove is more satisfactory and requires less filler metal than the single V-groove. The double V-groove joint requires approximately one-half the amount of filler metal used to produce the single V-groove joints for the same plate thickness. In general, butt joints prepared on both sides of heavy sections permit easier welding, produce less distortion, and insure better weld metal qualities than joints prepared on one side only.

Rigid butt joint. Figure 2-20 shows the proper setup for welding a rigid butt joint in the flat position. Place the joint edges in the same plane and support them with a material, like firebrick, that will not radiate the heat away from the plate you are welding. Tack weld rigid butt joints before welding to prevent the edges from being draw together, making penetration impossible. The importance of making tack welds cannot be overemphasized. The proper spacing, size, and penetration of tack welds help to make satisfactory welds. Figure 2-20 shows the desired dimensions. The torch should be approximately perpendicular to the joint edges. Make certain that you melt the base metal before adding filler rod. Unless the penetration is 100

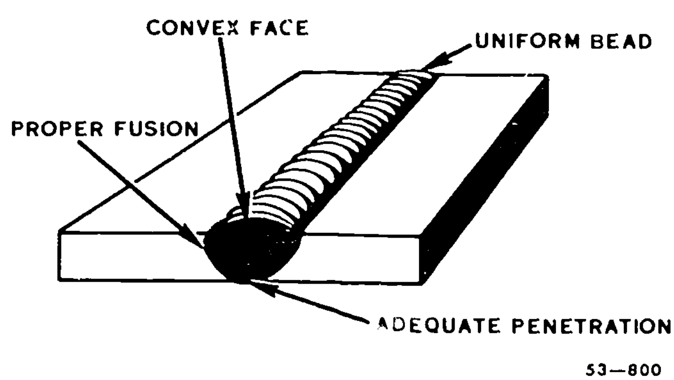
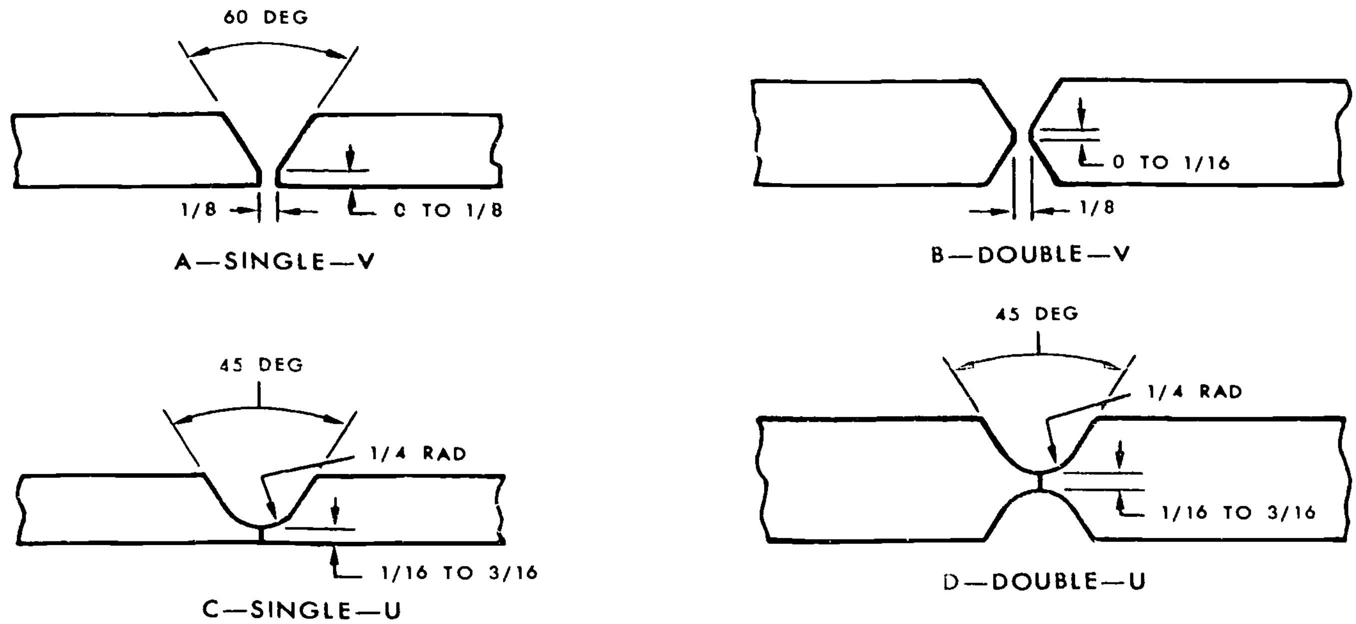


Figure 2-18. Characteristics of a good butt weld.



NOTE: ALL DIMENSIONS SHOWN ARE IN INCHES

53—788

Figure 2-19. Heavy section-butt joint preparation.

percent on the tack welds, it is impossible to obtain the required penetration when you weld along the seam over the tack welds. Make the tack welds every 1½ inch along the entire seam of the weld. After tack welding, the spacing of the joint edges should be equal to the metal thickness for metals up to 1/8 inch.

Open butt joint. When you weld open butt joints, do not tack the edges rigid before welding. This allows the edges to draw together as the weld progresses along the joint. To prevent the joint from closing up entirely, space one end of the joint an added amount equal to the calculated shrinkage of the weld, as shown in figure 2-21. For carbon steels, this space is 1/4 inch per foot of seam length plus the base metal thickness.

Welding Techniques. To make a good weld, you must:

a. Use the correct torch tip size.
b. Use the correct welding rod.
c. Adjust the flame properly.
d. Manipulate the torch and the rod properly.

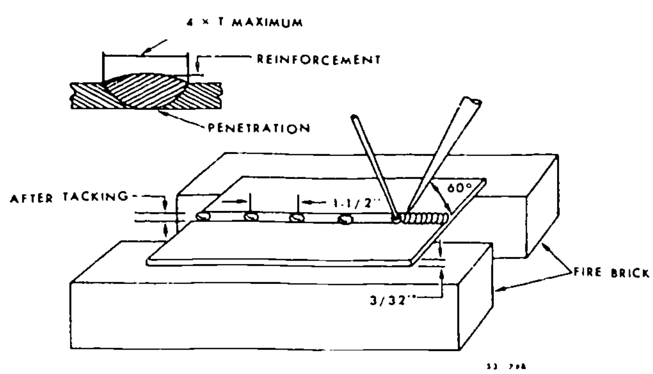


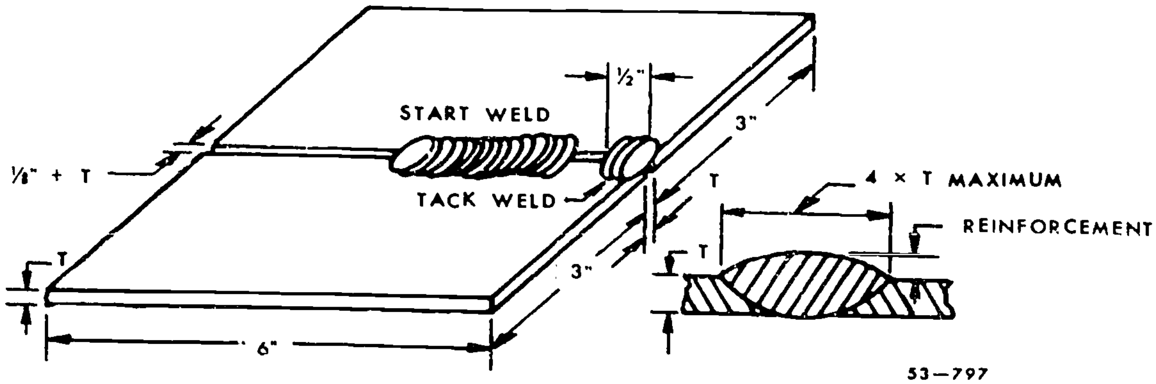
Figure 2-20. Setup for rigid butt joint.

Adjust the torch to produce a neutral flame. You need the correct torch tip size and the correct oxygen and acetylene regulator pressures to obtain the proper volume of heat for given metal thickness. The welding tip should form an angle approximately 60° with the plate surface. Always point the flame in the direction of the welding. Add the filler rod to the molten pool at an angle of about 45°. Control the motion of the flame to melt or break down the side walls of the sheets at the joint, as well as to melt enough of the welding rod to produce a pool of molten metaal of the desire size.

Rigid butt joint. Figure 2-22 illustrates the technique for welding rigid edge butt joints. Melt the edges of the metal to the bottom of the joint, causing the molten metal to form in the shape of a horseshoe. Add the filler rod to the molten pool behind the horseshoe opening. As you do this, molten metal bridges across the edges. Then use the force and ahead of the flame to reestablish the horseshoe opening. Repeat this procedure each time filler rod is added. By maintaining the horseshoe opening, you assure penetration to the bottom edges.

Open butt joint. The technique of welding open butt joints is the same as for welding rigid butt joints. Tack weld the joint edges approximately 1/2 inch from the edges of the sheet, as shown in figure 2-21. Start the weld without delay about 1/2 inch from the tack weld. As the weld progresses along the joint edges, the spacing you allowed before welding will gradually close to a space equal to the base metal. This spacing is necessary in order for penetration to be easily achieved. After completing this part of the weld, return to the other end and finish the weld backhand.

Weld Specifications. All types of welds have specifications that must be met. The butt joint is no exception. The specifications for the butt joint are as follows:



53—797

Figure 2-21. Setup for open butt joint.

- Penetration: 100 percent.
- Bead: Slightly convex and uniform.
- Toes: Properly fused.
- Bead width: 2 to 4 X T (thickness.)
- Reinforcement: 25 percent of T.

Exercises (817):

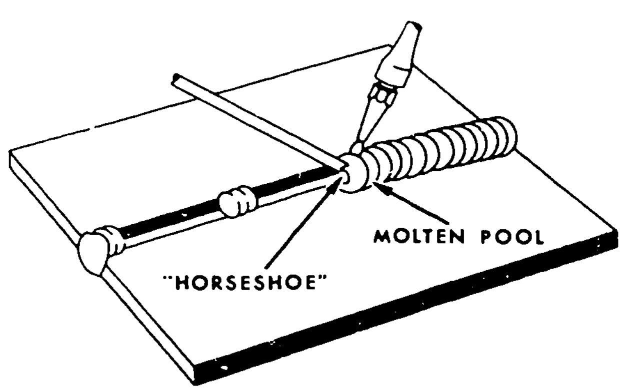
1. Give the two types of butt joints.

2. What is the correct interval for tack welds on a butt joint?

3. How are the edges prepared for a butt joint on ⅛-inch metal?

4. When welding rigid butt joints, in what shape do you want the molten metal to form?

5. Give the four rules for producing a sound weld.



53—799

Figure 2-22. Butt joint welding technique.

6. How much penetration is needed in each type of butt joint?

818. Cite procedures for setting up and welding tee joints.

Tee Joint. A tee joint is welded when the edge of one plate is approximately perpendicular to the surface of another. The weld is called a fillet weld because it approximates a triangular cross section. The sections of a tee joint are named in figure 2-23. The terms used to identify the sections of this weld are the same as for other types of welds.

Weld specifications. Figure 2-24 shows the specifications for welding the tee joint. When welds are made on metals of equal thickness, the upper leg and lower leg should be 1½ T. The specifications for metals of unequal thickness are based upon the thickness of the lighter gage sheet. Penetration of metals of unequal thickness are based upon the thickness of the lighter gage sheet. Penetration of metals ⅛ inch or less should be 30 to 50 percent of the metal thickness. For heavier gage, the minimum penetration is 1/16 inch. The throat thickness should equal the thickness of the base metal.

Joint preparation and setup. The tee joint (fig. 2-25) used on metal ⅛inch thick or less requires no special preparation other than cleaning the edge of the vertical sheet and the surface of the horizontal sheet. Welds on

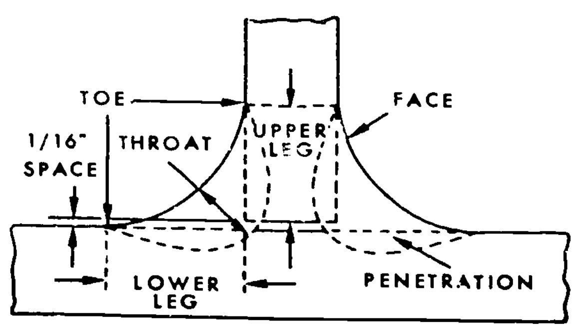


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Figure 2-23. Tee joint nomenclature.

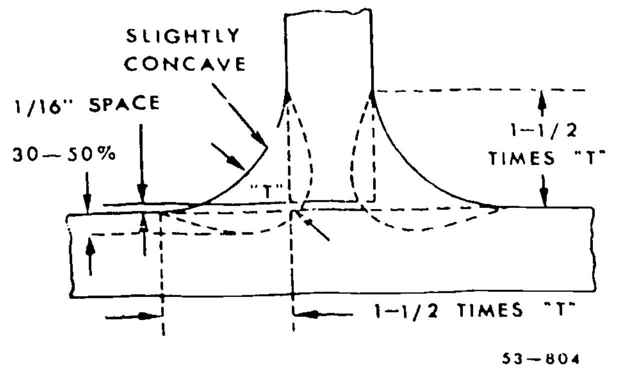


Figure 2-24. Tee joint specifications.

metals 1/8 inch up to 1/2 inch in thickness require beveling if the joint can be welded from one side only. Use the double-V 45° bevel on heavy plate if the joint can be welded from both sides.

Space the vertical sheet approximately 1/32 to 1/16 inch above the horizontal sheet. You cannot use the welding heat to the greatest advantage unless the edges and the surface are spaced to permit easy fusion without excessive heating The spacing should be uniform along the joint to obtain uniform penetration and fusion. When you weld the joint from both sides of the vertical sheet, tack weld alternately from on side to the other to maintain the alignment of the vertical sheet.

Welding Techniques. Before welding, you should preheat joint to raise the temperature of the metal to a point that will permit fusion into the root of the joint. Hold the torch about 60° from horizontal, thus directing most of the heat on the horizontal sheet of the tee joint. Adjust the torch to a neutral flame and point it in the direction of travel. When the base metal is heated to the molten state, the molten pool should extend equally upon the vertical and horizontal sheets. This technique will produce a weld with the upper and lower legs equal in length. To prevent undercutting at the upper edge of the weld and overlapping on the lower plate, as illustrated in figure 2-26, the angle of the torch must be correct and the filler rod should be added to the upper edge of the molten pool.

Exercises (818):

1. What should the legs measure on a tee joint of ½-inch thick metal?

2. Why is the vertical sheet spaced above the horizontal sheet?

3. When you are welding tee joint, where do you add the filler rod?

4. What is the torch angle when welding tee joints?

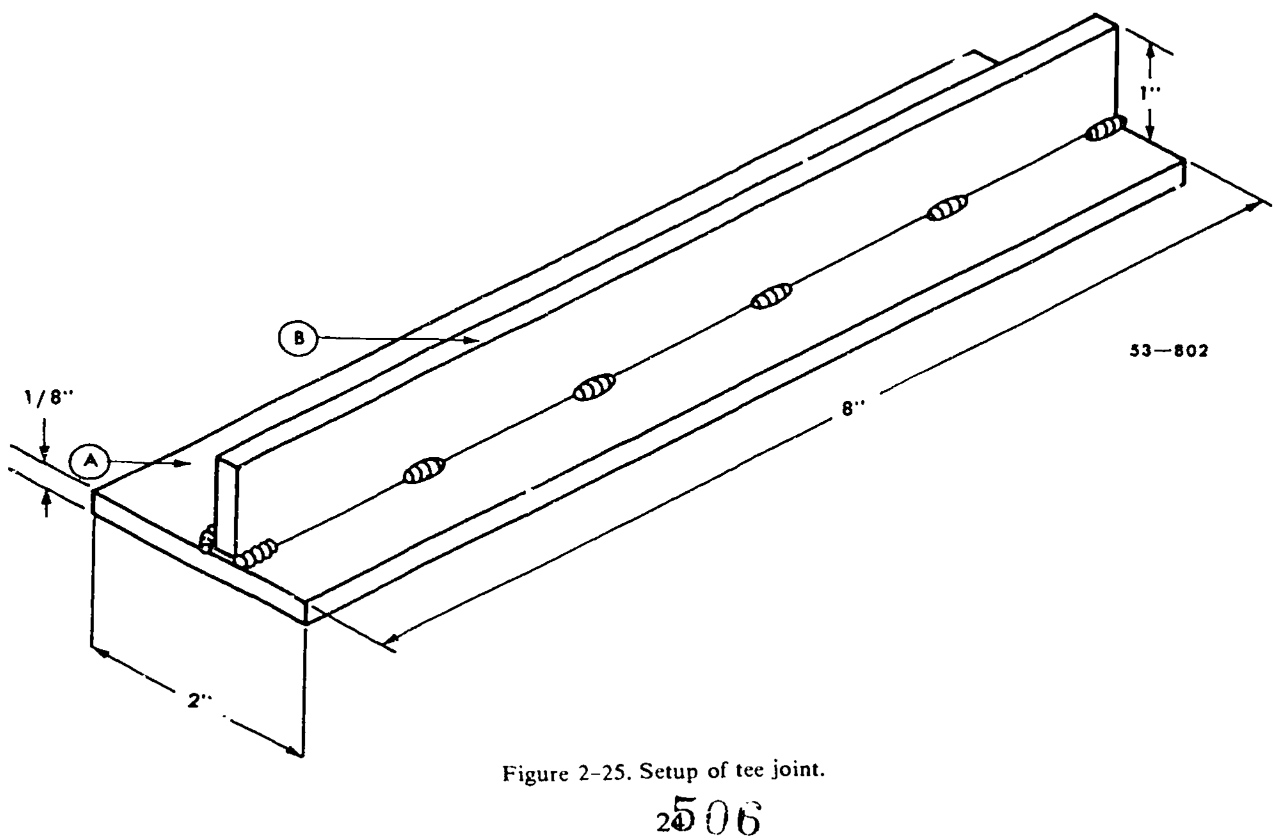
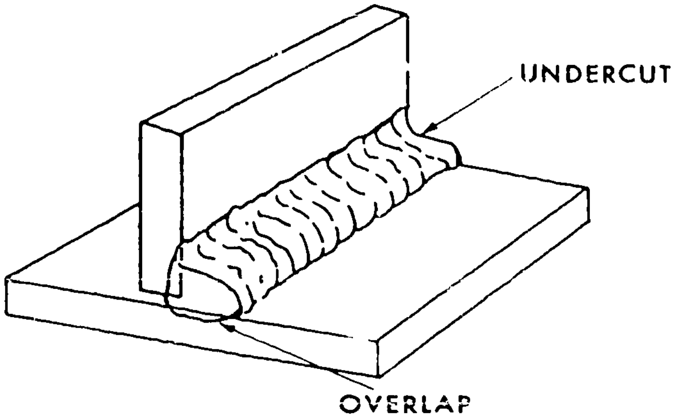


Figure 2-25. Setup of tee joint.



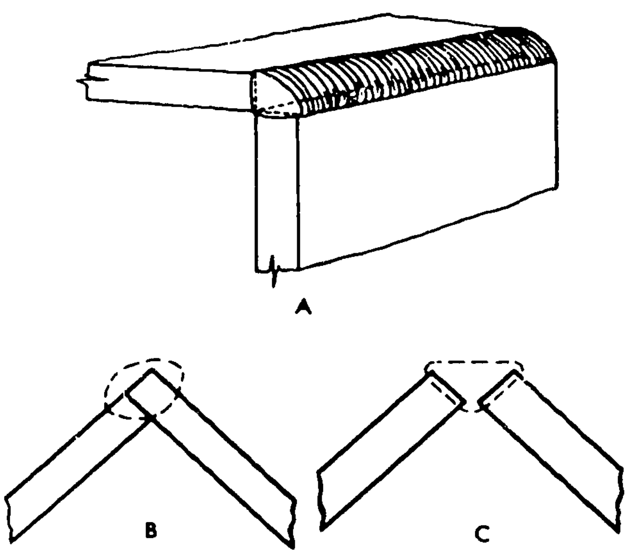
53—805

Figure 2-26. Overlap and undercut.

819. Name the uses of corner joints and edge joints.

Corner Joint. The fillet weld corner joint, figure 2-27, detail A, is used in the construction of boxes, box frames, tanks, and similar fabrications. The closed-type joint, figure 2-27, detail B, is used on lighter sheets where high strength at the joint is not needed. When the sed-type joint is used on heavy sections, the lapped plate is V-beveled or V-grooved to permit penetration to the root of the joint. The open-type corner joint, figure 2-27, detail C, is used on heavier sheet and plate.

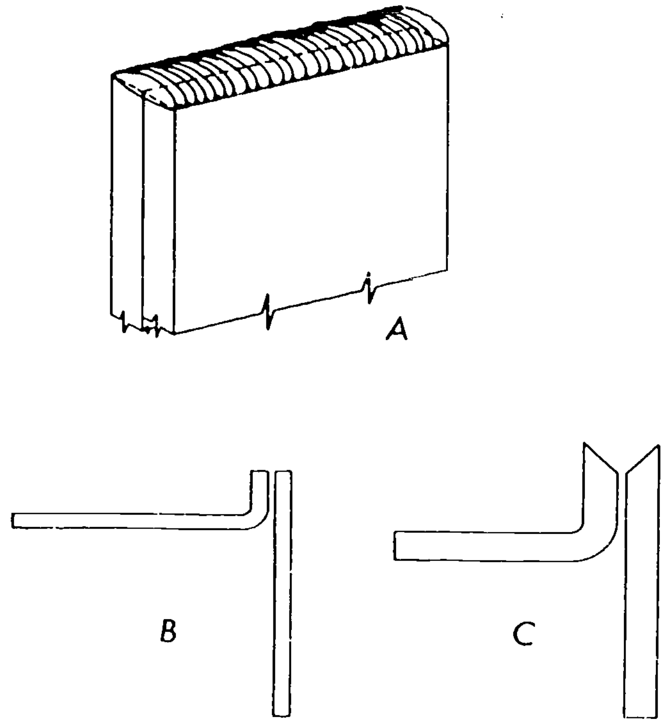
Edge Joint. This type of joint is not very strong and is used mainly to join the edges of sheet metal and to weld reinforcing plates in the flanges of I-beams or the edges of angles. Two parallel plates are joined together, as show in figure 2-28, detail A, by an edge-joint weld.



53—806

A. Fillet weld joint
B. Closed-type joint.
C. Open-type joint

Figure 2-27. Corner joints.



53—807

A. Parallel plate joint
B. Light sheet joint
C. Heavy plate joint

Figure 2-28. Edge joint.

On heavy plate, sufficient filler metal is added to fuse or melt each plate edge completely and to reinforce the joint. Two other common types of edge joints are shown in figure 2-28. Light sheets are welded by the joint type, shown in figure detail 2-28, detail B. No special preparation is necessary other than to clean the edges and tack weld them in position, and no filler metal is required. The edges are simply fused together. The joint shown in figure 2-28, detail C, is used for welding heavy plates, and the edges must be beveled to secure good penetration and fusion of the side walls. Filler metal is used on this joint.

Exercises (819):

1. What are edge joints used for?

2. What are fillet weld corner joints used for?

2-6. Types of Heat- and Corrosion-Resistant Ferrous Alloys

"Heat- and corrosion-resistant ferrous alloy" is the correct name for any of the alloy metals that are heat and corrosion resistant. Some of these alloys are

known by the trade name of stainless steels, so during our discussion we will refer to them as such.

Stainless steels are available for a variety of uses. Some are used for decorative purposes when corrosion resistance is required. Some are used when high temperature oxidation resistance is necessary. Some are used for cutlery and airhardened dies. The precipitation-hardened stainless steels have been useful in the construction of high-speed aircraft aircraft engines, and missiles.

820. Given its AISI number, identify the type of stainless steel as stabilized or unstabilized, and state some of the uses of stainless steel.

Stainless Steels. All stainless steels are identified by an AISI (American Iron and Steel Institute) number, which is composed of three digits, and, in some cases, an alphabetical suffix. These stainless steels, because of their chemical composition, may be divided into four families: austenitic, precipitation-hardening, ferritic, and martensitic. We will concern ourselves only with the austenitic family.

The austenitic stainless steel family is divided into three groups: (1) the normal unstabilized group, (2) the stabilized group, and (3) the extra low-carbon group. Their classification is determined directly by their chemical composition.

Unstabilized group. The unstabilized austenitic stainless steels include the 200 series and some of the 300 series. The 200 series contains the grades 201 and 202 and is different from the 300 series in that a portion of its nickel content is replaced by manganese and nitrogen. The chemical composition breakdown is as follows for grade 201:

Carbon	0.15%
Chromium	16.00% to 18.00%
Nickel	3.50% to 5.50%
Manganese	5.50% to 7.50%
Nitrogen	0.25% maximum
Iron	Approx 70% (base)

Also slight amounts of silicon, sulphur, and phosphorus.

The unstabilized 300 series contains 301, 302 (original 18-8), 303, 304, 305, 308, 309, 310, 314, 316, and 317. The main alloying elements of these iron-base alloys are chromium (Cr) and nickel (Ni), and they are sometimes referred to as 18-8 stainless steels. (The 18-8 means 18 percent Cr and 8 percent Ni.) Using as an example grade 302, the true 18-8 composition, the chemical composition breakdown is as follows:

Carbon	0.08% to 0.25%
Chromium	17.00% to 19.00%
Nickel	8.00% to 10.00%
Iron	Approx 70% (base)

Also slight amounts of manganese, silicon, phosphorous and sulphur.

Other unstabilized grades are similar in composition, with the main difference in the chromium and nickel content Some grades contain up to 26 percent chromium and 22 percent nickel.

Stabilized group. The stabilized austenitic stainless steels are in the 300 (18-8) series (chromium-nickel). These steels, 321, 347, 348, 309E, and 318, contain control amounts of titanium or columbium-plus-titanium, which acts as a stabilizer. Their chemical composition is similar to the other 300 series with the exception of the added stabilizer elements. The chemical composition breakdown for grade 321 is as follows:

Carbon	0.08%
Chromium	17.00% to 20.00%
Nickel	8.00% to 13.00%
Titanium	5 times the carbon content minimum (stabilizer)
Iron	Approx 70% (base)

Also slight amounts of silicon, sulphur, manganese, phosphorus.

The main difference in chemical composition of the remaining stabilized grades is the alloying element used as the stabilizer. The other stabilized grades contain columbian with tantalum in an amount 10 times the carbon content as minimum.

Extra-low-carbon group. The extra-low-carbon group of austenitic stainless steel completes the 300 series—and includes 304L 316L, and 317L—with the "L" suffix denoting low-carbon content. Each chemical composition is similar to its corresponding unstabilized grade, and the main exception is a very low carbon content. The chemical composition breakdown for grade 304L is:

Carbon	.08% maximum
Chromium	18% to 20.00%
Nickel	8.00% to 12.00%
Iron	Approx 70% (base)

Also slight amounts of manganese, silicon, suphur, and phosphurus.

The other extra-low carbon grades are similar in chemical composition, except that they contain 2.00 percent to 3.25 percent molybdenum.

Uses. The 18-8 series of stainless steels is the most widely used series for aircraft parts. Two types, the stabilized 321 and 347, are frequently found in the shop for aircraft applications. In type 321, the stabilizer is titanium; in type 347, it is columbium with tantalum. These elements help to prevent carbide precipitation during the cooling period from high temperatures. These steels are used for aircraft exhaust manifolds and expansion joints.

Unstabilized types of stainless steel, such as 316 and 317, have a higher corrosion resistance than other stainless. This is especially true when the metal is in contact with salt water. Where strength is very important, these steels can be serviceable up to 1500° F. They are used for chemical processing and die-making equipment.

Exercises (820):

1. Identify each of the following stainless steels as stabilized(s) or unstabilized(u):

a. 202	*d.* 309E	*g.* 347
b. 308	*e.* 314	*h.* 321
c. 310	*f.* 318	*i.* 201

2. Give the uses of stabilized 18-8 series stainless steel.

3. The stainless steels used for chemical processing equipment are in which group?

821. Identify factors that affect the weldability of stainless steel.

Weldability. A thorough understanding of the mechanical properties peculiar to stainless steels and the effect of heat upon these properties will help you in handling, fabricating, and welding stainless steel.

There are three main factors that affect the weldability of stainless steel. They are carbide precipitation, warpage and oxidation.

Carbide precipitation. When 18-8 stainless steel is heated to a temperature range of 800° F. to 1500° F., carbides precipitate at the boundaries of the crystalline grains. The carbon separates out of solution and unites with chromium to form chromium carbides. This action is "carbide precipitation."

Carbide precipitation decreases the corrosion resistance of the metal, but it has very little effect upon its tensile strength under normal conditions. However, when the metal is subjected to extremely corrosive conditions, the tensile strength of the material is greatly reduced.

When you weld stainless steels, the speed of carbide precipitation varies with the following factors:

a. The length of time the metal is held within the carbide precipitation range (800° F. to 1500° F.).

b. The nearer the actual temperature is to 1,200° F., the more harmful the precipitation becomes.

c. The less carbon present in the metal, the less susceptible the metal is to carbide precipitation.

To restore the metal to its maximum corrosion resistance reheat it to a temperature of 1,900° F. to 2,000° F. At this temperature, the carbide separates and the chromium and carbon return to their original state in the alloy. Hold this temperature long enough for this action to take place; then cool the metal to a black (0 to 1,000° F.) heat within 2 minutes. Cooling rapidly through the carbon precipitation range reduces the forming of carbides after they are redissolved. This procedure also relieves stresses and produces maximum softness in the metal.

When titanium or columbium is alloyed with stainless steel, as in types 321 and 347, the danger of carbide precipitation is eliminated. Since these stabilized types can be held within the carbide precipitation range without harmful effect, you do not need to heat-treat them to restore their corrosion resistance. These two types can be given the same heat treatment for stress relieving and annealing that is given to the rest of the 18-8 series stainless steels.

Warpage. Since stainless steels have a high coefficient (rate of measurement) of expansion and a low heat conductivity excessive warping and buckling will result unless you take preventive measures. If you have a large amount of light gage metal to weld, use a jig to hold it. The use of a proper holding device confines the strain to the small area of soft plastic weld metal and reduces warpage. If you do not use a jig, the proper tack welding procedure helps to control the warpage. When warping has occurred, you can remove it partially by peening the weld. This expands the weld metal and partially relieves the stresses that caused the warpage.

Oxidiation. Stainless steels oxidize very readily if they are heated with a flame containing too much oxygen. Since oxides prevent good fusion between the weld metal an the base metal, you must adjust the welding flame carefull A strictly neutral flame is most desirable, but it is difficult to maintain and can change to an oxidizing flame without notice. For this reason, you should use a slightly carburizing flame, in most cases, for welding stainless steels. The feather or brushlike second cone, indicating an excess of acetylene, should not extend more than 1/16 inch beyond the tip of the inner cone. If the flame contains more acetylene than is needed, the hot metal will take up free carbon and produce a brittle weld. An increase in carbon content also reduces the corrosion of the metal.

You must protect corrosion-resistant steel from the air during welding to prevent the oxygen and nitrogen in the atmosphere from combining with the hot metal. The flux used for oxyacetylene welding is available in powdered form. Mix it in accordance with the instructions on the container, or mix it with technical grade methanol (wood alcohol) to make a thin paste. Flux the underside of the joint liberally to protect it from the atmosphere and flux the welding rod lightly. Flux the top surface of the joint sparingly and only when the under surface is inaccessible. Do not, under any circumstances, use excessive flux on the top surface. The flux, when it dries, protects the metal that cannot be covered with the flame.

Exercises (821):

1. Name the factors that affect the weldability of stainless steel.

2. Because of carbide precipitation, for what types of stainless steels is the oxyacetylene process preferable?

3. Why does stainless steel warp when it is welded?

4. How do you prevent oxidation when you are oxyacetylene welding stainless steel?

2-7. Types of Joints

The joints used for stainless steels are the same as those for carbon steel. The weld specifications and nomenclature are the same. However, because of the difficulties encount in welding stainless steels (oxidation, carbide precipitation and warping), different welding procedures are required. In our next three objectives, we will describe the most common types of stainless steel joints; the lap, butt, and tee—joints.

822. Give the reasons for specific procedures in setting up and welding lap joints of stainless steel.

Lap Joints. Welding a lap joint in stainless steel is usually the easiest of the three processes. Lap joints are frequently used to repair aircraft manifolds if the additional thickness of a lap joint is permitted. They require less accurate fitup in repairing holes and worn surfaces. Since the penetration for lap joints does not extend to the bottom of the joint, the possibility of oxidation is greatly reduced. If the design of the part does not permit welding from both sides, the joint may be welded from one side only. For some applications, such as the repair of weldable jet or conventional aircraft parts, a patch forming a lap joint is applied to repair a hole or worn section. Freedom from pinholes, resistance to corrosion, and the strength to withstand expansion and contraction stresses are the main requirements for welds on these parts.

Joint preparation. Remove oxides, grease, and oil, as in welding other metals, to keep them out of the weld. The joint edges need no special preparation other than the removal of burrs. The burrs must be removed to permit a close fitup.

Setup and tack welding. For setup and tack welding, fit the edge of the lap sheet closely to the surface of the other sheet. Spacing causes the edge of the lap sheet to heat more rapidly, making welding more difficult. To prevent the edges from separating during welding, the tack welds must be rigid and spaced closely along the entire joint, insuring a close fitup after tacking. Proper tack welding reduces warping because of the high coefficient of expansion in the stainless steel. Figure 2-29 illustrates a properly tack-welded lap joint with the dimensions and spacing. Space the tack welds no more than 1 inch apart for best results. They must be rigid, yet small, to permit easy fusion with the weld.

Welding technique. Flux is not needed to prevent the molten metal from oxidizing at the bottom of the joint, but some oxidation can occur directly below the line of fusion. To prevent this, place a coating of flux directly beneath the line of weld on the underside of the sheet. Preheat the joint for several inches by directing the flame above and below the joint, raising the metal to

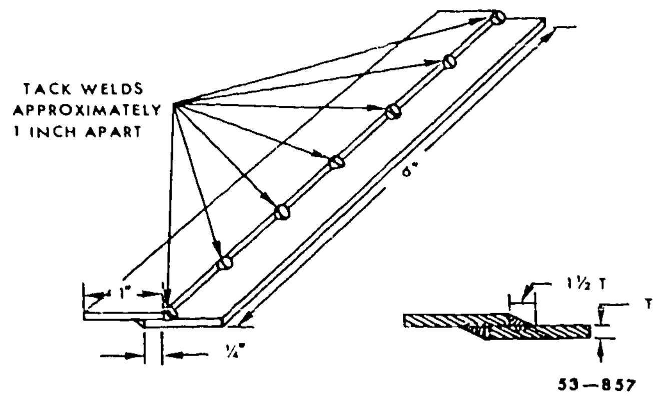


Figure 2-29. Welding lap joints.

welding temperature at the root of the joint. Direct the flame mainly upon the bottom sheet and point it in the direction of travel. Use the forehand method. When the edges reach the molten state, the center of the molten pool should be in line with the unmelted edge of the joint. This permits the base metal to melt into the molten pool, requiring less filler rod and assuring adequate penetration into the root of the joint and the edge of the sheet.

Hold the filler rod at the forward edge of the molten pool and let it melt simultaneously with the base metal. Keep the filler rod within the outer flame envelope so that it will not oxidize and transmit the oxidation to the weld. Complete the weld without interruption. If you must stop the weld for any reason, withdraw the flame slowly to prevent the oxidation of the melting metal.

Exercises (822):

1. Why is the chance of oxidation reduced in welding a lap joint?

2. What method of welding should you use in welding lap joints of stainless steel?

3. Why should you remove burrs before welding lap joints?

4. Why should you keep the filler rod in the outer flame envelope?

823. Specify procedures used to set up and weld butt joints of stainless steel.

Butt Joints. You can use square-edge butt joints on metal thicknesses up to ⅛ inch. You must bevel the edges when you weld metal of greater thickness.

5-10

Joint preparation. As usual, remove all scale, oxides, grease, and oil from the surface to keep from including them in the weld. When you weld stainless steel, the closer the characteristics of the deposited metal approximate those of the metal you are welding, the better the corrosion resistance of the welded joint.

In preparing open-butt joints on stainless steels, space the joint edges to permit fusion to the bottom of the joint. Proper spacing keeps the open end of the joint from closing; otherwise, excessive buckling will occur and penetration will be impossible. Since the coefficient of expansion in stainless steels is greater than that in carbon steels, a greater allowance per foot of seam length is needed. Space the open end of the joint ⅜ inch per foot of seam length.

Setup and tack welding. The proper spacing, size, and penetration of the tack welds help maintain the alignment of the joint and reduce the possibility of excessive warping. The spacing between the edges of the sheet should equal the metal thickness after tacking. Because of the high coefficient of expansion, make tack welds that completely penetrate the base metal and that are spaced approximately 1 inch apart along the entire joint. Figure 2-30 shows the proper setup for welding a rigid butt joint on stainless steel. Note the degree and dimension indications.

After applying flux to the bottom edges of the joint, place the edges of the joint in the same plane. Heat the metal to the molten state with the torch. Then add the filler rod to the melting edges to form the tack weld. To avoid oxidation which can result from removing the flame quickly from the molten metal, direct the outer flame envelope over the tack weld and slowly withdraw it until the weld solidifies. Tack welds must be rigid, with full penetration, yet small enough to permit easy fusion of the metal. Reflux the bottom edges of the joint after tack welding to replace the flux removed by the flame in the area of the tacks.

Welding techniques. To produce the best results in welding stainless steel, complete the weld as rapidly as possible with a minimum of heat. Excessive and prolonged heating produces greater carbide precipitation and increases distortion and buckling. The torch tip should be one or two sizes smaller than the tip used for carbon steels of an equal thickness because of the low heat conductivity of stainless steel.

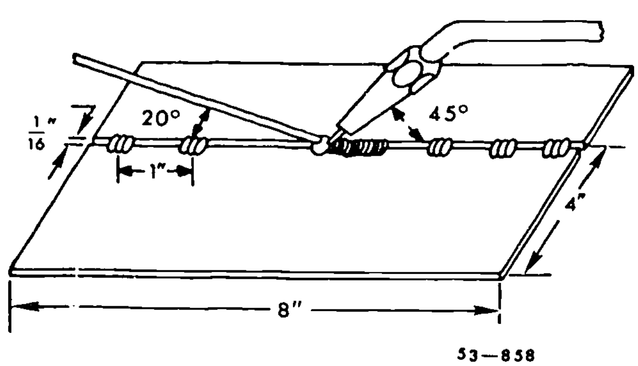


Figure 2-30. Welding butt joints.

Adjust the flame to slightly carburizing a direct it at an angle of 45° in the direction of travel. Add the filler rod to the molten pool at an angle of approximately 20° with the surface of the sheet. Keep the end of the rod within the flame envelope and add the filler rod to the weld by letting it melt into the molten puddle. Stirring or puddling the hot metal with the rod is unnecessary and should be avoided The outer flame serves as a protective atmosphere over the molten pool, the surrounding metal, and the melting end of the filler rod. The weld should progress with a steady movement of the torch. Do not move the torch laterally, since this causes the heat to spread, increasing the tendency of the metal to buckle and warp. After starting the weld, continue until it is complete. If you stop for any reason, reflux the joint and preheat it to a dull red for several inches beyond the end of the existing weld before restarting. This will prevent oxidation. When you reach the end of the joint, remove the flame slowly. Removing it rapidly from the molten pool before the weld solidifies causes oxidation. This method of flame removal is usually referred to as "feathering off." After completing the weld, remove all scale, slag, and remaining flux with a wire brush.

Exercises (823):

1. If you must stop welding a butt joint of stainless steel before completing it, what must you do to prevent oxidation before starting again?

2. How do you prepare an open-butt joint of stainless steel?

3. How does the tip for welding stainless steel compare to the tip used for welding the same thickness of carbon steel?

4. How should you use the flame to prevent oxidation when you complete a butt weld of stainless steel?

824. State how to set up and weld tee joints of stainless steel.

Tee Joints. The tee joint is probably the hardest of the joints to weld in stainless steel because of the oxidation of the vertical piece. The correct volume of heat is of utmost importance. If the heat is excessive, the opposite side of the metal on the vertical piece will oxidize, making welding extremely difficult. You can minimize oxidation by applying flux on the back side of the weld. If the joint is to be welded on both sides, clean off the flux on the back side of the first weld thoroughly before you attempt to weld that side.

Joint preparation. Use the plain tee joint on metals up to ⅛inch thick. Metals of greater thickness require beveling. Clean the joint edges by removing oxides, grease, and oil. The joint edges need no special preparation other than cleaning and removing burrs.

Setup and tack welding. To space, position the vertical sheet approximately 1/32 inch above the horizontal sheet to permit easier fusion into the root of the joint without excessive heating. Figure 2-31 illustrates the proper spacing of tack welds and gives other dimensions. The tack welds must be rigid and small enough to permit the metal to fuse easily. Do not space the tack welds more than 1½ inches apart. If the joint is to be welded on both sides of the vertical sheet, make the tack welds alternately on both sides of the sheet. Tack welding in this way helps to maintain the alignment of the vertical sheet.

Welding technique. To assist in stopping the oxidation of the horizontal sheet, brush a thin film of flux on the bottom of the horizontal sheet, directly in line with thhe weld. To preheat, direct the flame above and below the joint until the root of the joint reaches the welding temperature. Adequate preheating prevents cracks from forming along the line of weld. Point the torch in the direction of travel and direct the flame mainly upon the base of the tee joint. When the base metal reaches the welding temperature, the molten pool should extend equally upon the vertical and horizontal sheets. This produces a weld with upper and lower legs of equal length.

Hold the filler rod at the forward edge of the molten pool and add it at the upper edge. This lets the molten metal flow into the pool and prevents undercutting the upper sheet and overlapping the lower sheet. The flame must constantly shield the melting metal to prevent oxidation. When you stop a weld or reach the end of a joint, feather off to prevent oxidation. Remove scale, slag, and remaining flux from the finished weld.

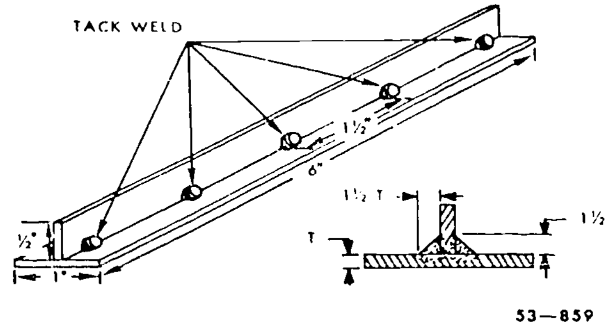


Figure 2-31. Welding Tee joints.

Exercises (824):

1. State the proper spacing of tack welds for stainless steel tee joints.

2. Describe the joint preparation for a tee joint of ¼-inch thick stainless steel.

3. Why should a tee joint be preheated?

4. How can you minimize oxidation when you are welding tee joints of stainless steel?

Welding and Brazing Castings

CAST IRON, an alloy of iron and carbon, is a product of the cupola furnace. The amount of carbon varies from .170 to 4.50 percent. In addition to a high percentage of carbon, this metal contains 90 to 94 percent of iron with varying proportions of manganese, phosphorus, sulfur, and silicon. The usual carbon content is 3 to 4 percent, of which only 1 percent combines with the metal to form iron carbide. The remaining carbon is free carbon. In this chapter we will discuss how three types of cast iron are produced and how their content affects their mechanical properties and weldability.

3-1. Oxyacetylene Welding of Ferrous Castings

To fully understand the precautions and limitations that are involved in oxyacetylene-welding ferrous castings, you must learn the properties and uses of cast iron and how to identify the various types of cast iron.

825. Identify properties and uses of the three types of cast iron.

Gray Cast Iron. If the iron is cooled slowly, the result is a soft, gray-colored metal called gray cast iron. It can be machined easily but cannot withstand heavy shock. It is malleable at any temperature. Gray cast iron is used for automobile cylinder blocks, machinery frames, pump bodies, wheels, gears, and pulleys, and for other applications in which weight, wear resistance and rigidity are required. Its tensile strength is low compared with that of steel, and it will fail under an excessive load or shock. Gray cast iron permits little or no bending but has a high compression strength. When gray cast iron breaks, the fractured surface is dark gray in color. This is the only cast iron that can be repaired satisfactorily by fusion welding.

White Cast Iron. If the iron is cooled rapidly from its molten state, the result is a very hard and brittle metal called white cast iron. This name was given to it because, when it is fractured, it has a silvery-white appearance. White cast iron is desirable where hardness is necessary and where good wear and abrasion resistance are needed. However, because of its hardness, white cast iron is often impossible to machine. The brittleness of the metal greatly reduces its strength, shock resistance, and similar mechanical properties. White cast iron can be fusion-welded but is more satisfactorily repaired by brazing. The fusion welding is done mainly at foundaries to reclaim defective white cast iron that is to be heat-treated for conversion into malleable iron.

Malleable Cast Iron. Malleable cast iron is produced by heating white cast iron to about 1,650° F., holding it at this temperature for several hours or days, and cooling it slowly. This heat treatment induces high strength, ductility, toughness, and shock resistance. Malleable cast iron can be bent slightly without breaking. Small tools, pipe fittings, and machine parts are made of malleable cast iron. The recommended method of oxyacetylene repair of malleable cast iron is brazing it with bronze, because fusion welding destroys its malleabilility. If its malleability is destroyed, a lengthy heat treatment process is needed to restore its original condition. The lower temperature of brazing makes it relatively simple to repair the casting without destroying its malleability.

Exercises (825):

1. The mechanical properties of gray cast iron that make it desirable for us as an automobile cylinder block are ________, ________, ________ and, ________

2. White cast iron is used where ________

3. All ferrous castings are identified as ________, ________ or ________

826. State the methods of identifying cast iron castings.

The two methods that are most commonly used to identify ferrous castings are the spark test and chip test. We will discuss these two tests before we describe welding ferrous castings.

Spark Test. Ferrous castings can be identified by the appearance of the spark stream that is generated when the metal touches a high-speed grinding wheel. The cast part should be touched lightly to the wheel. The spark streams of different metals vary in one or more of the following ways: color, density, shape, and length. You need considerable experience to identify castings by this method. But you can make a positive identification of an unknown metal by comparing its spark stream with that of a known metal.

Chip Test. The chip test is often used to distinguish one type of ferrous casting from another. Cut a narrow

chip from the part with a cold chisel. The ease with which the metal can be chipped and the form of the chip give some identification. The chips of gray cast iron break loose with each blow of the hammer and start to curl before they break off. The chip groove is smooth with a gray appearance. White cast iron is very hard and cannot be cut or chipped easily with a chisel. The chips are small and tend to crumble. The fractured surfaces of white cast iron are silvery-white. The chips from malleable cast iron are like those of steel on the outer surface; but, when this surface has been penetrated, the chips curl off more than those of gray cast iron. The fractured surfaces show a white, steely skin; the center of the casting appears gray like the color of cast iron.

Exercises (826):

1. How do you perform the spark test?

2. How can the chip test identify the type of casting?

3. To make a positive identification of a ferrous casting using the spark test, you must __________

4. Name the ways in which spark streams vary.

5. The chips from what type of casting will curl off?

827. State procedures for fusion-welding gray cast iron.

Welding Gray Cast Iron. Gray cast iron is the easiest of the ferrous castings to weld by the fusion method with the oxyacetylene flame. The weld, if made properly, has a fine grain structure, which is soft and easily machined. the weld is usually stronger than the base metal. When you weld this metal by the fusion method, you will find it difficult to keep the metal from forming hard spots. Another problem is to control its expansion and contraction. Each movement tends to distort the casting or to break it.

Preparation. To prepare a gray iron casting for weld repair, thoroughly clean the metal surrounding the break. Grind or sandblast the metal to remove rust and oxide. Remove the grease and oil with a solvent. If the cross section of the metal is more than 1/8 inch, bevel the edges to be welded. If you cannot remove the casting to bevel the break, you can chip it out with a flexible shaft or with a portable grinder, if either is available. When the casting is broken into several pieces, and has no machined surfaces that you can use to align the edges, leave two or three areas along the break unbeveled. You can use these areas to line up the broken sections.

The V-bevel should extend to within only 1/16 to 1/8 inch of the bottom of the break (fig. 3-1), depending upon the thickness of the metal. This shoulder keeps the metal from melting too rapidly at the bottom edge. Before welding a crack that extends in from the edge or that runs from an opening in a casting, always drill a small hole through the casting near the visible end of the fracture. If the crack starts to extend when heat is applied, the small hole will prevent its spreading.

Preheating. The method you should use to reduce expansion and contraction in the welding of castings depends upon the type and shape of the casting as well as the nature of the break. In some cases, the entire

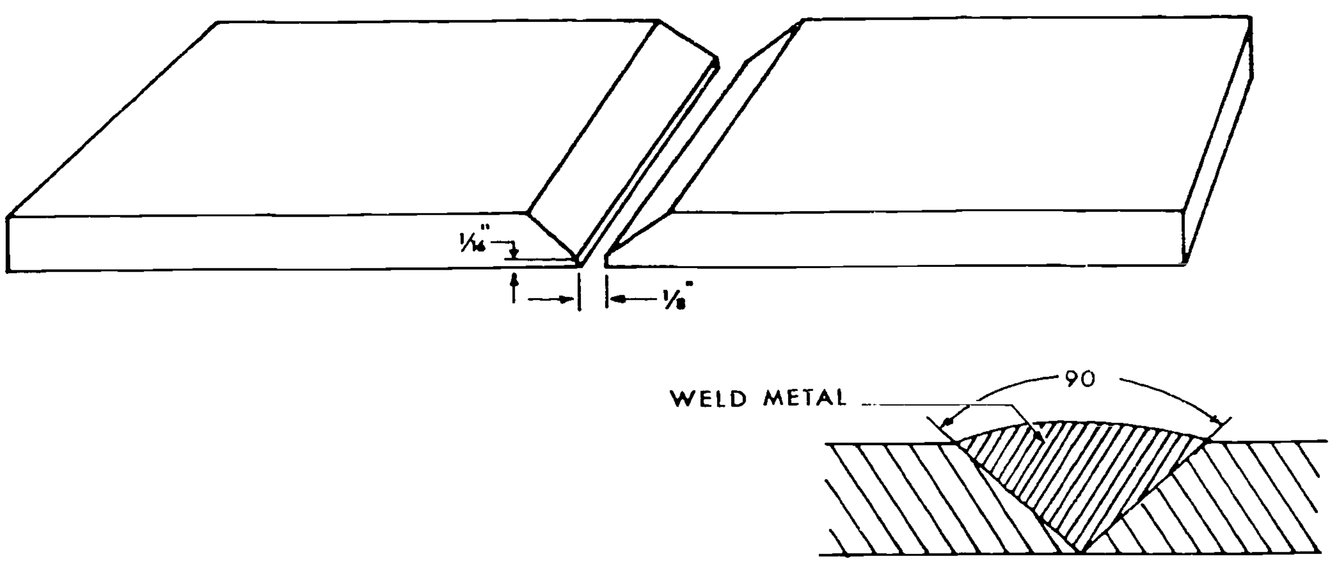


Figure 3-1. Cast iron butt joint.

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casting requires preheating to prevent serious expansion strains, while, in other cases, local preheating is sufficient. For large castings, such as cylinder heads and blocks, you usually must preheat the entire unit before you make a fusion weld. If only a boss or a lug is broken, local preheating is adequate. When the entire casting requires preheating, construct a temporary firebrick furnace in the desired size and heat with charcoal or a preheating torch.

When you are preheating with a flame of any kind, take care to prevent overheating at any one point. Place a baffle, such as firebricks, in front of the casting and direct the flame against it. This spreads the flame and produces an even temperature around the casting. The preheating temperature for gray cast iron is approximately 1,200° F. (medium cherry red). Shut off the preheating torch and protect the casting from drafts during the welding operation to keep if from cooling too fast. Cover the casting, leaving a section uncovered over the area to be welded. After welding, reheat the casting to the preheating temperature, then let it cool slowly in the furnace. When you preheat with charcoal, you do not need a double wall, but you do need more openings at the bottom to admit air to the fuel.

Flux. You must use flux for fusion-welding cast iron by the oxyacetylene process. Commercial flux is available in powder and paste form. Apply the flux either by dipping the hot end of the rod in the powder or by brushing the paste on the rod. When you fusion-weld the castings, keep the rod fluxed.

Weld application. To weld cast iron, use a tip slightly larger than the size you would ordinarily use to weld the same thickness of steel. With the larger size tip, there is less chance that you will blow the molten metal ahead into the cold surfaces of the joint. Be careful not to melt out the bottom of the vee too rapidly. After the lowest part of the joint is welded, the larger tip speeds the completion of the weld.

Adjust the torch to a neutral flame because this flame has practically no chemical effect upon the metal. Do not use too harsh a flame. Hold the tip of the central one ⅛ to ¼ inch from the molten pool. Use the forehand method to weld lig t sections and the backhand method to weld heavy sections. The backhand method helps to control the pool of molten metal and to obtain penetration. Use the flux to float the oxides and impurities to the surface of the weld. Heat the end of the filler rod in the outer flame envelope, dip it into the dry powder flux, and place at in the molten pool. A sufficient amount of flux will adhere to the rod for each application.

A cast iron filler rod, high in silicon and low in sulfur, phosphorus, and manganese, produces good results. The welding rod has several important functions. It supplies the metal needed to fill in the vee and reinforce the weld, it aids in removing impurities, and it is the means by hich flux is added to the weld. As you begin welding and are melting the bottom and sides of the vee, hold the end of the rod in the outer flame envelope. This prevents chilling the molten pool and causing hard spots in the weld Add the filler rod to the molten pool by melting it in the pool. The melted sides of the vee, which are thoroughly fused with the added filler rod, provide the necessary weld reinforcement.

To weld heavy sections, make successive short welds that start at the bottom of the vee, and build the weld to the proper height. Repeat this procedure until the weld is completed. Occasionally, some impurities are trapped in the pool and a blowhole appears as the metal solidifies. Remove these impurities as the weld progresses by melting beneath them and raking them out with the filler rod. Dispose of the impurities adhering to the welding rod by tapping the rod on the welding table. Figure 3-1 shows a buildup of metal and an angle for welding a cast iron butt joint.

Cooling. Following the fusion-welding operation, move the torch flame over the surface of the metal on both sides of the weld for a considerable distance to bring the sections of the base metal to an even heat. Cover small castings, or those preheated locally with a torch, with sand and allow them to cool slowly. If you use a preheating furnace, close all draft openings, cover the top and let the casting cool slowly. Protect the castings from drafts and cold air, which cause uneven cooling. Do not place any stress on a fused joint until it has completely cooled. Clean the finished deposit with a wire brush to remove excess flux and oxides that have risen to the surface.

Exercises (827):

1. Why must you preheat when you weld cast iron?

2. What should you do before welding cracks in a casting?

3. How is the tip size determined for fusion-welding gray cast iron?

4. To weld ½ inch thick cast iron, what welding method should be used?

5. The flux is applied to the weld joint for what reason?

3-2. Brazing Ferrous Metal

Brazing is a term of ancient origin. It comes from the word "brassing," the art of joining brass or copper parts by alloys. Today, brazing is a method of joining metals together without fusion by using a molten alloy with a melting point above 800° F. The melting point

of a brazing alloy must be below the melting point of the metals being joined.

828. Specify the characteristics of brazing.

Brazing Ferrous Metals. Since brazing requires less heat than fusion welding, it is faster. Since the base metal does not melt, the repair procedure is simple. It is much easier to make sound joints, even in intricate castings, by brazing. Because of the lower temperature, preheating is simple. The metal is preheated only to a black heat, and, as a result, expansion and contraction are much less than in fusion welding. The deposit and the adjacent metal are soft and form a physical bond. Most brazing operations can be done with only local preheating.

Bronzes yield readily as they cool until the temperature is below 500° F. They yield slowly under reasonably low stresses even at room temperatures. This yielding does not weaken the deposited bronze metal but materially reduces the locked up stresses in a brazed casting. The ductility of bronze acts further to take up minor stresses later when the part is used.

Most brazed joints are almost as strong as welded joints. They are even preferred for many joints in cast iron, nonferrous metals, tool steel, and malleable iron. Another advantage is that the heat r[illegible] make a joint is too low to alter the propertie[illegible] metals to be joined. This is a big advantage [illegible]n you are working with alloy steels and tool steels or with any other metal that has been heat-treated.

Brazing is a practical method of repairing malleable iron castings. Malleability, which is developed by a special, lengthy heat treatment, can be destroyed by the high temperature or fusion welding. The relatively low temperature used in brazing has little effect on malleability. You can use brazing to repair broken and cracked cylinder blocks, cylinder heads, and machine castings. Further applications of brazing are replacing worn surfaces, building new teeth in gears, and fabricating cast iron pipe.

Brazing has only one real disadvantage: color. The yellow color of the bronzes used to braze do not match the natural color of steel, cast iron, and some of the other metal for which brazing is practical.

Exercises (828):

1. How much preheating is required for most brazing operations?

2. What effect does brazing have upon malleability? Why?

3. In brazing cast iron, what type of bond is produced?

4. What effect does brazing have on the base metal?

829. Specify procedures for brazing steel and gray cast iron castings.

Brazing. Brazing steel or cast iron is different from fusion welding because a physical bond, rather than a chemical bond, is produced. Because it produces a physical bond, there are a few variations in joint preparation and weld application.

Joint preparation. To braze cast iron or steel with bronze, clean the metal in the area of the weld to remove all scale, rust, grease, and oil. Bevel the parts and grind off all sharp corners to produce round edges and a mooth surface. The joints in figure 3-2, showing the weld formation and base metal, develop the highest strength ecause the area of the bond between the bronze and the base metal is greater than you can obtain with the ordinary 90° V-bevel. You can make the V-bevel joint, shown in figure 3-2, detail A, by grinding. It will develop almost the full strength of the metal and should be used when high strength is required. You can also grind the U-joint, shown in figure 3-2, detail B, but n large castings, make the groove with a pneumatic chipping hammer. You may also use a portable grinder with a wheel shaped to produce the desired groove. You use this joint when you are brazing cracks in the water jackets of cylinder heads and blocks. After cleaning and beveling the edges, sandblast or sear the surfaces to remove the free carbon. To sear the edges, move an oxidizing flame along the surface of the joint with the central cone touching the metal. The free carbon combines with the excess oxygen in the flame, and a better bond results.

Flux. Flux is essential in brazing cast iron using the oxyacetylene process. Apply commercial flux, available in powder and paste form, either by dipping the hot end of the rod in the powder or brushing the paste on the rod. In brazing, flux should be used liberally in the tinning (coating) operation. In filling the vee, use the flux sparingly to avoid too much reduction of the oxide film covering the molten pool.

Flame. The flame should be slightly oxidizing to tin cast iron and large enough to raise the metal quickly to

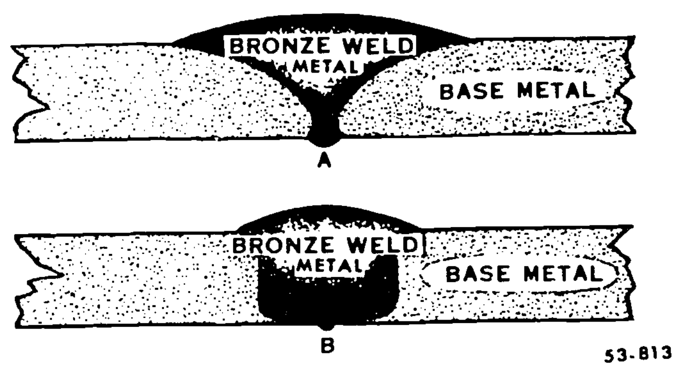

Figure 3-2. Brazed cast iron joints.

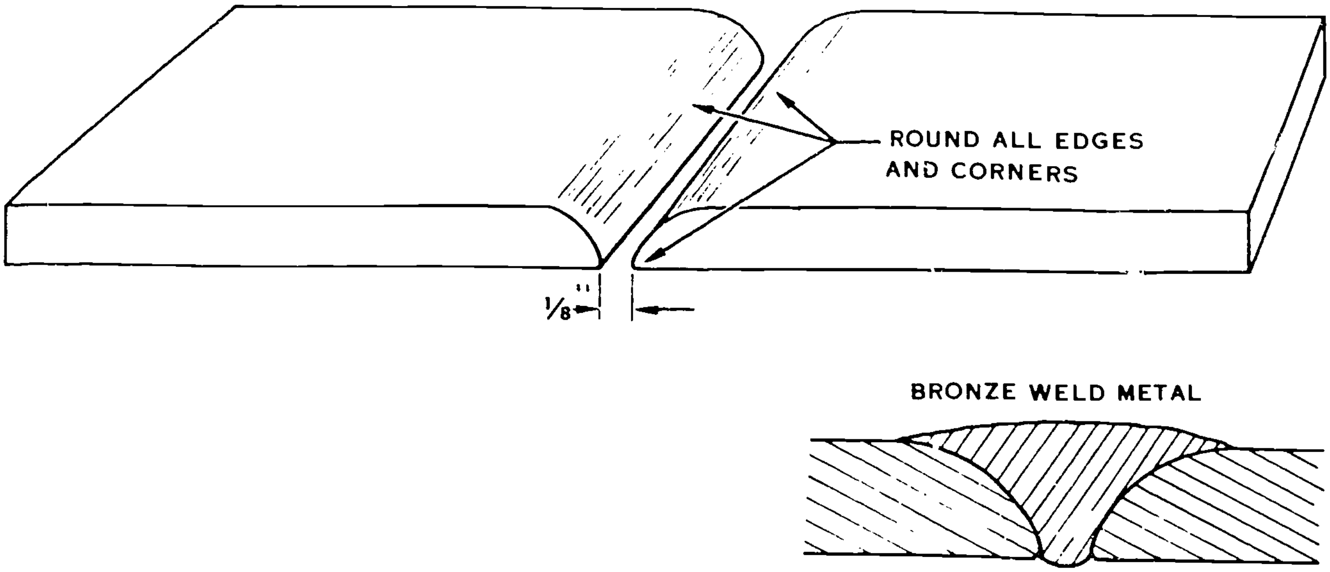

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Figure 3-3. Brazing cast iron.

a full red heat where the brazing is to start. The purpose of the oxidizing flame is to free the carbon that comes to the surface as the metal is heating to the brazing temperature. The free carbon combines with the excess oxygen in the flame and burns away, leaving the surface clean. After applying the tinning coat, adjust the flame to neutral. A neutral flame will prevent the oxidation of the material. However, if you are brazing with only one layer of bronze, the flame should carry an excess of oxygen. The torch tip should be about one size larger than the tip for fusion-welding steel of the same thickness.

Braze application. Figure 3-3 shows the beveling, the work setup, and the appearance of the finished brazed butt joint. Apply the flame slightly behind the point of rod application until the weld area attains a full red heat. When you apply the bronze, it should spread quickly and tin the heated area. Make a small molten pool at the bottom of the vee. Be sure that the tinning action takes place continuously just ahead of the molten pool. The proper brazing technique combines, into one continuous operation, the tinning action and the building up of the bronze to the desired size. To braze heavy material, it is frequently necessary to deposit the bronze in layers. In such cases, be sure that the base metal is well tinned as you put on the first layer. This insures a strong bronze deposit and a good bond with the succeeding layers.

To apply the bronze, hold the central cone of the flame 1/8 to 1/4 inch from the surface of the metal. Point the flame ahead of the deposit at an angle of about 45°, with the molten pool slightly behind the tip of the flame. This angle may vary, depending upon the position and thickness of the metal. The method of handling the torch and filler rod depends largely upon the size of the molten pool and the speed of brazing. The application of bronze to cast iron requires careful attention to insure good bond between the two metals. If the base metal gets too hot, the bronze balls up and fails to adhere to the cast iron. Excess fuming indicates a loss of zinc in the filler metal. If the metal is not hot enough, the bronze does not spread and adhere to the casting. The proper brazing speed is indicated by the speed of tinning and the contour of the deposit. Do not apply the bronze at a faster rate than the rate at which the tinning progresses.

When you braze a crack or break that terminates in a hole or an opening in the casting, the braze should progress toward the hole or opening. In long breaks on flat surfaces, the braze should progress from the ends of the break toward the middle. To braze branch cracks, start the braze at the end of the crack and progress toward the main break. After using the torch, protect the casting from drafts and cold air to prevent uneven cooling. Do not place any stress on a brazed joint until it has completely cooled. You can clean the finished deposit with a wire brush to remove any excess flux and any oxides that have risen to the surface.

Low carbon steels are easily brazed, the procedure is very similar to brazing gray cast iron.

Breaks in high carbon and tool steels should be braze welded only in an emergency and if the lower strength and hardness of the filler metal are acceptable.

Braze welding should never be done if the part will be subjected to severe conditions or if the temperature will be higher than 650° F. At temperatures ranging from 500° to 600° F., the strength of the filler metal is greatly impaired.

Exercises (829):

1. After the parts to be brazed have been beveled, what is the next step?

2. When you are brazing low carbon steel, how fast should you progress?

3. When brazing ½ inch thick cast iron, what flame should you use for depositing the bronze?

4. How does preparing the joint for brazing differ from preparing it for fusion welding?

Oxyacetylene Welding Applications

IN THIS CHAPTER on oxyacetylene welding applications, we will consider some operations that use the oxyacetylene process. These operations are used more in the civil engineering area than on the flight line, but all welders must understand them in theory. They are hard surfacing and soldering.

4-1. Hard Surfacing.

Hard surfacing or hard facing is the process of applying extremely hard alloys to the surface of a softer metal to increase its resistance to wear, abrasion, corrosion, or impact. In most cases, you can apply hard-facing alloys to the point, surface, or edge of any part by the oxyacetylene process. Treated with these special alloys, the wearing surface of drills, tools, bits, cutters, and other parts will outwear the common steels 2 to 40 times as long, depending upon the type of alloy used and the service to which the part is subjected.

830. State the mechanical properties that are affected by hard facing and list the metals that cannot be hard faced.

Alloys Used for Hard Facing. No single hard-facing material is suitable for all applications. Many types of hard-facing alloys have been developed to meet special requirements for hardness, toughness, shock, wear resistance, and other qualities. These alloys are generally separated into five broad groups.

Group 1. The alloys in group 1 consist mainly of an iron base with less than 20 percent of alloying elements. The alloying elements are mainly chromium, tungsten, manganese, silicon, and carbon. The alloys in this group have greater resistance to wear than any machine steel. Although not as hard, they have greater toughness and shock resistance than other hard-facing alloys. They are used to build up badly worn sections before a final harder surface with a better grade of hard-facing alloy is applied Stoodex and Stoody self-hardening rods are in this group. They are used for rock crushers and similar equipment where resistance to shock and impact is most important and hardness is only secondary.

Group 2. Group 2 is iron-base alloys with 50 to 80 percent iron and more than 20 percent alloying elements. These alloying elements are mainly chromium, tungsten, manganese, silicon, and carbon. Small percentages of cobalt and nickel are sometimes added. Some of the alloys in this group have the property of "red hardness;" that is, they remain hard even when they are at a red heat. They are used for the final hard, wear-resisting surface after the part has been built up with a high strength rod. Stoodite and Haschrome are types of rod used for this application.

Group 3. Group 3 contains nonferrous alloys of cobalt, chromium, and tungsten, as well as other nonferrous hard-facing metals. Some of these alloys also have the property of red hardness. They are available in different grades. All are highly resistant to wear but possess a special toughness and strength for a wide variety of purposes. The types of hard-facing rods in this group are Silfram and Stellite. Valves made from Stellite can handle gas, oil, acids, high temperature, and high-pressure steam. They must resist heat corrosion and erosion. This material is used extensively for the valve seats in internal combustion engines.

Group 4. Group 4 alloys are the carbide materials or diamond substitutes and are the hardest and most wear resistant of all hard-facing materials. Some of the alloys contain 90 to 95 percent tungsten carbide. The remainder is cobalt, nickel, iron, or similar metals. These give strength, toughness, heat resistance, and impact strength to the tungsten carbide. Some are almost pure tungsten carbide and contain no alloying elements. This group is supplied in the form of small castings to be welded onto the wearing surface of other metals. They are bonded to the surface of the hard-facing material. Applying tungsten carbide pieces to wearing surfaces is known as hard setting.

Group 5. Group 5 alloys are crushed tungsten carbides of various sizes. They are fused to strips of mild or low alloy steel embedded in hard-facing material or high stren rods, or they are packed in lengths, which are applied to the wearing surface as welding rod. Crushed tungsten carbides are also available in loose form as granular powder, which is sprinkled onto the wearing surface and melted into it. The materials in this group, although more expensive than other types, are used for many purposes because of their long life. Tube borium and borod are two types in group 5.

Group 4 and 5 alloys, since they are very tough and extremely hard, are used for the wearing parts that come in contact with earth, sand, and gravel. These include the blades of road scraping and grading equipment, rotary drill bits, airplane tail skids, power shovel teeth, and similar parts. The rods for these uses are borium and cobalt borium.

Metals and Hard Facing. You can apply hard-facing materials to most metals and alloys. The following is a

list of the metals and alloys that can or cannot be successfully hard surfaced:

a. All the plain carbon steels (low and medium) with a carbon content up to 0.50 percent can be hard faced.

b. The high carbon steels containing above 0.50 percent carbon can also be hard faced if the base metal is heat treated before and after hard facing to remove hardness and brittleness and prevent cracking.

c. Low carbon alloy steels can be hard faced in some cases, depending upon the composition of the base metal. Heat treatment is required after hard facing.

d. Hard facing is not recommended for high-speed steels because of their brittleness and the shrinkage cracks that develop in the base metal after hard facing.

e. Manganese steels should be hard faced by the shielded metal-arc process only with the work-hardening type of alloys and with alloys that bond easily with these metals.

f. Stainless steels, including the high chromium and chromium-nickel steels, can be readily hard faced. You should know the mechanical properties of your particular stainless steel so that you can avoid decreasing its corrosion resistance after hard facing. Uniform heatin and cooling help to prevent the warping or cracking caused by the higher coefficient of expansion in the stainless steel.

g. Gray cast iron can be hard faced.

h. Malleable iron can be hard faced. The surface beneath the hard-facing layer will become hard. You can remove some of this hardness by reheating the metal to approximately 1500° F.

i. Monel metal can be readily hard faced.

j. Since the melting points of brass and bronze are very low, hard facing cannot always be satisfactorily applied to these metals. In some cases, you can preheat heavy sections to a red heat and hard face them by using the group 3 alloys.

k. Copper and copper alloys have high heat conductivity and comparatively low melting temperatures. In some instances, you can hard face them in the same way as for brasses and bronzes.

l. Aluminum and aluminum alloys cannot be hard faced.

Exercises (830):

1. What mechanical properties are affected when a metal is hard faced?

2. Why aren't high-speed steels recommended for hard surfacing?

3. Name the metals that cannot always be successfully hard faced.

831. Specify the procedures for applying and finishing hard-surfacing deposits.

There are a number of things you must do before you can apply a hard-surfacing deposit sucessfully. These include preparing the metal, preheating, fluxing, adjusting the flame, and determining the deposit thickness.

Preparing the Metal. You must clean the surface of the metal to be hard faced, removing scale, rust, dirt, and other foreign substances by grinding, machining, or chipping. If you cannot use these methods, you must prepare the surface by filing, wire brushing, or sandblasting. The latter methods are not as satisfactory because the small particles of foreign matter that remain on the surface must be floated out during the hard-facing operation. Round all the edges of grooves, corners, and recesses to prevent overheating the base metal.

Preheating. You should take the same precautions in preheating for hard facing as for welding a base metal. Anneal steels in the heat-treated condition, if possible, before you apply the hard-facing layer. Water quenching will crack the hard-facing layer. If you must heat metal to the critical temperature after hard facing, use oil as the quenching medium. When it is impossible or undesirable to anneal high carbon steels or before you are hard facing high-tensile, low-alloy steels, deposit the hard face by the transition bead method. First, deposit a thin layer of stainless steel—such as the 25 percent chromium and 20 percent nickel rod, or the 18 percent chromium and 8 percent nickel rod (columbium stabilized). Then build up the section to approximately the original dimension, using an 11- to 14-percent manganese or high strength rod. Finish by hard facing with one of the group 2 alloys.

Fluxing. A flux is not needed when you apply hard-facing materials with the oxyacetylene torch; but, when you are depositing the hard-facing material in more than one layer a flux helps to remove the scale and oxides that have form on the base metal. This applies particularly to hard facing cast iron, in which operation a cast iron welding flux is satisfactory. The film of flux formed on the molten pool reduces the rate of cooling of the deposited material, permitting gas, oxides, and slag inclusions to come to the surface. This results in a hard and solid surface layer.

Adjusting the Flame. Use a carburizing flame to apply hard-surfacing to metal (fig. 4-1). You can find the exact amount of excess acetylene needed in the welding flame by varying the acetylene during the initial deposit of the rod. The oxyacetylene flame gives you close control over the operation and produces a smooth deposit. Adjust the flame to produce a quiet pool and good flowing qualities for the hard-surfacing material you are using.

Determining Deposit Thickness. In most cases, you can rebuild worn sections with hard-facing deposits ranging from 1/16 to 1/4 inch thick. If you must deposit hardfacing material in excess of 1/4 inch, rebuild the parts with a group 1 alloy to 1/16 to 1/4

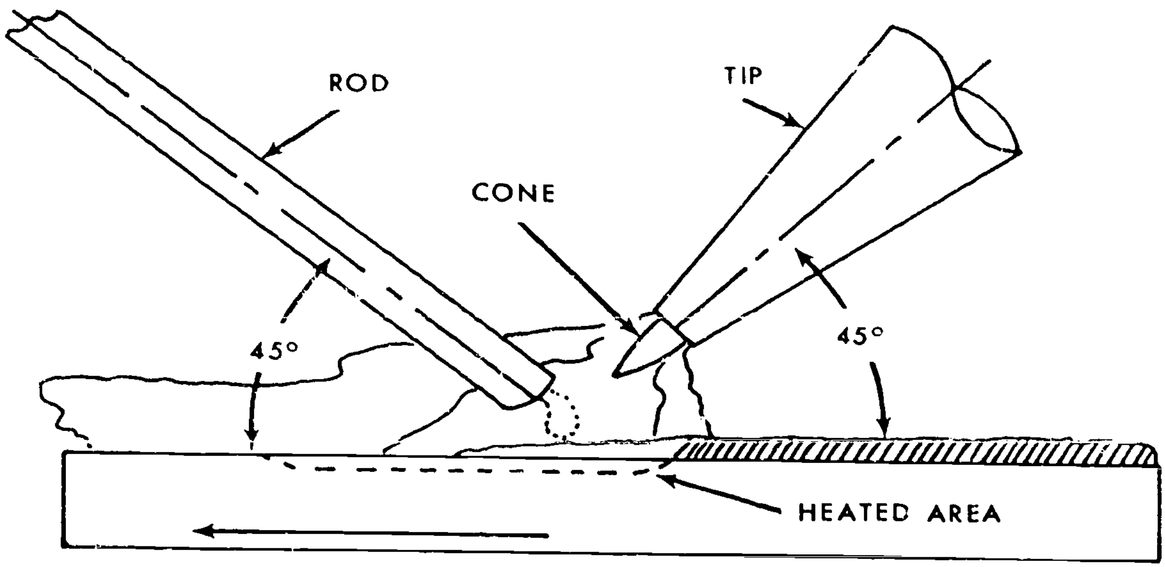


Figure 4-1. Hard surfacing with oxyacetylene.

inch of the finished size. Add the final hard-facing deposit, a group 2 or group 3 alloy, with some excess to permit your grinding it to the finished dimensions. When you apply the harder and more brittle group 4 or group 5 hard-facing materials, either as a final hard-facing deposit or as a single layer, you should control the shape of the deposit carefully. It is important to transmit impact or shock loads through the hard-facing metal into the tougher base metal. Corners, sharp edges, and built-up sections that are not backed up by tough base metal will chip or break off in service.

Torch Hard Facing. Hard facing can be done in either of the two ways illustrated in figures 4-2 and 4-3. The oxyacetylene flame lets you control the operation closely and produce a smooth deposit. The flame easily removes the particles of scale and foreign matter, and you can form edges and corners easily. This is particularly important when you must later grind the hard-facing deposit to close dimensions. Use the flame to control the penetration of the hard-facing alloy in the base metal, since some of the alloys are puddled into the base metal and others are merely "sweated" onto the base metal. Use a tip two sizes larger than you would need for welding a metal of the same thickness. When you apply any of the hard-facing alloys or materials to steel, determine the exact amount of excess acetylene needed in the welding flame by varying the acetylene during the initial deposit of the rod. As we have already pointed out, adjust the flame to give a quiet pool and good flowing quality for your particular hardfacing material. In some cases, when you are hard facing a thin edge or building up a desired shape with hard-facing materials, you can use a copper mold or backup strip. Check the following information concerning the groups of alloys.

Group 1. When you apply group 1 hard-facing alloys to steel, adjust the flame to a slight excess of acetylene. A neutral flame causes boiling and produces unsatisfactory results. If you want a greater hardness in

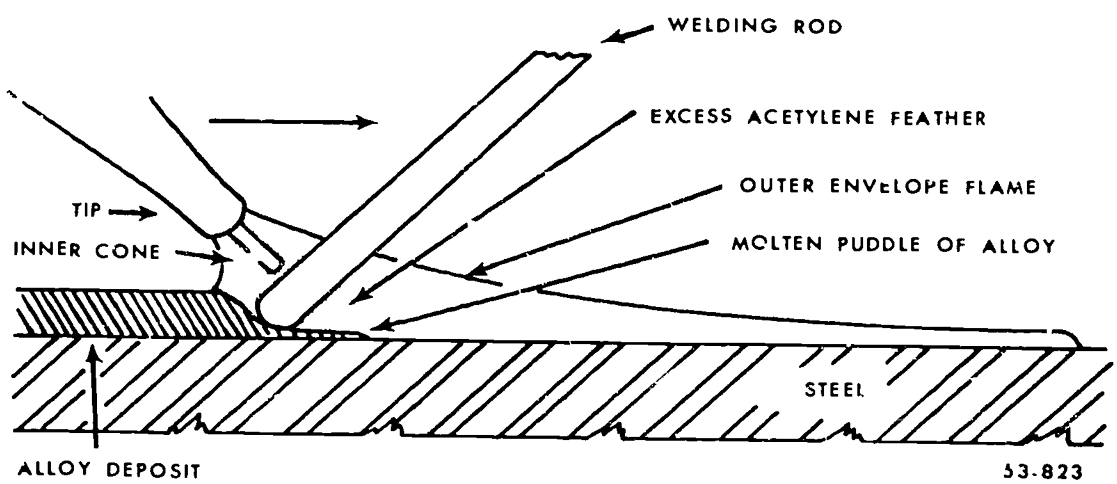


Figure 4-2. Forehand method of hard surfacing.

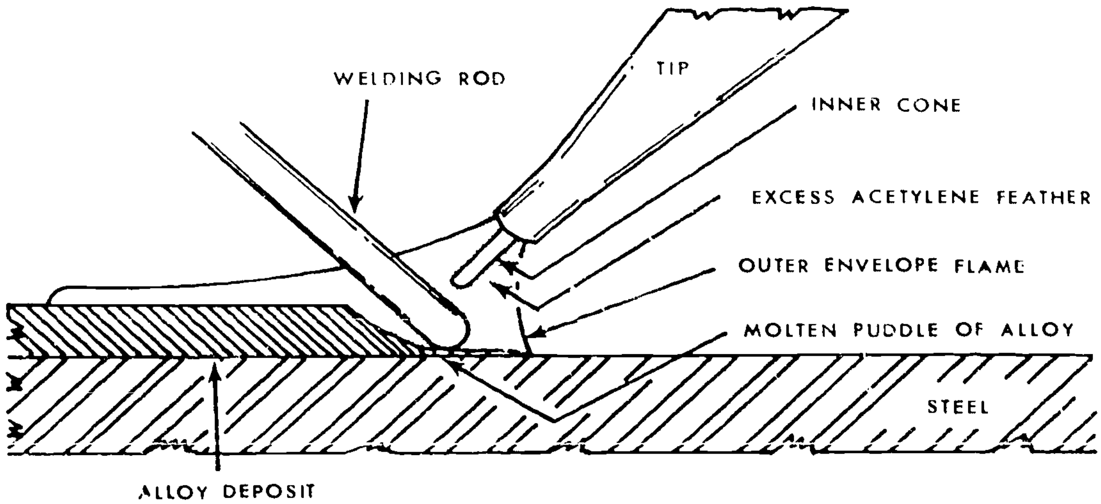


Figure 4-3. Backhand method of hard surfacing.

the deposit, increase the acetylene in the flame. Puddle the hard-facing rods into the base sufficiently to obtain good fusion without diluting the hard-facing metal with the base metal and thereby softening it. You can oil-quench group 1 deposits without any loss of wear resistance or toughness.

Group 2. Apply these hard-facing alloys to steel in the same way as the group 1 alloys. "Sweating" is not advisable. You should adjust the flame to an excess of acetylene with a feather approximately twice the length of the inner cone. The penetration of these hard-facing metals into the base metal does not materially affect the hardness of the deposit, as their carbon content is high. To eliminate porosity and shrinkage cracks, reheat the hard-faced part to an even temperature throughout, and then immediately pack it in lime or some other medium that retards cooling. You should not quench the deposits made with this group of alloys.

Group 3. The hard-facing alloys in this group are nonferrous and you should sweat them onto the surface witho stirring or puddling the rod or melting the surface of the base metal. Adjust the flame to an excess of acetylene. This excess prepares the base metal, allows free spreading of the alloy, and prevents oxidation ahead of the fusion zone. Bring a small area to be hard faced to a sweating temperature. At the proper temprature, the hard-facing material will melt and spread evenly over the surface. Control the thickness of the deposit by using the flame to spread the molten metal over the surface.

Group 4. Some tungsten carbide materials, such as those in group 4, are available as inserts in various sizes and shapes. Groove the surface of the base metal with a cutting torch or forging hammer. Space the inserts evenly to obtain uniform wearing qualities. Weld an insert to the end of a steel welding rod and melt the groove in the base metal. At this point, push the insert into place and melt enough welding rod to cover the insert completely. Repeat this procedure until the surface is covered with the desired number of inserts. Tube borium is made in the form of mild steel tubes filled with crushed particles of screen tungsten carbide (borium).

Group 5. The alloys in group 5 are crushed tungsten carbides embedded in steel strips, rods, or tubes. You can apply this alloy as thinly as 0.010 to 0.015 inch, making it possible to hard face thin cutting edges and equipment that require a thin overlay. Adjust the flame to an excess of acetylene with a feather about four times the length of the inner cone. Heat the base metal to the sweating temperature. Avoid puddling, since, in a thick deposit, borium particles settle away from the deposit. Deposit the alloy with a minimum amount of penetration.

In figure 4-4, typical applications of hard facing are shown on gear teeth, an exhaust valve, and a rocker arm.

Finishing. Many parts that are hard faced, like those shown in figure 4-4, require finishing to dimensions or shapes. If this is the case, be very careful to apply

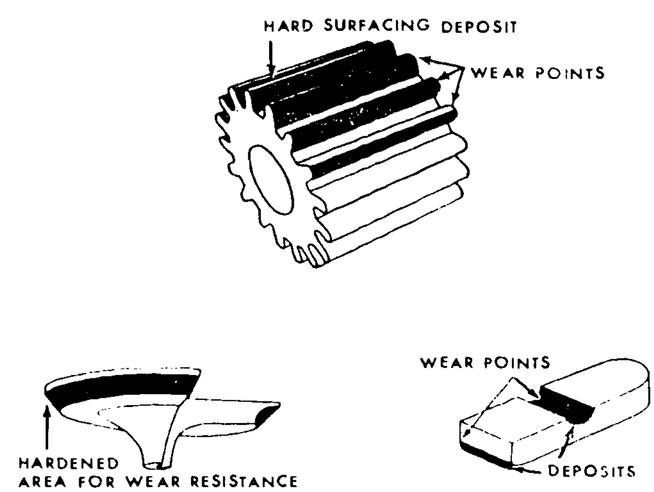


Figure 4-4. Hard-surfacing applications.

enough hard-facing alloy to allow for grinding to given specifications. Hard-facing deposits must be ground or machined with a carbide tool bit. The tools that are used to finish the product must be harder than the deposit.

Exercises (831):

1. What type of flame is used to apply hard-surfacing deposits?

2. How are the corners and edges prepared for hard surfacing?

3. Compare the tip size for hard facing with the tip size for fusion welding.

4. How are nonferrous hard-facing alloys applied to a base metal of steel?

5. True or False. Group 5 hard-facing alloy deposits are too hard and brittle to be finished.

6. How are the hard-facing alloys bonded to the base metal?

4-2. Soldering

Soldering is used for joining most common metals with an alloy that melts at a temperature below that of the base metal. In many respects, this operation is similar to brazing. The success of the soldered joint depends on the penetration of the solder into the pores of the base metal surface, the formation of a base metal solder alloy, and the mechanical bond between the parts.

832. State characteristics of silver and lead soldering.

Silver Soldering. In silver soldering, you produce the bond by heating the base metal to a temperature between 1,175° F. and 1,600° F. and adding a silver alloy filler metal with a melting point within this temperature range.

Joints that permit capillary attraction are best suited for silver soldering because of the high strength obtained. Since the silver alloy filler metal flows at a low temperature, less heat is required, thus offering a number of definite advantages. Because of the low temperature needed, you do not heat the metal to temperatures at which its physical properties or other qualities are impaired. Distortion is held to a minimum. The process is quite simple and can be completed rapidly. Silver alloy filler metals join virtually all ferrous and nonferrous metals with the exception of aluminum, magnesium, and several other alloys and metals with a low melting point.

The strength of a silver soldered joint depends upon the fitup and the quality of the bond between the filler metal and the base metal. The heat opens the crystal grain structure and lets the filler metal penetrate along the grain boundaries on the surface of the base metal. This creates a physical bond between the filler metal and the base metal. It is this bond that produces the high strength of a soldered joint. No fusion takes place between the filler metal and the base metal. Parts that are silver soldered should not be subjected to temperatures that exceed 500° F. The silver solder bond weakens at that temperature and becomes progressively weaker as the temperature increases.

There are numerous applications of silver soldering in the fabrication of aircraft parts, especially those in which high electrical and thermal conductivity is needed. Typical examples are aircraft radio shields, instrument fittings, copper oil and fuel lines, and inlet and outlet connections on some radiators and oil coolers.

Silver solder can be obtained in several grades, with silver content ranging from 10 to 80 percent and with a melting point from 1,160° F. to 1,600° F. It comes in rod, strip, wire, and granulated form. The strip or ribbon form is generally used for fixed setups in which the solder can be placed in the joint before heat is applied. The rod and wire forms are used mainly where it is preferable to apply the solder by hand.

Lead Soldering. The lead soldering process is the same as the silver soldering process except that bonding is produced at temperatures below 800° F. Again, the joint design and fitup affect the quality and strength of the bond.

Exercises (832):

1. Silver soldering is done in a temperature range of ____________

2. Solder joints are bonded by an action known as ____________

3. Lead soldering is accomplished at a temperature below ____________

4. The strength of soldered joints depends upon ____________

833. Specify procedures for silver soldering.

There are several factors that must be considered for successful accomplishment of a silver soldered joint. These factors are joint design, joint preparation, fluxing tip size, and technique.

Joint Design. The type of joint you use depends mainly on the base metal and the service requirements of the joint. The type of joint is important because the preparation, fitup, and results obtained with silver soldering differ from those of fusion welding. You should not use silver alloy as a filler. This alloy flows freely into narrow openings, and the strongest joints result from using very small clearances between the joint surfaces. The recommended joint clearance at soldering temperature is between 0.002 and 0.005 inch.

Two types of joints are used in silver soldering: the lap joint and the square-edge butt joint. However, the butt joint can be modified to include the flanged butt joint and the scarf butt joint, shown in figure 4-5. The lap joint is the most common type of joint because it provides more area for capillary attraction. The joint is most efficient when the overlapping of the base metals equals or exceeds three times the thickness of the thinnest section, shown in figure 4-6.

Joint Preparation. You need a clean, oxide-free surface to insure uniform quality and a soundly soldered joint. Remove all grease, oil, dirt, and oxides from the base metal and the filler rod to obtain uniform capillary attraction throughout the joint. Complete the soldering as soon as possible after cleaning the base metal and filler metal. Use either mechanical or chemical cleaning. For rust and heavy oxides, use sandblasting. For grease and oil, use trichloroethylene or trisodium phosphate. Other cleaning agents and machines are the grinder, buffer, emery cloth, vapor degreaser, file, and certain acids. When you use chemical cleaners, wash the metal to remove any residue because residues can attack the base metal or form an undesirable film on the surface. Solder-repairing broken tools and parts requires the thorough removal of paint, lacquer, and any other coating. Plating, such as chrome or cadmium, must also be removed. The solder must make contact with the clean surface of the original metal.

Flux. Flux serves various purposes in making strong, uniform soldered joints. A good flux performs the following functions:

a. Reacts chemically with surface films, such as oxides, reducing them and cleaning the metal surfaces to receive the molten silver alloy.

b. Forms a protective film during the soldering cycle, preventing reoxidation at the elevated temperatures required for soldering.

c. Assists the silvery alloy to flow freely.

The use of flux does not eliminate the need for cleaning the parts before silver soldering. The flux supplements the initial cleaning by dissolving, restraining, and otherwise rendering ineffective any products of the soldering operation that could impair the quality of the joint or prevent bonding.

The flux comes in a variety of forms, such as powder, paste, liquid, and solid. Remove the flux after the soldering is completed. Trapped flux can weaken or corrode the soldered joint. You can usually free the parts from flux by washing them with hot water. If the joint can take a moderate heat shock, you can remove the flux easily by immersing the joint in water while the joint is still warm. Several good ready-mixed fluxes are available commerically but the following mixtures can be used as a substitute: a mixture of equal parts of borax and boric acid for copper, brass, bronze, and monel metal; and a mixture of 3 parts boric acid and 1

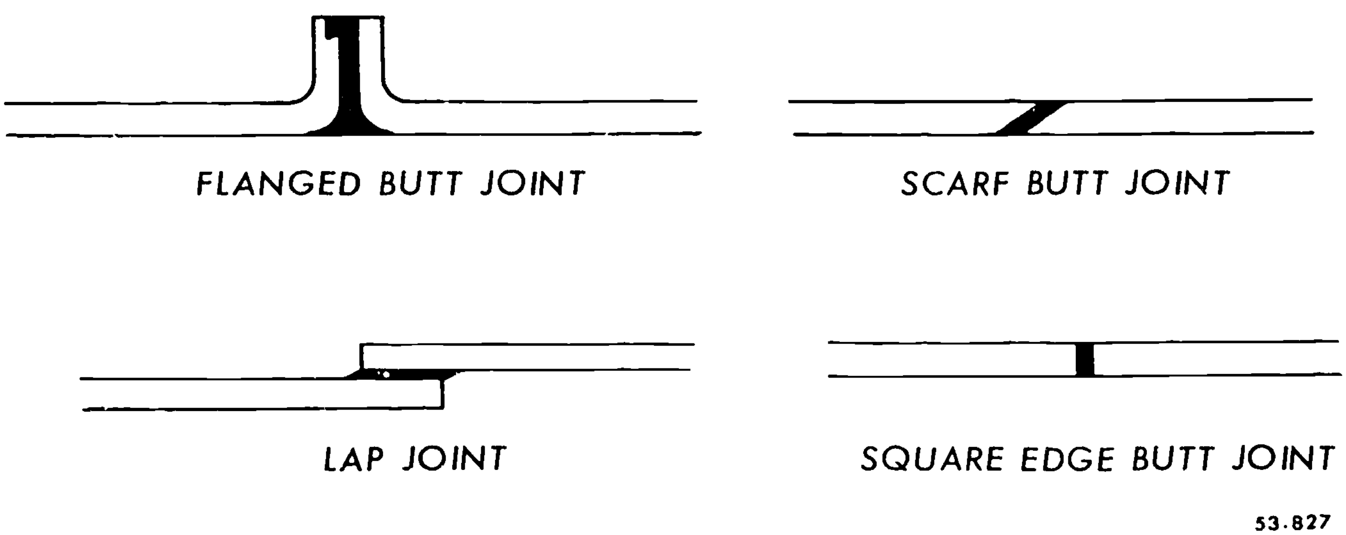


Figure 4 5. Silver soldered joints.

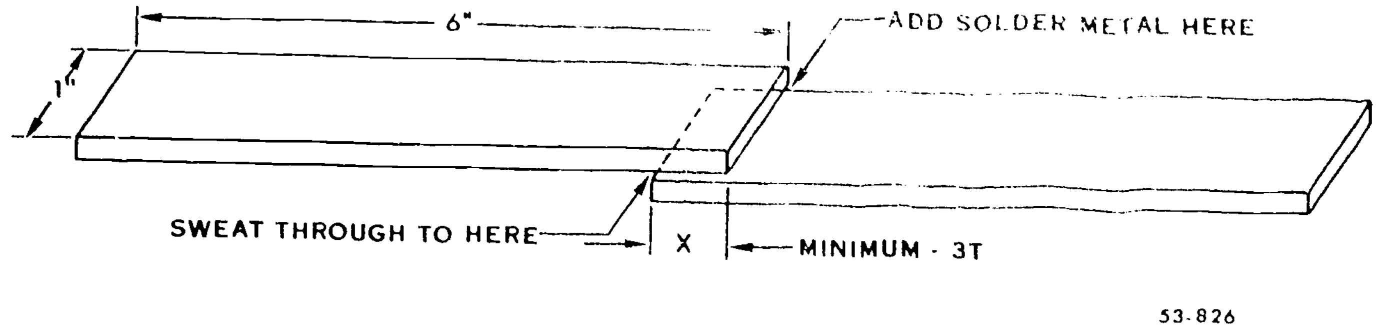


Figure 4-6. Silver soldering a lap joint.

part borax for steel. Apply the flux in powder form, or dissolve it in water and apply it with a brush. The temperature at which the flux begins to flow freely is the proper temperature for applying the solder.

Tip Size. The tip size depends basically upon the thickness of the base metal. However, because of the melting point of the silver solder and the joint design, you may use a slightly larger or smaller tip.

Soldering. For silver soldering, adjust the torch to a neutral or slightly carburizing flame. Do not let the inner cone of the carburizing flame touch the metal; to do so can cause the filler metal top be sluggish at the flow point and the flux to burn. Keep the torch in motion all the time it is in use. Holding it in one place too long can easily overheat the base metal and flux. If a part overheats and the capillary flow of the solder is hindered reclean the part and remove all oxides and foreign matter. Low heat and cleanliness are very important in silver soldering.

For large surfaces, preheat the metal well away from the joint, especially if you are soldering metals with high heat conductivity. Be careful in soldering metals of unequal thickness or unequal heat conductivity because all metal parts should reach the soldering temperature at the same time. The forming of a small fillet at the face of the joint indicates complete bonding through the joint. Figure 6-6 shows the dimensions, the overlap, and the location of the solder for silver soldering a lap joint.

Exercises (833):

1. What type of flame is used for silver soldering?

2. When silver soldering two metals of uneven thickness, where should you apply most of the heat?

3. Why is it necessary to completely clean the metal surface and filler rod when silver soldering?

4. How should you remove the following from the metal?
   a. Rust.
   b. Grease.
   c. Flux.

834. State the procedures for lead soldering joints.

Lead Soldering. In lead soldering, metal is joined by an alloy that melts below the temperature of the metal and always below 800° F. The strength of the soldered joint depends upon the penetration of the solder into the pores of the base metal, to create a physical bond between the parts.

Soft solder composition. Several types of soft (lead) solders are available. They consist mainly of lead and tin and range in content from 5 percent tin and 95 percent lead (5-95 solder) to 50 percent tin and 50 percent lead (50-50 solder). Some undesirable impurities in these solders are antimony, arsenic, zinc, iron, and bismuth, all in very small quantities. In general, the higher the lead content, the higher the melting point. The solders with higher lead content can be used on joints that will be subjected to temperatures up to 400° F., but the most common general purpose solder is 50-50 solder.

Joint preparation. The parts to be soldered should be free of all oxide, scale, oil, and dirt. Clean the parts by pickling them in a caustic or acid solution, filing, scraping, sandblasting, or other suitable means, and tin the base metal before you make the joint and, of course, make sure that the parts are properly fitted together.

Flux. All lead soldering operations require flux for a complete bond and full strength at the joints. Flux clean the joint area, prevents oxidation, and increases the wetting power of the solder by decreasing its surface tension. Several types of soft soldering flux are in common use: rosin or rosin and glycerin, used on clean joints to prevent the formation of oxides during the soldering operation; zinc-chloride and ammonium-chloride, used on tarnished surfaces to permit good tinning; and a solution of zinc cut in hydrochloric (muriatic) acid, used by tin workers.

Application. You can make soft solder joints in several ways: oxyacetylene flame heating, wiping, sweating, or dipping in a solder bath. Dipping is useful in the repair of radiator cores. Electrical connections and sheet metal are soldered with soldering irons, which are heated in a gas flame or furnace or by an electrical heating unit in the iron. Wiping is used for joining lead pipe and the lead jackets of underground and other lead-covered cables. You can sweat joints by applying a mixture of solder powder and paste flux to the joints, or by tinning the mating surfaces of the members to be joined and applying heat to complete the joint. When you are using the oxyacetylene flame, it is best to use indirect heating. Apply the heat to the sides or underside of the joint and not directly on the joint area. This heating technique prevents overheat the joint and burning the flux or solder.

Exercises (834):

1. State the ways to make soft solder joints.

2. What must you do to the parts before soldering them?

3. How does its lead content affect the melting point of solder?

4. What is generally the best method of heating a joint for soldering with the oxyacetylene flame?

Oxyacetylene Cutting

OXYACETYLENE CUTTING is a fast and economical method of cutting steel. The cutting torch allows the welder to make accurate fitups and prepare joint edges on the job without having to rely on time-consuming mechanical methods.

5-1. Oxyacetylene Cutting Equipment.

Although it is fast and economical, oxyacetylene cutting requires some special equipment. The basic equipment is a cutting torch or cutting attachment with cutting tips. Additional items are radial or multiple cutting machines and aids for performing manual cutting operations.

835. Specify the fundamentals of oxyacetylene cutting equipment.

Cutting Equipment. The oxyacetylene cutting equipment is generally the same as the welding equipment, with the exception of the torch. The oxygen regulators used for heavy cutting operations furnish a larger volume and higher pressure than is needed for welding. The oxygen outlet is fitted with a working pressure gage, graduated to 400 psi, and the oxygen hose is designed to withstand these high pressures.

Cutting torch. The cutting torch mixes oxygen and acetylene in definite proportions, burns the mixture in a preheating flame, which heats the work, and directs a jet of high pressure oxygen to sever the metal along the line of cut. The hand cutting torch looks like a welding torch, but it differs in construction and method of control. It consists mainly of a handle, connecting tubes, and a head, as shown in figure 5-1. At the rear of the handle are the oxygen and acetylene hose connections. A needle valve in the acetylene inlet connection controls the acetylene supply. The preheating oxygen is regulated by a preheat valve on the side of the handle. A high pressure oxygen valve, operated by a trigger or lever, controls the cutting oxygen. In some cutting torches, the preheating oxygen and the acetylene do not mix until they are in the cutting tip. These cutting torches have three gas tubes: one of high pressure oxygen, one of preheating oxygen, and one for acetylene. In other cutting torches, the preheating oxygen and acetylene premix in the torch body in a common mixing chamber. These torches have only two gas tubes: one for high pressure oxygen and one for the mixing of gases.

Cutting attachment. The construction and operation of the cutting attachment, figure 5-2, are like those of an ordinary cutting torch. The simple attachment fits the body of the standard welding torch, converting it quickly into a cutting torch. Since it is unnecessary to disconnect the hoses, the changeover can be made in a very short time. This attachment is very useful for the occasional cutting of lighter section The cutting attachment is not recommended for the constant cutting of heavy materials. Such work should be done with a regular heavy duty cutting torch.

Cutting tips. The taper-seated, separable cutting tip is held in the cutting torch head by the tip nut. The tip has a central orifice through which the cutting oxygen flows. This orifice is surrounded by several preheating holes, as shown in figure 5-3. Cutting tips with cutting

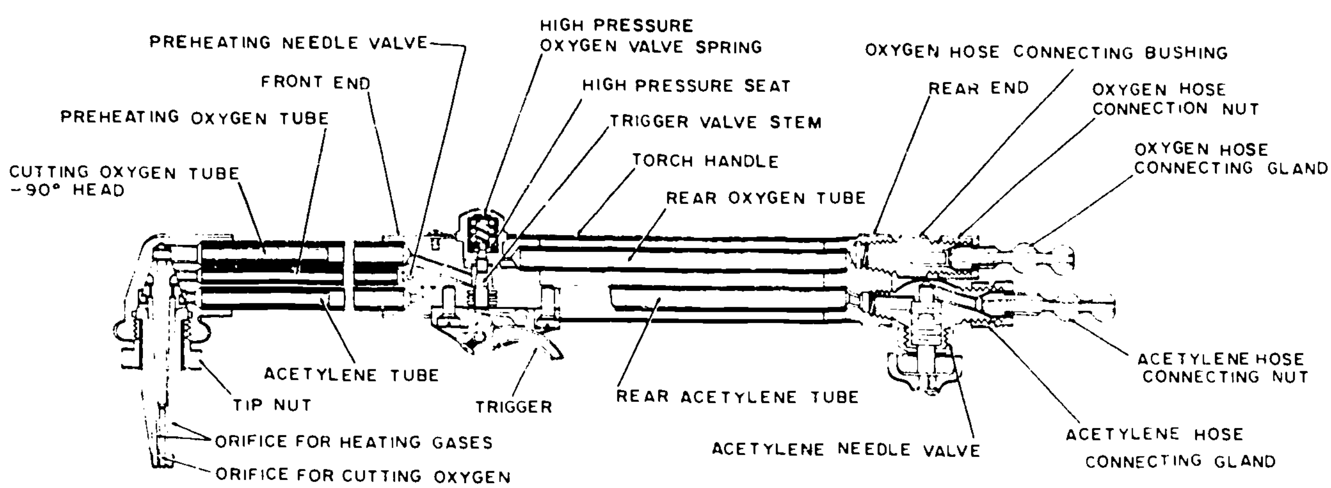


Figure 5-1. Cutting torch.

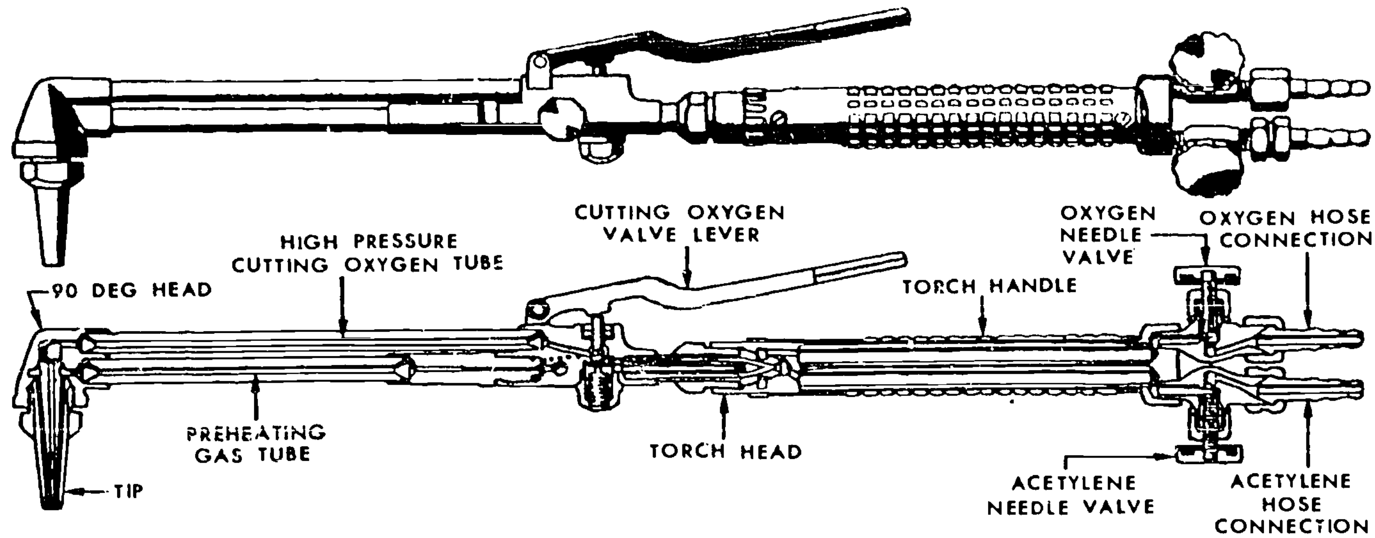


Figure 5-2. Cutting attachment.

and preheating orifices of various sizes are available for cutting practically any thickness of metal and are supplied in various lengths for special jobs. Bent tips are also used under certain conditions. Many special operation such as flame machining, gouging, scarfing, and rivet cutting, are done with cutting tips designed for the purpose. Figure 5-4 shows these different designs.

Cutting machines. Although many types of cutting machines are available and identified by commercial trade names, they are usually classified according to their mean of control and the type of work they perform. Cutting machines have been improved by the use of electric solenoid valves to control the gas flow and, by the use of electronic and magnetic devices for controlling the torch movement. Many machines perform automatic cutting operations. Special machines cut a specific number of specially shaped objects, cut a number of object of the same size at the same time, cut straight kerfs, and bevel metal. A multiple cutting machine is shown in figure 5-5. To make uniformly clean cuts on steel plate, motor-driven cutting machines support and guide the cutting torch. The machine does straight line cutting and beveling by guiding the torch as the machine travels along a straight line on steel tracks. It cuts arcs and circles by guiding the torch with a radius rod pivoted about a central point, as shown in figure 5-6.

Cutting aids. A cutting aid is any device that helps you perform the desired operation. It can be a simple straight edge, such as a piece of angle iron, for straight line cutting, a circular cutting attachment for cutting circles, or a sheet metal pattern for cutting specific shapes and angles.

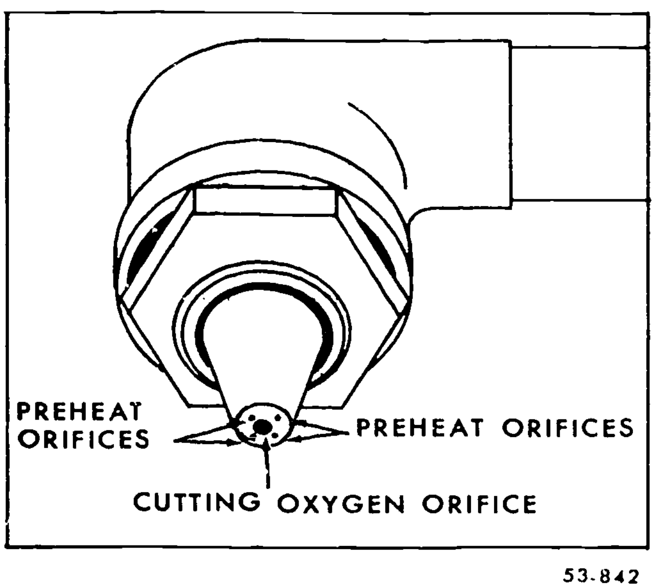


Figure 5-3. Cutting tip.

Exercises (835):

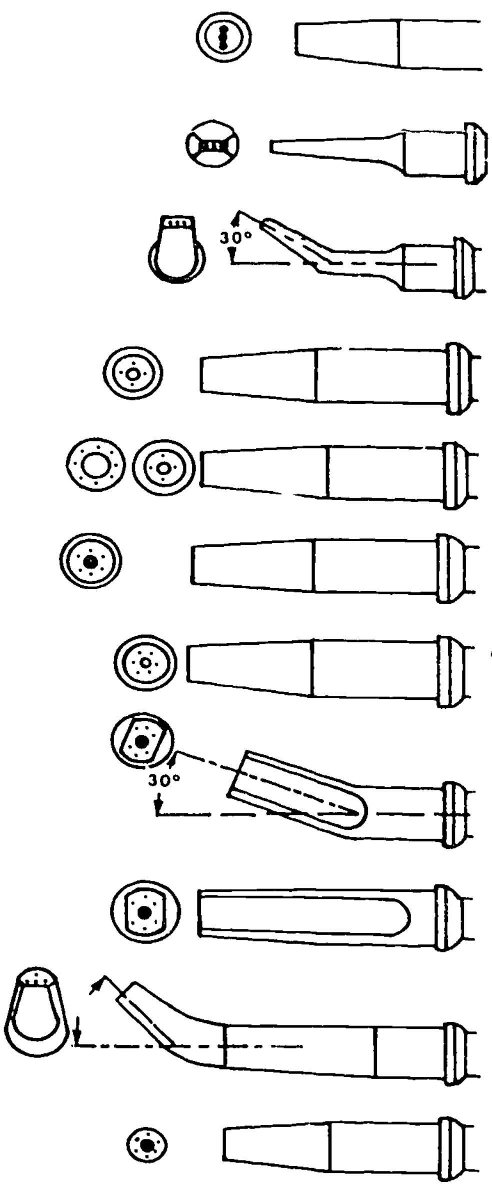
1. What are the functions of the cutting attachment?

2. A light cutting tip for cutting rivet heads manually has an angular bend of ________

3. What are the outer orifices on a cutting tip used for?

4. Give the minimum number of tubes in a cutting torch.

5. What is a multiple cutting machine?



NUMBER OF PREHEAT ORIFICES	DEGREE OF PREHEAT	APPLICATION
2	Medium	For straight line or circular cutting of clean plate.
2	Light	For splitting angle iron, trimming plate and sheet metal cutting.
2	Light	For hand cutting rivet heads and machine cutting 30 deg. bevels.
4	Light	For straight line and shape cutting clean plate.
4, 6, 8	Medium	For rusty or painted surfaces.
6	Heavy	For cast iron cutting and preparing welding V's.
6	Very Heavy.	For general cutting also for cutting cast iron and stainless steel.
6	Medium	For grooving, flame machining, gouging and removing imperfect welds.
6	Medium	For grooving, gouging or removing imperfect welds.
3	Medium	For machine cutting 45 deg. bevel or hand cutting rivet heads.
6	Heavy	Flared cutting orifices provides large oxygen stream of low velocity for rivet head removal (washing).

Most of the above cutting tips are available in two or more sizes and should be selected on the basis of the thickness of the metal and the job to be performed.

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Figure 5-4. Cutting tips and their uses.

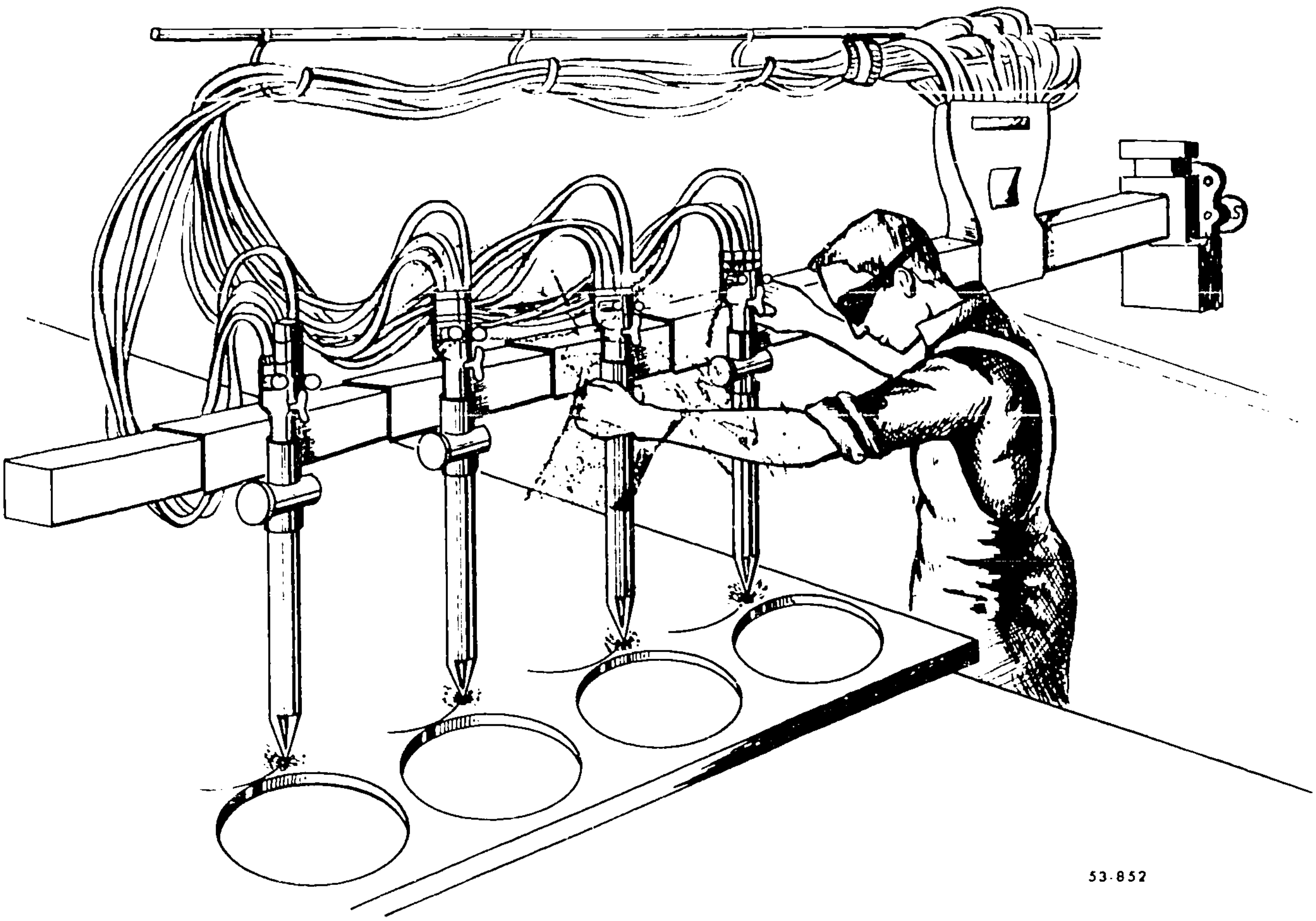

Figure 5-5. Multiple cutting machine.

5-2. Cutting Operations

The speed and economy with which you can sever and shape iron and steel by oxyacetylene cutting make the cuttin torch an indispensable tool. It is useful in the shipyard for cutting plate to the desired shape, in the steel mill for beveling plate edges before welding in scarfing operations, and in shops of all types for fabrication and repair.

836. Point out key factors in oxyacetylene cutting.

Cutting. To cut metal by the oxyacetylene process, there must be rapid oxidation of the metal in a localized area. Heat the metal to a bright red or "kindling" temperature and direct a free jet of high-pressure oxygen against it. This oxygen blast combines with the hot metal and burns it to an oxide. The resultant reaction generates an intense heat that is used for cutting. The high-temperature oxide heats the metal in its path to the ignition temperature as it passes down the side of the cut. The affected area combines with the cutting oxygen and also burns to an oxide. The oxide is blown away on the opposite side of the piece, leaving a narrow slot or "kerf" which separates the metal.

Only the metal in the path of the oxygen jet is acted upon. In linear cutting, a narrow kerf with uniformly smooth and parallel walls is cut. A skilled workman, using a mechanically guided and controlled torch, can make very accurate cuts. Heavy sections that cannot be economically cut by any of the mechanical processes can be easily and smoothly cut with oxygen.

Although practically all metals combine readily with oxygen when they are heated to a high temperature, some of them cannot be cut successfully by this method because their oxides have a higher melting point than the parent metal, and they mix with it when they are melting, instead of separating from it. The nonferrous metals are of this type. Iron and steels of medium carbon content can be cut successfully by the oxyacetylene process without special preparation. High carbon tool steels can be cut if the entire section is first properly preheated. For ordinary tool steel, a black heat is usually sufficient, through some alloy tool steels require a full red heat. Cast iron is more difficult to cut than steel because it melts at a lower temperature than its oxide. Chromium and stainless steels require a special process.

Cutting Procedures. To get ready to cut metal with the oxyacetylene torch, you must first select the right tip size and adjust your regulators for the correct

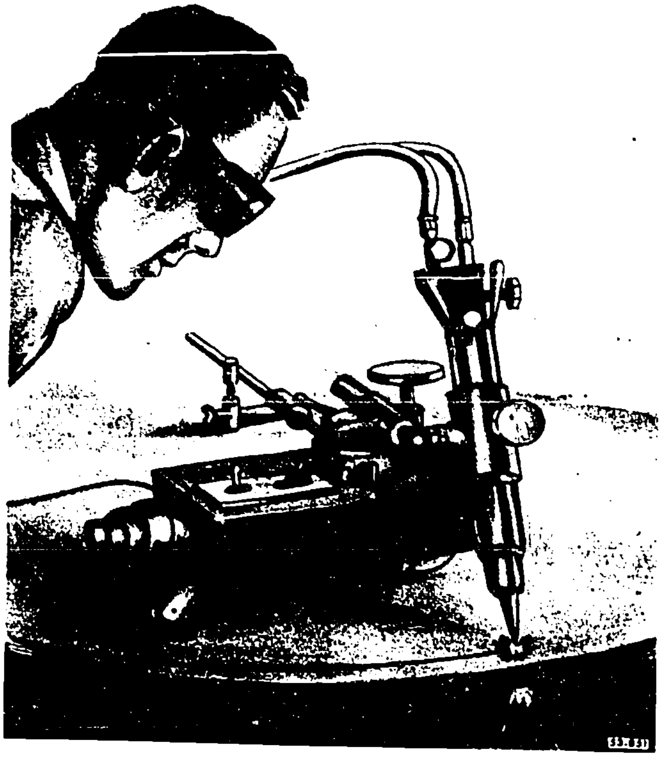

Figure 5-6. Using a cutting machine.

pressure. Figure 5-7 gives the recommended pressures and tip sizes for various thicknesses of low carbon steels.

Now adjust the preheating flame to neutral with the torch needle valves, open the cutting oxygen valve, and again adjust to a neutral flame. Because of rapid oxidation the oxygen actually separates the metal. Make sure that the metal on both sides of the line of cut is free from scale and heavy rust deposits. To start the cut, hold the torch perpendicular to the work with the inner cone of the preheating flame slightly above the surface of the metal. When a red heat has been reached, open the cutting oxygen valve slowly until it is fully open, as shown in figure 5-8. If you start the cut properly, a shower of sparks will fall from the opposite side, indicating that the cut has penetrated all the way through the metal. If you use proper pressures and cutting speeds, you can cut the metal without interruption. Near the end of the cut, raise the torch. If you have performed the cut properly, it will be a clean, narrow kerf, comparing favorably with a cut made by sawing. Figure 5-9 illustrates different results obtained in cutting considering such factors as oxygen pressure, preheating, and speed of travel. The figure shows work views, drag, and direction of cut. If the speed is too fast, the metal is not preheated sufficiently to continue the cut. To restart, direct the flame slightly behind the point where you lost the cut. When the metal is preheated properly, resume the cutting.

Metal Composition. The composition of the metal determines how effectively it can be cut with an oxyacetylene torch.

Plate Thickness	*Tip Size Nr*	*Acetylene Pressure, lbs per sq inch*	*Oxygen Pressure, lbs per sq inch*
¼ in	0	3	25 to 30
⅜ to ½ in	1	3	30 to 40
¾ to 1 in	2	3	40 to 50
1½ in	3	3	45 to 50
2 in	4	3	50 to 55
3 to 4 in	4	4	55 to 65
5 to 6 in	6	5	55 to 60
8 to 10 in	7	6	60 to 70
12 in	8	6	70 to 80

CP-38

Figure 5-7. Recommended pressure for cutting low carbon steel.

Carbon steels. Plain carbon steel whose carbon content does not exceed 0.35 percent can be cut without special precautions other than those required for any cut of good quality. For higher carbon steels, you must be careful to prevent the formation of a hard layer at the edge of the plate. To avoid this, preheat the plate edges in advance of the cut. Use preheating temperatures of 500° F. to 600° F. in cutting steels in this class.

Chromium and stainless steels. These and other alloy steels, which formerly could be cut only by melting, can now be cut by oxidation. Iron powder or a special nonmetallic powdered flux is added to the cutting oxygen stream. The iron powder oxidizes quickly and liberates a large quantity of heat. This high heat, in turn, melts the refractory oxides that normally protect the alloy steel from the action of the oxygen. These molten oxides are flushed from the cutting face by the oxygen blast, and the cutting oxygen continues to react with the iron powder and cut its way through the steel. The nonmetallic flux in the cut‘'ng oxygen

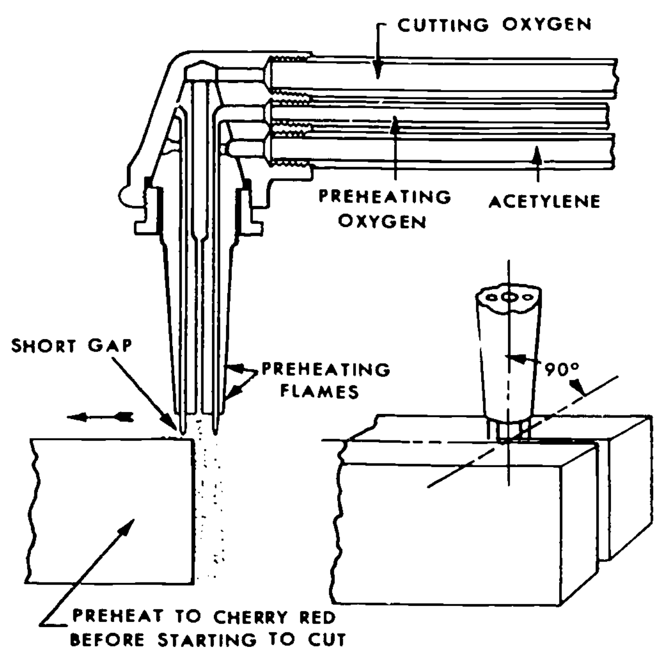

Figure 5-8. Starting a cut.

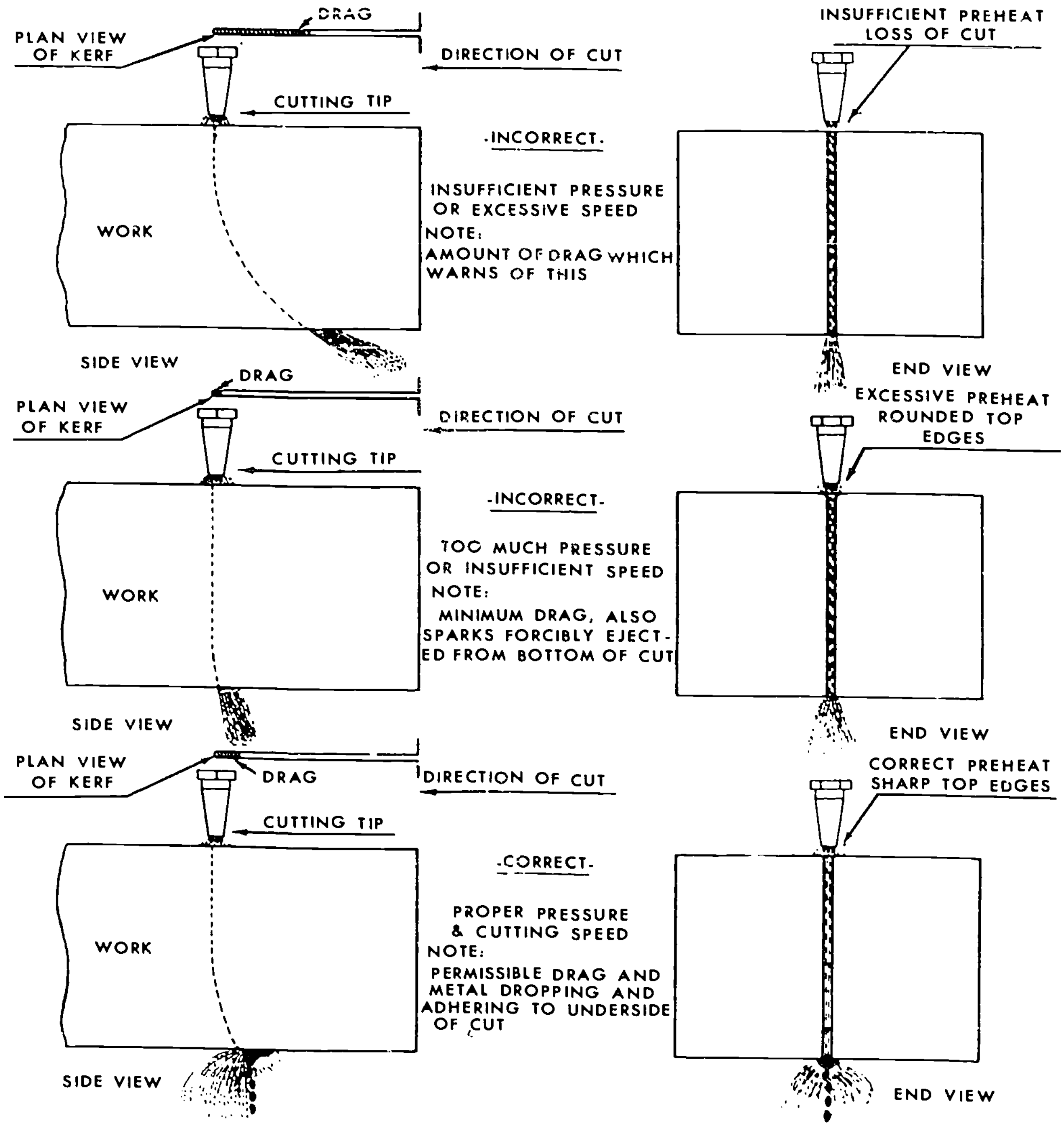

Figure 5-9. Cutting results.

stream combines chemically with the refractory oxides and produces a slag of a lower melting point, which is washed or eroded out of the cut, exposing the steel to the action of the cutting oxygen.

Without iron powder, cutting these steels is a melting process. The best way to cut with the melting method is to lay a steel welding rod or steel plate along the line of cut The heat developed by the reaction of the oxygen with the steel rod or plate is high enough to melt a slot in the stainless steel, and thus produce the cut.

Cast iron. Cast iron melts at a lower temperature than its oxide; therefore, in the cutting operation, the iron tends to melt rather than to oxidize. To prevent melting, use the oxygen jet to wash out and erode the molten metal. To make this action effective, the cast iron must be preheated to a high temperature and a great amount of heat must be liberated deep in the cut. You do this by adjusting the preheating flame to produce an excess of acetylene. The length of the acetylene stream and the procedure for advancing the cut are shown in figure 5-10. Using a mild iron flux to

maintain a high temperature in the deeper recesses of the cut is also shown in figure 5-10.

Safe Cutting Practices. During all cutting operations you must be alert to prevent damage to equipment and injury to personnel from fire and explosion. Observe the following rules to insure safe operation:

a. Never dismantle or salvage magnesium parts with an oxyacetylene cutting torch.

b. Never cut used drums, barrels, tanks, or other containers until they have been thoroughly cleaned. Do the cutting as soon after the cleaning as possible.

c. Move combustible materials to a safe location or move your work to a safe distance from such materials. Set up asbestos or sheet metal guards if they are needed.

d. Do not cut material in a position that permits sparks, hot metal, or the severed section to fall on the cylinder hose, or on your legs or feet.

e. Always wear proper clothing, such as high top shoes, gloves, and clothing without cuffs. Cuffs can collect hot metal and cause a serious burn.

f. Use a fire guard if the work requires protection against fire.

g. When you stop cutting for short periods, release the regulator adjusting screw. Close the complete outfit down when you leave the job.

Exercises (836):

1. How does the oxygen stream affect the red hot metal?

2. What is the space called that is developed in the metal from the cutting action?

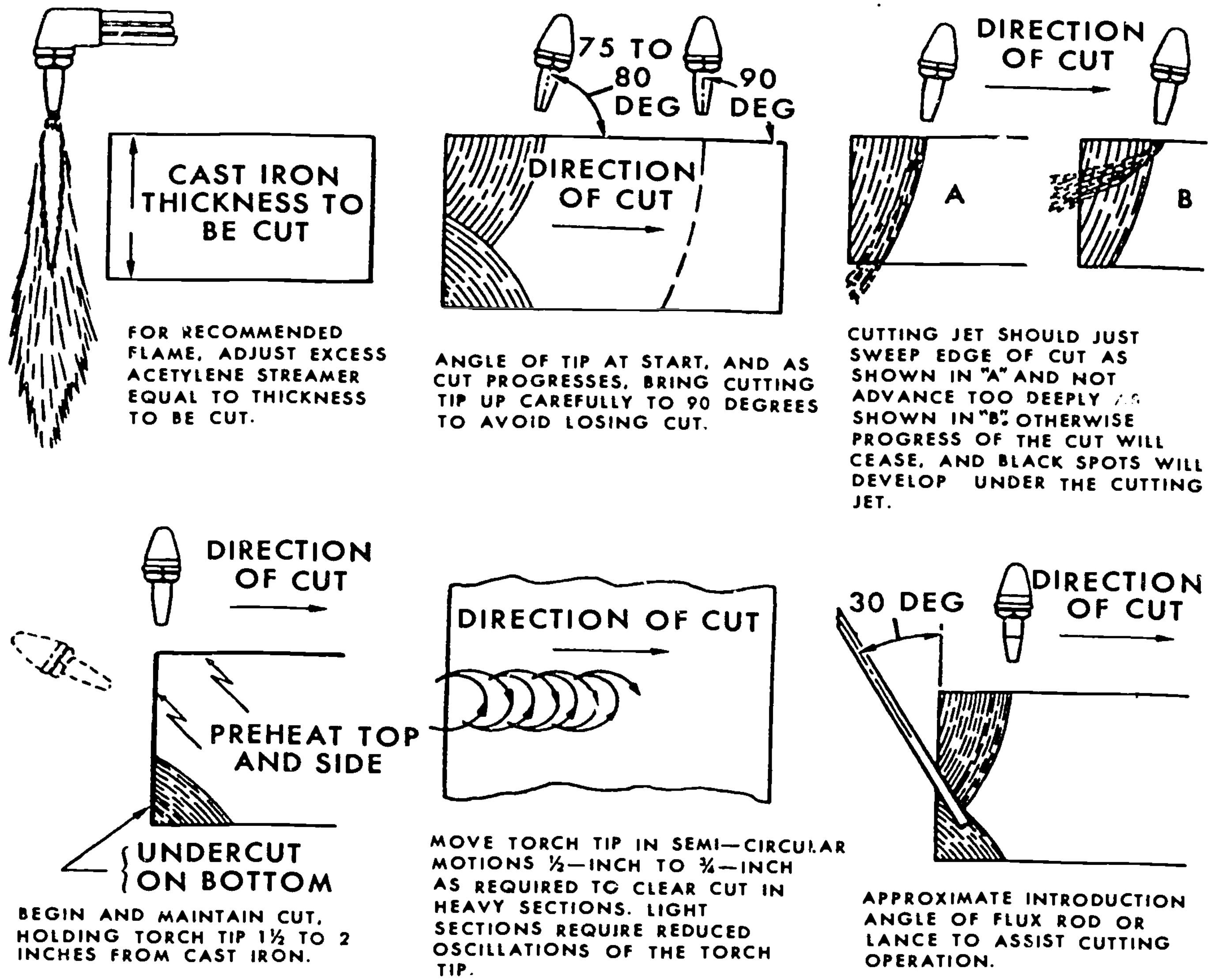

Figure 5-10. Cutting cast iron.

3. How should you adjust the flame for cutting?

4. Which of the metals discussed here is the easiest to cut?

5. Why is safety of great importance in cutting operations?

837. Given a list of procedures, identify the oxyacetylene cutting operation to which each refers.

Several cutting operations can be performed with the oxyacetylene process. Among these are straight line cutting circular cutting, piercing, beveling, cutting round stock, and flame gouging.

Straight Line Cutting. To perform straight line cutting mark the line of cut clearly with a center punch or clamp a guide bar into position to guide the torch accurately, as shown in figure 5-11. The latter method is preferred for a cut of any considerable length.

Circular Cutting. Circular cutting with a hand cutting torch is done with the circular cutting attachment shown in figure 5-12. This attachment is a rod with a clamp attached to one end. The clamp fits the torch head. You can set the adjustable center point on the bar to the desired radius. When you start the cutaway from the edge of the metal, drill or burn a small hole through the metal in the scrap portion a short distance from the circular outline. Start the cut from the edge of this hole.

Piercing. To pierce a hole, you need more time to heat the metal to a kindling temperature than you need for edge-starting. When the desired spot is sufficiently heated, raise the torch about ½ inch above the normal position for cutting, and open the cutting oxygen valve slowly. After burning through the metal, lower the torch to the normal height of the work and complete the cut. Keep the slag from plugging the cutting orifice. This will occur if you hold the torch too close to the work when you first open the cutting oxygen valve.

Beveling. Torch control during beveling is more difficult than for straight square-edge cutting. The speed at which you move the torch and the steadiness with which you move it are essential in a smooth bevel cut. A line made with chalk to indicate the top edge of the bevel will help you. Use a straight edge, clamped into position, as a rest to help you maintain the proper torch angle. The angle made by the cutting oxygen with the surface of the metal produces the bevel.

Cutting Round Stock. To cut round stock, use a chisel to raise a burr on the surface of the metal where the cut is to begin. The burr makes it possible to start cutting without prolonged heating. Start the cut at the side, about 90° from the vertical centerline, as shown in figure 5-13. After starting the cut, raise the torch to the vertical position and hold it in this position for the remainder of the cut. Hold the preheating flame at the same distance from the surface of the metal as you do for cutting sheet stock.

Flame Gouging. By flame gouging, you can quickly and accurately remove a narrow strip of surface metal from steel plate, forgings, and castings. Flame gouging differs from other flame cutting because the cut does not go all the way through the metal (fig. 5-14). By using a tip that deliver a relatively large jet of oxygen at low velocity and by properly controlling and

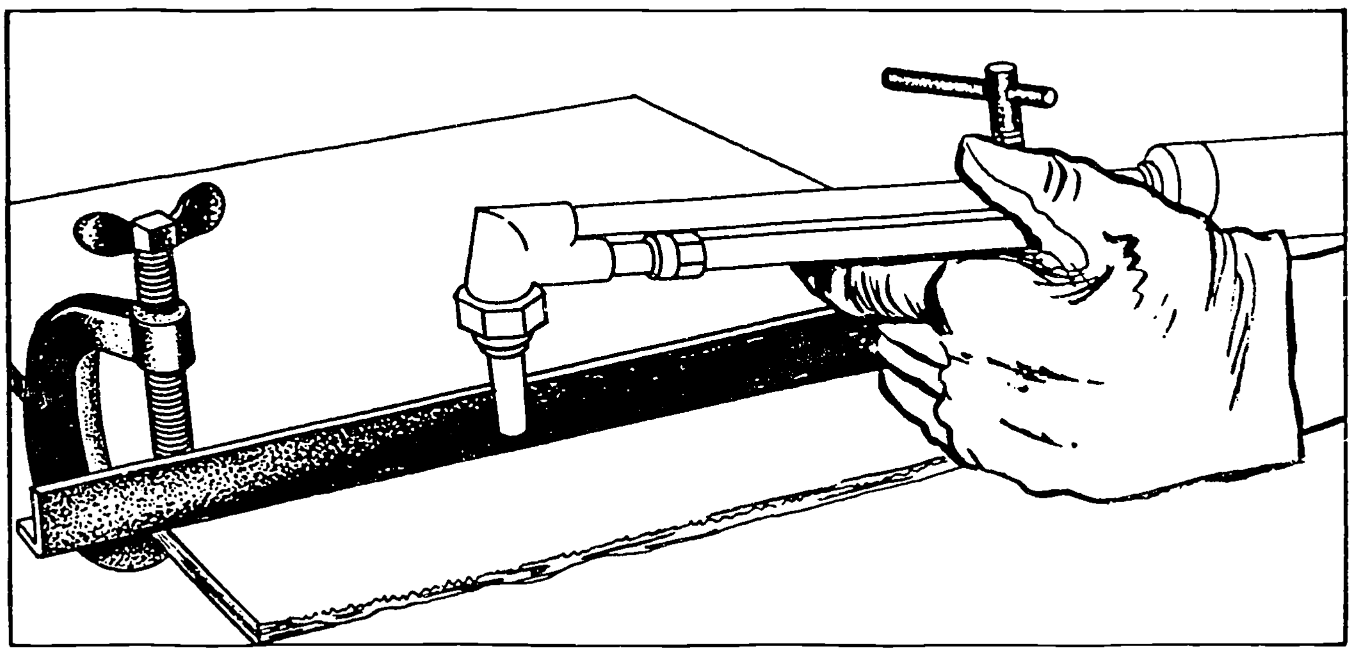

Figure 5-11. Straight line cutting.

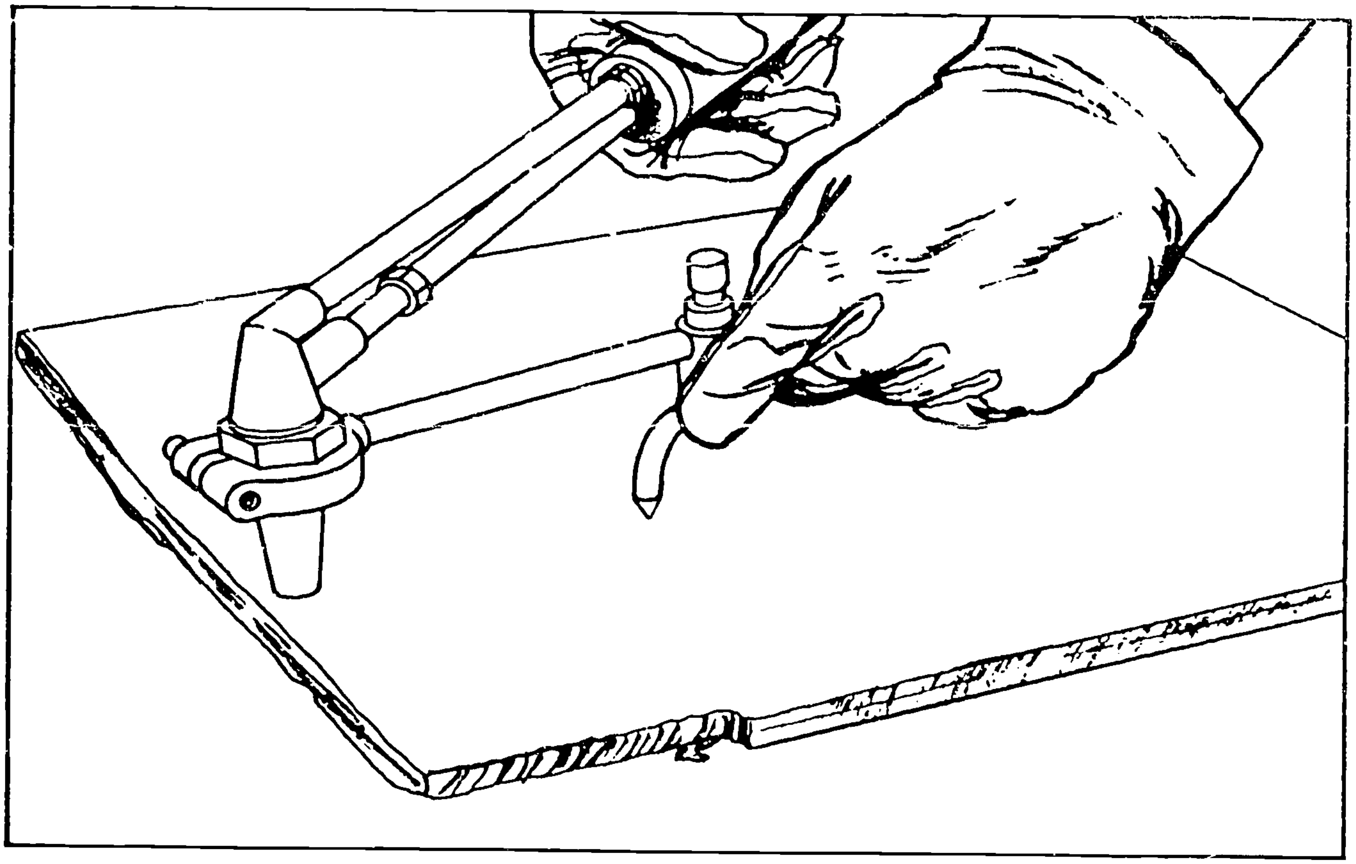

Figure 5-12. Using a circle cutter.

manipulating it, you can gouge and smooth, accurately defined groove out of the surface of the metal. Use different tips and torch manipulations to vary the width and depth of the groove. In general, there are two gouging techniques. In the first, you make the groove progressively across a plate, as when you remove metal from the back of a weld or when you prepare remote cracks for welding. In the other, you gouge out a small area, as when you remove isolated weld defects.

Progressive gouging. To start the cut for progressive gouging, hold the torch with the end of the tip at an angle of about 20° to horizontal. Direct the preheat flame to the starting point until the surface reaches a red heat; then gradually open the cutting oxygen lever. To start the cut, lower the angle of the torch to produce the depth of cut required. The depth of groove depends upon the size of tip, the speed of travel, and the angle between the cutting oxygen stream and the work. To cut a deep groove, increase the angle of the torch in relation to the groove and decrease the speed correspondingly. To make a shallow groove, reverse the procedure. The contour of the groove depends upon the characteristics of the tip and the operating conditions. If the cutting oxygen pressure is too low, the cutting has a washing effect, leaving ripples in the bottom of the groove. The effect of a too high cutting

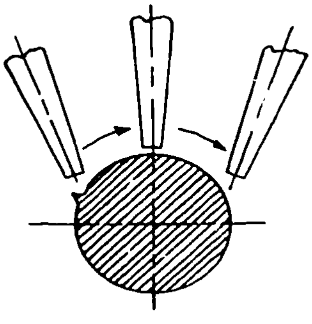

Figure 5-13. Cutting round stock.

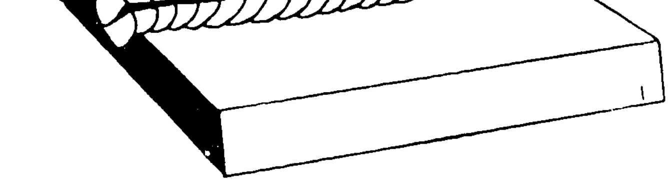

Figure 5-14. Flame gouging.

pressure, especially in the shallow groove, is to advance the cut nearest the surface ahead of the rest of the molten zone, resulting in loss of cut.

Spot gouging. To gouge out a single spot, as in spot gouging a weld defect, first mark on the surface the area to be removed. Adjust the preheat flame to slightly oxidizing. Preheat a point slightly to the rear of the defect and start the cut in the usual way. Gradually increase the torch angle so that the oxygen jet is directed downward, making the cut increasingly deeper. You can detect defects during gouging because they appear as dark spots in the molten zone. Hold the torch with the preheating flame approximately 1/16 inch above the plate surface during the cut. Use an oxidizing preheat flame, because it provides a sufficient amount of concentrated heat for starting and eliminates the need for raising a burr to help start the cutting.

Exercises (837):

1. Match each procedure with the correct type of cutting operation:

___ 1. Hold the torch with the preheating flame about 1/16 inch above the plate surface.	a. Straight line cutting.
___ 2. Clamp a guide bar into position.	b. Circular cutting.
___ 3. Hold the torch with the end of the tip about 20° to horizontal.	c. Piecing.
___ 4. Set the adjustable center point to the correct radius.	d. Beveling.
___ 5. Remove surface metal.	e. Cutting round stock.
___ 6. Raise the torch about ½ inch above the normal position and open the cutting oxygen valve slowly.	f. Flame gouging.
___ 7. Raise a burr on the surface where the cutting is to begin.	g. Progressive gouging.
___ 8. Use a chalk line to indicate the top edge and a clamped straightedge as a rest.	h. Spot gouging.

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Forging

IN THIS CHAPTER we will discuss one of the many other applications of oxyacetylene welding: forging. We will examine forging in three areas: temperatures, operations, and heat treating.

6-1. Forging

The oldest process for joining metal parts is forge welding, a process used by the village blacksmith. Today, the forge and the sledge hammers have been replaced almost completely by a variety of welding processes for fabricating and welding metals and their alloys. Occasionally, however, small tools, rings, and hooks are forged, and various hammering operations, such as drawing, upsetting, and bending are needed.

If the forging process is properly carried out, it does not damage the metal; in fact, it actually improves it. The grain structure is refined because the large grains are broken up to form a fine grain structure.

838. State the heat colors of steel in their corresponding forging temperature.

Temperatures. Steel is forged at temperatures that ar well above the critical range but also well below the melt point. *Normally* (not always), you will be equipped with temperature sticks, crayons, or drops. These measuring device indicate the temperature of heated steel to within a workable tolerance. If you do not have temperature measuring equipment you must judge temperature by the color of the hot iron or steel.

For good forging, you must heat the metal uniformly. A parts should be at the same temperature all the way through Too rapid heating expands the metal unevenly and starts cracks. This is especially dangerous in high carbon or high alloy steel. Forging temperatures that are too high produce a large grain size in the finished product. If you overheat the metal, there will be holes or oxide inclusions in the finished product. This is commonly called burning. Oxide forms as a crust on metal that is heated excessively and the met may overlap the oxide, forming a weak spot. Forging at temperatures that are too low leaves the steel highly stressed, a condition to avoid, as it shortens the life of the finished product. If stresses do occur, you can correct them by heat treating.

Now look at figure 6-1. Note that when the heated steel reaches a dull orange color at slightly above 2100° F., it can be forged. For pieces requiring more forging, heat to higher temperatures. Continue forging until the color changes to a cherry or full red at some point between 1,300° F. and 1,400° F. Continue until the full red color begins to change to dark cherry red and strike the final forging blows at this point. If you do not continue to this lower temperature, the structure of the steel will be weakened and the grains will "grow" to larger size because of the heat retained in the steel.

Exercises (838):

Refer to text figure 6-1 to answer some of the following questions.

1. What color is steel in the upper forging limit?

2. What color and temperature is steel with 0.8 percent of carbon before it enters the "Danger of Burning" zone?

3. Between what forging temperatures do steels change to a cherry or full red?

4. Forging operations may begin when the steel reaches a ____________ color and should stop when the color ____________

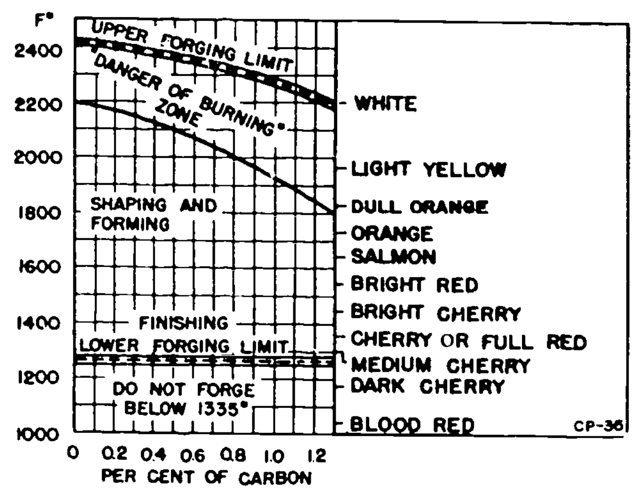


Figure 6-1. Forging temperatures.

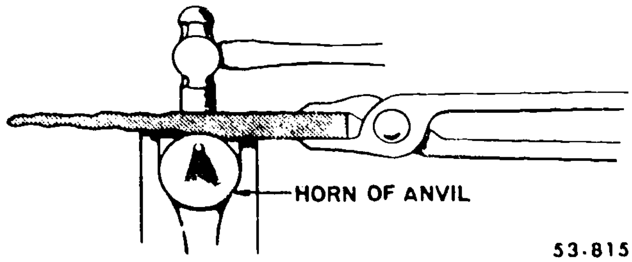


Figure 6-2. Drawing flat stock.

839. Specify the techniques used in forging.

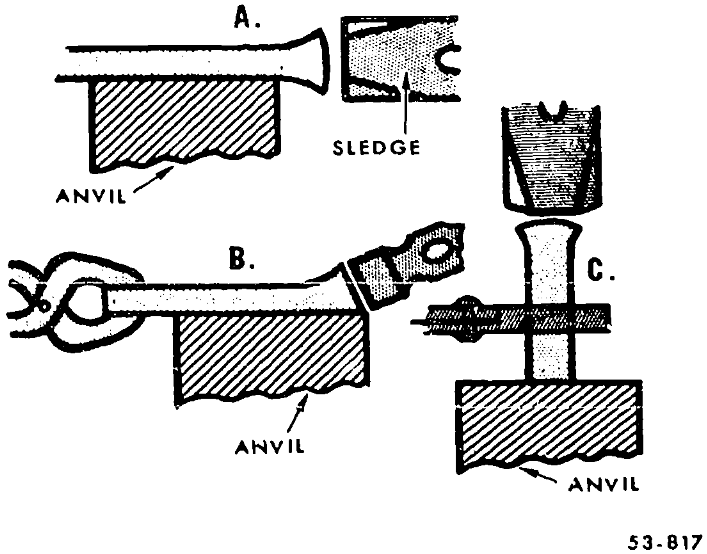
Operations. When they are heated to the proper forging temperatures, steel and soft iron can be hammered into almost any shape. The forging operations are called drawing, upsetting, and bending.

Drawing. To draw is to work a piece of metal to increase its length or width, or both, and to reduce its cross secton. To increase both length and width, hammer the metal over the flat face of the anvil. To increase the length only, hammer the metal over the anvil horn, as shown in figure 6-2. The horn acts as a blunt wedge to spread the metal and force it lengthwise. Round stock can be drawn out to a point tip by the method shown in figure 6-3. Forge it square first, then octagonal, and then round again. Forge it with as few blows as possible. Try to do all the forging without reheating.

Upsetting. Upsetting is the reverse of drawing. The length is decreased and the cross section is increased. A higher temperature is required for upsetting than for drawing. The temperature must be near the upper forging limit. You can upset a short piece of steel by placing it on the anvil and striking it with a hammer or sledge. Hold longer pieces with tongs. If a long piece bends as it is being upset, straighten it immediately. Heat only the portion of the metal to be upset. Upsetting may be done by the method shown in figure 6-4.

Bending. Square and angle bends are formed over an edge of the anvil face, as shown in figure 6-5. A helper holds the metal down with a heavy sledge. Note that you start the bend at the end of the piece and not at the point of bend. The bend may be finished square inside or outside or rounded. If you need an inside radius, bend the metal over a rounded corner of the anvil. An angle bend is stronger if the area to be bent is enlarged by upsetting. To upset the rod or bar, heat it at the point of bend and, holding it vertically by one end, strike the other end against the floor. Then bend the rod or bar in a vise or over an anvil to the desired angle, using the extra metal to reinforce the bend. Start curved bends over the rounded anvil horn, as shown in figure 6-6. Remember that you start the curve at the end of the piece.

Rings are also forged in this way. One method of bending an eye is illustrated step by step in figure 6-7. Start the bend over the edge of the anvil (step 1) and complete it around the horn to desired size (steps 2, 3, and 4). Figure 6-8 illustrates forged parts.



A. Horizontal upsetting
B. Angular upsetting
C. Vertical upsetting

Figure 6-4. Upsetting.

Exercises 839:

1. When a piece must be made thicker at one end, the operation is known as ____________

2. Where are most forging bends started?

3. What can you do to reinforce curved bends?

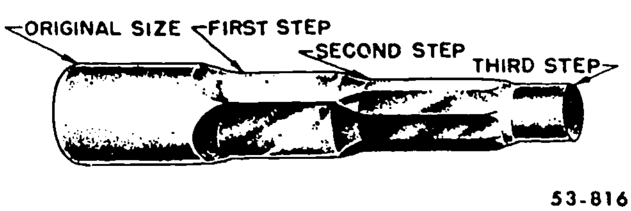


Figure 6-3. Drawing round stock.

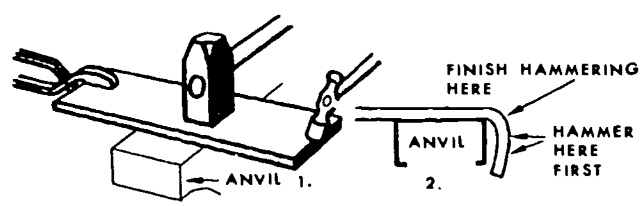


Figure 6-5. Square bending.

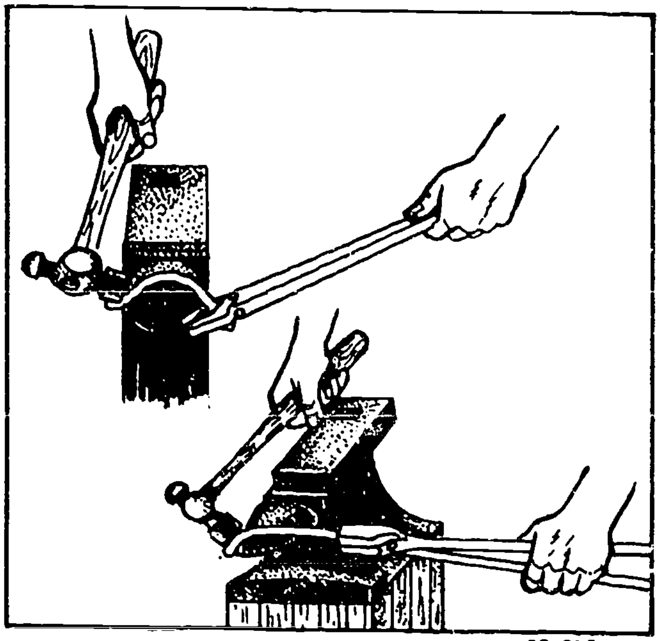


Figure 6-6. Bending curves.

4. The forging operation in which is lengthened or widened is known as ____________

840. Cite factors in stress relieving and tempering.

Stress Relieving. Stress relieving is a heat treating operation to relieve stresses induced by forging, welding, forming, and machining. The temperature for stress relieving is usually 1,200° F. The metal must cool slowly, as in furnace cooling. If the metal cools rapidly, no structural change occurs, but the minor stresses set up during cooling can lead to later failure of the part. To eliminate this danger, you must apply enough heat to practically anneal the metal, but above the low critical point. Frequently, steels that can be hardened require stress relieving.

Tempering. Color tempering is based on the oxide color that appear on the surface of steel as it is heated. If the surface is polished and the hardened steel is heated slowly, the surface turns various colors, which

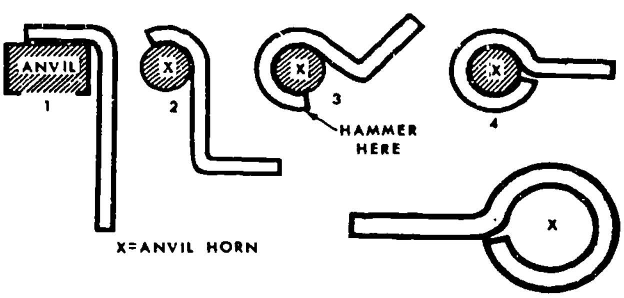


Figure 6-7. Bending an eye.

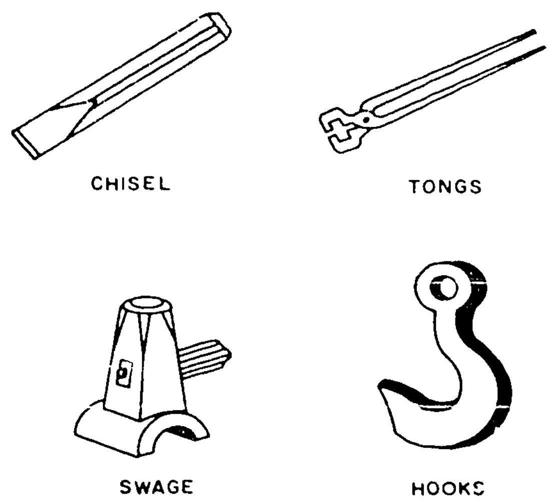


Figure 6-8. Forged parts.

are approximate indications of temperatures. Figure 6-9 shows the temperatures according to the colors of tempering steel In soft steel, these colors indicate no structural change; but in hardened carbon steel, they denote changes that correspond to specific temperatures. When the proper color appears, quench the part rapidly to prevent further structural change. In color tempering, the surface of the steel must be free of oil and reasonably smooth, like the smoothness produced by a coarse emery wheel. You can heat the part with a torch, in a furnace, over a hotplate, or by radiation.

Cold chisels and similar tools must have hard cutting edges and softer bodies and heads, with the head tough enough to prevent its shattering when you strike the chisel with a hammer. The cutting edge must be more than twice as hard as the head, and the zone separating the two must be blended carefully to prevent the development of a line of demarcation. A method frequently used to color temper chisels and similar tools is to heat the cutting end with the hot end of the same tool. To harden and temper a cold chisel by this method, heat the entire tool to the proper hardening temperature, then quench the cutting end only. Bob the chisel up and down in the bath, always keeping the cutting edge below the surface. The head air-cools and

Very light straw	**430°**
Straw	**445°**
Dark straw	**470°**
Brown or bronze	**490°**
Bronze dappled with purple	**510°**
Purple	**530°**
Dark blue	**550°**
Bright blue	**570°**
Pale blue	**600°**
Bluish gray	**640°**

CP-34

Figure 6-9. Color temperature indications.

the cutting edge quenches rapidly. The head becomes tough, the cutting edge hardens fully, and the two structures blend properly.

When the cutting end has cooled, remove the chisel from the bath, quickly polish the cutting end with a buff stick (emery) so that you can watch the polished surface as the heat from the opposite end feeds back into the quenched end. As the temperature of the hardened end increases, oxide colors appear, progressing from a pale yellow, throug the straw colors to the blues, as shown in figure 6-9. As soon as the correct shade of blue appears on the cutting edge, the body and head will have cooled in the air to below the critical point and will not be hardened during the final quench. When the process just described is completed, the chisel is hardened and temperated and needs only to be ground to be ready for use. A slight stress is set up by the quench from the tempering temperature, but it is minor.

During color tempering, you must have favorable light, and you must turn the part from side to side so that you can see the colors. You obtain the same structure as you obtain when you heat the part in a furnace with accurate temperature controls, but your chance of error is greater if you depend upon visual temperature indications.

Exercises (840):

1. What type of steel frequently requires stress relieving?

2. To eliminate stress, how hot must the metal be and how is it cooled?

3. At what temperature will a dark straw color appear when steel is tempered?

4. What color should appear on the steel when the final quench is performed in the tempering process?

5. When you are tempering a cold chisel, why do you polish the cutting end quickly when it has cooled?

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ANSWERS FOR EXERCISES

Chapter 1

Reference:

800 - 1. Stationary outfits are supplied from manifolded cylinders, and portable outfits are supplied from portable tanks.
800 - 2. To within 12 ½ to 15 feet of the welding outfit.
800 - 3. Until that one part is repaired or replaced.

801 - 1. Single-stage regulator.
801 - 2. Acetylene gas.
801 - 3. Welding goggles, flint lighter, and fire extinguisher.
801 - 4. In the mixing head and torch tip.
801 - 5. The slot is the correct size to tighten all connections.
801 - 6. To keep acetone from escaping.
801 - 7. Replace the safety cap, mark the cylinder "MT," and secure it in an upright position and separated from other type cylinders in the empty area.
801 - 8. Oxygen is under great pressure, and a broken valve or pierced cylinder could make a missile out of the cylinder and cause injury and damage.
801 - 9. The cylinder is filled with acetone to 40 percent of its liquid volume, allowing space for expansion as the acetone absorbs the acetylene and stabilizes it under pressure.

802 - 1. To blow out any dirt which may be lodged in the outlet nipple.
802 - 2. Oxygen valves are opened fully. Acetylene valves are opened no more than one-half turn.
802 - 3. Torch wrench.
802 - 4. Acetylene threads are left-handed, and oxygen threads are right-handed.

803 - 1. The acetylene valve.
803 - 2. Direct the flame away from yourself and anything flammable.
803 - 3. Keep your hand at one side of the tip.
803 - 4. The disappearance of the feather at the end of the central cone.
803 - 5. Within the inner cone of the flame.

804 - 1. The gas volume is one to one in a neutral flame. There is slightly more than 1 volume of oxygen to 1 volume of acetylene in an oxidizing flame.
804 - 2. Oxidizing flame with a temperature of approximately 6,300° F.
804 - 3. An excessive amount of acetylene in the flame.
804 - 4. The presence of three distinct flame cones.

805 - 1. To prevent the fire from moving through the hose and regulator into the supply line or cylinder an causing an explosion.
805 - 2. To relieve the pressure on the regulator diaphragm and prevent damage to it.
805 - 3. The acetylene valve.
805 - 4. A flashback is the burning of the acetylene gas inside the torch. It is indicated by a high-pitched whistle.

806 - 1. Be sure the gas supply is shut off.
806 - 2. Replace the cylinder valve safety cap.

807 - 1. A container of soapy water, a brush, and a bucket of clear water.
807 - 2. Brush the soapy water on the connection. If it bubbles, it leaks.
807 - 3. Ten.
807 - 4. Submerge them in the bucket of clear water and watch for bubbles.

808 - 1. The working pressure gage after the cylinder valve is opened.
808 - 2. Fluctuating gage pressure; gas leaking from the gage case.
808 - 3. Replace.
808 - 4. Manufacturer.

809 - 1. Number 1 tip cleaner. To keep from enlarging the orifice.
809 - 2. To prevent enlarging the orifice.
809 - 3. Yes, because too much cleaning will eventually enlarge the orifice.
809 - 4. Stop using it and check the tip seats for nicks or flat spots; and if you find any, replace the tip. Also check the torch seats. Leaking gas can produce flashback.
809 - 5. To prevent flame distortion.

810 - 1. Low carbon steel, medium carbon steel, high carbon steel, and high carbon tool steel.
810 - 2. Medium carbon steel.
810 - 3. High carbon content and the heat treatment needed to develop special mechanical properties.
810 - 4. You should stress-relieve this steel by heating it uniformly to a temperature between 1,200° F. and 1,450° F. and cooling it slowly.

811 - 1. Metal thickness and its rate of heat conductivity and radiation.
811 - 2. It produces excessive heat, burns the weld metal, and produces a weak weld.
811 - 3. The type depends upon the type of the metal welded and the size depends on the thickness of the metal welded.

812 - 1. Raise and lower the flame with a slightly circular motion while progressing in a forward direction to make beads without a rod. Move the flame slightly side to side when using a rod.
812 - 2. Hold the torch tip at a 45°-860° angle to the plate surface with the flame always pointed in the direction of welding.
812 - 3. In the backhand method, positioning the welding rod and tip requires less transverse motion.
812 - 4. By the speed of welding and the amount of metal deposited from the weld rod.

813 - 1. Flat, vertical, horizontal, and overhead.
813 - 2. Force of gravity upon the molten pool.
813 - 3. The parts are at an angle greater than 45°, and the seam runs vertically.
813 - 4. Keep the tip at an angle of 45° to the plate surface and inclined slightly in the vertical plane. The seam runs parallel to the flat surface.

814 - 1. Square weld.
814 - 2. By the weld symbol on the side of the reference line toward the reader.
814 - 3. Fillet.

815 - 1. Single-fillet lap joint, double-fillet lap joint, and joggled lap joint.
815 - 2. Joggled lap joint.
815 - 3. Fillet welds.
815 - 4. Double-fillet.

816 - 1. 1/16 inch minimum.
816 - 2. Slightly convex.
816 - 3. Upper leg should equal the thickness (T) of the base metal; the lower leg should equal 1 ½ times T.
816 - 4. Penetration.

817 - 1. Rigid and open.
817 - 2. 1 ½ inches.
817 - 3. Special edge preparation is not required.
817 - 4. Horseshoe shape.
817 - 5. Use the correct tip size, use the correct welding rod, adjust the flame properly, and manipulate the torch and rod properly.
817 - 6. 100 percent penetration for all butt joints.

818 - 1. ¼ inch.
818 - 2. To allow the use of the welding heat to the greatest advantage.
818 - 3. To the upper edge of the molten pool.
818 - 4. Approximately 60° from horizontal.

819 - 1. To join the edges of sheet metal and to weld reinforcing plates in flanges of I-beams or edges of angles.
819 - 2. Boxes, box frames, tanks, and similar fabrications.

820 - 1.
a. Unstabilized.
b. Unstabilized.
c. Unstabilized.
d. Stabilized.
e. Unstabilized.
f. Stabilized.
g. Stabilized.
h. Unstabilized.
i. Unstabilized.

820 - 2. Aircraft exhaust manifolds and expansion joints.
820 - 3. Unstabilized group.

821 - 1. Carbide precipitation, warpage, and oxidation.
821 - 2. Stabilized group such as 321 or 347.
821 - 3. Because of the high coefficient of expansion and the low heat conductivity.
821 - 4. By using a slightly carburizing flame and by applying flux to heat-affected areas not protected by the flame.
822 - 1. The penetration does not extend to the bottom of the joint.
822 - 2. Forehand welding.
822 - 3. To permit a close fit up.
822 - 4. To prevent the oxidation of the rod, which would be transferred to the weld.

823 - 1. Reflux the joint.
823 - 2. Remove all scale, oxides, grease, and oil from the surface, and space the open end of the joint ⅛ inch per foott of seam length.
823 - 3. The tip for welding stainless steel is one or two sizes smaller than the tip used for the same thickness of carbon steel.
823 - 4. The flame should be "feathered off."

824 - 1. A maximum of 1 ½ inches apart.
824 - 2. Bevel the vertical plate and clean the edge of that plate and the surface of the other plate to remove all oxides, grease, and oil. Be sure there are no burrs to hinder spacing. Space the vertical plate 1/32 inch above the horizontal plate and tack weld.
824 - 3. To prevent cracks from forming along the line of weld.
824 - 4. By proper joint preparation, proper and sufficient fluxing, and using correct wwelding techniques, such as feathering off.

825 - 1. Weight; wear resistance; rigidity; high compression strength.
825 - 2. Hardness is necessary and where good wear and abrasion resistance are required.
825 - 3. Gray cast iron; white cast iron; malleable cast iron.

826 - 1. Lightly touch apart of the casting to a high-speed grinding wheel.
826 - 2. By the ease with which the metal is chipped and the form of the chip.
826 - 3. Compare its spark stream with that of a known metal.
826 - 4. In color, density, shape, and length.
826 - 5. Gray cast iron to some extent; malleable cast iron to a greater extent.

827 - 1. To reduce the expansion and contraction that cause distortion, cracks, and breaks.
827 - 2. Clean the casting and drill a small hole at the end of the crack to keep the crack from spreading.
827 - 3. The tip should be slightly larger than the tip used for the same thickness of steel.
827 - 4. Backhand method.
827 - 5. To keep oxides and impurities out of the welded by floating them to the surface.

828 - 1. Only local heating.
828 - 2. Brazing has little effect upon malleability because of the lower temperature needed.
828 - 3. A physical bond.
828 - 4. Most brazed joints are almost as strong as welded joints, with no effect upon the base metal's properties.

829 - 1. Sandblast or sear the edges to remove the free carbon.
829 - 2. Progress only as fast as the tinning progresses.
829 - 3. Neutral.
829 - 4. For brazing, all sharp corners are removed to produce round edges and a smooth surface.

830 - 1. Hard facing affects hardness, toughness, shock resistance, wear resistance, and other special qualities.
830 - 2. Because of their brittleness and the shrinkage cracks that develop in the base metal after hard facing.
830 - 3. High-speed steels, brasses and bronzes, copper and copper alloys, and aluminum and aluminum alloys.

831 - 1. Carburizing.
831 - 2. Corners and edges are rounded before hard surfacing.
831 - 3. It should be two sizes larger.
831 - 4. They are sweated onto a base metal of steel.
831 - 5. False.
831 - 6. Some hard-facing alloys are puddled into the base metal, and others are merely sweated onto it.

832 - 1. 1,175° F. to 1,600° F.
832 - 2. Capillary attraction.
832 - 3. 800° F.
832 - 4. Joint fitup and the quality of the bond.

833 - 1. Neutral to slightly carburizing.
833 - 2. Most of the heat should be applied on the thicker metal.
833 - 3. Complete cleaning is necessary to insure uniform capillary attraction throughout the joint.

833 - 4.
a. Sandblasting.
b. Chemical cleaner— trichloroethylene or trisodium phosphate.
c. Hot water.

834 - 1. Oxyacetylene flame heating, wiping, sweating, or dipping in a solder bath.
834 - 2. The parts must be cleaned of oxide, scale, oil, and dirt, and must be adequately fluxed and fitted together.
834 - 3. The higher the lead content, the higher the melting point.
834 - 4. Indirect heating.

835 - 1. It converts a welding torch to a cutting torch and is used for intermittent cutting of lighter sections.
835 - 2. 30°.
835 - 3. Preheating.
835 - 4. Two.
835 - 5. One in which several torches perform identical cutting actions at the same time.

836 - 1. The oxygen stream combines with the hot metal to burn it to an oxide, which generates the intense heat used for cutting.
836 - 2. Kerf.
836 - 3. use the torch needle values to adjust the flame to neutral. Then open the cutting oxygen valve and adjust the flame to neutral again.
836 - 4. Plain carbon steel (no more than 0.35 percent carbon).
836 - 5. During all cutting operations, you are dealing with intense heat, fire, and the possibility of explosion.

837 - 1. h.
2. a.
3. g.
4. b.
5. f.
6. c.

7. e.
8. d.

838 - 1. White.
838 - 2. Light yellow and 2,000° F.
838 - 3. 1,300° F. to 1,400° F.
838 - 4. Dull orange, begins to change to a dark cherry red.

839 - 1. Upsetting.
839 - 2. Most bends start at the end of the piece to be bent.
839 - 3. Before bending, upset the piece at the point of bend.
839 - 4. Drawing.

840 - 1. Steel that can be hardened frequently requires stress relieving.
840 - 2. 1,200° F. and cooled very slowly.
840 - 3. 470°.
840 - 4. Blue.
840 - 5. So you can see the colors change when the cutting end reheats.

1985-631-028/20749 AUGAFS,AL(860968)600

STOP- 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

55252 05 22

OXYACETYLENE WELDING

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (800) Which welding outfit uses single-stage regulators and why?
   a. Portable, low pressure tanks.
   b. Portable, high pressure tanks.
   c. Stationary, manifold supplies low pressure.
   d. Stationary, manifold supplies high pressure.

2. (801) The purpose of a single-stage regulator in oxyacetylene welding equipment is to reduce
   a. cylinder pressure to working pressure.
   b. line pressure to cylinder pressure.
   c. manifold pressure to line pressure.
   d. tank pressure to torch pressure.

3. (801) Oxygen and acetylene hoses are colored
   a. red and green, respectively.
   b. green and black, respectively.
   c. green or black and red or maroon, respectively.
   d. red or black and maroon or green, respectively.

4. (802) When assembling oxyacetylene equipment, the acetylene cylinder valve is opened a maximum of
   a. one tum.
   b. one-half turn.
   c. one and one-half turns.
   d. one and one-quarter turns.

5. (802) A safety feature in the assembly of oxyacetylene equipment is that
   a. acetylene connections have left-handed threads and oxygen connections have right-handed threads.
   b. acetylene connections have right-handed threads and oxygen connections have left-handed threads.
   c. all connections have right-handed threads.
   d. all connections have left-handed threads.

6. (803) When adjusting regulators for working pressure, the torch valves are
   a. opened.
   b. closed.
   c. either opened or closed.
   d. opened together.

7. (803) When lighting the welding torch you should always use
   a. safety matches.
   b. a flint igniter.
   c. an electric sparker.
   d. a torch igniter.

8. (804) The temperature of a neutral oxyacetylene welding flame is
   a. 5700 degrees F.
   b. 5750 degrees F.
   c. 5850 degrees F.
   d. 6300 degrees F.

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9. (804) The neutral flame is produced by mixing approximately

   a. one part of acetylene to one part of oxygen.
   b. open and one-half parts of acetylene to one part of oxygen.
   c. one and one-half parts of acetylene to two parts of oxygen.
   d. one part of acetylene to one and one-half parts of oxygen.

10. (805) When closing down welding equipment, the regulators are bled primarily to

   a. clean out the hoses.
   b. prevent relighting of the torch.
   c. release pressure on the diaphragm.
   d. release pressure on the torch valves.

11. (805) If a flashback occurs in oxyacetylene welding equipment, the correct action to take is to first close the

   a. acetylene valve.
   b. acetylene valve and then the oxygen valve.
   c. oxygen valve and then the acetylene valve.
   d. oxygen and acetylene valves simultaneously.

12. (806) When disassembling welding equipment, you must first

   a. bleed the regulators.
   b. turn off the gas supply.
   c. disconnect the cylinders.
   d. remove the cylinder safety cap.

13. (806) Part of disassembly of oxyacetylene welding equipment is to

   a. tighten the union nut.
   b. safety cap cylinders or lines.
   c. check the regulators for leaks.
   d. check the high pressure in the cylinders.

14. (807) Welding apparatus connections should be tested for gas leaks with

   a. soapy water.
   b. a bar of soap.
   c. caustic soda.
   d. liquid salammoniac.

15. (807) What is used to check hoses for leaks?

   a. Powder.
   b. Gas leak detector.
   c. Bucket of clear water.
   d. Soapy water and a brush.

16. (808) Creeping regulators are caused by

   a. damaged diaphragms.
   b. broken bourdon tubes.
   c. broken or worn out springs.
   d. cracked or worn regulator seats.

17. (808) Leaking oxyacetylene hoses are usually repaired by

   a. replacing them.
   b. using hose tape.
   c. using a hose splice.
   d. using a special hose sealer.

18. (809) When cleaning a tip you must use a straight back-and-forth motion to prevent

   a. distorted preheating.
   b. scouring the tip face.
   c. enlarging the orifice.
   d. clogging the tip with fillings.

19. (809) What size of welding tip cleaner is used for a number 6 tip when it malfunctions because of dirtiness?

a. Number 4 tip cleaner.
b. Number 5 tip cleaner.
c. Number 6 tip cleaner.
d. Number 7 tip cleaner.

20. (810) Steels that are used extensively for ground installation parts are known as

a. low carbon steels.
b. medium carbon steels.
c. high carbon steels.
d. high carbon tool steels.

21. (810) What group of carbon steels has a carbon content of .35 percent?

a. Low carbon steels.
b. High carbon steels.
c. Medium carbon steels.
d. Tool steels.

22. (810) The group of steels which have the highest degree of hardness are the

a. low carbon steels.
b. medium carbon steels.
c. high carbon steels.
d. high carbon tool steels.

23. (811) The selection of the filler rod and torch tip size depend upon the

a. size of the base metal.
b. thickness of the base metal.
c. composition of the base metal.
d. heat conductivity rate of the base metal.

24. (811) Selecting a welding tip size that is too large will usually result in

a. burning of holes in material.
b. excessive penetration of heat.
c. metals protruding on the side of the weld.
d. all of the above.

25. (811) What is the smallest oxyacetylene filler rod available?

a. 1/64 inch diameter.
b. 1/32 inch diameter.
c. 1/16 inch diameter.
d. 1/8 inch diameter.

26. (812) When using the forehand method of welding, the torch tip is held at an angle of

a. 45 degrees to 60 degrees.
b. 45 degrees to 70 degrees.
c. 40 degrees to 70 degrees.
d. 40 degrees to 60 degrees.

27. (812) Backhand welding is primarily used for welding

a. heavy sections.
b. light sections.
c. tubular assemblies.
d. square edges.

28. (813) What welding position is used for parts flat on the table, or inclined at an angle less than 45°?

a. Flat position.
b. Overhead position.
c. Vertical.
d. Horizontal.

29. (813) On a horizontal weld, what should you do to keep the molten metal from sagging to the lower edge of the weld?

a. Incline the tip slightly.
b. Add the filler on the high side.
c. Place a heat sink on the high side.
d. Start at the bottom and weld up.

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30. (814) A weld symbol that looks like a right triangle indicates a

a. plug weld.
b. seam weld.
c. spot weld.
d. fillet weld.

31. (814) A circle is a supplementary symbol indicating

a. field weld.
b. fillet weld.
c. weld all around.
d. plug weld.

32. (815) When welded from one side and with no edge machining required, use the

a. doub'e-fillet.
b. single-fillet.
c. joggled single-fillet.
d. double-or-single fillet.

33. (815) Which type of lap joint develops the full strength of the base metal?

a. Butt.
b. Joggled.
c. Single-fillet.
d. Double-fillet.

34. (815) What type of welding joint is used to keep metal on the same plane?

a. Butt-lap joint.
b. Joggled lap joint.
c. Double-fillet lap joint.
d. Single-fillet lap joint.

35. (816) Penetration for a lap joint of 1/4 inch metal is a minium of

a. 20 percent.
b. 30 percent.
c. 40 percent.
d. 50 percent.

36. (816) The throat of a lap joint should always equal the

a. minimum penetration.
b. same as the lower leg.
c. thickness of the base metal.
d. thickness of the heaviest metal.

37. (816) Where is the flame pointed when welding a lap joint?

a. At the vertical sheet.
b. In the direction of travel.
c. Into the heart of the weld.
d. At a 45 degree angle to the metal.

38. (817) The requirement for penetration on butt joints regardless of metal thickness is

a. 30 to 50 percent.
b. 50 to 75 percent.
c. 80 to 100 percent.
d. 100 percent.

39. (817) When welding a butt joint, how is the horseshoe reestablished?

a. With the end of the filler rod.
b. With the torch tip and filler rod.
c. By using heat and force of the flame.
d. By using filler rod and flame pressure.

40. (818) When oxyacetylene welding tee joints, the metal is spaced to

a. permit easy fusion.
b. prevent overheating.
c. prevent underheating.
d. decrease the penetration.

41. (818) When welding tee joints, the filler rod is added to the upper edge of the molten pool to help guard against

a. over thick throat.
b. overlapping the upper edge.
c. undercutting the upper edge.
d. undercutting the lower plate.

42. (819) The common type of corner joint used to construct boxes is the

a. open-type joint.
b. closed-type joint.
c. fillet weld joint.
d. beveled-edge joint.

43. (819) Reinforcement plates in I-beam may be satisfactorily welded for strength by using

a. a butt joint.
b. an edge joint.
c. a corner joint.
d. all of the above.

44. (820) The stabilization of 321 stainless steel is accomplished by using

a. carbon.
b. chromium.
c. titanium.
d. columbian.

45. (820) The use of a suffix ''L'', such as 316L, indicates a stainless steel which has

a. a low-carbon content.
b. an extra-low-carbon content.
c. 50 percent lithium.
d. 3 percent lead.

46. (820) 321 and 347 stainless steels are used primarily for repair of

a. intake shafts.
b. aircraft exhaust manifolds.
c. aircraft propeller shafts.
d. kitchen equipment.

47. (821) When oxyacetylene welding stainless steel, warping is sometimes caused by a

a. high coefficient of expansion and low heat conductivity.
b. low coefficient of expansion and heat conductivity.
c. high coefficient of expansion and low heat conductivity.
d. low coefficient of expansion and high heat conductivity.

48. (821) Oxyacetylene welding causes the oxidation of stainless steel when

a. hot metal contacts the atmosphere.
b. too much acetylene is used.
c. welded with a neutral flame.
d. too much acetylene is used.

49. (822) When welding stainless steel why is it necessary to fit parts of a lap joint closely together?

a. Reduce the warping.
b. For a better looking joint.
c. Space causes the edge to cool easily.
d. Space causes the edge to heat rapidly.

50. (822) Why are tack welds spaced so close together when welding stainless steel?

a. To make them rigid.
b. To reduce the warping.
c. So they will fuse with the weld.
d. So there will be no pinholes.

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51. (823) When preparing to oxyacetylene weld an open-butt jont of stainless steel, the open end should be spaced

a. 3/8 inch per foot of seam length
b. 1/2 inch per foot of seam length.
c. 1/4 inch per foot of seam length.
d. 3 thicknesses per foot of seam length.

52. (823) Improper spacing of a butt joint of stainless steel will cause

a. excessive warpage.
b. excessive oxidation.
c. excessive penetration.
d. all of the above.

53. (824) When oxyacetylene welding a tee joint of stainless steel, the most important adjustment to make is the

a. tip size.
b. torch angle.
c. welding speed.
d. volume of heat.

54. (824) Preheating a stainless steel tee joint before welding with an oxyacetylene torch will prevent

a. scales from forming.
b. oxidation of the weld.
c. discoloration of the weld.
d. cracking along the weld line.

55. (824) During the welding of a stainless steel tee joint, what do you do to prevent oxidation?

a. Constantly shield the melting metal with the flame.
b. Constantly add flux to cover the weld bead.
c. Feather off the flame and cool quickly.
d. All of the above.

56. (825) What is the only cast iron that can be repaired satisfactorily by fusion welding?

a. Gray cast iron.
b. White cast iron.
c. Black cast iron.
d. Malleable cast iron.

57. (825) When white cast iron is heat treated and cooled slowly, the metal formed is primarily used for

a. pipe fittings and dies.
b. dies and machine parts.
c. pipes and machine parts.
d. pipe fittings and machine parts.

58. (825) When malleable cast iron is produced, the heat treatment induces

a. strength, ductility, and toughness.
b. wear resistance and hardness.
c. hardness, strength, and toughness.
d. hardness, strength, and ductility.

59. (826) The two tests that are most used for identifying ferrous castings are the

a. spark and flame test.
b. spark and acid test.
c. spark and chip test.
d. flame and acid test

60. (826) When the spark test is used to identify an unknown metal, you must use

a. a specimen of a known metal.
b. a sample of gray cast iron.
c. a spark color chart.
d. two unknown metals.

61. (827) When fusion w   ng cast iron, preheating is used to control

a. stresses and hardness.
b. warpage and distortion.
c. expansion and contraction.
d. overheating and underheating.

62. (827) The correct preheating temperature for fusion welding gray cast iron is approximately

a. 1200 degrees F.
b. 1500 degrees F.
c. 1200 degrees C.
d. 1500 degrees C.

63. (828) The ductility of bronze is an advantage in

a. the takeup of minor stresses under load.
b. added resistance to stress under load.
c. that exact line up is not necessary.
d. that only a black heat is required.

64. (828) When a joint is brazed properly, its strength will be

a. stronger than welded joints.
b. half as strong as welded joints.
c. twice as strong as welded joints.
d. almost as strong as welded joints.

65. (829) When high strength is required in a brazed joint, the joint should be prepared as a

a. U-joint.
b. V-bevel joint.
c. J-bevel joint.
d. double V-bevel joint.

66. (829) When preparing a cast iron joint for brazing, free carbon is removed by

a. beveling.
b. searing.
c. fluxing.
d. decarbonizing.

67. (829) If the base metal (cast iron or steel) gets too hot when brazing, the bronze will

a. ball up.
b. run off.
c. fume and smoke.
d. fall through the joint.

68. (830) Metals are hard faced to improve their

a. harness and wear resistance.
b. hardness and ductility.
c. wear resistance and appearance.
d. ductility and appearance.

69. (830) Three metals that may be successfully hard faced are

a. carbon steels, aluminums, and steel alloys.
b. steel alloys, gray castings, and aluminums.
c. aluminums, steel alloys,and gray castings.
d. gray castings, carbon steels, and steel alloys.

70. (831) What flame is normally used to apply all hard-facing alloys with oxyacetylene equipment?

a. A neutral flame.
b. An oxidizing flame.
c. A carburizing flame.
d. A slightly oxidizing flame.

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71. (831) When applying hard-surfacing deposits, what controls the action and flowing quality of the molten pool?

a. The amount of acetylene in the flame.
b. The amount of filler rod added.
c. The amount of oxygen in the flame.
d. All of the above.

72. (831) All hard-facing alloys are applied to the base metal by

a. fusion.
b. sweating only.
c. puddling only.
d. puddling or sweating.

73. (831) What step should be taken to eliminate porosity and shrinkage cracks when hardfacing?

a. Submerge in cold water.
b. Allow the furnace to cool.
c. Pack in a cooling retardant.
d. Allow the material to slowly cool.

74. (832) Silver soldering is accomplished best with joints designed to allow

a. solder buildup.
b. free solder flow.
c. oscillating action.
d. capillary attraction.

75. (832) Silver solder bonds weaken as

a. pressure increases.
b. vibration increases.
c. temperatures exceed 500 degrees F.
d. temperatures exceed 1175 degrees F.

76. (832) Lead soldering is accomplished at a temperature below

a. 500 degrees F.
b. 600 degrees F.
c. 800 degrees F.
d. 1175 degrees F.

77. (833) For a good silver solder joint, the inner cone of the flame should

a. not touch the metal or be held still.
b. not touch the metal or moved around.
c. always touch the metal for ample heat.
d. none of the above.

78. (833) What are two very important things that affect soldering?

a. Low temperature and cleanliness.
b. High temperature and flux.
c. Direction of travel and size of filler metal.
d. Cleanliness and speed of travel.

79. (839) Before a lead solder joint is made the base metal should be

a. ground.
b. tinned.
c. beveled.
d. crimped.

80. (834) To obtain a complete bond when using lead solder, you must

a. always use a flux.
b. never use a sandblaster.
c. always preheat the joint.
d. never tin the metal base.

81. (834) When making a solder joint where should heat be applied, and why?

a. To the underside so the flux won't be burned.
b. To the tinned surface so the bae metal won't be overheated.
c. To the tinned surface so the flux will melt and clean.
d. To the underside so oxides will not interfere.

82. (835) When a welding torch is converted to a cutting torch, the cutting attachment makes the torch useful for

a. cutting heavy sections.
b. gouging welds on plate.
c. beveling 2-inch plate.
d. intermittent cutting of light sections.

83. (835) A cutting tip has several small openings which are used for

a. preheating metal.
b. cutting metal.
c. heating metal.
d. severing metal.

84. (836) The oxygen blast of the cutting torch combines with the red hot metal and

a. produces a narrow slot.
b. produces a melting effect.
c. burns it to an oxide.
d. burns it into slag.

85. (836) What determines whether or not a particular metal can be cut by the oxyacetylene process?

a. Hardness.
b. Structure.
c. Composition.
d. Heat treatability.

86. (837) When performing straight line cutting, the line of cut is marked by using a

a. metal scribe.
b. center punch.
c. magic marker.
d. piece of chalk.

87. (837) Which of the following pertains to oxyacetylene cutting?

a. Use the forehand method.
b. Add filler rod to the molten pool.
c. Adjust the single inner cone to neutral.
d. Preheat before adding additional oxygen.

88. (838) While forging, if metal is heated rapidly it will

a. oxide and becomes brittle.
b. work easily and uniformly.
c. expand unevenly and start cracks.
d. become large grained and very strong.

89. (838) When steel reaches a dull orange color, the steel is at the

a. working temperature.
b. stress relief temperature.
c. tempering temperature.
d. forging temperature.

90. (838) A full red color of steel indicates the metal can

a. be forged.
b. be shaped.
c. not be forged.
d. not maintain its form.

91. (839) When metal is hammered on an anvil to increase both length and width, the operation is known as

a. drawing.
b. hot bending.
c. lengthening.
d. upsetting.

92. (839) What are the three steps necessary to forge and draw round stock to a point tip?

a. square, octagonal, then round.
b. square, hexagonal, then round.
c. octagonal, square, then round.
d. hexagonal, square, then round.

93. (839) When metal is shortened by hammering, the operation is known as

a. drawing.
b. upsetting.
c. hot bending.
d. lengthening.

94. (840) When stress relieving steel, the steel is usually heated to

a. 1200 degrees F. and then quenched.
b. 1200 degrees F. and then cooled slowly.
c. 1500 degrees F. and then furnace cooled.
d. 1500 degrees F. and then cooled slowly.

95. (840) The color tempering of steel is based on the

a. oxide color when heated.
b. color of sparks when grinding.
c. tempering color where heated.
d. carbon content of basic material.

96. (840) When tempering a cold chisel, the final quench is made when the cutting edge turns the correct shade of

a. red.
b. blue.
c. straw.
d. yellow.

END OF EXERCISE

MAIL TO: ECI, GUNTER AFS AL 36118-5643

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 10 USC 8012. PRINCIPAL PURPOSE: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package, and used by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's inquiry. Failure to provide all information would result in slower action or inability to provide assistance to the student.

I. CORRECTED OR LATEST ENROLLMENT DATA

1. THIS REQUEST CONCERNS COURSE (1-6)	2. TODAY'S DATE	3. ENROLLMENT DATE	4. AUTOVON NUMBER

5. SOCIAL SECURITY NUMBER (7-15)	6. GRADE/RANK	7. NAME (First initial, second initial, last name)
___ - __ - ____		(17) – (18) – (19-32)

8. ADDRESS	
OJT ENROLLEES Address of unit training office with zip code.	(33-53)
ALL OTHERS Current mailing address with zip code.	(54-75)

9. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE	10. TEST CONTROL OFFICE ZIP CODE/SHRED (33-39)

II. REQUEST FOR MATERIALS, RECORDS, OR SERVICE

FOR ECI USE ONLY

X	*Place an 'X' through number in box to left of service requested.*		
1	Request address change as indicated in Section I, Block 8.		
2	Request Test Control Office change as indicated in Section I, Block 10.		
3	Request name change/correction. *(Provide Old or Incorrect data here)*		
4	Request Grade/Rank change/correction.		
5	Correct SSAN. *(List incorrect SSAN here.)* *(Correct SSAN should be shown in Section I.)*		
6	Extend course completion date. *(Justify in "Remarks")*		
7	Request enrollment cancellation. *(Justify in "Remarks")*	16 G	33
8	Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 10 Originals were: [ ] Not received [ ] Lost [ ] Misused	K	VOL 33-35 GR 36-38
9	Send course materials. *(Specify in "Remarks")* [ ] Not received [ ] Lost [ ] Damaged	M	33-34 35-40
10	Course exam not yet received. Final VRE submitted for grading on ________ (date).	N	33-35
11	Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 10 not yet received. Answer sheet(s) submitted ________ (date).	P	VOL 33-35
12	Results for CE not yet received. Answer sheet submitted to ECI on ________ (date).	P	TC 36-37 38
13	Previous inquiry ([ ] ECI Fm 17, [ ] ltr, [ ] msg) sent to ECI on ________ (date).	P	OOE 39-45
14	Give instructional assistance as requested on reverse.	Q	33-34 ØØ 38 1
15	Other *(Explain fully in "Remarks")*	Q	MC 39-42

REMARKS *(Continue on reverse)*

OJT STUDENTS must have their OJT Administrator certify this record. *ALL OTHER STUDENTS may certify their own requests.*	*I certify that the information on this form is accurate and that this request cannot be answered at this station.* SIGNATURE

ECI FORM 17 DEC 84 PREVIOUS EDITION WILL BE USED.

REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of subject matter should be forwarded directly to preparing agency. For an immediate response to these questions, call or write the course author directly, using the AUTOVON number or address in the preface of each volume. All other inquiries concerning the course should be forwarded to ECI.

VRE ITEM QUESTIONED:	MY QUESTION IS:
COURSE NO ____ VOLUME NO ____ VRE FORM NO ____ VRE ITEM NO ____ ANSWER YOU CHOSE ____ *(Letter)* HAS VRE ANSWER SHEET BEEN SUBMITTED FOR GRADING? ☐ YES ☐ NO REFERENCE *(Textual reference for the answer I chose can be found as shown below)* IN VOLUME NO ____ ON PAGE NO ____ IN ☐ LEFT ☐ RIGHT COLUMN LINES ____ THROUGH ____	

REMARKS

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. Course workbooks have a Form 17 printed on the last page.

ECI FORM 17, DEC 84 *(Reverse)*

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METAL FABRICATING SPECIALIST

(AFSC 55252)

Volume 6

Electric Welding, Metallic Arc Equipment

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Air University

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Preface

CONGRATULATIONS! You have reached the sixth volume, and this means you have completed most of the training you will need in your specialty. You may give a sigh of relief, but don't stop just yet. This volume provides the knowledge you need to become proficient in different phases of electric welding.

The first four of the seven chapters in the volume cover metallic arc welding equipment, metallic arc preparation, metallic arc welding, and metallic arc application. Chapter 5 covers gas-shielded welding principles and equipment; Chapter 6 deals with TIG (tungsten-inert gas) welding; and Chapter 7 covers pipe welding using metallic arc and TIG welding.

Foldout 1 is printed and bound at the back of this volume.

Direct your questions or comments related to the accuracy or currency of this volume to the course author: TCHTG/TTGIC, ATTN: MSgt Arnold D. Ringstad, Sheppard AFB TX 76311. If you need an immediate response, call the author, AUTOVON 736–2879, between 0800 and 1600 (CST), Monday through Friday. *(NOTE: Do not use the suggestion program to submit changes or corrections for this course.)*

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This volume is valued at 15 hours (5 points).

Material in this volume is technically accurate, adequate, and current as of August 1982.

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NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its texxt.

Metallic Arc Welding Equipment

METALLIC ARC welding is one of three major welding processes which does not require pressure to complete the weld. Arc welding consists of a local progressive melting and adhering together of the adjacent edges of metal by arc temperatures ranging from 500° to 10,000° F. developed between a suitable electrode, or electrodes, and the parent metal.

In this chapter, we will discuss the principles of arc welding and the various types of arc welding machines, as well as the operator maintenance necessary for safe and efficient operation of the machine.

1-1. Principles of Arc Welding

In this section we will discuss what makes an arc welder work. Principles of electricity, things that affect a weld the base metal, and the arc itself are covered.

A01. Explain the meaning of selected electrical terms, and supply details relating to the principles of arc welding.

Electricity. There are some basic electrical terms which we must present to enable you to understand the purpose and use of electricity in arc welding.

Circuit. An electric current cannot flow without a complete conducting path. This path is called a *circuit.* In arc welding, this circuit is made up of the welding leads (one attached to the electrode and the other, to the base metal), electrode, and arc (between the electrode and the base metal), as shown in figure 1-1.

Voltage. Electricity needs a push to move through the circuit. This push is supplied by the electromotive force which is commonly known as *voltage.* The voltage is created by an imbalance of electricity. This imbalance is created when the welding generator builds up an electrical charge greater than the resistance in the leads. The voltage then forces the electric current through the welding lead and electrode. As the current reaches the end of the electrode, the voltage builds up until, like lightning, has the necessary push to force the current across the arc gap. The current passing across the arc gap releases energy in the form of heat, causing the molten pool to form almost immediately.

Ampere. In order to control the amount of electricity in any given circuit, it must be measured. The unit of measurement is called an *ampere.* The ampere tells the amount of electricity flowing per second past a given point.

Ohm. The amount of current flowing in the circuit is determined by the amount of resistance in the circuit. This resistance is measured by a unit known as an *ohm.* Each metal has its own resistance. In welding, you need leads made from a metal which has a low resistance. Since copper is one of the best conductors, it is used in all electrical appliances, generators, lines, and welding leads. Steel has a much higher resistance and becomes too hot for any use in welding, other than its use as an electrode.

Arc length. In metallic arc welding, the proper length of arc is necessary to make good welds. With the proper *arc length,* the heat is concentrated on the work. With a long arc, much of the heat is lost by radiation to the atmosphere. A short arc is more stable than a long arc, giving you more control of the molten pool. With a short arc, vapors from burning electrode coating surround the electrode metal and the molten pool, preventing air from reaching these hot points.

Current. When a circuit carrying a current breaks, the *current* continues to flow across the gap between the terminals until it is no longer able to jump the gap. Superheated gases from the atmosphere and particles of metal from the terminals carry the current to bridge this gap. This action causes an intensely bright light called the *electric arc.* Since the resistance is very high in the arc, a great deal of electrical energy is converted into heat, both in the arc and at the points where it enters and leaves the terminals. The proper length of arc causes the metal exposed to it to melt instantaneously.

The direct-current (DC) arc welding machine used for electric arc welding has a generator driven by some suitable motive power (electric motor, gas or diesel engine). The voltage of the generator usually varies from 15 to 45 volt across the arc, although any setting may vary because of changes in arc length. Current output varies from 20 to 800 amperes, depending upon the type of unit, since a fairly wide range is necessary to

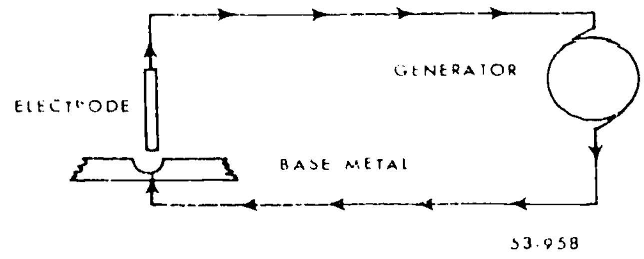

Figure 1-1. Arc welding circuit.

accommodate the various classes of work. In most welding machines, the generator is a variable voltage type arranged so that the voltage automatically adjusts to the demands of the arc. You may also be able to manually adjust the amperage of the welding current. Usually you can set it to the proper range by means of a selector switch or a series In either case, you obtain the desired amperage by tapping into the field coil of the generator at different points to increase or decrease its strength. When you can manually adjust both the voltage and amperage of the welder, the machine is a dual-control type

Polarity. The use of the term "polarity" in arc welding depends upon the fact that electrical circuits have negative and positive terminals or poles. In a DC circuit, the current flows in one direction only; the line that carries current from the supply is *positive*, and the line that returns the current to the supply is *negative*.

When you use a bare or lightly coated electrode, 60 to 75 percent of the heat is liberated at the positive side of the circuit and 25 to 40 percent at the negative side. Since the mass of the work to be welded is larger than the mass of the electrode, you usually connect the work to the positive, or hot, side of the circuit when you are welding with bare or lightly coated electrodes. This condition is known as *straight polarity* and is illustrated in view A of figure 1-2. Check the leads and the current flow directions. In some cases, such as in welding cast iron and using certain types of heavily coated ferrous and nonferrous electrodes, the work is negative and the electrode positive. This condition is known as reverse polarity and is illustrated in view B figure 1-2.

When you use an alternating-current (AC) welding machine you have no choice of polarity, since it is the characteristic of AC to change its polarity twice during each cycle. For this reason, it is not possible to use AC machines for all types of welding. For instance, you cannot use AC in bare electrode welding. It is difficult to use in carbon arc welding. Alternating-current welding has one advantage over DC welding: in AC welding, the changing of polarity with each cycle reduces arc blow.

Weld Metal Deposition. In metallic arc welding, five separate and distinct forces are responsible for the transfer, or depositing, of molten filler metal and molten slag to the base metal.

Gravity. Gravity is the main force which accounts for the transfer of filler metal in flat position welding. In other positions, smaller electrodes must be used to avoid excessive loss of weld metal and slag, since the surface tension is unable to retain a large volume of molten metal and molten slag in the weld crater.

Gas expansion. Gases result from the burning of the electrode covering. The heat of the boiling electrode tip rapidly expands the gases, projecting the metal and slag of the electrode in globular form away from the solid electrode tip and into the molten crater. The coating extending beyond the metal tip of the electrode controls the direction of gas expansion and directs the molten metal globule into the weld metal crater formed in the base metal.

Electromagnetic. The electrode tip acts as an electrical conductor; the molten metal globule is also an electrical conductor and is affected by magnetic forces acting at 90° to the direction of the current flow. These forces produce a pinching effect on the metal globules and act to speed up the separation of the molten metal from the end of the electrode. This effect is particularly helpful in transferring metal in horizontal, vertical, and overhead position welding.

Electric. The force produced by the voltage across the arc acts to pull the small, pinched-off globule of metal regardless of the position of welding. This force is especially helpful when DC straight-polarity, mineral-coated electrodes, which do not produce large volumes of gas, are used.

Surface tension. The force which keeps the filler metal and slag globules in contact with molten metal and slag globules in contact with molten base or weld metal in the crater is known as *surface tension*. It helps to retain the molten metal in horizontal, vertical, and overhead welding and also to determine the shape of the weld contours.

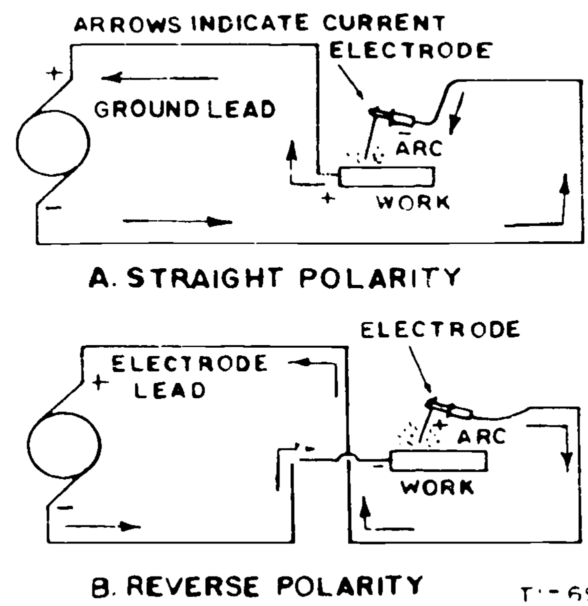

Figure 1-2. Welding circuit polarity.

Magnetic or Arc Blow. A phenomenon of DC arc welding is the tendency of the arc to waver as though a blast of air were being blown against it. This trouble is often encountered in welding in corners and at the start and end of butt joints. The arc is forcibly moved by a magnetic field set up in the work by the flow of the welding current. The direction and amount of bending of the arc depend upon the direction and strength of the magnetic field. Various methods are used to try to eliminate this interference; all of them attempt to minimize or counteract the magnetic field at the point at which it is desired to hold the arc. Changing the position of the ground plate with reference to the arc may change the path of the current through the work and eliminate the magnetic field surrounding the arc. Changing the angle of the electrode to the work is helpful in some cases. It is impossible to lay down definite rules, since so many variable factors are involved. When welding with AC, there are practically no magnetic disturbances of the arc.

Exercises (A01):

1. Briefly explain each of the following:

   a. Circuit.

   b. Voltage.

   c. Ampere.

   d. Ohm.

2. When performing arc welding, why is a long arc length undesirable?

3. What polarity is present when the electricity flows from the electrode to the work?

4. List the forces responsible for transferring the molten metal when arc welding.

5. Arc blow is the wavering of the electric arc caused by what condition?

1-2. Arc Welding Machines

The principal function of the electric arc welding machine is to provide the current necessary for welding. Although arc welding machines are of different types, operators are mainly interested in the type of current producing the arc. Therefore, for practical purposes, consider the currents as direct current (DC) or alternating current (AC) In recent years, electronic and selenium plate rectifiers, which operate on AC and produce DC welding current, have been available.

A02. Supply operational details concerning types, functioning, characteristics, and parts locations of AC and DC arc welding machines.

Direct-Current Arc Welding Machines. Direct-current welding machines have the advantage of being suitable for use on all metals. They usually produce satisfactory results on thin materials which require low current settings. The choice of the type of machine best suited for metallic arc welding depends upon many factors. In general, the main difference between AC and DC welding is the lower initial cost and the lower operating cost of AC equipment.

Electric motor-driven generator. The most widely used welding machine is the motor-generator type, operated by electric power to produce DC of the proper characteristics for arc welding. This type consists of a driving motor and a DC generator, with the armature of the generator mounted on the same shaft as the rotor of the driving motor The shaft is supported at each end by ball bearings, and the machine is made as compact as possible. Two controls for the welding current are usually provided—one for the large increases or decreases and the other for small changes. Some machines provide a switch for changing polarity, while others require changing the position of the welding cable leads. A pushbutton switch located on the control panel permits convenient starting and stopping of the machine, and provides overload protection for the driving motor. A voltmeter and ammeter, or a combination of the two, permit you to set the machine for a prescribed output. Some machines use mechanically operated dials to show the voltage and amperage. Most machines are mounted on a chassis to permit moving them in the shop. Both horizontally and vertically mounted sets are available. Figure 1-3 illustrates, on a vertically mounted motor-generator arc welder, the component parts that are common to both types. Motor-generator welding sets are rated in terms of welding current output—such as 100, 200, 300 amp, etc. Current ratings represent the amount of current which the machine will generate continuously for 1 hour without exceeding a specified temperature rise. These sets are capable of delivering more than the rated current for a short time without damage to the machine.

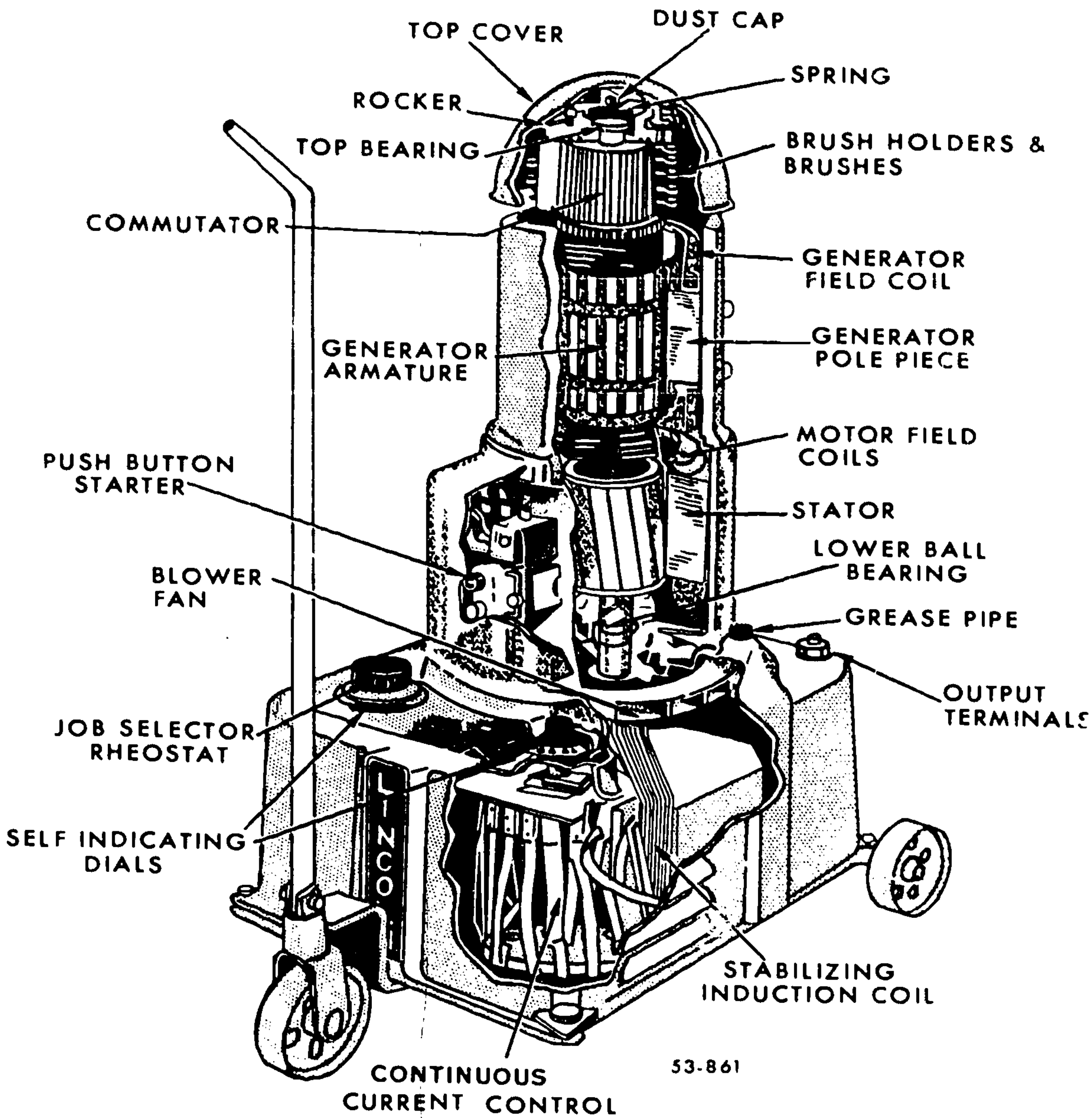

Figure 1-3. Portable motor-generator arc welder.

Engine-driven generator. When a source of electrical power is not available, a gasoline or diesel engine is used to drive the welding generator. The engine is equipped with a governor to control the demand on the generator. The complete unit, shown in figure 1-4, is usually mounted on a trailer-type chassis and can be towed to the location where the work is to be done.

Rectifier welder. Welding machines equipped with rectifiers operate by changing or rectifying AC to DC for welding. Electronic tubes or selenium plates rectify 3-phase AC to DC. Controls are provided for changing the welding current the open circuit voltage, and the polarity. The current output of these machines is sufficient to maintain a stable arc at any setting from 5 to 75 amperes; therefore, you can weld metals from 32 to 10 gage with equal ease and success.

Alternating-Current Arc Welding Machines. Two general types of AC arc welders suitable for metallic arc welding are the transformer and rotating types of machines. Most AC arc welding machines are static transformers that offer these three advantages: (1) low initial cost, (2) low operating cost, and (3) low maintenance cost. The absence of rotating parts makes the initial and maintenance costs less than they are for DC machines.

Transformer type. This type of AC arc welding machine operates from one phase of the power supply—the primary winding being connected to the powerline and the secondary winding to the welding cables. For making changes in the amount of welding current, some machines have the transformer windings tapped at intervals. By using different taps, the current and voltage can be increased or decreased. Other machines use a variable resistance controlled by turning a handwheel which alters the current according to the position of a movable coil or core. The ratings of these machines are available in a wide range of current ratings. Since the transformer draws current only when in use, the machines are remarkably economical in electric power consumption. They are easy to adjust to the required current settings and require little maintenance.

Rotating type. This type of AC arc welding machine may be of the motor-generator, frequency changer, phase changer, or combination type. The driving motor is connected to the powerline, and the generator or rotor of the frequency changer is connected to the welding cables. A two-position switch permits the current output to be changed from a high to a low value, and an auxiliary control permits fine current adjustment.

AC/DC Welders. The AC/DC welding machine (rectifier-type) is now being adopted by the Air Force because of its versatility. The welder has the choice of AC or straight or reverse polarity direct current by throwing a switch to one of three positions. This machine can be used in areas where only single-phase power is available. It occupies less floor space, eliminates the need for two independent arc welders of the same rating, and reduces maintenance upkeep.

Accessories. All arc welding machines require certain accessories to make up a complete welding outfit.

Welding cables. The *size* of welding cables depends upon the normal welding current and the length of the welding cable. For lengths up to 50 feet, a 200–ampere machine requires a #2 cable; a 300–ampere, a #0 (#1/0); and a 400–ampere, a #00 (#2/0). Rubber-covered, multistrand, copper cable made specifically for arc welding is used. The greater the number of strands in a given size cable, the more flexible and convenient for movement are the welding leads.

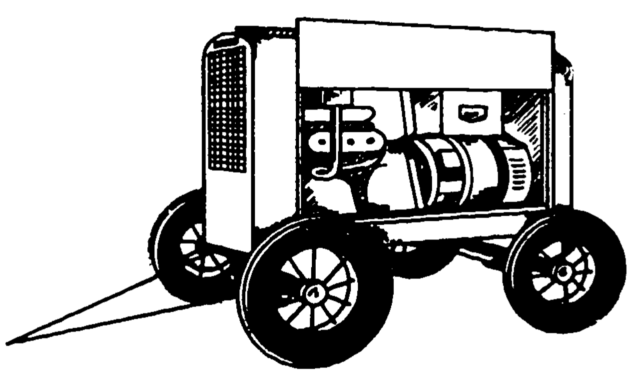

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Figure 1–4. Portable engine-driven arc welder.

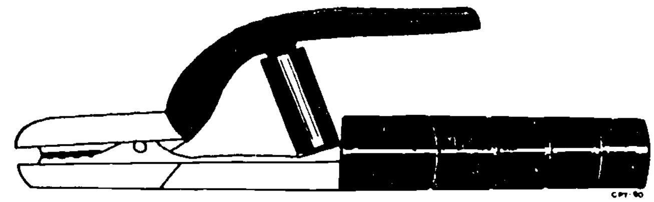

Figure 1–5. Electrode holder.

Electrode holder. An electrode holder is essentially a clamping device for holding the electrode securely in any position. The welding cable passes through the hollow,insulated handle of the holder. The advantage of having an insultated holder is that it may be touched to any part of the work without danger of short circuiting. Electrode holders permit quick and easy change of electrodes.

Electrode holders are made in a number of different sizes and designs, one of which is shown in figure 1–5. Each holder is intended for use within a specified range of electrode diameters and within a maximum welding current amperage. A larger holder is required when welding with a machine having a 300–ampere rating than when welding with 100–ampere unit. If the holder is smaller than that specified for use with a particular amperage, the holder will overheat.

Ground clamp. The work must be connected to the welding machine. This is done with a second cable. For best results mount a ground clamp, as shown in figure 1–6, to the grounding cable. This clamp is made of brass and is an excellent ground. With little care this type of clamp will provide excellent service for an extended time.

Exercises (A02):

1. Direct-current arc welding machines may be of the __________ or the __________ type.

2. What two types of AC arc welders are suitable for metallic arc welding?

3. Why are AC arc welding machines preferred over DC welders?

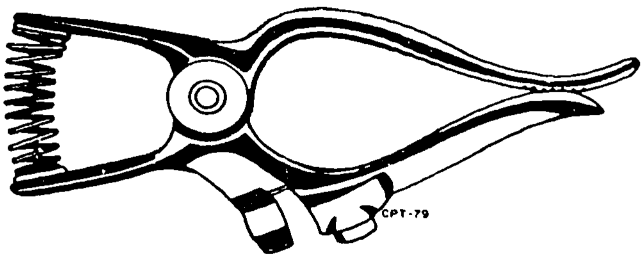

Figure 1-6. Ground clamp.

4. The transformer type of arc welding machine operates from one phase of the power supply, the primary winding being connected to the __________ and the secondary winding to the __________ __________.

5. What are four types of rotating AC arc welding machines?

6. What determines the size of welding cables?

7. Where is the electrode holder located?

A03. Identify operator maintenance requirements for arc welding machines and identify the definitive information source for such machines.

Because of the amount of dust and grit present in all welding shops, proper maintenance of equipment is very important. Although you can perform routine maintenance, you should have a qualified electrician perform any extensive repair or adjustment. The following periodic maintenance schedule should help you prevent a major breakdown and prolong the life of the equipment. You can find detailed instructions about the operation, maintenance, and overhaul, and a parts catalog for specific types of arc welding machines in the 34W4 series TOs, *Welding Machines and Related Equipment*. Keep an inspection record noting all maintenance performed and dates for each machine.

Cleaning and Inspection. A maintenance schedule should be set up to keep the welding machine in good operating condition. This maintenance should be scheduled in accordance with the frequency with which it is performed.

On a daily or an as-used basis, the cables, ground, and electrode holder should be checked for bare wires and loose connections.

On a weekly basis, the welding machine should be checked for loose nuts, bolts, screws, or parts. These will work loose due to the vibrations caused by the cooling fan and generator.

Air is drawn into the machine by the cooling fan and circulated through passages and around the windings. An accumulation of dust in these areas will cause increased operating temperatures. Clean out the machine with dry compressed air, as shown in figure 1-7. If the machine is greasy, take it apart and thoroughly clean it on a monthly basis.

Electrical Parts. During the monthly inspection, check the condition of the brushes and commutator, shown in figure 1-8. Also check the switch contact points and the bearings. Replace brushes that have worn enough to reduce their spring tension appreciably and brush springs that have been weakened from overheating to assure positive brush contact.

Each time the brushes are replaced, the commutator should be checked for cleanliness and wear. A commutator in good condition has a deep bronze color. Ridges or pockets on the surface of the commutator should be removed by turning it down on the lathe.

Electrical switch contacts should be sanded smooth if they are pitted, as shown in figure 1-9. Badly burned contacts should be replaced.

The windings of the generator and motor should be inspected once a year and given a coat of shellac, if they are dry or cracked.

Lubrication. Lubricate welding machines that have moving parts at 4- to 6-month intervals, depending upon the number of operating hours. The more you use the welder, the shorter the time between lubrications should be. Be sure you do not use too much grease.

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Figure 1-7. Cleaning the windings.

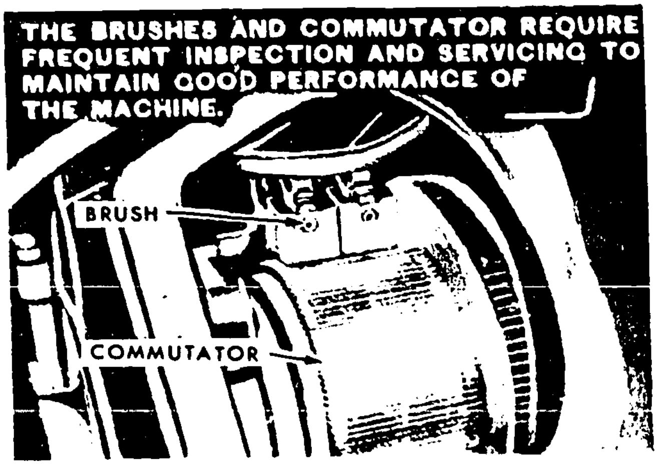

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Figure 1-8. Arc welder inspection.

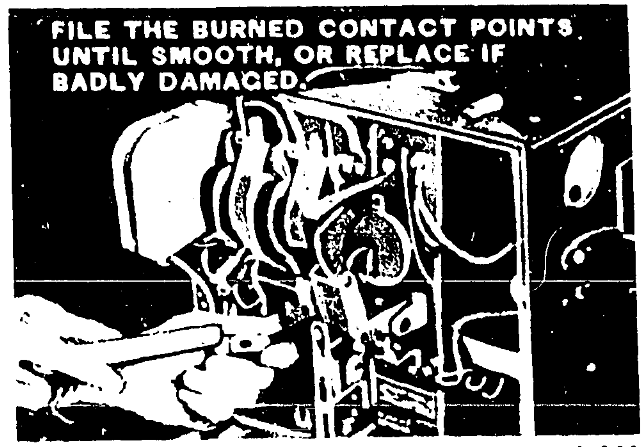

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Figure 1-9. Contact point care.

Excess grease can be thrown on the commutator or windings, causing deterioration of the insulation and a possible short circuit. Use the grease specified by the manufacturer on the data plate or in the Mil Spec.

Exercises (A03):

1. Where can you find detailed instructions about the maintenance of arc welding machines?

2. What should you do to dried or cracked generator windings?

3. What four electrical parts must be checked monthly?

4. How often should machine moving parts be lubricated?

Metallic Arc Preparation

IN THIS CHAPTER, we discuss the identification and selection of arc welding electrodes and the factors involved in setting up for arc welding.

2-1. Identification and Selection of Arc Welding Electrodes

The electrodes used for metallic arc welding are designed to do the same job as the filler rod does in oxyacetylene welding. The major difference between the two rods is in the flux coating on the electrode. This flux coating serves to protect the weld from oxidation while it cools. There are two basic types of flux coatings, with variations of each one. Since these electrode and coatings are designed for a specific purpose, it is necessary for you to be able to identify them by their number or color code.

A04. Define given electrode numbers, and furnish the color coding used on specific electrodes.

The American Welding Society (AWS) has established a number and color code system for the identification and selection of electrodes (E). You must understand the system in order to select the proper electrode for a given job.

AWS Number Code. The AWS number code is made up of either a four- or five-digit number. This number tells you the tensile strength of a properly made weld using that particular electrode (rod). The number also indicates the type of current to use and the recommended welding position suitable for that rod.

Four-digit number electrodes. All mild steel and low alloy electrodes have codings with four-digit numbers, such as E-6010, E-7020, and E-8030. The breakdown of the four-digit electrode E-6010 is as follows:

1st two digits—the tensile strength in thousands of psi.
3rd digit—the recommended position.
4th digit—the type of current.

As this explanation demonstrates, always read the first two digits together. They designate the minimum ultimate tensile strength in thousands of pounds per square inch. The E-6010 electrode, for instance has a minimum ultimate strength of 60,000 psi; whereas E-7020 has a minimum ultimate strength of 70,000 psi.

The third digit (the 1 in E-6010) specifies the position (or positions) in which you can use the electrode most satisfactorily. This digit—a 1, 2, or 3, indicates the recommended welding positions as follows:

1—all positions.
2—flat and horizontal positions.
3—flat position only.

The fourth digit, which may be any number from zero to eight, refers to the current and also indirectly to the type of electrode coating as follows:

0—DC reverse polarity when the third digit is 1.
0—AC when the third digit is 2 or 3.
1—AC* or DC reverse polarity.
2—DC straight polarity or AC.
3—AC* or DC straight polarity.
5—DC reverse polarity (lime or titanium sodium—low hydrogen).
6—AC* or DC reverse polarity (titanium or lime potassium—low hydrogen).
*7—AC or DC reverse polarity (iron powder plus low hydrogen sodium covering).
*8—AC or DC reverse polarity (iron powder plus low hydrogen sodium covering).
*—preferred.

Five-digit number electrodes. Electrodes with five-digit numbers are also available. The only difference between reading these and the briefer numbers is that here the first three digits occur together; for example, E-10010 designates an electrode having a tensile strength of 100,000 psi. The fourth and fifth digits correspond to the third and fourth digits of a four-digit number and specify the same thing. Here is a breakdown for the five-digit number E-10010:

1st three digits—the tensile strength in thousandths of psi.
4th digit—the recommended position.
th digit—the type of current.

AWS Color Code. This code consists of three markings: the (1) primary, (2) secondary, and (3) group. The primary and secondary color indicates the composition of the electrode, while the color group indicates the type of current. The primary color is on the top of the base or grip end of the electrode. The secondary color is located on the grip end midway between the end of the electrode and the flux coating. The group color is located on the flux coating just below the grip end of the electrode. The color coding for common electrodes is shown in foldout 1, bound at the back of this volume.

As you can see in foldout 1, not all electrodes have all three markings. Also, some electrodes have a special marking at the center of the electrode. This marking, which is usually three spots, is a manufacturer's trademark.

MIL-E-6843 Classification. Air Force supply catalogs identify arc welding electrodes by military specification number MIL-E-6843 rather than AWS classification numbers. The following information is important to Air Force welders and can be found in the 34W4 series technical orders.

Class A. Class A electrodes correspond to the AWS electrodes whose last two digits are 12 or 13, such as E-6012 or E-6013.

Class B. Class B electrodes correspond to the AWS electrodes whose last two digits are 10 or 11, such as E-6010 or E-6011.. This type of electrode is used with DC reverse polarity, except when specified as an AC electrode. Penetration is deep, which is normally preferred for good fit-up and vertical or overhead welding. This electrode is not used when heat treatment is required.

Class C. Class C electrodes are alloy steel electrodes used in welding chrome molybdenum and chrome nickel molybdenum steels when heat treatment is required. The corresponding AWS electrode specifications would be E-7020 or E-10020. This type of electrode is generally used with straight polarity, but it may also be used with AC. Only the smaller diameter electrodes, 5/64 and 3/32 inch, are adaptable to all positions. The larger diameter electrodes are generally used for horizontal fillets and flat work where deep penetration is not required.

Class D. Class D electrodes are companion rods to the class C electrodes under the same specification and are used when deeper penetration is required. They are used to weld chrome molybdenum (4135 and 41400) and chrome nickel molybdenum (8735 and 8740) steels (with preheat of the parts to 400° to 500° F.). The corresponding AWS electrode specifications would be E-7030 or E-10030. These electrodes are generally used with reverse polarity, but they may also be used with AC. They are all-position electrodes.

Exercises (A04):

1. Explain briefly the meaning of the electrode number E-12030.

2. Which class does electrode E-7512 belong?

3. Identify each of the following phrases as true or false: The electrode number

   ___ a. is established by the AWS.
   ___ b. recommends the welding position.
   ___ c. indicates the amount of current to use.
   ___ d. tells you the maximum yield strength.
   ___ e. indicates the type of current to use.

4. Indicate the color coding used on each of the following electrodes:
   a. E-7018.
   b. E-6012.
   c. E-6028.
   d. E-11018G.

A05. Specify the most stable type of electrode and label a series of terms relating to bare, light-coated, or heavy-coated electrodes.

The selection of electrodes for a particular job depends upon the type of coating and the characteristics of the electrodes.

Some form of protection must be provided in the arc stream to protect the weld metal from harmful effects of air during the time that the metal is molten and solidifying. Steel when heated to high temperature, readily combines with the oxygen and nitrogen in the air surrounding the arc. This results in the formation of oxides and nitrides, which causes brittleness. To prevent this from occurring, the electrodes have a wire core and a suitable coating. The coatings on metal arc welding electrodes are generally more than mere fluxing agents, such as the fluxes used in certain oxyacetylene welding applications. These coatings produce a gas which excludes air from the arc and forms a slag which acts as a blanket on the pool of molten steel and purifies the steel.

Types of Electrode Coatings. The metal arc electrodes may be classified as (1) bare electrodes, (2) thinly coated or light-coated electrodes, and (3) shielded-arc or heavy-coated electrodes. Let's look at each.

Bare electrodes. Bare electrodes are made of wire of a definite composition. Their surface does not have special coatings other than those materials retained from wire drawing operations. These coatings are necessary for wire drawing, and their slight stabilizing action on the arc is only incidental.

Light-coated electrodes. Light-coated electrodes are made of wire of a definite composition. The surface has a thin coating applied by washing, dipping, or drawing. These coatings are chiefly of iron oxide and titanium dioxide.

Shielded-arc electrodes. Shielded-arc, or heavy-coated, electrodes are of wire of a definite composition, with a heavy coating around the wire. The coatings of the principal types of heavy-coating or shielded-arc, electrodes are made of three general types of material: (1) cellulose, (2) mineral, or (3) a combination of both materials. The cellulose-coated, shielded types (reverse polarity electrodes) are wood pulp, sawdust, cotton, or various compositions secured from the manufacture of rayon. The mineral-coated, shielded types (straight polarity electrodes) are made of metallic oxides or of specially manufactured forms of silicates.

Characteristics of Electrodes. Each of the three types of electrodes has its own special characteristics, which either help or hinder the welder.

Bare electrodes. Bare electrodes are the most difficult to produce a satisfactory weld with, because of their tendency to cause arc to waver. These electrodes can also be overheated very easily and cause excessive splatter in the weld area. However, they are still used to produce welds in areas where post cleaning is difficult. Bare electrodes are now more commonly used in MIG (metal-inert gas) welding.

Light-coated electrodes. These electrodes, having a very light protective coating, produce a more stable arc than bare electrodes, but they usually do not produce slag. The ones that do produce a slag produce only a very thin layer, which does not give very much protection to the weld.

Heavy-coated electrodes. The heavy-coated electrodes are the most commonly used because the coating improves the physical properties of the weld deposit. The coatings also control arc stability and increase the speed and ease of welding in the vertical and overhead position. This control is produced, because the filler metal (rod) actually burns (melts) about 1/16 of an inch inside the coating. Figure 2-1 illustrates shielding produced by heavy-coated electrodes. The cellulose type of electrode coating depends upon a gaseous shielding, or covering, for protection. The mineral type of coated electrode uses the slag as a shield. The slag is mainly of silicon dioxide and aluminum oxide, which forms a blanket over the weld deposit to reduce the cooling rate of the molten metal. The characteristics of some common heavy-coated electrodes are as follows:

a. The E-6010 electrode is the most universally used of all metallic arc welding electrodes, mainly because it can be used in all positions and the weld deposit has physical properties at least as good as those of any other electrode. It is sometimes referred to as the *cellulose type*, because the coating contains a considerable amount of cellulose, such as wood flour or paper flour, combined with other ingredients which are added to obtain certain specific qualities, such as volume and fluidity of the slag. The heat of the arc causes the coating to burn and generate large volumes of gases, which effectively shield the molten metal from air, preventing the formation of harmful oxides and nitrides. Good penetration is characteristic of this type, as well as quick freezing of the weld metal slag, which makes it applicable for vertical and overhead work.

b. The E-6011 electrode is designed to perform the same work, using alternating current, that E-6010 performs on reverse polarity direct current. It is an all-position electrode with somewhat more slag than the E-6010. The coating contains not only gas- and slag-forming ingredients, but others for the purpose of sustaining the arc when both current and voltage are alternating from maximum positive values through zero to maximum negative values. The range of welding current in which various sizes of electrodes can be used satisfactorily is narrower than in the case of E-6010, which means that the welding current controls must be set more exactly.

c. The E-6012 electrode is used with DC straight polarity but does very well with AC, as is the case with most straight polarity electrodes. The penetration is not deep; consequently, the E-6012 electrode has many advantages on jobs where the fit-up is poor and on light gage material, because there is less tendency to burn through than with the E-6010 or E-6011. The E-6012 is an all-position electrode, which is used for fast welding speeds and produces less splatter than most other types. The bead profile is not as flat as that of the E-6010, but it is often desirable for producing horizontal fillets because of the appearance of the weld.

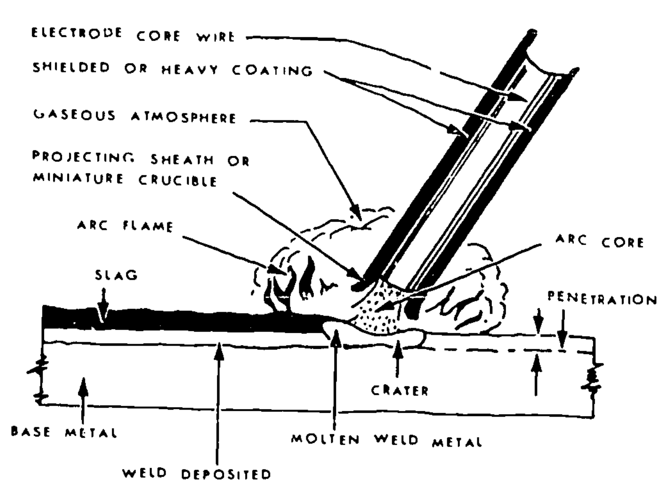

Figure 2-1. Arc characteristics of heavy-coated electrode.

d. The E-6013 electrode, operating on AC, serves the same purpose as the E-6012 operating on DC straight polarity. The coating contains a high percentage of material for stabilizing and maintaining the arc. Penetration is less than usually obtained with the E-6012 and splatter loss is low. This electrode is the most effective for welding lightweight tubular assemblies. It is satisfactory with DC straight polarity, but the original intention was to pair it with E-6011, as the E-6012 pairs with the E-6010.

Exercises (A05):

1. What is the most stable of the three types of electrodes?

2. Associate each of the following terms with *bare, light-coated,* or *heavy-coated* electrodes, writing the corresponding word by each:

    ___ a. Cellulose-coated.
    ___ *b. Coating retained from drawing.*
    ___ c. Used where post cleaning is not applicable.
    ___ d. Increase ease of vertical welding.

Electrode diameter (in)	Amperes Minimum	Maximum	Standard Electrode Length (in)
1/16	40	60	11 1/2
3/32	70	90	14 or 18
1/8	110	135	14 or 18
5/32	150	180	14 or 18
3/16	180	220	14 or 18
1/4*	250	300	14 or 18
5/16*	300	425	14 or 18
3/8*	450	550	14 or 18

*Diameters 1/4", 5/16", and 3/8" are in for flat position welding only.

53-862

Figure 2-2. Current setting range.

___ e. E-6010.
___ f. Create excessive splatter.
___ g. Coating applied by washing or dipping.
___ h. Controlled gaseous shield.
___ i. Improve physical properties.
___ j. Most commonly used.

2-2. Setting Up for Arc Welding

This may be a small section but its contents are very important. We will discuss items of common sense and safety. Things you should do to protect yourself.

A06. Concerning arc welding safety, cite factors to consider when setting up for such welding, the conditions in which personnel are highly susceptible to severe shock, and how to protect hands and eyes when welding.

When any one sets up to perform arc welding, several factors must be considered. These are: (1) type of work, (2) type of machine, (3) type of electrode, (4) the current, and (5) safety factors. The first four factors are very closely related, so we will discuss them together.

Work, Machine, Electrode, and Current. Consider the four factors in this heading first; they are dependent upon each other and along with proper safety, enable you to accomplish the correct setup to produce a sound weld. We will discuss correct setup to produce a sound weld. The type of work or welding that you must perform will influence your selection of electrodes which, in turn, will affect the current and voltage and thus determine the type of machine for you to use. If your work requires deep penetration and it is thick plate, you would need a different electrode than you would for shallow penetration or thin work. At the same time, in this area of interdependency, the selection of the proper welding current and voltage depends upon the size of the electrode, the thickness of the plate, and the welder's skill. In the flat position, you can use higher current and voltage than for vertical or overhead position welding with an electrode of the same size. Because of this relationship of factors affecting one another, we can only use generalized data, such as shown in figure 2–2, to aid us in setting up for arc welding. Consequently, each one of us may set up for welding in a slightly different way from others, because of that person's individuality. However, there is one thing none of us should ever overlook—that is SAFETY.

Safety Precautions. Many accidents can be caused by defective equipment, deliberate violation of safety precautions, and ignorance or neglect of safety rules or practices. In the event of an emergency not covered by the rules listed here, you should obey the orders of your supervisor or follow posted instructions.

Hazards of electrical shock. The AC and DC open circuit voltages are low in comparison with voltages used for lighting circuits and motor-driven shop tools and, normally, will cause neither injury nor shock. These voltages will, however, cause severe shock, particularly in hot weather, when you are perspiring. Consequently, you should always check the welding equipment to make certain that the electrode connections and the insulation on holders and cables are in good condition. Keep your hands and body insulated from the work, the metal electrode, and the holder, and avoid standing on wet floors or coming in

contact with grounded surfaces. Perform all welding operations within the rated capacity of the welding cables. Excessive heating will impair the insulation and damage the cable leads. Inspect the cables periodically for looseness at the connections, defects due to wear, or other damage. Defective or loose cables are a fire hazard. Defective electrode holders should be replaced and connections to the holder should be tightened.

Eyes. The helmet is the most important item of the safety equipment; make sure that it is fitted with a lens that is suited to your eyes (lens shade #10 or #12 may be used for amperages from 75 to 400; #14 is recommended for amperages over that). Since the rays of the arc are also harmful to the eyes of anyone in the vicinity, the arc should always be screened by booths or curtains. When welding must be done in the open, persons working nearby should wear goggles or be warned against the hazard of exposing themselves to, or looking directly at, the arc.

Clothing. Wear leather gloves of the gauntlet type to protect your hands from the heat and injurious rays emitted by the arc. A leather apron is recommended for protection against flying globules of molten metal. A leather jacket or sleeves are required for vertical and overhead welding. You should wear high-top shoes. Turn down trouser cuffs and wear leggings for the most hazardous operations. Do not wear torn or ragged clothing, as it catches fire easily and exposed parts of the body may be painfully burned.

Exercises (A06):

1. List the factors to be considered in setting up for arc welding.

2. When are you particularly susceptible to severe shock from AC and DC open circuit voltages?

3. What feature of your helmet should you check to provide eye care when welding?

4. How can you effectively protect your hands when welding?

Metallic Arc Welding

METALLIC ARC welding can be defined as: "Progressive, localized fusion produced by electric heating with an electric arc and not requiring pressure using a suitable electrode." The electric arc produces temperatures ranging from 5,000° to 10,000° F. and fuses (melts) the edges of the metal together. This fusion is aided, and filler metal is added to the weld by the melting electrode.

In this chapter, we discuss metallic arc welding broken down into six numbered sections. These sections are arc welding problems, building up flat surfaces, preparing and welding joints in the flat position, horizontal position welding, vertical position welding, and overhead position welding.

3-1. Arc Welding Problems

Arc welding is a very modern means of uniting metal because of all the advances which have been made in our field. However, it is not without its problems. The biggest problem, the one which will discuss, is the effect that the heat has upon the base metal involved in the actual fusion and the surrounding area.

A07. State how heat from electric arc welding affects the metal involved and the surrounding area.

Heat Effect in Arc Welding. The heat-affected area in welding operations is that portion of the base metal that is changed metallurgically by the welding heat. This heat-affected area consists of three zones: (1) the very hot section next to the molten filler metal, (2) the annealed section next to the heated base metal, and (3) the zone adjacent to the cold base metal.

The rate at which heat is applied to the plates is greater in arc welding than it is in oxyacetylene welding; this causes a higher concentration of heat at a particular point. Therefore, a steeper heat gradient results, and less metal is affected by the heat. In bare wire arc welding, the heat-affected zone is narrowest; it increases with heavy-coated electrodes. Stainless steel electrodes produce a smaller disturbed area than do the heavy-coated steel electrodes.

Factors Affecting the Heat-Disturbed Area. In general, the extent of the heat-affected area will increase with the amount of welded energy used in arc welding, the welding energy being a function of the voltage and amperage settings. Greater penetration for arc welds is not necessarily obtained with an increase in the heat-affected area, because this increase is in width rather than in depth. With the exception of cored and stainless steel arc welds, the smaller the heat-affected area, the more rapid the removal of heat from the area by the surrounding parent metal will be. In arc welding, the extent of the heat-disturbed area is increased under these conditions listed below:

- When, with a constant current, the welding speed is decreased.
- When, with a constant welding speed, the current is increased.
- When the arc length is shortened and the settings on the welding machine remain unchanged.
- When the heat-affected area is increased in lighter sections of the plate.
- When preheating increases the heat-affected area.

Hardness in Arc Welding. Arc welding produces greater hardness than does oxyacetylene welding in the heat-affected area for the same type of welding operation, and the hardened zone is more concentrated. In general, the greater the hardness produced in arc welds, the more likely the weld is to crack when the molten metal solidifies. Arc welds on plate containing 0.35 percent carbon or a higher percentage show a greater rate of increase in hardness than do steels containing a lesser amount of carbon. In alloy steels, certain elements are added to increase the strength, but they also increase the hardness produced by the carbon. The carbon content in easily welded grades of plate is usually kept low to prevent excessive hardness in the welding operation. In plain carbon steels having 0.25 percent carbon or less, welds made by either arc or gas welding do not change to a noticeable degree in hardness, ductibility, or tensile strength.

Exercises (A07):

1. What are the heat-affected zones when arc welding?

2. How is the heat-affected area changed when the current is kept constant but the welding speed is decreased? Increased?

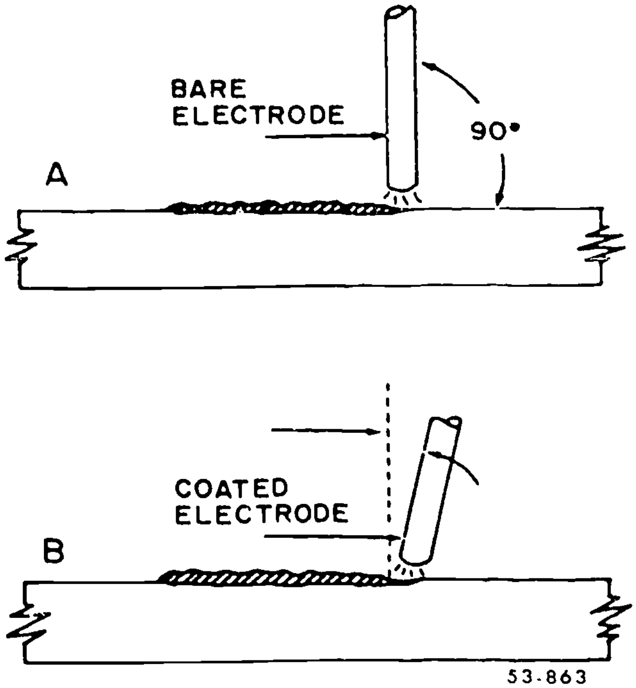

Figure 3-1. Electrode angle for making beads.

3. Comparing arc welding to oxyacetylene welding, which produces greater hardness in the heat-affected zone?

4. How does the arc length affect the heat-affected area?

5. Does greater penetration mean you will have a larger heat-affected area? Why?

3-2. Building Up Flat Surfaces

A welder can always correct his short mistakes if they aren't too big. That is, if he knows how to build up surfaces. In this section, we will discuss just how to run beads and to build up flat surfaces (padding).

A08. Identify procedures involved in bead welding and building up flat surfaces.

The first requirement for good welding is to make sure that you have clean working surfaces. Oil, dirt, and other foreign matter on the metal to be welded can cause such defects as lack of fusion, porosity, and slag inclusions.

Bead Welding. In bead welding with bare or lightly-coated electrodes, hold the electrode at 90° to the base metal as shown in view A, figure 3-1. When you use coated electrodes, tilt the electrode 5° to 15° in the direction of travel, as shown in view B. Tilting the electrode gives you a clearer view of the crater and helps to control the molten slag. The proper arc length or gap between the end of the electrode and the plate should be approximately equal to the diameter of the electrode used. However, when striking the arc figure 3-2, and starting the weld, hold a long arc momentarily to preheat the base metal and permit fusion at the beginning of the weld. At the end of the weld, shorten the arc length to prevent forming a crater or depression.

If the current, polarity, and length of the arc are correct, the metal melts to form a pool of molten metal at the point where the arc strikes the plate. Molten metal is forced out of the pool by the blast from the arc. A small depression forms in the base metal and the molten metal piles up around it; this is called an *arc crater*, and appears in figure 3-3. The size and depth of craters depend upon the current settings, the speed of travel, the diameter of the electrode, and the length of the arc. The depth of the crater provides a means of observing the penetration or depth to which the arc melts into the base metal. The depth of penetration should not be less than 1/16 inch.

The speed of travel depends upon the proportions of the bead desired, current value, and size of the electrode being used. The speed of travel is governed by observing the trailing edge of the crater. By closely watching the crater and its trailing edge, you can determine the penetration and the width and height of the reinforcement. Since the speed of travel and current setting are related factors in determining the quality of a weld, you must learn to recognize the weld appearance resulting if either factor is wrong. Figure 3-4 shows the results of using various welding speeds and current values.

Padding. Padding (building up) is a welding operation which is used to increase the thickness of the parent metal Padding may be used to build worn parts up to their original dimensions. The padding of large

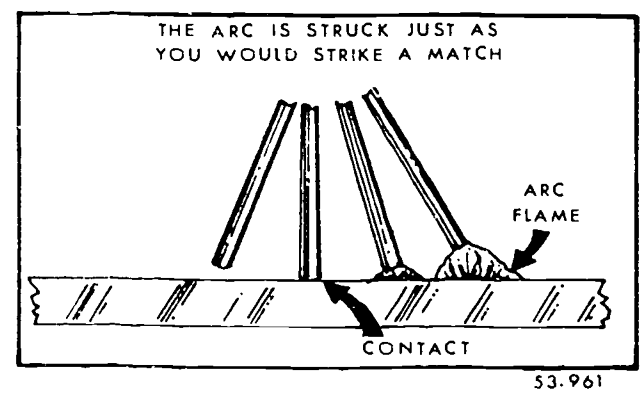

Figure 3-2. Striking the arc.

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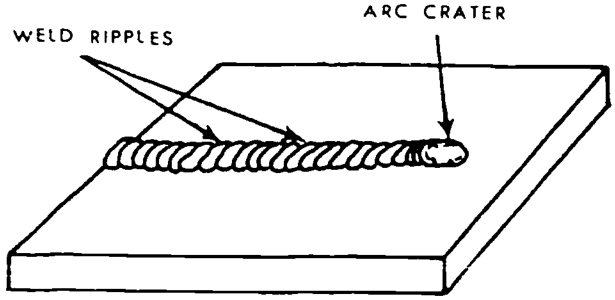

Figure 3-3. Arc-welded bead.

parts is generally done in layers of stringer beads welded in at right angles to each other, as shown in figure 3-5. When only a thin layer of added filler metal is required, padding is done by weaving the electrode to produce a wide bead of thin cross section.

Kind and size of electrode. Bare electrodes are used when ductility and strength are of secondary importance. If dense, ductile, hard, or corrosion-resistant properties are required in the deposited metal, coated electrode may be used. The size of the electrode depends upon the size of the work; for example, the mass of a 6-inch-diameter shaft would permit the use of larger electrodes and higher current values than a shaft of 1 inch diameter.

Welding procedure. It is essential in padding to correctly merge successive and adjacent stringer beads. In laying each pass, hold the electrode so that it bites into the parent metal at the same time, as shown in figure 3-6. When the beads are not merged in this manner, defects will show up in the form of voids and slag inclusions, as shown in figure 3-7. You usually have a choice of running the beads either parallel or at right angles to the longest dimension of the work. You would normally choose the lengthwise direction, because it permits a longer interval of time before the concentrated heat of the arc comes back to the starting point. This procedure minimizes welding stresses by providing a greater length of time for the work to absorb and distribute the heat input of the arc.

In most cases, the edges of the part being padded should first be encircled with beads (fig. 3-8) so that the stringer beads may be ended with less difficulty. This procedure reduces the possibility of causing crater cracks and overheating with the melting away of the edges of the work. Hold a long arc momentarily in starting each pass. Fill all craters and carefully avoid overheating the edges. When you use coated electrodes, every bead must be cleaned with a slag hammer and wire brush. Wire buffing between layers is generally adequate when you use bare electrodes. When one layer of beads has been deposited, turn the plate so that the next layer is deposited at a right angle to the previous layer. Quench the plate often enough to keep it from becoming excessively hot.

Exercises (A08):

1. What is the angle of the electrode when using a bare electrode? A heavy-coated electrode?

2. What is the minimum penetration acceptable when welding beads?

3. What determines the speed of travel when bead welding?

4. Why are the edges first encircled with beads when padding?

5. How are the layers deposited when padding?

6. What is the first step in producing a good padding?

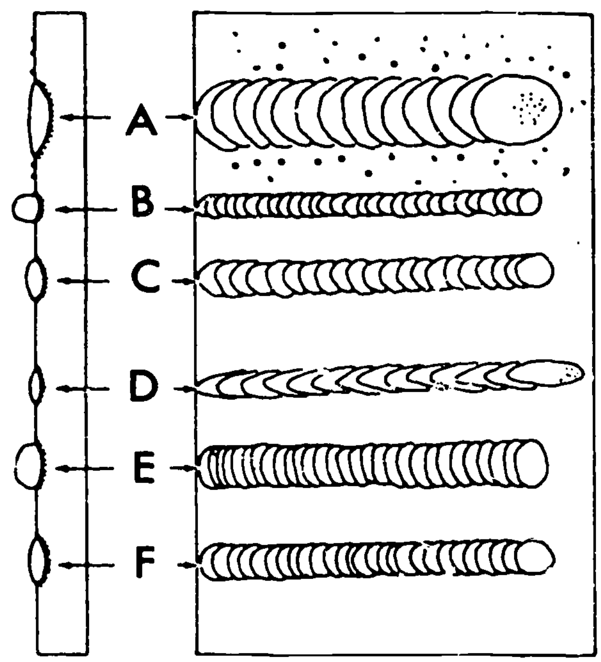

Figure 3-4. Arc welding results.

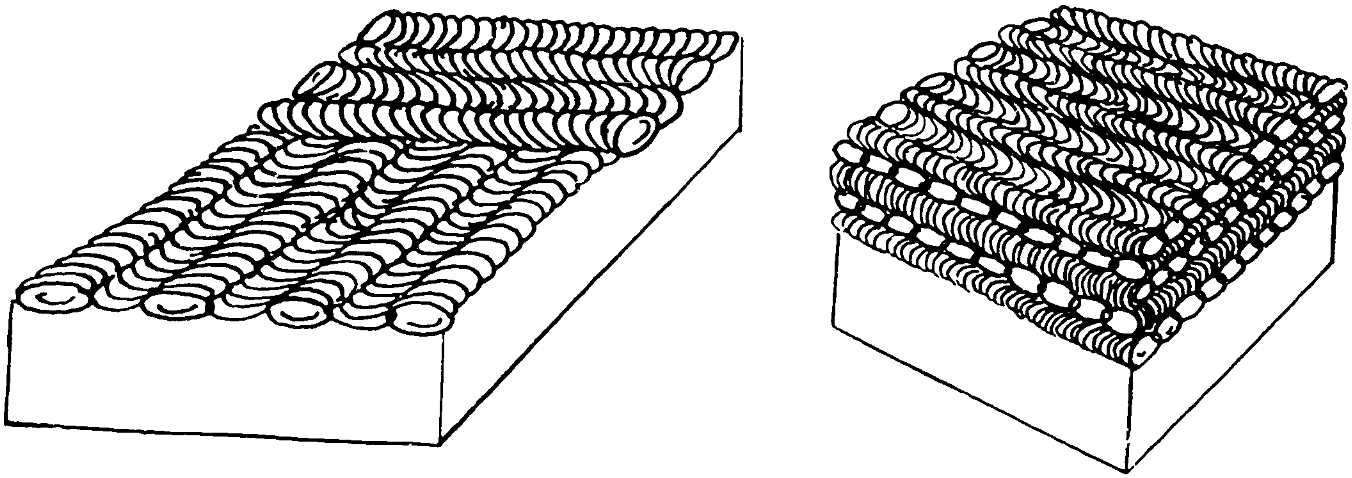

Figure 3 5. Padding.

3-3. Preparing and Welding Joints in the Flat Position

An important part of arc welding is the selection of the best type of joint to be used for a particular job. The selection is sometimes dictated by conditions, but very often a choice is possible. Of course, the best joint is the most economical one that will stand up under the usage required. In making the selection, you must consider three main factors:

(1) The load and unload characteristics. This refers to whether the load is under compression, tension, bending, fatigue, or impact stress, or any combination of these.

(2) The manner in which the load is applied; that is, whether the load application is steady, variable, or sudden.

(3) The cost of joint preparation and the actual welding Also to be considered are the effects of warping, the ease of welding, and the smoothness of the joint.

In this section, we discuss the three most common types of joints: (1) lap, (2) tee, and (3) butt. We also see how each is affected by the three factors just stated above.

A09. Identify factors to consider in making lap joints and tee joints.

Lap and Tee Joints. The *lap joint* is a joint in which the edges of two plates are set one above the other and welded, binding the edge of one sheet to the surface of the other sheet. It is frequently used where a flush joint is not required. The ease of preparation and welding makes it an ideal joint for structural work.

The two most common lap joints used to join metals by arc welding are the *single fillet lap joint*, figure 3-9, and the *double fillet lap joint*, figure 3-10. The single fillet lap joint is used frequently, since it requires no machining to fit the edges of the plate. If the loading is not too severe, this joint is suitable for welding plates of all thicknesses; but if fatigue or impact loads are

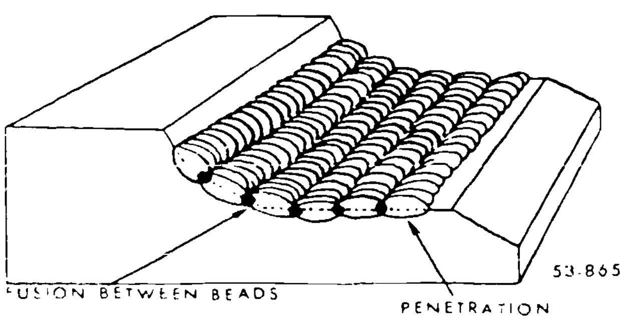

Figure 3 6. Correct padding.

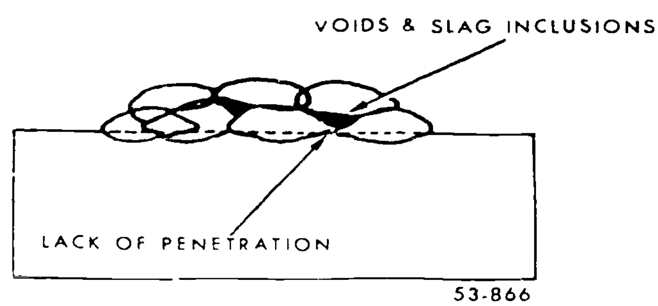

Figure 3 7. Incorrect Padding.

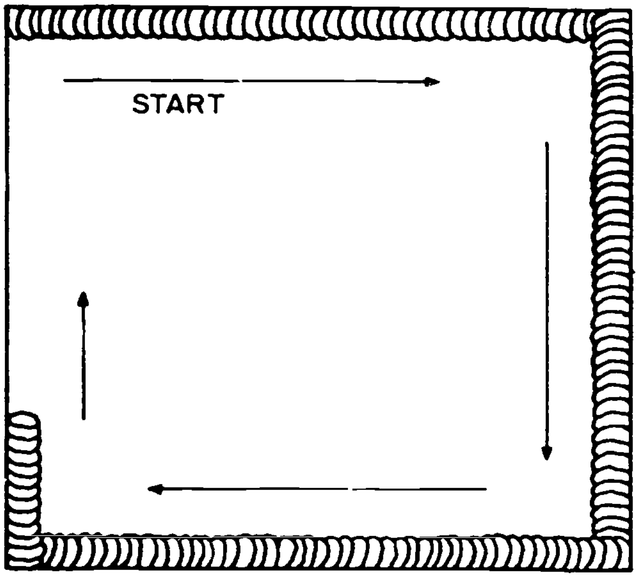

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Figure 3-8. First step of padding.

encountered, concentrations of stress will occur at the edge of the weld. Under tension, the plates will pull out of line, thus subjecting the root to bending. The double fillet lap joint is suitable for more severe loading conditions than can be met by the single fillet lap joints. Lap joints are not desirable under fatigue or impact, but they are capable of developing high efficiency under shear and tension stresses.

A *tee joint* is formed when the edge of one plate is joined approximately perpendicular to the face of another plate. The weld in this joint is a fillet weld and is approximately triangular in cross section. It is a very rigid joint and is used extensively in structural work. View A of figure 3-11 shows a square edge or plain tee joint used for joining metals up to [illegible] inch thick in which no edge preparation is required. You may weld from one or both sides, depending upon the strength desired. When heavier metal is involved, up to 3/8 inch, use a single bevel, as shown in view B of figure 3-11, and weld the joint from one side. View C of figure 3-11 shows a doublebeveled tee joint used on steel over 1/2 inch thick, with the joint welded from both sides.

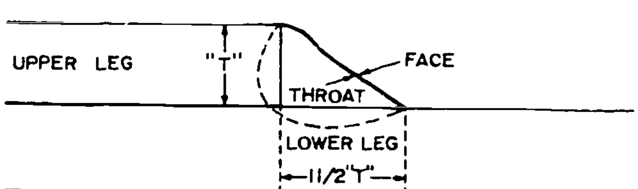

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Figure 3-9. Single fillet lap joint.

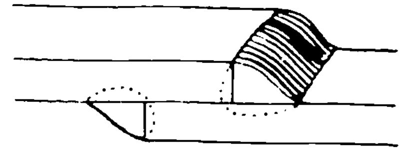

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Figure 3-10. Double fillet lap joint.

Lap welding procedure. When you are joining metal thicknesses greater than 1/8 inch, the edges of the sheet should overlap approximately three to four times the metal thickness. Tack the plates at intervals of approximately 8 inches. If you must force the fit-up by means of dogs, as illustrated in figure 3-12, short welds are preferred to tack welds.

Hold the electrode at an angle of 30° with the vertical, and tilt the top of the electrode to an angle of 15° in the direction of travel, as shown in figure 3-13. Hold a long arc momentarily at the start of the weld to insure penetration. Heavy plates conduct heat away more quickly than light sheets; therefore, the speed of travel should be slower. For the same reasonn, higher current values may be used on heavy work. Direct the arc so that penetration will be obtained in both the upper and lower plates. When one pass or bead will not provide the proper size of weld, make a multiple-pass fillet weld. In making lap joints on plates of different thicknesses, hold the electrode at an angle of approximately 20° with the vertical. Take care not to overheat or undercut the thinner plate edge. You must control the arc in such a manner that the molten metal flows to the edge of this plate.

Tee welding procedure. Tee joints may be welded in the flat, horizontal, vertical, and overhead positions. In the flat position, the weld is included from 0° to 45° and rotation of the face is 0° to 45° from the 180° flat position. Make the fillet weld in a tee joint by depositing multiple passes of stringer beads, as fig. 3-14 shows or by weaving the electrode as fig. 3-15 shows, to form a wide bead. The electrode should be held at a 45° angle to both plates and a 75° angle to the direction of travel (as shown in fig. 3-16). Stringer beads are generally preferred for fillet welds of maximum strength and ductility, since each successive layer of beads tends to refine the grain structure of the previous layer. The sequence of the first three passes of a multiple-pass flat fillet weld is shown in figure 3-14. Note the slightly changing angle of the electrode with each pass. Figure 3-17 shows several accepted weave motions for depositing a weave bead (overlay) to cover the stringer beads of a multiple-pass flat fillet weld. The weave shown in the top view, figure 3-17, with a slight pause at the apex of each angle, is an elementary motion preferred for beginners. The other views in the figure show more advanced motions, including each staring point.

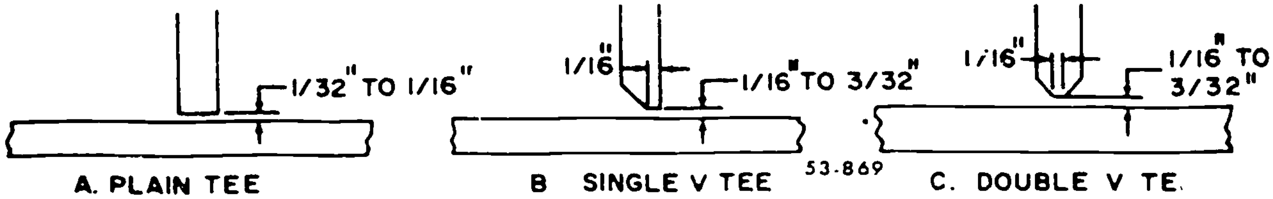

Figure 3-11. Tee joint preparation.

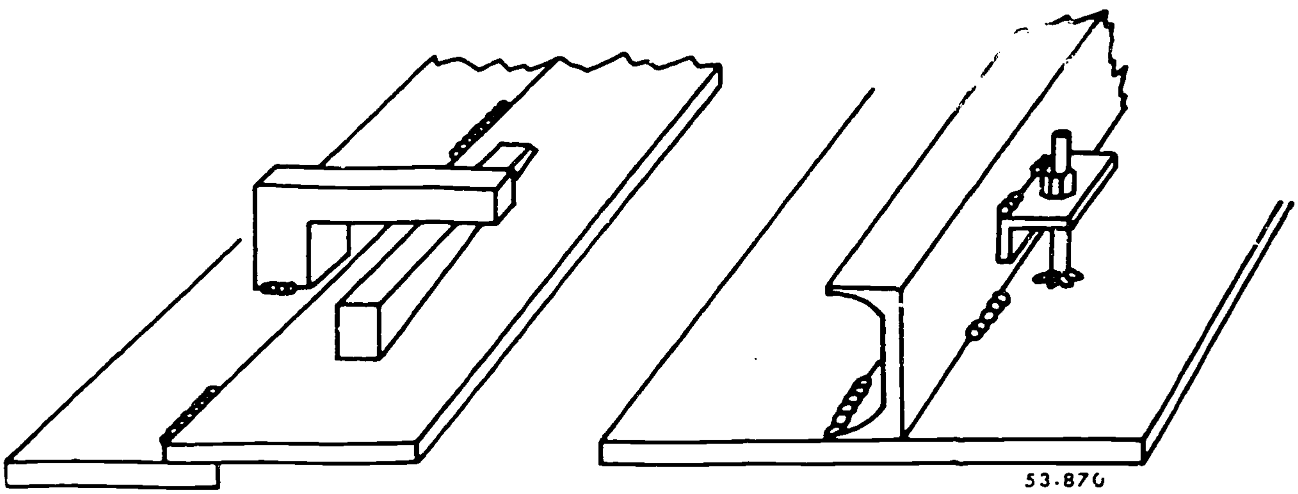

Figure 3-12. Using fit-up dogs.

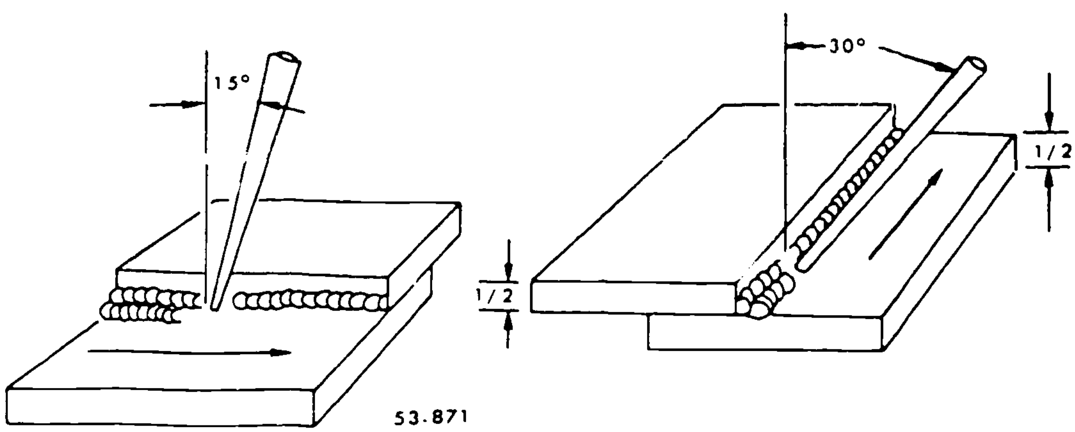

Figure 3-13. Angle of electrodes.

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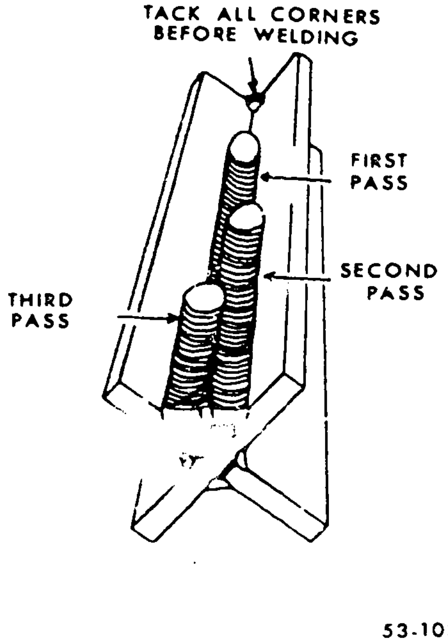

Figure 3 14. Multiple passes for a tee joint (flat position).

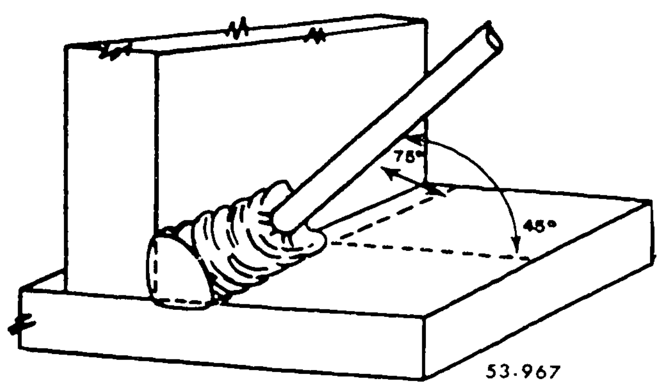

Figure 3 16. Electrode angle for a t[illegible]int [illegible]osition).

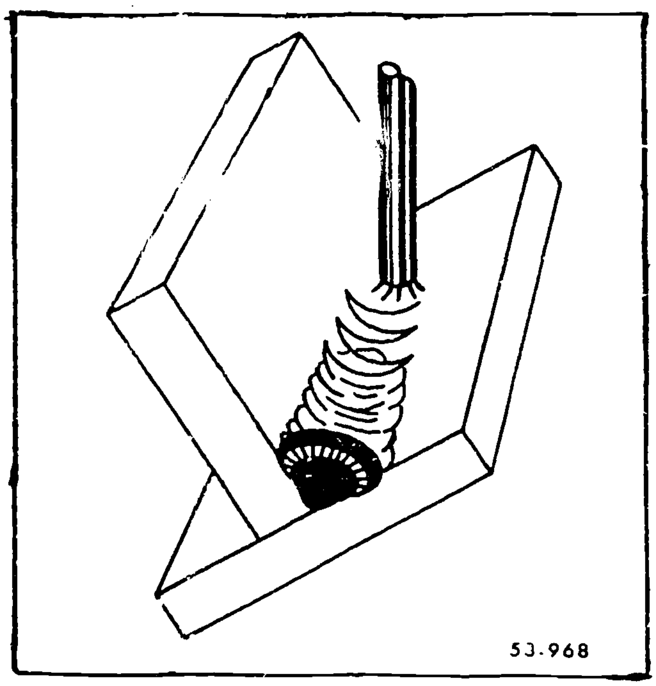

Figure 3 15. Electrode weave motion.

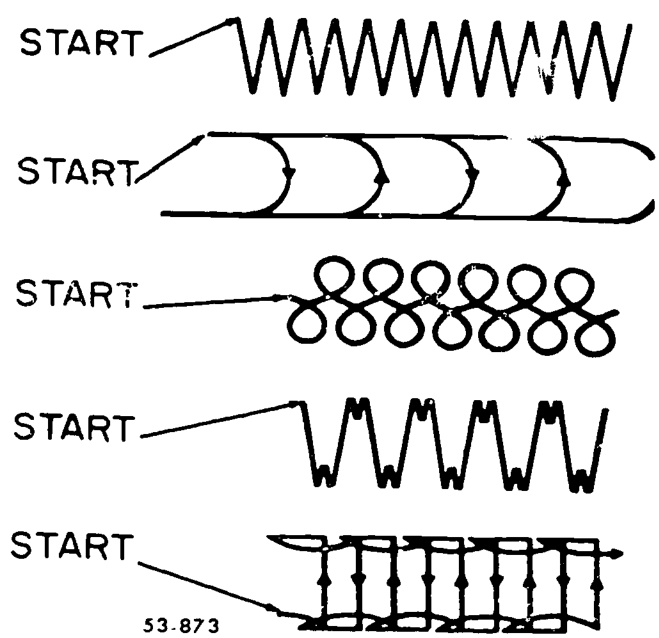

Figure 3-17. Weave motions in the flat position.

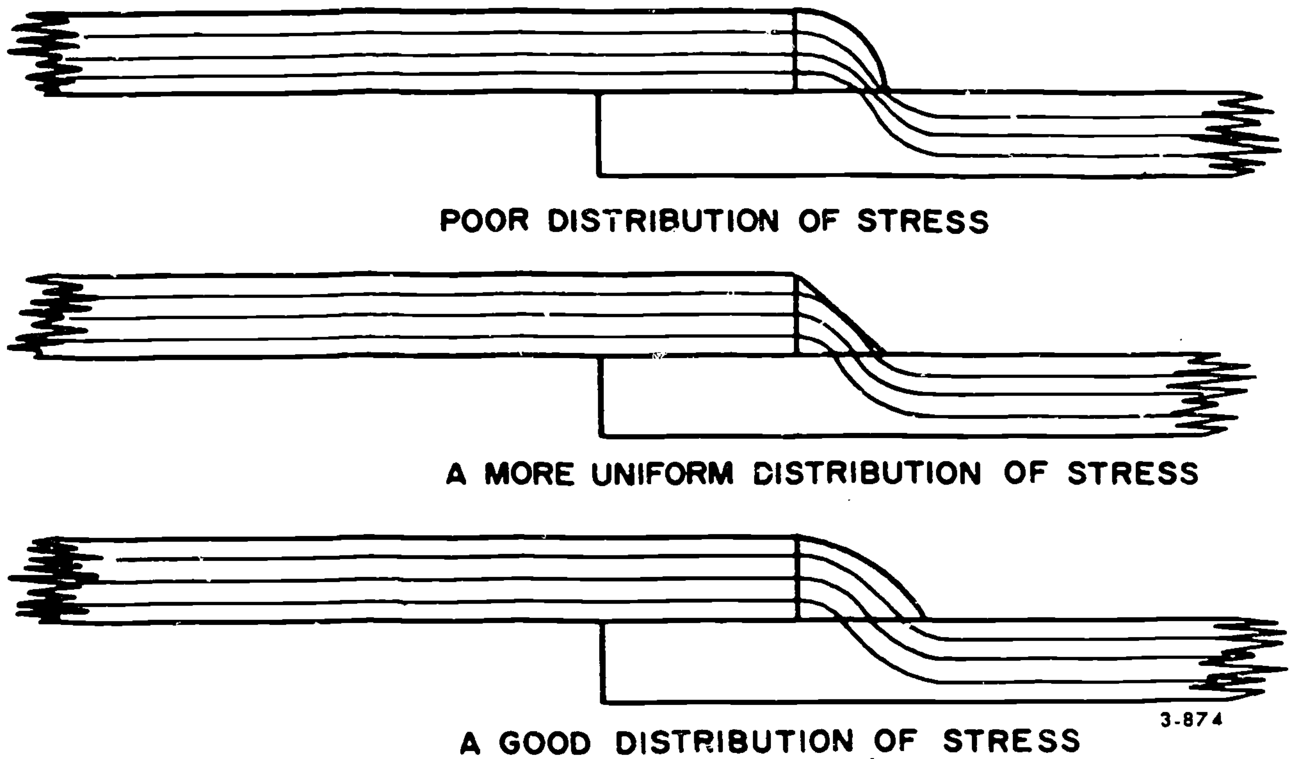

Figure 3-18. Lap joint weld stress distribution.

Weld requirements for lap joints. When the lap weld (figs. 3-9 and 3-10) is properly made, the upper leg will equal the thickness of the metal. The lower leg will equal 1½ times the metal thickness, while the throat thickness should equal the thickness of the base metal.

If metals of unequal thicknesses are used, the weld specifications are based upon the thickness of the thinner sheet. Penetration for metals 1/8 inch thick should be 1/16 inch. For lighter gages, the penetration should be 30 to 50 percent of the metal thickness. The face on lap joints should be slightly convex in shape, thus permitting a smooth flow of stress lines through the face of the weld. Any abrupt change in shape of the face, such as undercutting or overlapping at the edge or toe of the weeld, will cause points of stress concentration, thus reducing the strength of the weld. Figure 3-18 shows proper and improper stress distribution.

In many cases, the strength of the welded joint is affected by the location of the welds in relation to the parts joined. Other factors being equal, welds that have their linear dimensions transverse to the lines of stress, as shown in figure 3-19, are approximately 30 percent stronger than welds with linear dimensions parallel to the lines of stress. Figure 3-19 illustrates this condition in view B. In welds that have their linear dimensions approximately parallel to the line of force, the stress upon the weld is in the shear. The shear in this case is greater at the ends of the welds than at the middle. In certain cases, to obtain greater resistance to the tearing action of the weld, it is advisable to hook the bead around the joints, as shown in figure 3-20.

Weld requirements for tee joints. The requirements for tee joints are expressed by nomenclature, as shown in figure 3-21. Regardless of whether stringer or weave beads are used in making a tee joint, the size of the weld remains the same. The size of a fillet weld is expressed in terms of the length of the legs of the largest isosceles triangle which can be described in the weld cross section, as shown by the hidden object lines in figure 3-22. The length of the legs and the thickness of the throat are based on the thickness of the base metal, as shown in figure 3-22.

In the welding of tee joints, undercutting frequently occurs along the toe of the upper leg. This defect is a groove melted in the base metal adjoining the toe of the weld, as shown on the right in figure 3-23. The chief causes of this are a welding current that is too high and improper, and the angle of the electrode. Correcting the current setting and changing the electrode angle and manipulation of the electrode to wash molten metal up to the toe of the vertical leg usually corrects this fault. The characteristics of a good tee joint are shown on the left in figure 3-23.

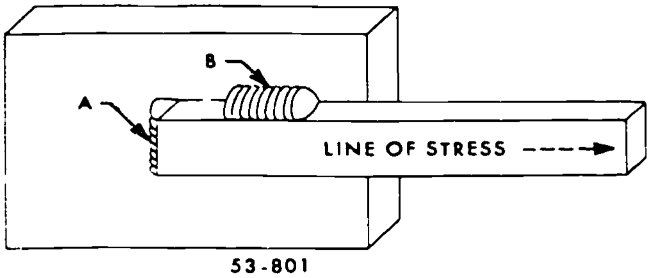

Figure 3-19. Weld loction in relation to the line of stress.

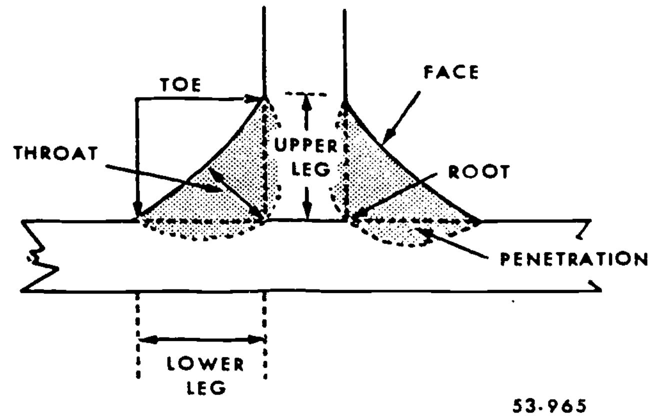

Figure 3-21. Tee joint nomenclature.

Exercises (A09):

1. When welding a lap joint of steel 1/4 inch thick, what is the approximate minimum plate overlap?
2. Write *true* or *false* beside each of the following:

___ a. Tee joints are welded with multiple passes.
___ b. Lap joints cannot be made using unequal plate.
___ c. Single lap joints are welded using only one pass.
___ d. Tee joints are used in structural repair.
___ e. The throat of tee joints is equal to "T."
___ f. Undercut occurs on lower legs of tee joints.
___ g. Weld requirements are always based on the thickness of the base metal.
___ h. Lap joint fit-up can reduce stress distribution.

A10. Cite factors in preparing and welding butt joints in the flat position.

Butt Joints. A butt joint is used to join two plates having surfaces in approximately the same plane. Several methods of edge preparation for joints are used to make butt welds in the flat position; the most important are shown in figure 3-24.

The heat developed at a joint by welding causes the metal to expand and, upon cooling, to contract a corresponding amount. Distortion caused by the contraction of a welded joint is shown in figure 3-25.

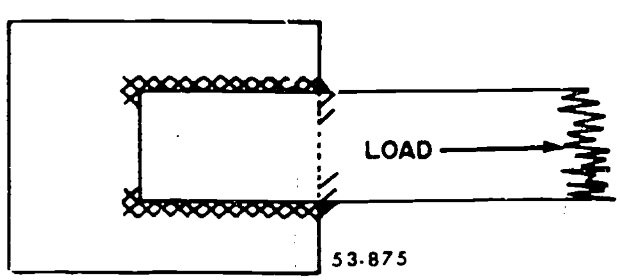

Figure 3-20. Welding around corners to resist tearing.

This distortion is caused by a greater amount of hot metal at the top of the weld than at the root, thus causing more contraction across the top of the weld joint.

If the expansion of the part being welded is restrained buckling or warping may occur as a result of the expansion stresses developed. If the contraction is restrained, the parts may be distorted.

Welding thick material presents additional problems. To meet the weld requirements for heavy metal sections, prepare the joint edges by beveling. This is necessary to aid in securing complete penetration to the root of the joint. Because of the thickness of the plates and the beveling, welds cannot be made by a single weld bead, so a series of either stringer or weave beads is used. This method of depositing the weld metal is called *multiple-pass welding*. It is used in welding thick plates to avoid carrying too large a pool of molten metal which can

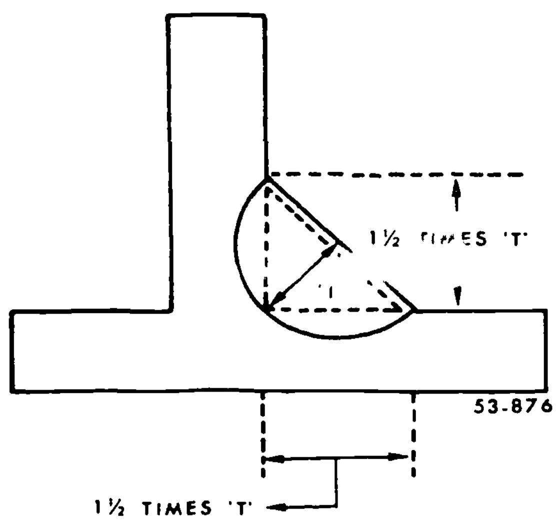

Figure 3-22. Tee joint specifications.

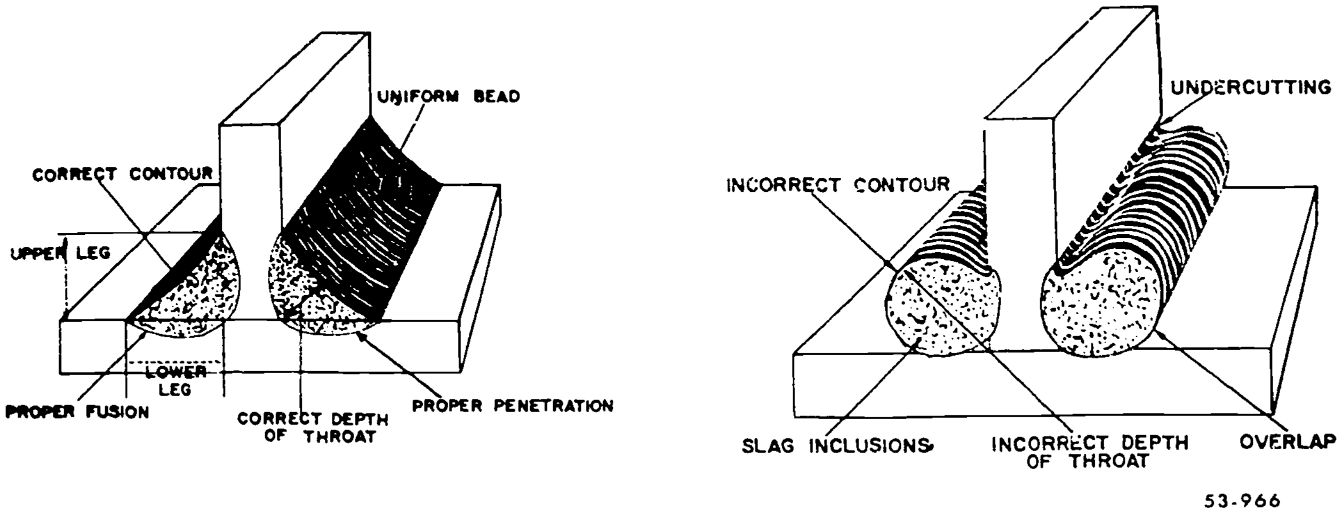

Figure 3-23. Characteristics of a good tee joint and of a bad tee joint.

cause slag inclusions or cold spots in the weld. A large molten pool of metal is difficult to control, requiring high heat and slow speed of travel, which results in excessive grain growth and unnecessary melting down of the joint faces.

By using multiple-pass welds on heavy butt joints, you can concentrate on getting good penetration at the root of the weld in the first pass. On succeeding layers, you can concentrate entirely on getting good fusion with the sides of the bevel and the preceding layer. You can easily control the final layer to obtain a good, smooth surface. The lower layer of weld metal often cools to a black heat and reheats to a temperature high enough to permit grain refinement, which, in effect, is a form of heat treatment. The depth of metal affected by this action depends upon the penetration of the welding heat. In some classes of work, when you desire grain refinement in the top layer of the welded joint, you can deposit an excess layer of weld metal on the finished weld and then machine it off. The purpose of this last bead is to supply enough welding heat to refine the weld metal in the final layer at the surface of the joint.

When [illegible] ails, the simplest thing to do (before [illegible] the pieces slightly in the opposite [illegible] contraction is to take place. Then, upon cooling, the contraction forces will pull the pieces back into position.

Joint preparation. In making various types of butt welds, consider the following examples as typical. They should serve as a general guide for welding plates of various thicknesses. In addition to the plate thickness, another factor that can influence the method of joint preparation is the type of equipment available for beveling or grooving. You can prepare joint edges by flame cutting, shearing, flame grooving, machining, chipping, and grinding.

Plates 1/8 to 3/8 inch thick can be welded with no special edge preparation by making a bead weld on both sides of the joint if possible. Use a single bevel to weld metals that are 1/8 to 3/8 inch thick when welding on both sides is not possible. Bevel the edge to an angle of 30° to 35°. Use the single bevel (shown in fig. 3-24) view D, when you cannot bevel one of the plates because of its shape location, or fixed position. In this case, the weld is made from one side. The single "V" (shown in view B of fig. 3-24) differs from the single bevel in that you bevel the edges of both plates. The included angle of the bevel should be 60° to 75°. Use it on the same thickness of metal that you use for the single bevel. Make the weld from one side only. The number of passes required will depend upon the metal thickness.

Use the double bevel (shown in view E of fig. 3-24) on metals over 3/8 inch thick. Bevel the edge on both sides to an angle of 30° to 35°. Use the double bevel when you cannot bevel the joining plate in the same manner and fo[illegible] ork you can weld on both sides. The double "V" [illegible] n fig. 3-24 view C) differs from the [illegible] bevel in that you bevel the edges of both plates. The included angle of the double "V" bevel should be from 60° to 75°. Use it on the same thickness of metal that you use for the double bevel. The double "V" requires approximately one-half as much electrode as the single "V" butt joint. In general, butt joints prepared from both sides permit easier welding, produce less distortion, and insure better weld metal qualities in heavy sections than the joints prepared from one side only.

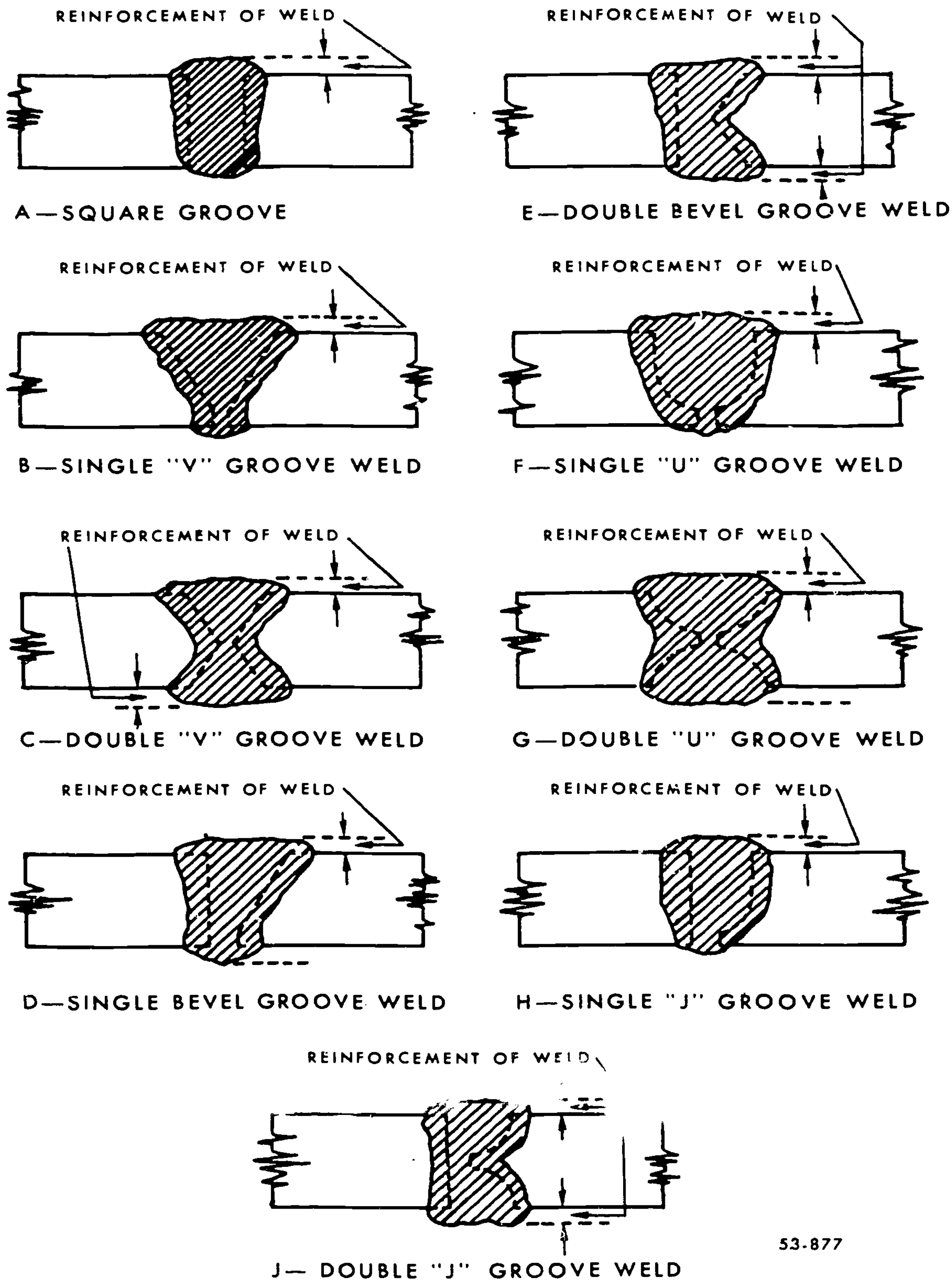

Figure 3-24. Butt joints in the flat position.

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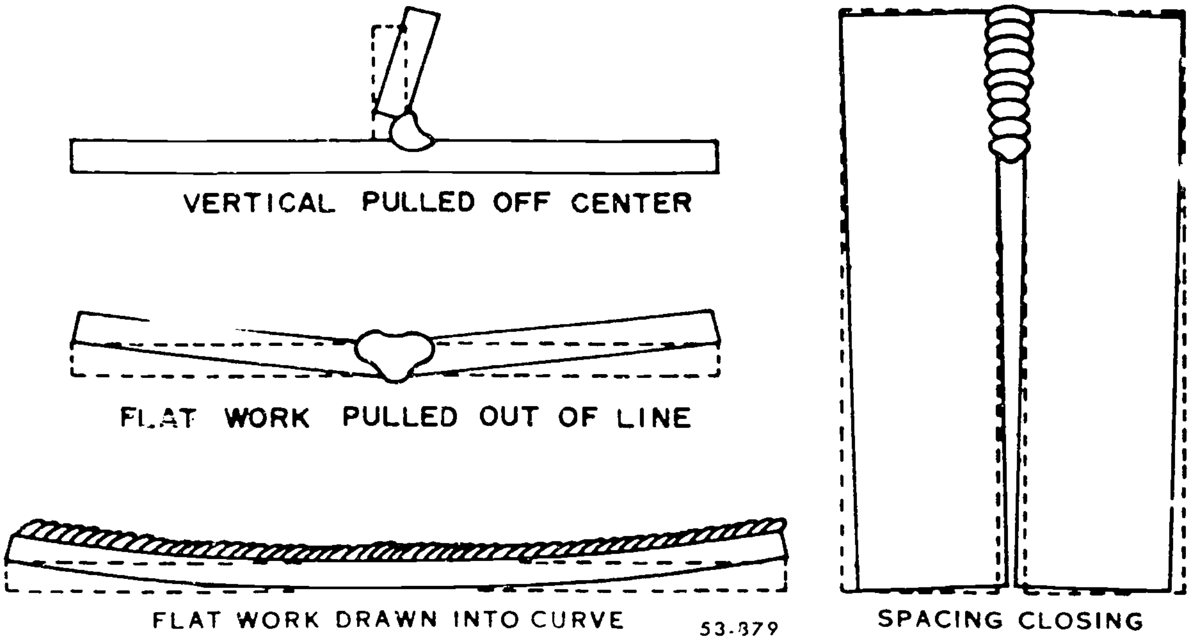

Figure 3-25. Results of weld metal shrinkage.

You can use the single "U" (shown in view F of fig. 3-24) in place of the single or double "V" for joining 1/2 to 3/4-plates. It is more satisfactory and requires less filler metal than the single "V" for welding heavy sections or welding in deep grooves. Make the weld from one side, except for a single bead that you make last on the opposite side of the "U," if possible. Use the double "U' (shown in view G of fig. 3-24) for joining heavy plates, usually 3/4 inch and thicker. It requires less weld metal than the single "U." Weld from both sides.

The single "J" joint (shown in view H of fig. 3-24) is used to weld plates 1 inch thick or heavier from one side. The double "J" type (pictured in view J of fig. 3-24) is used to welc [illegible]ery heavy p[illegible]es fr[illegible] both s[illegible]es. Care is neces[illegible] [illegible]ion [illegible]t of [illegible] weld [illegible] romoted by root openings. Less [illegible] is required in making the single "J" than [illegible] sing[illegible] "V," and the same is true of double "J" and "V" joints.

Butt joint weld requirements. The welds shown in figures 3-26 and 3-27 illustrate the requirements for butt joints on steel plates with a thickness of 3/16 inch and over. The width of the fusion zone for thick plates is governed by the way in which you prepare the joint. When you bevel the edges, the weld should be approximately 1/8 inch wider than the included angle of the bevel. The depth of fusion in the beveled edges of the joint should be at least 1/16 inch. A height of reinforcement of 1/8 inch is usually sufficient for heavy plate. The penetration for butt welds must be 100 percent, regardless of the thickness of th[illegible] double-edged penetration. You obtain [illegible]nt of [illegible]etration from each side to produce the [illegible]red full base metal penetration.

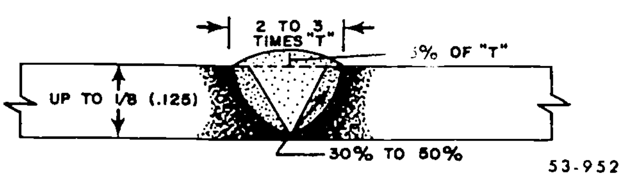

Figure 3-26. Butt joint specifications (steel sheet).

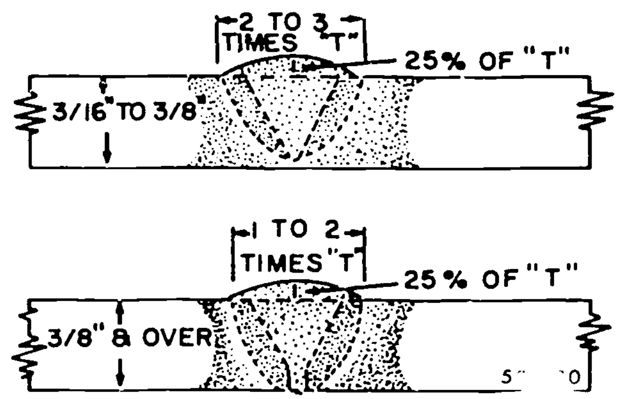

Figure 3-27. Butt joint specifications (plate).

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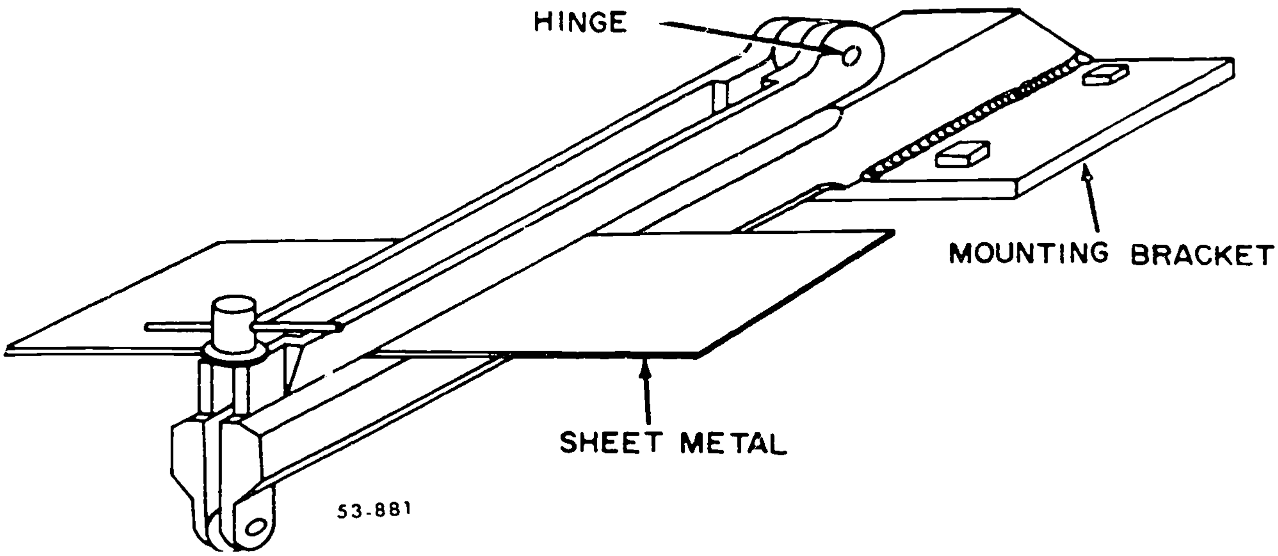

Figure 3-28. Welding jig.

Butt joint welding procedure. The welding procedure should be so devised that contraction stresses will be held to a minimum while the desired shape and strength of the welded part are retained. Here are some methods for controlling contraction. In the welding of long seams, the contraction of the metal deposited at the joint will cause the edges to pull together and possibly overlap. You can adjust for this contraction by using a wedge to hold the edges apart. Move the wedge forward as you weld. Spacing by means of the wedge depends upon the type of metal and its thickness. Metal under 1/16 inch thick may be welded by flanging the edges. When you use flanging, tack the metal at intervals along the seam before welding.

You can also use jigs to hold metal parts in position for welding. You can align most points and hold them in place with pieces of angle iron and C-clamps, or you may have to use special jigs and clamps for some jobs, as shown in figure 3-28.

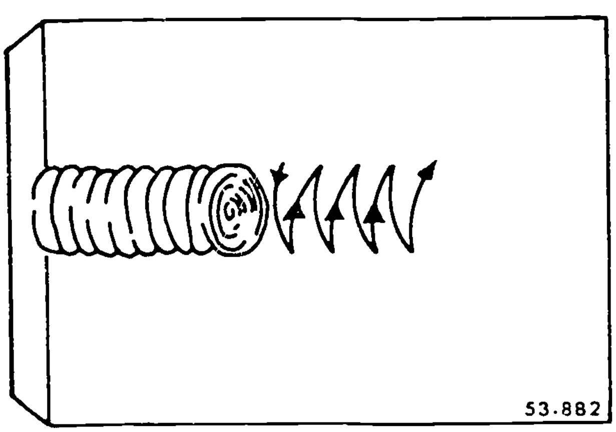

Figure 3-29. Weave on heavy plate.

When the edges of the joint are beveled, the spacing should be exactly the same as the thickness of the shoulder at the bottom of the joint edge. Tack-weld the parts in place at short intervals along the seam and remove thhe slag deposited while tack-welding to prevent including it in the weld. To make the root bead, use an electrode small enough in diameter to obtain good penetration and fusion at the base of the joint. A 1/8-or 5/32-inch electrode is suitable for this purpose.

To obtain penetration at the beginning of the weld, hold a long arc momentarily. Tilt the top of the electrode slightly in the direction of travel, the exact amount depending upon the type of electrode and the current setting. You must then clean the root bead thoroughly by chipping and wire brushing before you deposit additional layers of weld metal. Use a 5/32-or 3/16-inch electrode to make these additional layers of filler metal in the joint.

Weaving makes it possible to deposit more metal in a single pass when you are welding in a "V" on thick plates. Figure 3-29 shows the electrode weaving motion that will give the best results. The movement of the electrode is semicircular across the line of weld, and a slight pause in movement of the electrode at the toes of the weld will aid in preventing undercutting. The number of layers of weld metal will depend upon the thickness of the metal you are welding. Use a sufficient number to build up the weld with a series of small stringer or weave beads, keeping the heat input and the formation of hard zones in the base metal at a minimum. Each bead or layer of weld metal will refine the grain in the weld immediately beneath it and will anneal or soften the hardness produced in the base metal by the previous bead.

To weld thick sections beveled from both sides, deposit the weave beads alternately on one side and then on the other to reduce the distortion which might

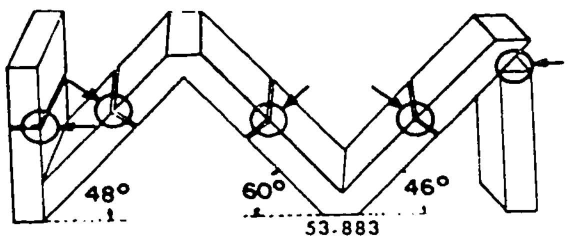

Figure 3-30. Positions of horizontal welds.

occur in the welded structure. Thoroughly clean each bead or layer of weld metal, and remove all scale oxides and slag before you deposit any additional metal. Control the motion of the electrode to make each bead uniform in thickness and to prevent undercutting or overlap at the edges of the weld.

Exercises (A10):

1. Define a butt joint.

2. How can edges be prepared for butt joints on heavy plates?

3. What edge preparation is necessary for butt joints on 5/32-inch-thick plate?

4. When welding butt joints, what is the minimum penetration?

5. List three devices that may be used to control contraction and keep butt joint edges aligned.

6. A height of reinforcement of ________ ________ is usually sufficient when butt welding thick plate.

7. What is the angle of bevel used for (a) a single bevel joint? (b) A single "V" joint?

8. Provide the missing words to complete each of the following statements about butt joints and butt joint welding:

   a. If the expansion of the part being welded is restrained ________ . ________ or warping may occur as a result of the expansion stresses developed.
   b. In welding thick material, welds cannot be made by a ________ bead, so a method of depositing weld metal called ________ ________ welding must be used.
   c. When the joint edges are beveled, the spacing should be exactly the same as the ________ of the ________ *at the bottom of the joint edge.*
   d. The number of layers of weld metal will depend upon the ________ of the metal you are welding.

3-4. Horizontal Position Welding

When you cannot position the material for flat position welding, use the process known as *Position welding*. This is welding in the position normally assumed by the joint. When you are making a weld in which the metal parts incline more than 45° from the horizontal and the line of weld runs horizontally, as shown in figure 3-30, the weld is a horizontal weld. The arrows in the figure indicate electrodes.

A11. State the procedures for completing a tee joint in the horizontal position.

Tee Joints. To make tee joints in the horizontal position, position the two plates at approximately right angles to form an inverted "T." The edge of the vertical plate may be tack-welded to the surface of the horizontal plate, as shown in figure 3-31. The horizontal tee joint is designed and prepared the same

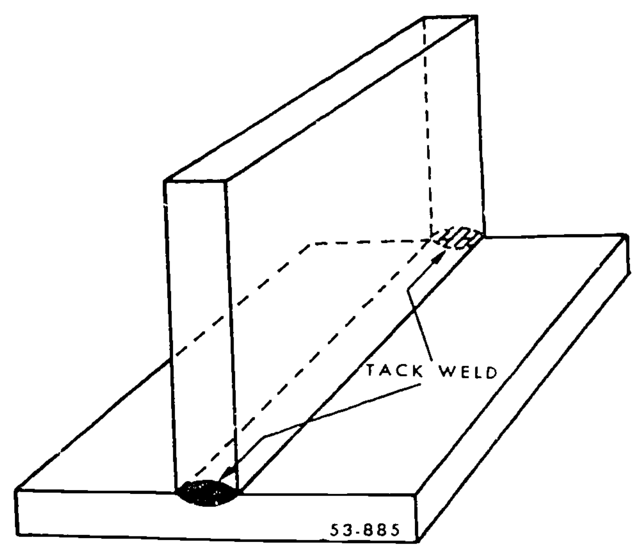

Figure 3-31. Tee joint tack welds.

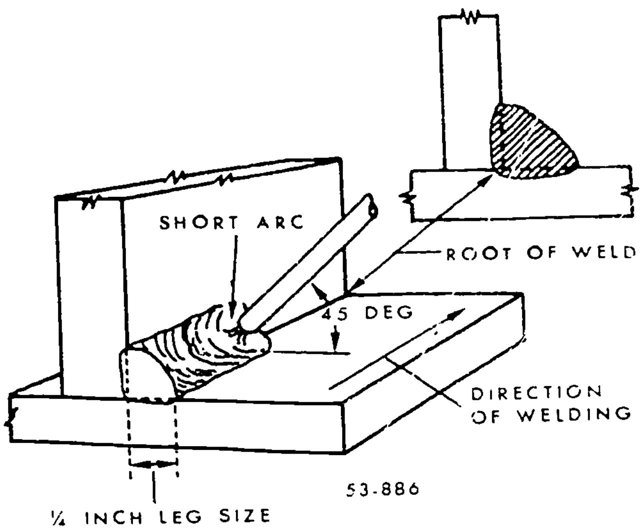

Figure 3-32. Electrode position for tee joint (horizontal).

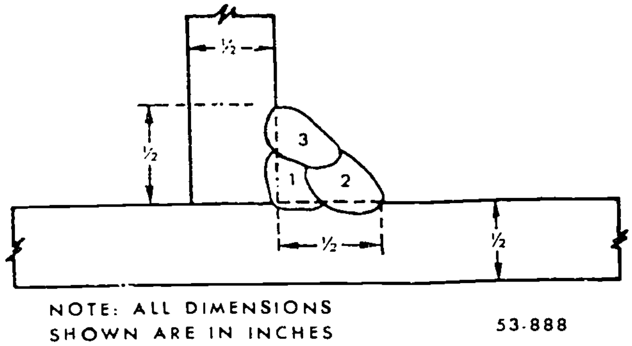

Figure 3-34. Fillet welds on heavy plate.

way as the flat tee joint, which we discussed earlier in this chapter. Use a fillet weld to make the tee joint and a short arc to provide good fusion at the root and along the legs of the weld. Hold the electrode at an angle of 45° to the plate surfaces and incline it approximately 15° in the direction of the welding, as shown in figure 3-32.

Light plates, 1/4 inch or less, can be welded with a fillet weld with one pass, with little or no weaving of the electrode. Welding of heavier plates may require two or more passes, in which each pass after the first is made in a semicircular weaving motion, as shown in figure 3-33. A slight pause at the end of each weave will insure good fusion between the weld and the base metal without any undercutting. A fillet-welded tee joint on 1/2-inch plate or heavier can be made by depositing stringer beads in the sequence shown in figure 3-34, in which a 1/2-fillet is illustrated.

Use chain intermittent or staggered intermittent fillet welding (shown in fig. 3-35) for long tee joints. Use fillet welds of these types when high weld strength is not required; however, arrange the short welds so that the finished joint is equal in strength to a fillet weld along the entire length of a joint from one side only. The warpage and distortion of the welded parts are held to a minimum with intermittent welds.

Exercises (A11):

1. At what angle is the electrode held when welding horizontal tee joints?

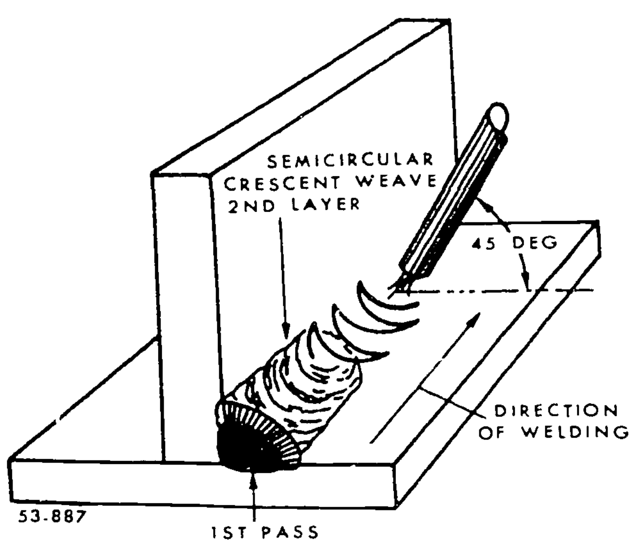

Figure 3-33. Multipass fillet weld weave motion.

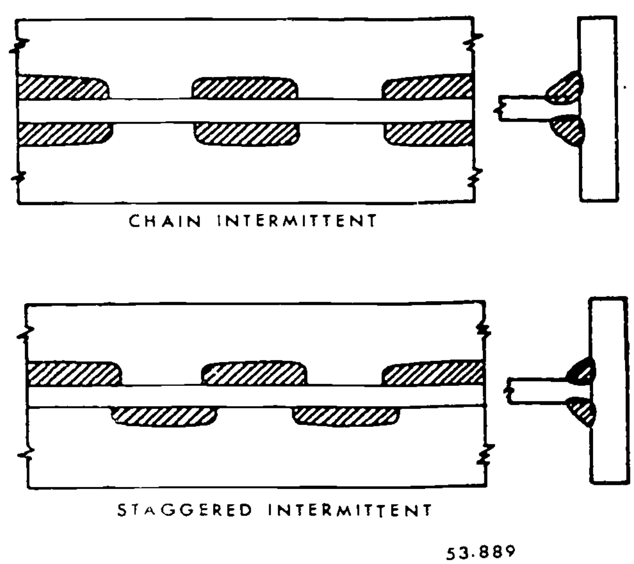

Figure 3-35. Intermittent fillet welds.

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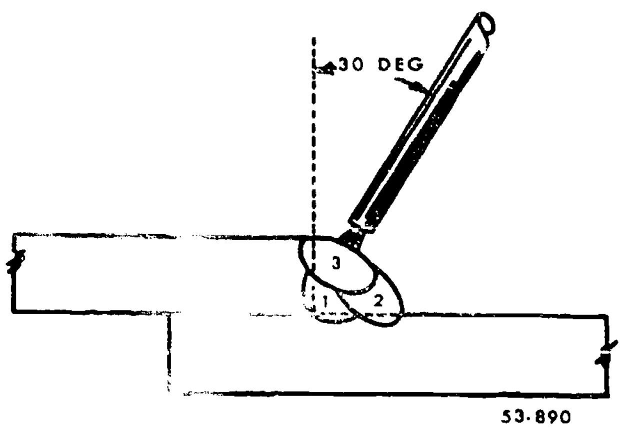

Figure 3-36. Electrode position for lap joints.

2. How can the warpage be held to a minimum when horizontally welding a tee joint?

3. How many stringer beads should be used to weld a 1/2-inch-thick tee joint in the horizontal position?

4. How is a horizontal tee joint formed?

A12. Furnish operational features significant in making lap joints.

Lap Joints. To make lap joints, tack-weld two overlapping plates in place and deposit a fillet weld in the horizontal position along the joint. The procedure for making this fillet weld is similar to that for making a fillet weld in tee joints. Hold the electrode to form an angle approximately 30° from the vertical and tilt it 15° in the direction of welding. The position of the electrode in relation to the plates is shown in figure 3-36. The weaving motion is the same as that for tee joints, except that the pause at the edge of the top plate is long enough to insure good fusion and no undercutting. You can make satisfactory lap joints on 1/2-inch plate or heavier by depositing a sequence of string beads, as shown in figure 3-36. To make lap joints on plates of different thicknesses, hold the electrode at an angle between 20° and 30° from the vertical. Do not overheat or undercut the thinner plate edge. The arc must be controlled to wash the molten metal to the edge of this plate.

Exercises (A12):

1. To make lap joints, tack-weld ____________ ____________ ____________ in place and deposit ____________ ____________ in the horizontal position along the joint.

2. Why is a weaving motion used when welding horizontal lap joints?

3. Why does the electrode angle favor the upper edge when welding lap joints?

3-5. Vertical Position Welding

In many areas you will be required to weld up or down. Among other things, we will include the type of electrode, polarity, arc length, and weave involved. The things you can do to use gravity and speed to aid in obtaining a good weld.

A13. Explain functions and operations involved in vertical position welding.

Welding on a vertical surface is more difficult than welding in the flat position, because the force of gravity tends to cause metal to flow downward. For this reason, the current settings should be lower than those used for the same electrode in the flat position, and the currents used for welding upward on vertical plates should be slightly higher than those used for welding downward on the same plate. The proper angle between the electrode and the base metal is also necessary in order to deposit a good bead weld in vertical welding.

Electrodes. The electrode used for vertical welding is a heavy-coated, reverse-polarity electrode which has slightly lighter coatings than the type used only for flat position welding. Electrodes of this type allow the weld metal and slag to solidify quickly. Since the greater amount of heat is at the positive side of the welding circuit (the tip of an electrode), you can obtain penetration more easily with reverse polarity. This serves as an aid in a position in which penetration is otherwise difficult to obtain.

When you use coated electrodes in the vertical position, it is necessary to use smaller electrodes at lower current settings, as compared with those for flat position welding. Use of smaller electrodes is an aid in maintaining a small pool of molten metal, permitting surface tension to overcome the force of gravity. The current settings recommended by the electrode manufacturer are your guides when you are making initial settings for a given electrode size.

Bead Welds. To weld upward, vertical up, hold the electrode 90° to the vertical, as shown in A, figure 3-37. To weld downward, vertical down, incline the outer end of the electrode downward about 15° from

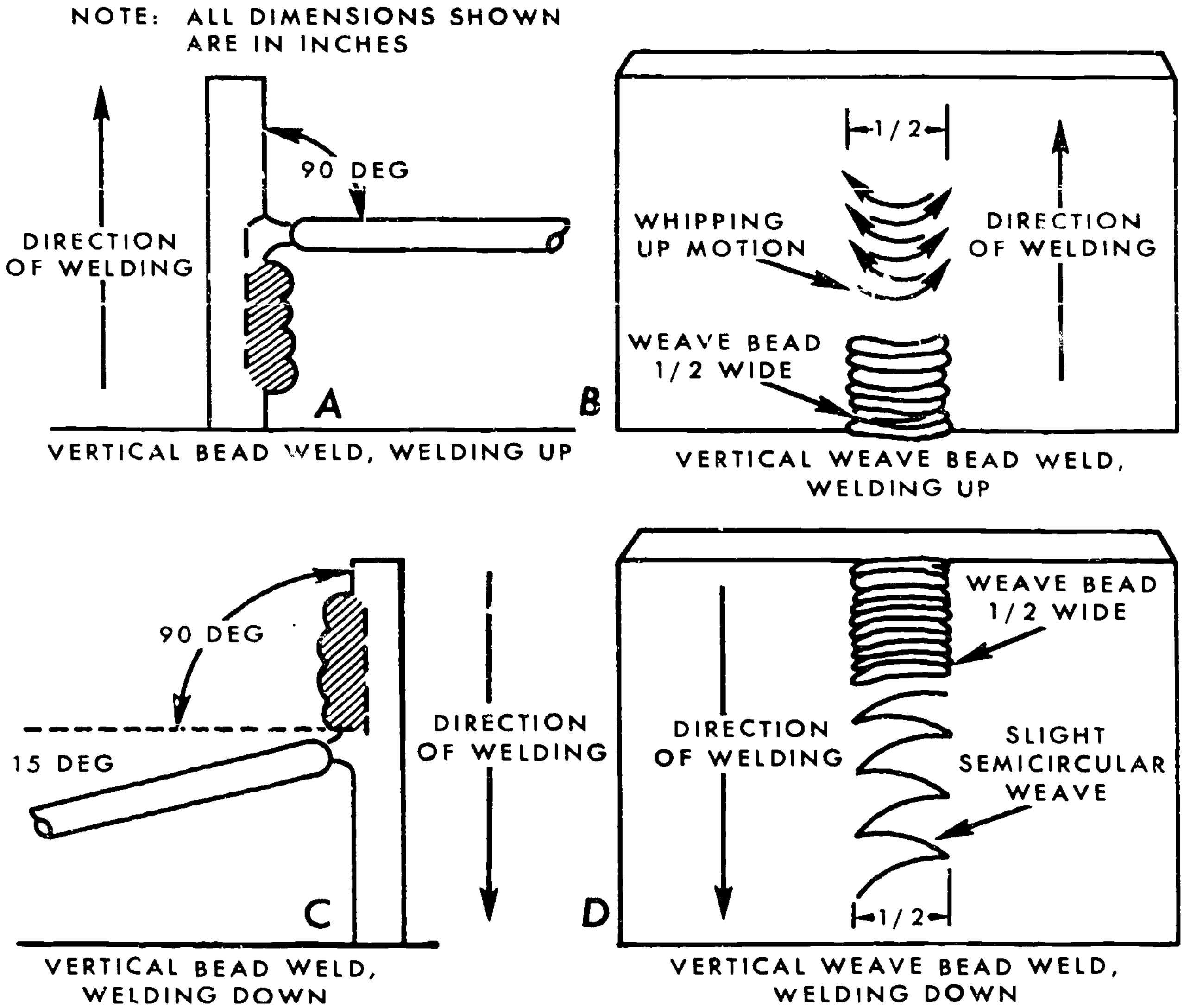

Figure 3-37. Bead welding in the vertical position.

the horizontal, with the arc pointing upward to the deposited molten metal, as shown in C, figure 3-37. To weld downward in the vertical position when a weave bead is required, oscillate the electrode, as shown in D, figure 3-37.

Exercises (A13):

1. Concerning the force which must be overcome when welding vertically, name it and tell how to overcome it.

2. What polarity is best to use for vertical welding?

3. When a whipping motion is used, what type of vertical weld is made?

4. If you hold the electrode at a 75° angle to your work, you are welding ______________________ .

5. Compare the current settings for vertical welding with those used for welding in the flat position.

A14. Cite the techniques to use when welding joints in the vertical position.

Butt Joints. Butt joints on plates in the vertical position are prepared for welding in the same way that butt joints in the flat position are. In order to obtain good fusion and penetration with no undercutting, hold a short arc and carefully control its motion. Make butt joints on beveled plates 1/4 inch in thickness by using a triangular weave motion, as shown in A, figure 3-38. Make welds on 1/2-inch plate or heavier in several passes, as shown in B, figure 3-38. Deposit the last pass with a semicircular weaving motion with a slight "whip up" and pause of the electrode at the edge of the bead. When you use a backup strip, make the welds in the same manner.

Fillet Welds. To make fillet welds on either tee or lap joints in the vertical position, hold the electrode 90o to the plates and not more than 15° above the horizontal for proper molten metal control. Hold a short arc to obtain good fusion and penetration.

Tee joints. To weld tee joints in the vertical position, start at the bottom of the joint and weld upward. Move the electrode in a trianglular weaving motion, as shown in A, figure 3-39. A slight pause in the weave, at the points indicated, will improve the sidewall penetration and provide good fusion at the root of the joint. If the weld metal should overheat, shift the electrode away from the crater quickly without breaking the arc, as

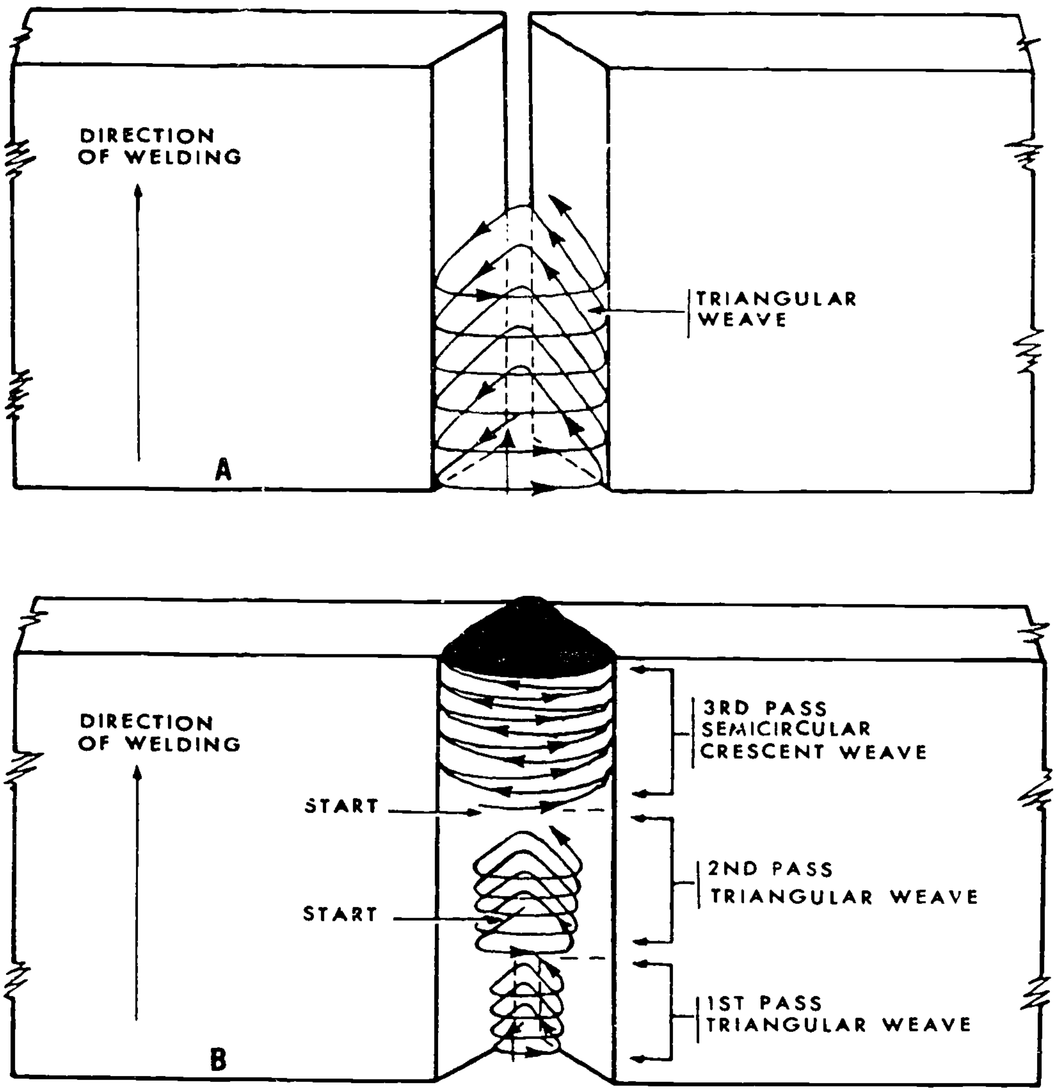

Figure 3-38. Vertical position butt joint welding.

shown in B, figure 3-39. This will permit the molten metal to solidify without running down. Return the electrode immediately to the crater of the weld in order to maintain the desired size of the weld. When more than one pass is necessary to make a tee weld, use the weaving motions shown at C and D, figure 3-39. A slight pause at the end of the weave will develop good fusion without undercutting at the edges of the plates. To avoid trapping slag, thoroughly clean each layer of weld by first removing the slag coating with a chipping hammer and follow by wire brushing.

Lap joints. To weld lap joints in the vertical position, move the electrode in a triangular weave motion, as shown in E, figure 3-39. Use the same procedure, as outlined above for the tee joint, but direct the electrode more toward the vertical plate marked "G." Hold a short arc, and pause slightly longer at the surface of plate G. Be careful not to undercut either of the plates or to allow the molten metal to overlap at the edges of the weave. Lap joints in the vertical position on heavy plates require more than one layer of metal. Thoroughly clean each layer of weld and deposit succeeding layers, as shown in F, figure 3-39. The precautions outlined above to insure good fusion and uniform weld metal deposit in tee joints apply also to lap joints in the vertical position.

Exercises (A14):

1. What should you do to obtain good fusion in vertical welding?

2. What do you do with the electrode if the molten pool gets too hot?

3. The recommended method of vertically welding butt joints is ____________ ____________.

4. State the angle of the electrode to the plate in all vertical up welded joints.

3-6. Overhead Position Welding

The overhead position is the most difficult in welding, and an extremely short arc must be constantly maintained in order to retain complete control of the molten metal. As is true in vertical position welding, the force of gravity tends to cause the molten metal to drop down or sag on the plate. Holding too long an arc increases the difficulty in transferring metal from the electrode to the base metal, and large globules of molten metal will drop from the electrode and base metal. This action can be prevented by shortening and lengthening the arc at intervals; however, be careful not to carry too large a pool of molten metal in the weld.

You should use only those electrodes designed for overhead welding. Welding with large diameter electrodes is difficult. The 3/16-inch-diameter electrode is the practical maximum size for welding overhead. Adjust the amount of current carefully to hold a short arc length. Usually, only a slight movement of the electrode is necessary for deposition if other factors, such as current adjustment and electrode angle, are correct.

A15. Identify functional features in overhead position welding.

Bead Welds. For bead welding, hold the electrode 90° to the base metal, as illustrated in figure 3-40, or tilt it approximately 15° in the direction of welding to provide a better view of the arc and crater of the weld. Weave bead can be made in the overhead position by using the motion illustrated in figure 3-41 and maximum electrode diameter of 3/16 inch. A rather rapid motion is necessary at the end of each semicircular weave to control the molten metal deposit. Avoid excessive weaving, because this will cause overheating of the weld deposit and the formation of a large pool which will be hard to control.

Butt Joints. Prepare the plates for butt welding in the overhead position in the same manner as that required in the flat position. The most satisfactory results are obtained by using backup strips. If the plates are beveled with a featheredge and you do not use a backup strip, the weld will tend to burn through repeatedly unless you are very careful. For overhead butt welding, bead rather than weave welds are preferred. Clean each layer of beads and chip the rough areas out before depositing the following layer. The positions of the electrode and the order to be followed in depositing beads on 1/4- and 1/2-inch plates are shown at B and C, figure 3-42. Make the first pass with the electrode held 90° to the plate, as shown at A, figure 3-42. The electrode should not be too large, because if it is, this fact will prevent holding a short arc and developing good penetration at the root of the joint. Excessive current will create a very fluid puddle which will be difficult to control.

Fillet Welds. To make fillet welds in either tee or lap joints in the overhead position, hold a short arc with no weaving of the electrode. Hold the electrode approximately 30° to the vertical plate and move it uniformly in the direction of welding, as shown in at B, figure 3-43. Control the arc motion to secure good penetration to the root of the weld and good fusion with the sidewalls of the vertical and horizontal plates. If the molten metal becomes too fluid and tends to sag, whip the electrode quickly away from the crater and ahead of the weld to lengthen the arc and allow the metal to solidify. Return the electrode immediately to the crater and continue the welding.

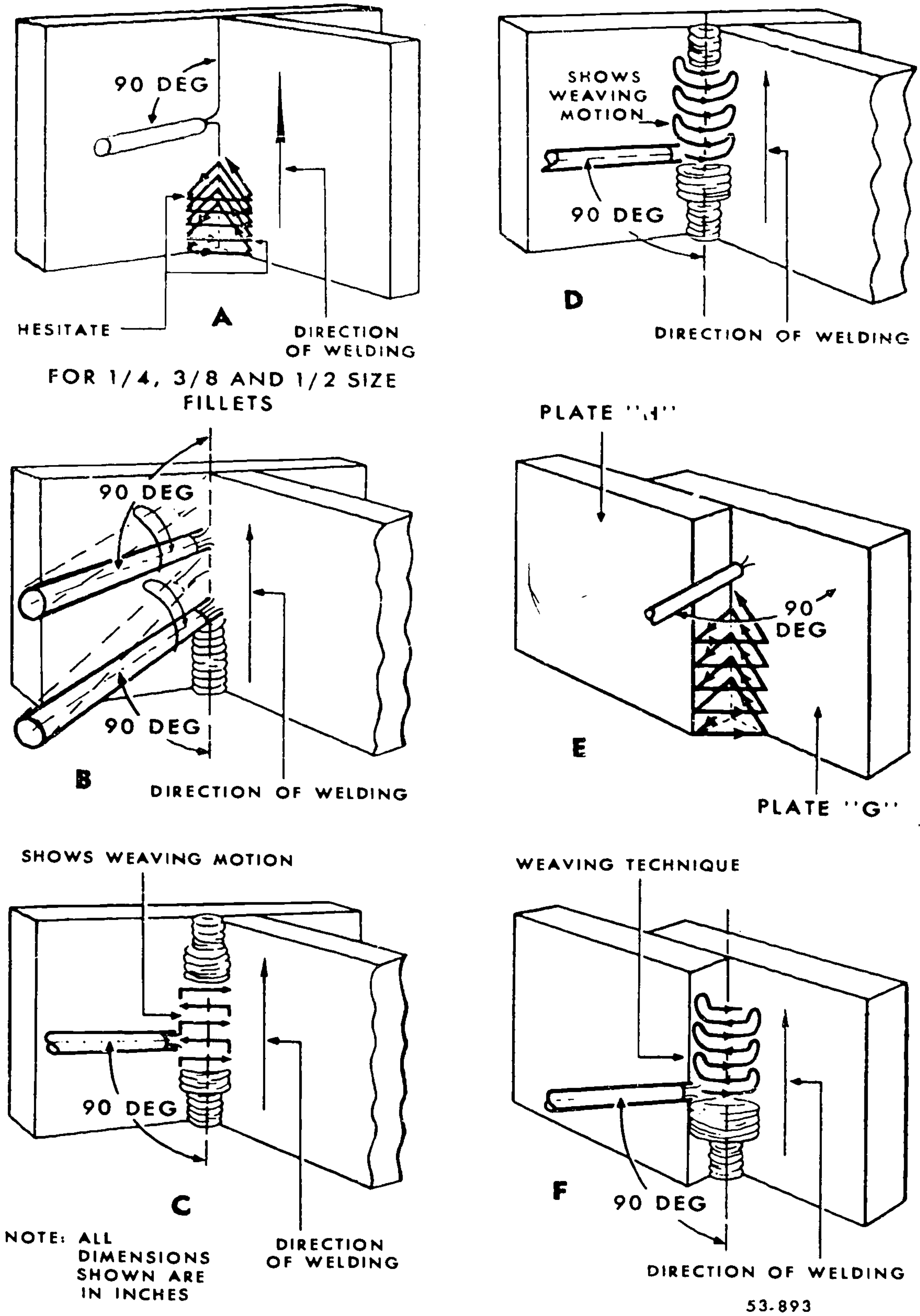

Figure 3-39. Fillet welds in the vertical position.

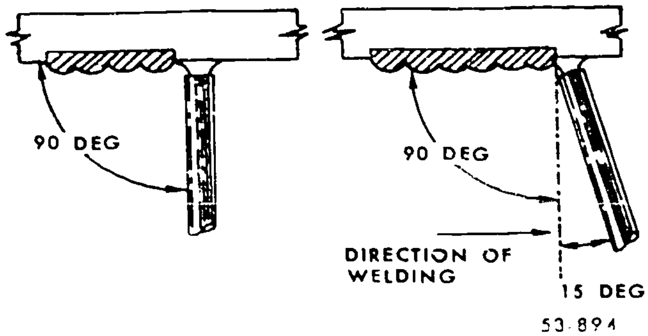

Figure 3-40. Electrode position for overhead welding.

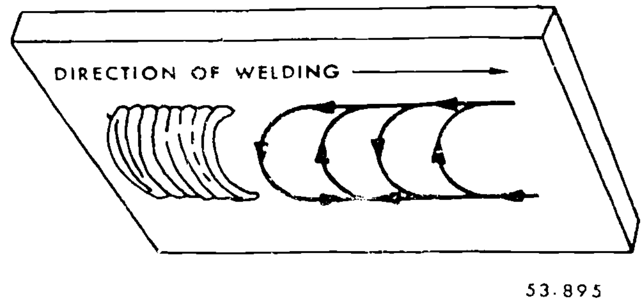

Figure 3-41. Weave motion in overhead welding.

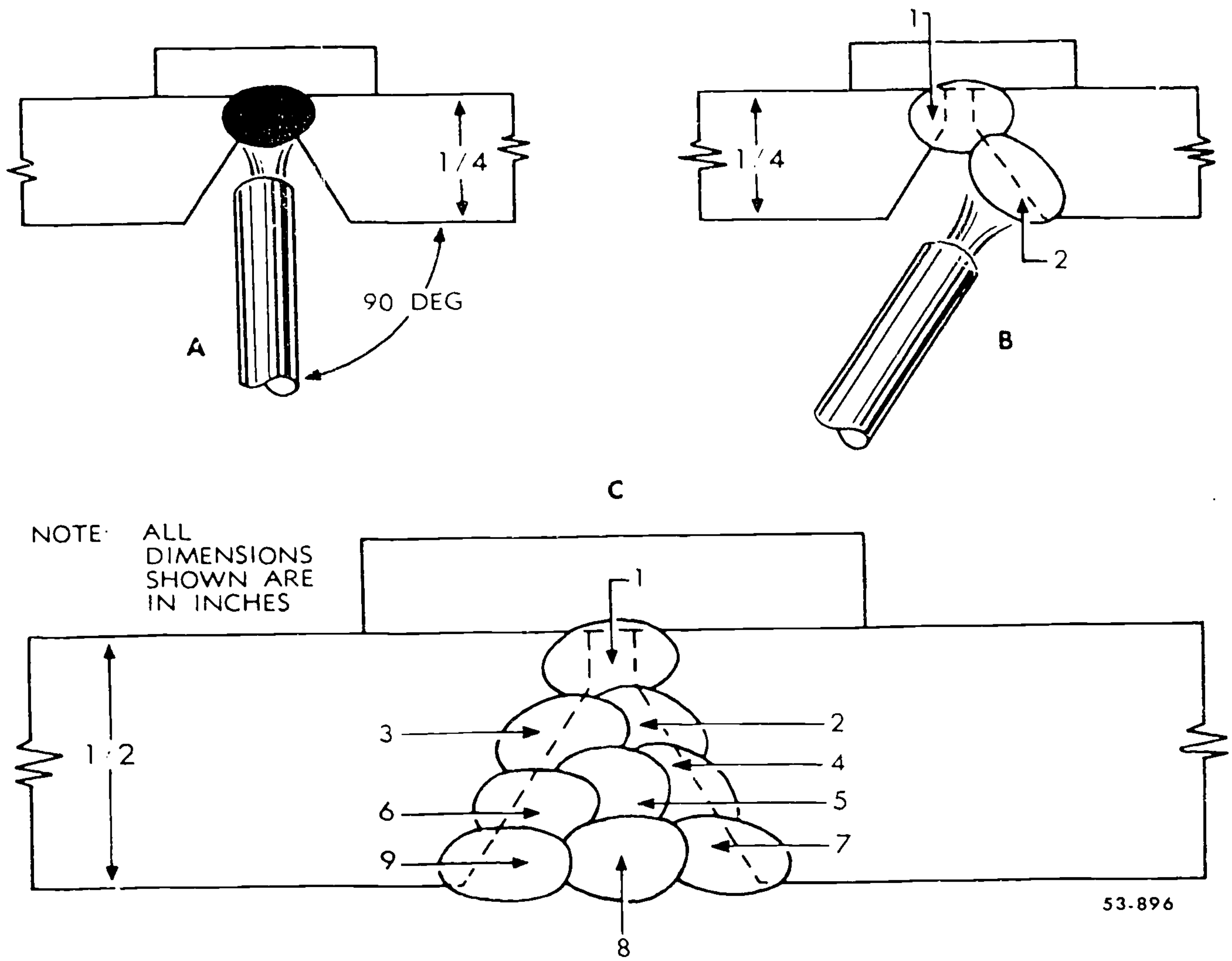

Figure 3-42. Multipass butt joint (overhead position).

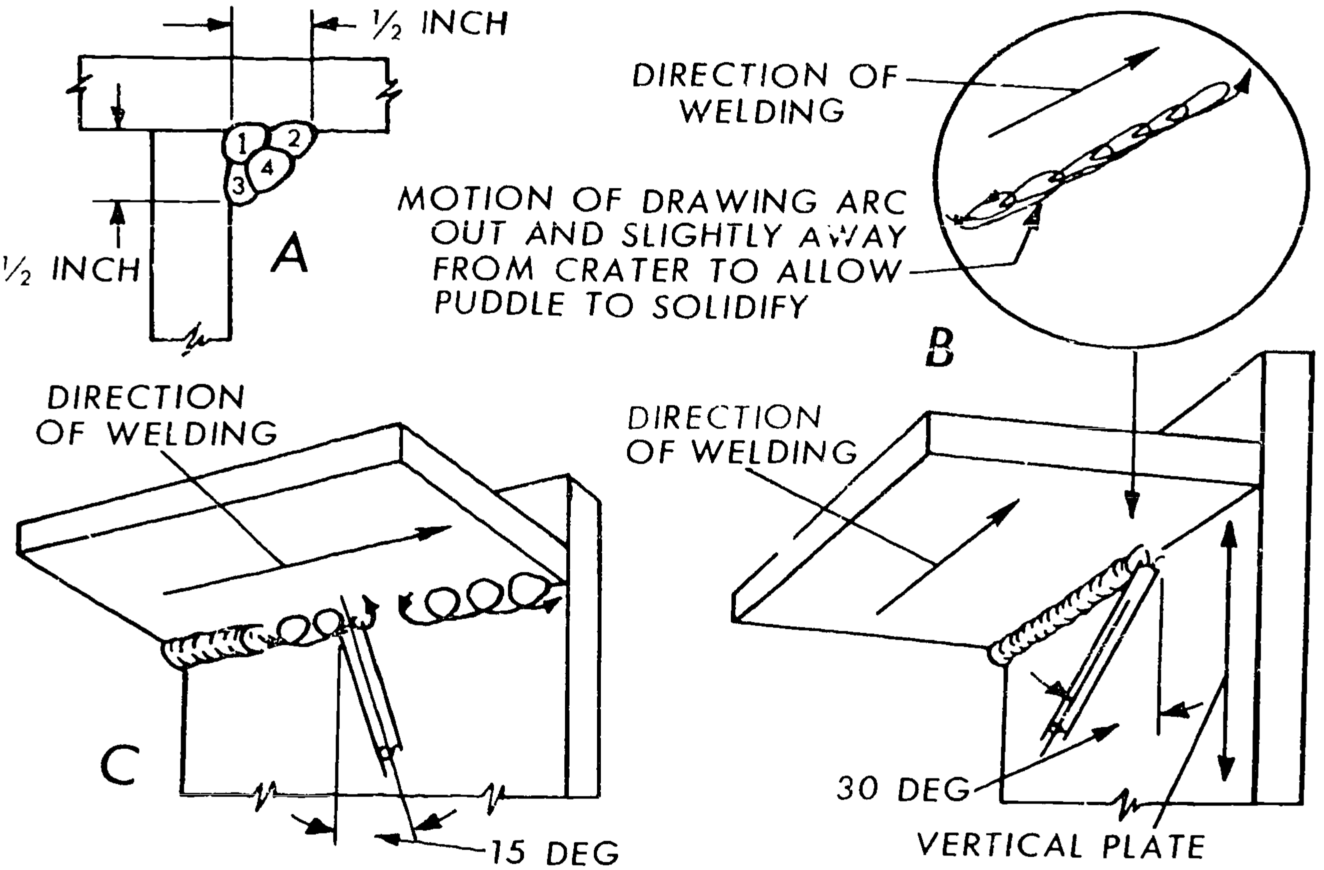

Figure 3-43. Fillet welding (overhead).

Fillet welds for either tee or lap joints on heavy plate in the overhead position require several passes or beads to make the joint. The order in which these beads are deposited is shown at A, figure 3-43. The first pass is a string bead with no weaving motion of the electrode. Make the second, third, and fourth passes with a slight circular motion of the electrode with the tip tilted about 15° in the direction of welding, as shown at C, figure 3-43. This motion of the electrode permits greater control and better distribution of the weld metal being deposited. Remove all slag and oxides from the surface of each pass by chipping or wire-brushing before applying additional beads in the joint.

Exercises (A15):

1. When welding overhead tee joints, is the second pass placed on the vertical or the horizontal plate?

2. A current setting that is too high makes the weld ______ ______.

3. How is a welded joint prepared for multipasses?

4. How are tee and lap joints prepared for overhead welding?

5. What is the practical maximum size of the electrode desired for overhead bead welding?

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Metallic Arc Application

THE METALLIC ARC is not used on carbon steel alone, nor is it used just for welding. The metallic arc is almost as versatile as the oxyacetylene flame and can be used for welding heat-and corrosion-resistant ferrous alloys and gray iron castings, and in applying hard-facing alloys. The metallic arc can also be used for cutting. In this chapter, we discuss these four areas.

4-1. Welding Heat and Corrosion-Resistant Ferrous Alloys

In this section on welding heat-and corrosion-resistant ferrous alloys, we will concern ourselves with the most common alloy of this group—stainless steel.

Stainless steels have come into their present wide use mainly because they are resistant to corrosion and oxidation. Corrosion resistance results from a chromium content in excess of 10 percent. Other elements added to impart certain desirable properties are nickel, manganese, columbium, titanium, molybdenum, silicon, and carbon.

We already know from volume 6 in this CDC that stainless steel can be gas-welded. However, this is a slow process and the warpage and distortion factors are very high. The metallic arc may be used with the electrode of the proper composition to greatly reduce both of these factors.

A16. Identify operational factors applicable to the use of stainless steel in welding heat- and corrosion-resistant ferrous alloys.

Stainless Steel. From the standpoint of welding, you can divide practically all stainless steels into two general classes: those containing only chromium (regardless of the amount) and those of the austentite type, which contain both chromium and nickel. When you heat metals in the first class to melting temperatures, they undergo rapid grain growth and do not respond to grain refinement through heat treatment. Such alloys, when welded, possess very little ductility. Welding of a part is not practical when the part is to undergo movement or shock at room temperatures. Metals of the second class, the chromium-nickel group, are highly desirable for welding. These metals are extremely tough and ductile in the welded condition.

The techniques and procedures employed in welding stainless steel are very different from those for welding carbon steel. For stainless steel not only must you maintain the strength of the parent metal across the weld area but also, in practically all cases, you must retain the corrosion resistance as well. A weld must frequently be made on very thin gage metal. Often, too, you must protect the appearance of a polished stainless steel surface. Preserving these qualities depends not only on your skill as a welder but also on your knowledge of stainless steel. You should know how each stainless steel responds to heat and thereby anticipate this effect, so that you can avoid or control the damaging effects of welding.

Metal arc welding stainless steel. You may use fusion welding with the metallic arc for the fabrication of stainless steels. For best results in welding, do not hold stainless steels at melting temperatures for too long a period. This would cause the loss of corrosion resistance, induce excessive strains, and promote undesirable grain growth. Metallic arc welding, however, helps you to avoid these harmful effects, because heat application is instantaneous. When making the weld, the metal deposited and the joint edges are heated to the melting temperature. The body of the work, however, remains comparatively cold. Hence, there will be a zone parallel to and near the weld which will heat to between 1000° and 1500° F., causing carbide precipitation (nonstabilized stainless steel). Since arc welding is rapid, this zone will be narrow and close to the weld. Good heat control is possible, because the composition of the weld deposit is the result of the interfusion of two known compositions; the metal you are joining and the metal in the electrode. When the metal thickness permits, metallic arc welding of stainless steel is practical for the following reasons:

a. The intense heat of the arc permits faster welding speeds with a minimum heat input and warping of the part.

b. The coating of the electrode provides a fluxing action, a protective gas shield, and a slag covering during the depositing of the electrode and the cooling of the weld metal.

c. Various electrode combinations are available, making it possible to compensate for the loss of certain elements, such as chromium and columbium, during the welding process.

Selection of electrode, polarity, and current setting. The composition of electrodes for welding stainless steel affects corrosion resistance and tensile strength. Many jet engine repairs require that the weld deposit meet exacting requirements. Manufacturers of electrodes must consider commercial and military

standards that the steel industry and the using agencies set up. The specifications for welding electrodes for heat and corrosion-resistant steels are in military specification number MIL-E-6844.

Manufacturers of electrodes know that certain elements disappear as they pass through the arc. Such losses increase the known volatile elements necessary to produce welds whose composition will be similar to that of the base metal. Approximately 30 percent of the columbium in an electrode will disappear while you are welding. When you are welding 18-8 stainless steel, you may often use an electrode containing 19 percent chromium and 9 percent nickel. Titanium cannot transfer from the electrode through the arc and, for this reason, you cannot use titanium bearing rods in arc welding.

You can use direct current with reverse polarity for metallic arc welding on stainless steel. The hotter end of the welding circuit is the tip of the electrode. This has the effect of causing faster melting and faster depositing of filler metal from the electrodes. It also results in less heat input into the base metal. Straight polarity is sometimes suitable for use on heavy gages of stainless steel.

Adjust the welding current to provide only enough current to insure good fusion. Use lower current settings for stainless steels than for ordinary steels of equal thickness, because they have lower heat conductivity than common steels. This tends to keep the heat of the arc localized at the point of contact rather than allowing it to travel rapidly back into the plate. Stainless steel will also permit penetration better than ordinary steel, because it is very fluid when molten. Ordinarily, steels tend to be more viscous and sluggish in the molten state. Besides heat conductivity, other factors like metal thickness, mass, type of stainless steel, and the skill of the welder are factors to consider in determining the exact current settings for a welding job. Listed below are average current settings for commonly used electrodes:

Electrode Diameter	*Average Current Settings*
3/32 inch	40-60 amperes
1/8 inch	75-100 amperes
5/32 inch	90-150 amperes

Exercises (A16):

1. What are three ways in which procedures used in welding stainless steel differ from those used in welding carbon steel?

2. Which is the preferred stainless steel for a welded joint—austentite or chromium?

3. What would be the results of holding a long arc and causing stainless steel to remain at melting temperature for a long period?

4. What military specification covers specifications for welding electrodes for heat-and corrosion-resistant steels?

5. What current is used for light gage stainless steel? For heavy gage?

6. Name five factors to consider in determining the exact current settings for welding stainless steel.

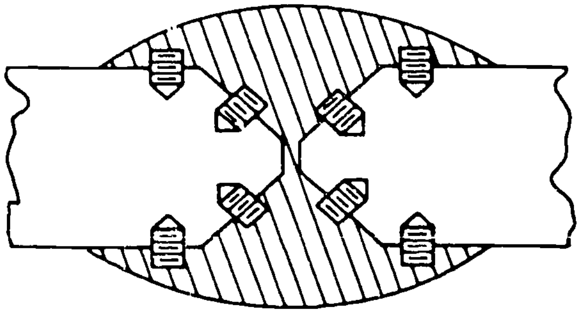
4-2. Arc Welding Cast Iron

Gray cast iron has low ductility and, therefore, will not expand to any considerable extent before breaking or cracking. Because of this, preheating is necessary when cast iron is welded by the oxyacetylene process. Use of the metallic arc eliminates this costly preheating if the correct techniques and procedures are followed.

A17. Cite techniques and procedures for arc welding butt joints of cast iron.

Edge Preparation. The edges of a cast joint should be chipped out or ground to form a 60° included angle bevel. The vee should extend to approximately 1/8 inch from the bottom of the crack. Always maintain alignment of the parts. When you are welding a crack, drill a small hole at each end of the crack to prevent it from lengthening when the welding heat is applied. Remove all grease, dirt, and other foreign substances by washing with a suitable cleaning agent.

Welding Techniques. Cast iron can be satisfactorily welded with a coated steel electrode. When you use a steel electrode, you must consider the contraction of the steel weld metal, the carbon pickup from the cast iron by the weld metal, and the hardness of the weld metal caused by rapid cooling. Steel shrinks more than cast iron when it is cooled from a molten to a solid state; and, when you use a steel electrode the uneven shrinkage will cause strains to the joint after welding. When you apply a large quantity of filler metal to the joint, the cast iron may crack just back of the line of fusion. To overcome these difficulties, weld the prepared joint by depositing the weld metal intermittently in short stringer beads, 3/4 to 1 inch long, and in some cases, by using the back step and skip procedure. Using this procedure confines the heat of



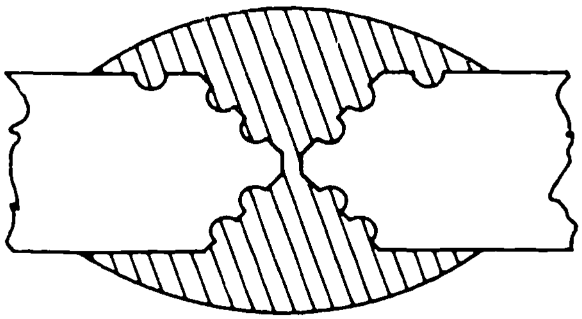


Figure 4-1. Reinforcing cast iron welds.

welding to a small area and eliminates the danger of cracking the casting. To keep hard spots from forming, strike the arc in the vee and not on the surface of the base metal. Each short length of weld metal applied to the joint should be lightly peened while it is hot with a small ball-peen hammer and allowed to cool before additional weld metal is applied. The peening action forges the metal and relieves the cooling strains. Use electrodes 1/8 inch in diameter to prevent excessive welding heat, weld with reverse polarity, and hold the weaving of the electrode to a minimum. Thoroughly clean each weld metal deposit before applying additional metal.

Cast iron electrodes are used when machining of the welded joint is required. Monel and stainless steel electrodes area also used when machining of the weld is required. The procedure for welding with these electrodes is the same as that outlined for welding with mild steel electrodes. Stainless steel electrodes provide excellent fusion between the filler and base metals; but great care must be taken to avoid cracking in the weld, because stainless steel expands and contracts approximately 50 percent more than does mild steel in equal changes of temperature.

Reinforcing. Use studs of steel approximately 1/4 to 3/8 inch in diameter when maximum strength is necessary in heavy cast iron parts. Figure 4-1 illustrates methods of using studs and grooves for reinforcing cast iron joints. Vee out the cast iron. Drill and tap along the vee to permit screwing the studs into the casting. Use a coarse-threaded bottoming tap. The studs should project about 3/16 to 1/4 inch above the cast iron surface. The studs should be long enough to screw into the casting to a depth of at least the diameter of the studs. The cross-sectional area of the studs should be 25 to 35 percent of the area of the weld surface. It is good practice to first weld one or two beads around each stud, making sure that you obtain fusion with the stud and cast iron base metal. Try to avoid straight lines of weld metal. When it is difficult to apply studs to a joint, you can machine or chip out the edges of the casting with a nose tool to form long, U-shaped grooves on the surface and face of each bevel. These grooves serve as anchors for the weld metal deposits in the joint. The grooves help increase joint strength.

Use reverse polarity with a minimum current setting for the metallic arc welding of cast iron. A list of recommended current settings for cast iron electrodes follows:

Electrode Diameter	*Average Current Settings*
3/32 inch	60-90 amperes
1/8 inch	80-100 amperes
5/32 inch	110-115 amperes

Exercises (A17):

1. Besides beveling the edges of the joint when welding cast iron, what other preparation is necessary?

2. How is the formation of hard spots prevented when arc welding cast iron?

3. What reaction may occur when large amounts of filler metal are used on cast iron?

4. Why is peening used when arc welding cast iron?

5. List four types of electrodes available for arc welding cast iron.

4-3. Hard Surfacing

Hard surfacing or hard facing is the process of applying extremely hard alloys to the surface of a softer metal to increase its resistance to wear, abrasion, corrosion, or impact. You can hard surface most steels, but you cannot always satisfactorily hard surface

metals such as brass and bronze. In most cases, you can apply hard-facing alloys to the point, surface, or edge or a part by using the electric arc process. The wearing surfaces of scrapers, grader blades, trencher teeth, front-end loader parts, and other parts, when treated with these special alloys, will outwear surfaces of common steels.

A18. Identify procedures, effects, and advantages involved in hard surfacing various metals.

Metal Preparation. Before hard surfacing, free the surface of the metal of all scale, rust, dirt, and other foreign substances by grinding, machining, or chipping. When you cannot use these methods, prepare the surface by filing, wire brushing, or sandblasting. The latter methods are not the most satisfactory, since small particles of foreign matter remaining on the surface must float out during hard surfacing. Round all edges of grooves, corners, or recesses to prevent overheating the base metal.

Preheating. Take the same precautions for preheating in hard surfacing that you take in welding the base metal You should anneal steels in the heat-treated condition, if possible, before applying the hard-surfacing layer. Quenching in water will crack the hard-surfacing layer. When it is necessary to heat metal to the critical temperature after hard surfacing, use oil as the quenching medium. When it is impossible or undesirable to anneal high carbon steels or before hard surfacing hard tensile low alloy steels, deposit the hard surfacing by the transition bead method. First, deposit a thin layer of stainless steel, such as 25 percent chromium and 20 percent nickel rod, or 18 percent chromium and 8 percent nickel rod (columbium stabilized): Next, build up the section to approximately the original dimension, using an 11 to 14 percent manganese or high-strength rod. Finally finish by hard surfacing with one of the group 2 alloys.

Thickness of Hard-Surfacing Deposits. In most cases, worn sections are rebuilt with hard-surfacing deposits varying in thickness from 1/16 inch to 1/4 inch, depending upon the specific application. When it is necessary to deposit metal more than 1/4 inch thick, rebuild the parts with group 1 alloy to from 1/16 inch to 1/4 inch of the finished size. Add the final deposit, consisting of group 2 or group 3 alloys, with some excess to permit grinding to the desired finished dimensions. When you apply harder and more brittle group 4 or group 5 hard-surfacing materials, either as a final deposit or in a single layer, the shape of the deposit should be carefully controlled. This is important in order that impact or shock loads may be transmitted through the hard-surfacing metal into the tougher base metal. Corners, sharp edges, or builtup sections, when not backed up by tough base metal, will chip or break off in service.

Hard Surfacing with the Metal Arc. Hard surfacing by arc welding is done in the same manner and is similar in principle to joining by arc welding, except that the added metal has a composition that is not the same as that of the base metal. The characteristics of the added metal would be changed or impaired if it were excessively diluted by or blended with the base metal. For this reason, penetration into the base metal should be restricted by applying the hard-surfacing metal with the minimum welding heat. In general, the current, voltage, polarity, and other conditions recommended by the manufacturer of the electrodes are based on this factor.

You can apply every hard-surfacing metal, except some alloys in groups 4 and 5, with every type of electrode coating or with a bare electrode by using reverse polarity. The flux coating on coated electrodes reduces spatter loss, assures good penetration, prevents oxidation of the deposited metal, and helps to stabilize the arc. Use the bare, hard-surfacing electrodes when it is necessary to apply a heavy bead or to deposit the metal against a copper form. For best results, use a long arc to deposit the filler metal.

On parts subject to very hard wear, the entire surface may be covered with a layer of hard-surfacing alloy. On most jobs a solid cover of the point and a network of beads will be adequate.

When equipment will be exposed to the abrasive action of sand, soil, and small stones, run stringer beads of hard-surfacing alloy perpendicular to the flow. Run a series of beads close together along the point; then space stringer beads a small distance apart, as seen in figure 4-2. Dirt packs between the beads and further protects the base metal.

For equipment designed to handle rocks, run stringer beads parallel with the flow of material, as figure 4-3 shows. This pattern will support the rocks while offering the least resistance to the flow. The use of stringer beads is more economical and will do the job.

When a series of self-cleaning beads is desired, the diamond pattern is recommended. In figure 4-4 you can see how dirt would slide up and over to one side or the other, thus cleaning itself.

Exercises (A18):

1. When preparing metal for hard surfacing, which are the preferred methods of cleaning (choose one from each pair)?
   a. Chipping or sandblasting.
   b. Filing or machining.
   c. Grinding or sandblasting.

2. Why are the edges of corners rounded preparatory to hard surfacing?

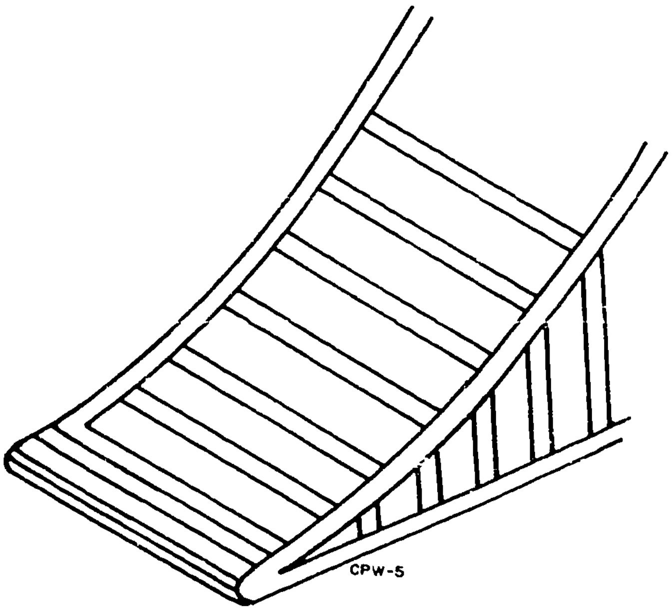


Figure 4-2. Stringer beads, perpendicular to flow.

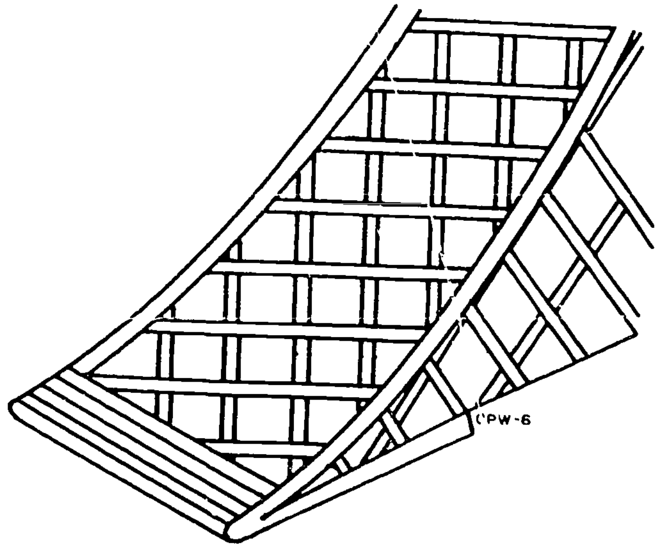


Figure 4-4. Diamond pattern.

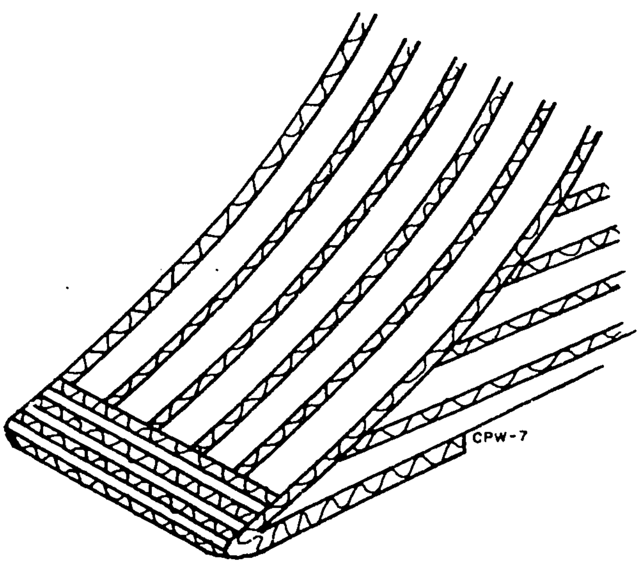


Figure 4-3. Stringer beads, parallel with the flow.

3. When hard surfacing steel in the heat-treated condition, what must be done first?

4. What effect will water quenching have upon hard surfacing?

5. Normally, hard-surfacing deposits will vary in thickness from ____________ ____________ to ____________ ____________.

6. Why must the shape of the hard-surfacing deposit be carefully controlled?

7. What advantages are achieved by using a coated electrode for hard surfacing with the metallic arc?

4-4. Electric Arc Cutting

Electric arc cutting is a melting process in which the heat of the electric arc is used to melt the metal along the desired line of the cut. The quality of the cut is not as good as that produced by the oxyacetylene process, but it is satisfactory when a smooth cut is not essential. Arc cutting is generally confined to the cutting of nonferrous metals and cast iron. You can cut most metals by using one of the several processes of electric

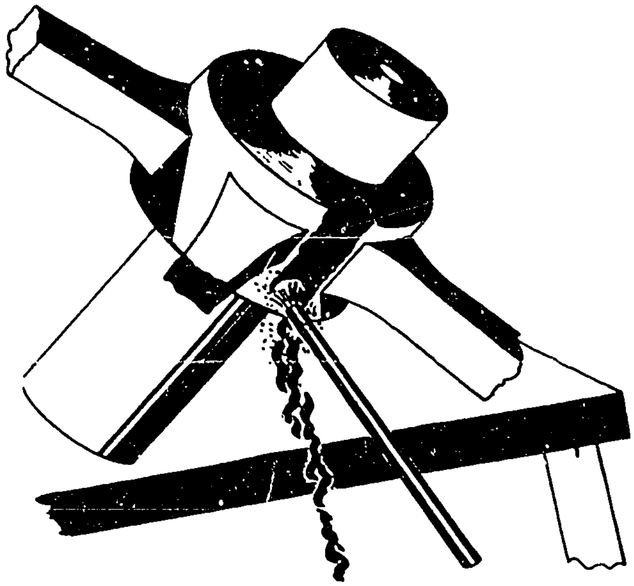


Figure 4-5. Groove cutting with metallic arc.

arc cutting: metallic arc, carbon arc, or oxy arc. The metallic and the carbon arc processes depend upon gravity, heat, and the force of the arc to remove the molten metal from the kerf. The oxy arc uses a hollow steel electrode and the heat of the arc with oxygen to produce a cutting action comparable to off-hand, oxyacteylene cutting.

A19. In given applications, state the most appropriate arc cutting operation, and state how electrodes differ for the various kinds of electric arc cutting.

Metallic Arc Cutting. *Metallic arc cutting* is a progressive operation in which a low-carbon-steel, covered electrode is used, as shown in figure 4–5. The covering on the electrode is a nonconducting refractory material which permits the electrode to be inserted into the gap of the cut without being short-circuited. This insulating coating also stabilizes and intensifies the action of the arc. Direct current, straight polarity is preferred, but alternating current can be used. Standard electrode holders are used for metallic arc cutting in air.

Cutting with an arc leaves something to be desired, because it does not make a smooth precision cut. However, it is quick and often the most expedient way to cut plates and angles and to make holes.

The intense heat generated by the arc is more than hot enough to melt most metals. The force of the arc is used to propel the molten metal away. While cutting, use a long arc then a short arc, to aid in melting the metal. Also, the movement of electrode will speed the job and require less heat. Figure 4–6 illustrates cutting

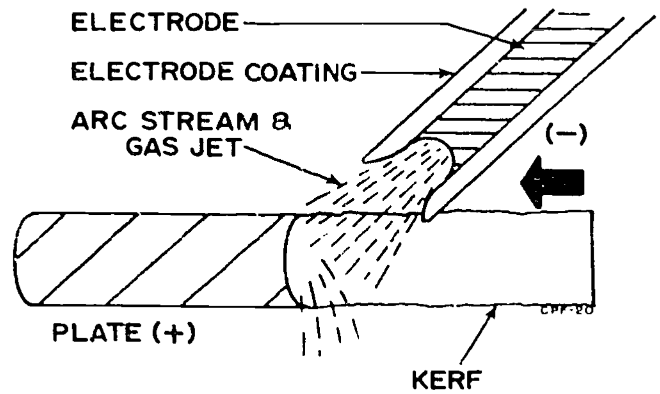


Figure 4-6. Metallic arc cutting.

with an electrode. Notice how the arc stream and gas jet from the covering of the electrode blow the melted metal away. Just as a reminder, remember the law of gravity—HOT LIQUID will fall; so don't be under it.

Carbon Arc Cutting. In *carbon arc cutting* a carbon electrode is used to melt the metal progressively by maintaining a steady arc length and a uniform cutting speed. Direct current, straight polarity is used, because it develops a higher heat at the base metal (the positive pole). Direct current also permits a higher cutting rate and easier control of the arc than alternating current. Air-cooled carbon electrode holders are used for currents up to 300 amperes. Water-cooled electrode holders are desirable for currents in excess of 300 amperes.

Arc air is another type of carbon electrode cutting that is assisted with compressed air. A jet of air from a nozzle in the electrode holder blows the molten metal out from the arc area, as seen in figure 4–7. This type of torch will groove, bevel, cut, gouge, or pierce metal at a rapid rate. One great advantage of arc air is that the joint needs no grinding or chipping.

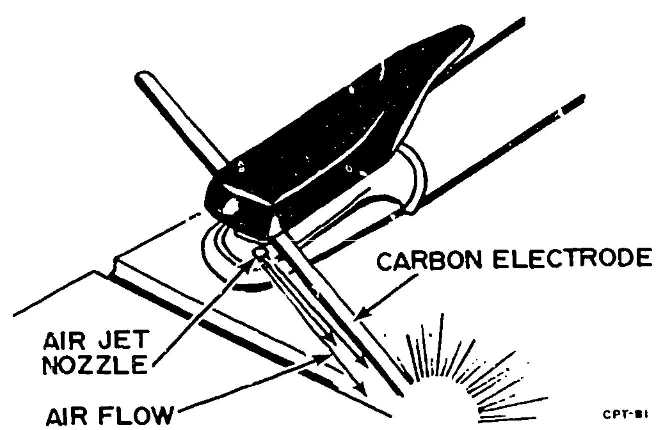


Figure 4-7. Arc Air cutting.

Oxy Arc Cutting. *Oxy arc cutting* is a progressive operation in which a tubular electrode is used. The steel or conducting-type ceramic electrode maintains the arc and also serves as a conduit through which oxygen is fed into the cut. In this process, the arc provides the heat, and the oxygen reacts with the metal in the same manner as occurs in oxyacetylene cutting. Both direct and alternating currents may be used.

Exercises (A19):

1. For each of the following phrases provide the most appropriate electric arc cutting operation.

   a. Uses a hollow electrode: ________ ________ ________

   b. Uses water-cooled holders: ________ ________ ________

   c. Uses water-cooled holders: ________ ________ ________.

   d. Must be insulated underwater: ________ ________ ________.

   e. Reaction similar to oxyacetylene cutting: ________ ________ ________.

   f. Flux prevents short-circuiting: ________ ________ ________.

   g. Uses ceramic electrodes: ________ ________ ________.

2. How do the electrodes differ in the various types of electric arc cutting?

8 2

Gas-Shielded Welding Principles and Equipment

METALS NOT previously used in industry, national defense, or atomic energy projects because of welding purity difficulties are now being welded. Research and testing is being conducted constantly to improve the weldability of such metals as aluminum, magnesium, and titanium. Tungsten-inert gas (TIG) and metal-inert gas (MIG) have been the most successful and widely used welding processes to join these metals.

In this chapter, we discuss the principles of gas-shielded welding, the advantages that are gained by its use, and the equipment required to perform it.

5-1. Principles of Gas-Shielded Welding

The three elements that can contaminate metals during welding are *oxygen, nitrogen,* and *carbon.* Contamination of the weld by any one of these elements will cause severe embrittlement. The purer the base metal and the purer the welding environment, the more the tendency toward embrittlement of the welded joint will be reduced. The base metal is protected and the atmosphere is pure when gas-shielded welding is used.

A20. Differentiate between TIG and MIG welding, identify uses of these processes on specific items, and compare welds made by gas-shielded welding with these made by ordinary metal arc welding.

Gas-Shielded Welding. Gas-shielded welding is a fusion-welding process that uses the heat produced by an electric arc between a metal electrode and the work. The principles involving the arc, or heating source, are the same as those for metallic arc welding. However, in the gas-shielded process, an inert gas (helium or argon) is used to shield the electrode. The shielding gas flowing from the orifices in the torch head forms a protective blanket over the weld area. This protection prevents the air, which causes the formation of harmful oxides and nitrides, from coming in contact with the molten metal.

Uses of Gas-Shielded Welding. Tungsten-inert-gas--shielded welding is especially adapted for light gage metal requiring the highest quality of weld and/or finish because of good concentration of heat, precise heat control, and the ability to weld with or without filler metals. It is one of the few processes which permits the rapid, satisfactory welding of tiny or light-walled objects. For heavier gage metal, metal-inert-gas-shielded welding is used.

There are many types of inert gas-shielded welding processes. The types that we will discuss are tungsten-inert gas (TIG), shown in figure 5-1, and metal-inert gas (MIG), shown in figure 5-2. A significant difference between the two is that tungsten-inert gas uses a nonconsumable tungsten electrode, while metal-inert gas uses a consumable alloy wire with approximately the same chemical composition as that of the metal being welded.

Advantages of Gas-Shielded Welding. Gas-shielded welding produces welds that are stronger, more ductile, and more corrosion resistant than are welds made with ordinary metal arc welding. The protective shield that envelops the weld enables the joint to be made without the use of flux, thus eliminating the corrosion due to flux entrapment and expensive post welding and flux cleaning operations. The entire TIG welding action takes place without spatter, sparks, or fumes. MIG welding produces some spatter, but it is very easily cleaned off.

Exercises (A20):

1. How does inert gas help produce a more pure weld?

2. What is a significant difference between TIG and MIG welding?

3. State the process (TIG or MIG) that you would use on each of the following:

   a. Thin wall tubular parts: ____________.
   b. 1/2-inch-thick diamond hinges: ____________.
   c. Fireproof safe hinges: ____________.
   d. Aluminum foil: ____________.

4. How do welds produced by gas-shielded welding compare with those made with ordinary metal arc welding?

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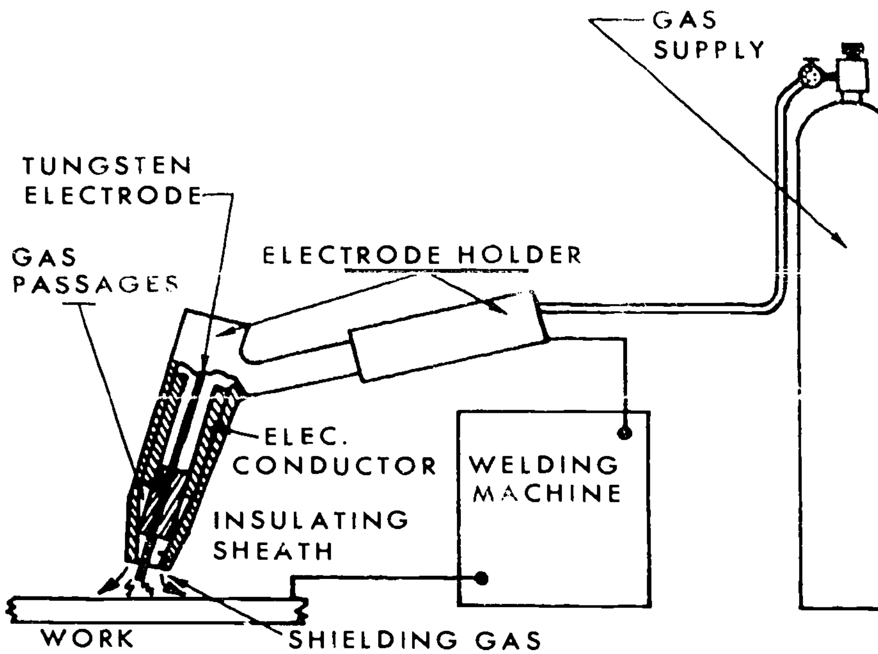


Figure 5-1. Tungsten-inert-gas-shielded process (TIG).

5-2. Gas-Shielded Welding Equipment

The basic equipment requirement for gas-shielded welding consists of a power source, a gas-shielded welding torch, hose, shielding gases and controls, and protective equipment.

A21. Identify operational functions, purposes, causes, and terms involving equipment used in gas-shielded welding.

Power Source. The welding current may be supplied by a welding generator, a DC rectifier, or an AC transformer, as shown in figure 5-3. It is important that the unit have good current control at the lower end of its current range. Standard DC welding machines are designed to produce the current output and the range necessary to meet the requirements of the work. Superimposed high frequency is used in some machines to permit starting the arc without the electrode contacting the work.

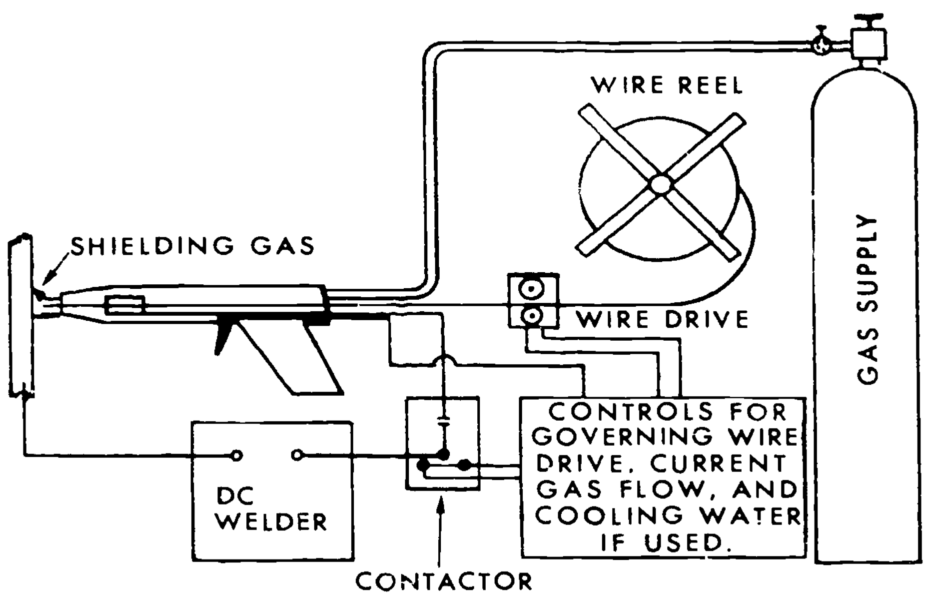


Figure 5-2. Metal-inert-gas-shielded process (MIG)

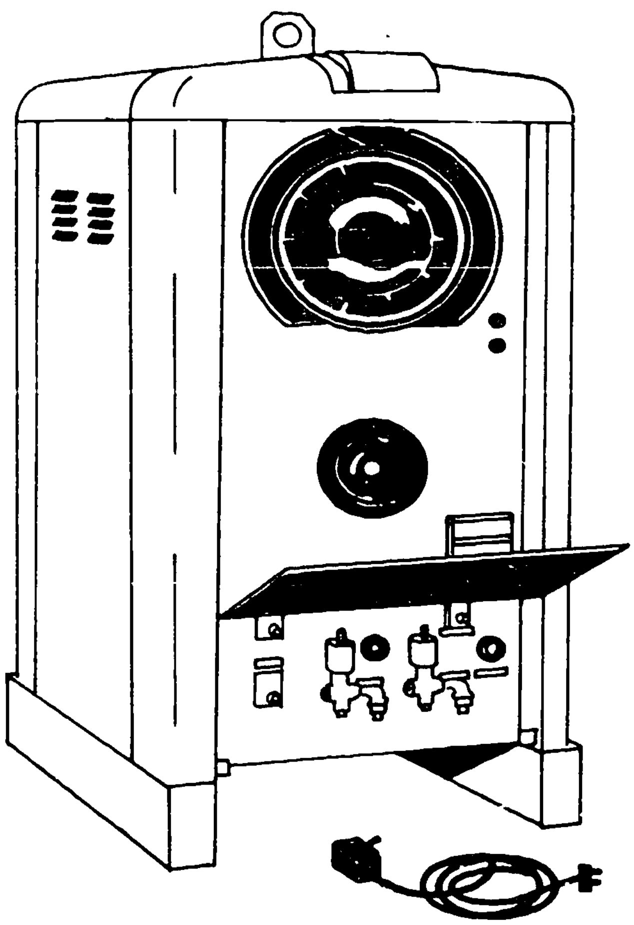


Figure 5-3. TIG welder. 53-905

Gas-Shielded Welding Torch. Several types and models of gas-shielded welding torches are used. The operation and design are basically the same, except for the method by which they are cooled—by air or by water.

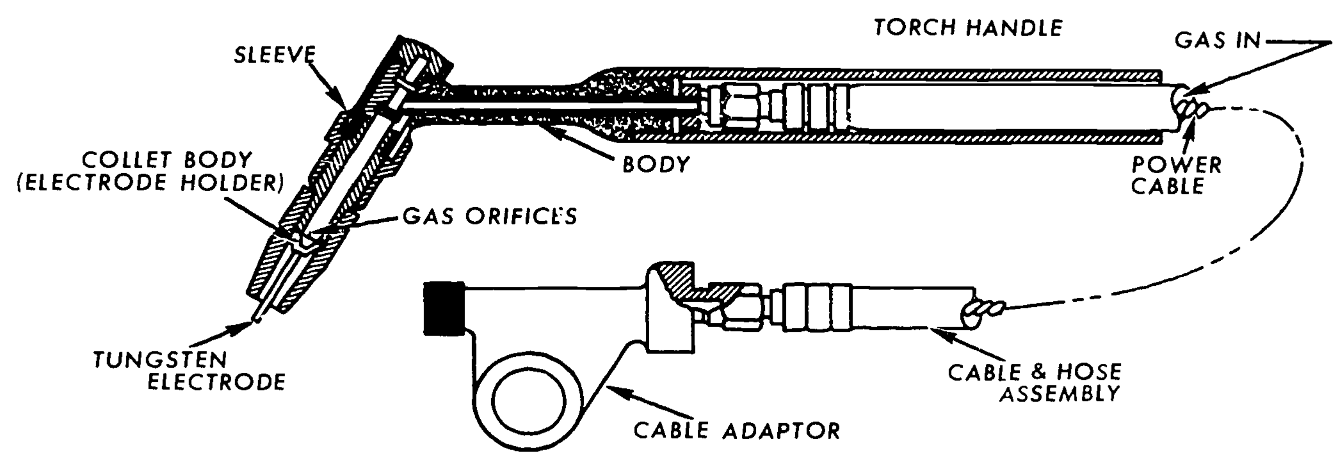
Air-cooled torch. The air-cooled torch, shown in figure 5-4, is designed for manual welding of thin gage metals. It is excellent for weld-repairing thin section jet engine parts. This torch can be used for welding with high-frequency stabilized alternating current or straight polarity direct current, depending upon the job requirements. It can perform continuously on AC or DC current up to 100 amperes.

Water-cooled torch. The water-cooled torch, shown in figure 5-5,is designed to operate at current ratings from 100 to 300 amperes. Water cooling of the torch and power cable for inert-gas-shielded welding makes it possible to use lightweight parts capable of carrying the rated current without danger overheating. The power cable is located in the water discharge hose. Water flow should be from 1 to 2 pints per minute. A special fuse of about 45 amperes is installed in the power leadline to the torch to protect the equipment from overheating in case of water stoppage. The torch head consists basically, of these three parts: (1) the collet or electrode holder, (2) the gas-shielding cup, and (3) the tungsten electrode. The shielding gas enters through a plastic hose fitted to the rear of the torch handle, passes through the body, and emerges from the gas orifices in the torch head. It is then guided down toward the weld or molten pool by the gas-shielding cup that surrounds the electrode.

The tungsten electrode is held firmly in place by a replaceable electrode holder (collet) that screws into the torch head. The threaded end that screws into the torch head is split into four parts. When the electrode holder is tightened, it clamps on the electrode, holding it in place. The holders are made in various sizes to hold electrodes from 0.020 to 0.025 inch in diameter and from 3 to 12 inches in length.

Hose. A rubber or plastic hose is used to circulate water for cooling the torch and power lead cable. The bare flexible lead cable is inclosed in the water outlet hose. A separate hose is used for the water inlet, and another is used for feeding the shielding gas to the torch. In case of water stoppage, welding must be discontinued to prevent damage to the welding equipment.

Water stoppage may result from an accumulation of dirt in the small passages of the torch. This condition can usually be corrected by disconnecting the waterlines and momentarily reversing the flow of



53-908
Figure 5-4. Air-cooled, inert-gas-shielded welding torch.

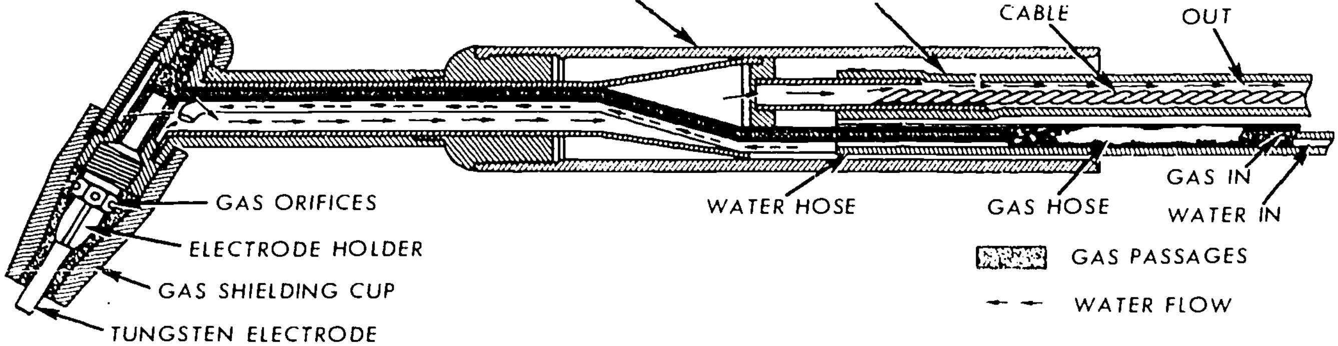


Figure 5-5. Water-cooled, inert-gas-shielded welding torch.

water. Three possible causes of leakage in waterlines are (1) excessively high water pressure, (2) mistreatment of equipment, and (3) improperly sealed hose connections. If leaking occurs in the torch handle, soldered repairs may be necessary. When the hose is damaged near a fitting, it is only necessary to cut away the damaged section and to attach a hose to the fitting. Rubber cement or a hose clamp may be used to make a leakproof joint. When the water outlet hose is shortened, an equal length of electrical cable must be removed.

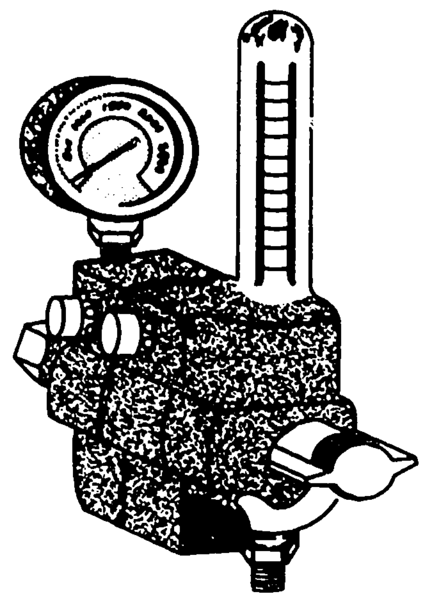
The argon or helium hose must be gastight. If the molten pool becomes cloudy or the tungsten electrode turns blue on cooling, this is in indication of a leak in the hose or the hose connections. If the plastic hose is subjected to temperatures above 125° F., it will become soft and lose its strength. It should therefore be protected carefully and not allowed to come into contact with hot metal. Hose that has been burned or broken must be replaced, since it cannot be repaired. Leaks will cause the shielding gas to become diluted with air and will contaminate the molten pool metal.

Shielding Gas. Helium and argon are inert gases that used in gas-shielded welding. The term "inert gas" indicates a chemically inactive gas; it will not combine with any other element. Whether the welder uses helium or argon for the shielding gas depends upon the distinctive charactistics he requires to produce the desired results. In some cases, h 'ium is preferable to argon, because helium produces more heat per ampere of welding current, if other factors are equal. This characteristic becomes a disadvantage, however, when you are welding very light gage metal (1/32 inch or less). Here, arc stability becomes a very important factor. With higher current settings, it is better to use argon with its lower arc voltage. In some instances, the type of shielding gas to use depends upon the cost of the job, as well as the particular characteristics of the gases. Both gases are plentiful. Helium is much cheaper than is argon, but you use more helium to perform the same shielding operation, because of the difference in the weight of the two gases. Since helium is several times lighter, it does not settle down around the work as well as argon. Also the consumption of argon is about one-third less than that of helium.

consumption of argon is about one-third less than that of helium.

Argon. Argon is a colorless, odorless, nontoxic, and nonflammable inert gas which is somewhat heavier than air. It is supplied in cylinders similar in size and shape to oxygen cylinders; argon cylinders carry pressures of 2000 to 2500 psi. The cylinder may be identified by the distinctive color markings of gray with a white band paint horizontally around it. The cylinder is considered empty when the pressure is reduced to 40 psi.

Helium. Helium is a colorless, odorless, nontoxic, and tasteless inert gas. Much lighter than air, it is the second lightest of all gases. Helium is nonflammable and, like argon, is placed under pressure in cylinders at 2000 or 2500 psi. The cylinder may be identified by the distinctive color markings of gray with a buff (light brown) top. The cylinder is considered empty when the pressure is reduced to 25 psi.



53-907

Figure 5-6. Argon regulator flowmeter.

Gas Control Equipment. Suitable metering devices are used to control the flow of shielding gases. A combination regulator and flowmeter, as shown in figure 5-6, is available. It steps down the high pressure in the cylinder or manifold cylinders to a lower working pressure. The gas flow to the apparatus is indicated on a flowmeter tube. In operations in which the gas consumption is high, a central cylinder manifold system can be installed, and the gas can be piped to the various welding stations. The flowmeter is equipped with a manual throttle valve for gas flow adjustment, and the welder can set the flow required. The flowmeter tube is calibrated at a positive pressure which normally exceeds any back pressure produced by the apparatus. This makes a true reading of the gas flow possible.

When a combination regulator flowmeter is not available, a regulator identical in design and construction to the two-stage oxygen regulator can be used for argon. When only oxygen regulators are available for welding with helium, use an adapter to attach the regulator to the helium cylinder. An adapter is also necessary to attach the hose to the regulator.

A flowmeter must be installed between the regulator and torch. It indicates gas flow to the torch in liters per minute or cubic feet per hour. You can determine gas flow in cubic feet per hour from the flowmeter setting. A flow of 1 liter per minute is equivalent to a flow of 2.12 cubic feet per hour. The cylindrical tube of the flowmeter should be mounted vertically, since a lightweight metal spinner in the tube indicates gas flow by rising or lowering with the flow of gas.

Auxiliary Equipment. The foot control is a foot-operated rheostat which is installed in the field circuit of the welding machine to change the arc for varying thicknesses of metal. This provides a convenient method of making slight changes in the current settings as you weld. Another advantage of the foot control is that you can shut off the welding current while the gas continues to flow, protecting the weld during cooling and helping to prevent crater cracking. If a machine does not have a built-in water and gas flow control, a water-gas shutoff valve can be installed. It should be insulated from the grounded side of the welding circuit. The flow of water and gas going to the torch can then be shut off by hanging the torch on a hooked arm provided for that purpose.

Protective Equipment. The protective equipment necesarry for inert gas welding is the same as that for metal arc welding—helmet, gloves, and proper clothing. MIG welding requires a darker lens in the helmet and more protective clothing than does TIG welding.

Exercises (A21):

1. list the three power sources available for use in gas-shielded welding.

2. For what purpose is superimposed high frequency used?

3. What are the advantages of using a water-cooled welding torch?

4. What are three possible causes of leakage in waterlines?

5. Explain the term "inert gas."

6. If you have a gas flow of 5 liters per minute, what is the flow per hour?

7. If a number 10 lens is safe for TIG welding, would you use a number 8 or 14 for the MIG welding?

8. Write *true* or *false* for each of the following statements:

___ a. The head of the water-cooled torch consist, basically, of these three parts: (1) the collet, (2) the gas-shielding cup, and (3) the tungsten electrode.

___ b. Argon cylinders have a distinctive color marking of gray with a buff (light brown) top.

___ c. A true reading of the gas flow is possible because the flowmeter tube is calibrated at a positive pressure—one normally exceeding any back pressure produced by the apparatus.

___ d. A disadvantage of the foot control is that you cannot, using it, shut off the welding current while the gas continues to flow; so the weld is not protected during cooling and crater cracking is not prevented.

A22. Associate current to use with expected results or type or work, and identify operational factors governing setting up inert welding equipment.

The factors that govern the setting up of inert welding equipment preparatory to welding are welding current, shielding gas, electrodes, and gas-shielding cups. We will discuss these in turn next.

Welding Current. The welding current may be either AC or DC. However, certain distinctive weld characteristics obtained with AC or DC make proper

current selection necesary if you are to satisfy a specific requirement. Thus the choice of polarity used in DC welding depends upon the type of metal you weld. Direct current with straight polarity (DC-SP is suitable for welding stainless steel, copper, copper alloys and low and medium alloy steels. In straight polarity welding the electrons striking the plate at high velocity have a considerable heating effect on the plate. However, in reverse polarity (DC-RP) welding, the opposite occurs; the electrode absorbs the extra heat, which then tends to melt off the end of the electrode. For any given current setting, DC-RP requires a larger diameter electrode than does DC-SP. These opposite heating effects influence not only the welding action but also the shape of the weld, as shown in figure 5-7.

Direct current with straight polarity produces a narrow, deep weld; direct current with reverse polarity, because of the larger diameter electrode and lower current used, produces a wide, relatively shallow weld. Direct current with reverse polarity breaks up oxide film on metal, permitting flux-free welding of such metals as aluminum and magnesium. Because of this characteristic, early users adopted DC-RP as standard for welding magnesium. However, subsequently alternating current with high frequency has replaced it, because of the latter's stability. Alternating current, in principle is a 50-50 combination of DC-SP and DC-RP. It reverses, in cycles, between the two polarities. In effect, the straight polarity component delivers adequate heat to the work, resulting in satisfactory penetration and speed, while the reverse polarity component breaks up the oxide film. Foreign matter—such as moisture, oxides, and scale—on the surface of the plate tends to prevent the flow of the current in the reverse polarity direction. If no current flows in the reverse direction, rectification has occurred. To prevent this, it is common practice to superimpose on the standard welding current (60 cycle), high voltage (300 volt), and high frequency (120,000) to produce a low-intensity arc. When high frequency is superimposed on AC current, a continual flow of electrons is jumping the gap between the electrode and the work piece, piercing the oxide film and forming a path for the welding current to follow. This makes arc stabilization possible while maintaining a reverse polarity current flow. Some advantages obtained from using high-frequency current are as follows: the arc may be started without

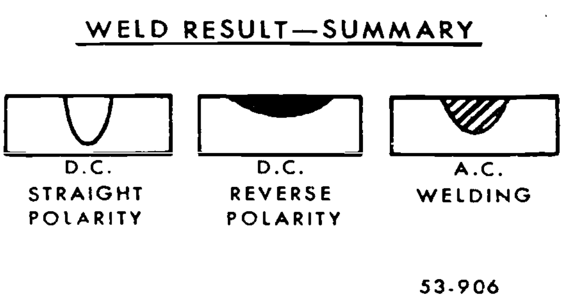


Figure 5-7. Comparison of weld contours.

touching the electrode to the work piece, better arc starting and stability are obtained, a longer arc is possible, welding electrodes have a longer life, and the use of wider current ranges is possible. A typical weld contour produced with high-frequency stabilized AC is shown in figure 5-7.

Shielding Gas. Gas purity may have considerable effect on welding, depending upon the extent to which the metal is affected by impurities. Consequently, stainless steel, as a rule, is not significantly affected by small percentages of impurity in the shielding gas. In contrast, nonferrous metals, such as aluminum and magnesium, are sensitive to impurities and so should be welded with high purity gas. The argon and helium gases, which are commercially available, average well over 99.95 percent in purity.

Argon is generally used for all altenating-current welding applications, such as the welding of aluminum, magnesium, and copper. The arc is relatively hard to start in helium gas shielding when very low welding current is used. This difficulty is not encountered with argon and the low arc voltage characteristic is particularly helpful in welding thin material, because the tendency to burn through is reduced. Helium is used mainly in DC-SP welding. It can be used in the DC-SP welding of magnesium.

Electrodes. In inert-gas-shielded welding, there are two types of electrodes—(1) the tungsten, nonconsumable electrode used in TIG welding, and (2) the metal, consumable electrode used in MIG welding.

Tungsten electrodes. The two types of tungsten electrodes used for gas-shielded welding are: (1) the tungsten type containing I or 2 percent thorium and (2) the commercially pure type (99.4 percent).

Thoriated tungsten electrodes are superior to pure tungsten electrodes, because of their higher electrode flow, better arc starting and stability, higher current-carrying capacity, and higher resistance to contamination.

The tungsten electrodes are practically nonconsumable. However, if an electrode touches the molten pool, a small ball will form on the end of the tungsten rod. The contaminated end may cause an erratic arc, but this can be stabilized by striking the arc on a copper plate. Remove the excess metal pickup from the end of the electrode by grinding or breaking it off with a pair of pliers. Electrode loss from oxidation can be prevented by permitting the gas to flow a short time after the arc is broken, thus allowing the electrode to cool in the protected atmosphere of the shielding gas. The diameter of the electrode to be used depends upon the current setting used in welding.

The tungsten electrode may be identified by color; for example, a green marking on the box or rod identifies it as pure tungsten; a yellow marking; as 1 percent thoriated; and a red marking, as 2 percent thoriated. The electrode should extend beyond the end of the gas-shielding cup a distance equal to its diameter for butt welding and slightly farther for fillet welding. Selecting the right size of electrode for each job is important in preventing electrode damage (pure tungsten

Electrode	Gas Cup	Welding Current (Amperes)		
Dia In.	No.	AC	DCSP	DCRP
.040	6	10-40	10-40	
1/16	6	20-60	20-75	10-20
3/32	6-7-8	30-100	30-100	15-20
1/8	6-7-8	150	100-150	25-40
3/16	7-8	200	125-200	40-80

53-910

Figure 5-8. Selection of electrode diameter, gas cup, and current setting.

melts at 6125° F.) and poor welds caused by a current that is too high or too low. Excessive current will cause tungsten particles to transfer to the weld, while insufficient current allows the arc to wander erratically over the end of the electrode. Recommended electrode sizes for various ranges of welding current are shown in figure 5–8.

Metal electrodes. The electrode used for MIG welding operations is a consumable alloy wire with approximately the same chemical composition as that of the metal being welded. The gas-shielding cup size and current also vary with the diameter as well as the composition of the alloy wire.

Gas-Shielding Cups. Gas-shielding cups are made of plastic, metal, and ceramic tile. They are made in various sizes, and the size selected will depend upon the diameter of the electrode used, as shown in figure 5–8. The cup number indicates the diameter of the cup opening in multiples of 1/16 inch. Thus, a number 8 cup has an opening of 1/2 inch. Continued use of the torch at high amperage tends to deteriorate the shielding-gas cup. For this reason, metal water-cooled cups are used with currents above 100 amperes.

Exercises (A22):

1. Match each current to use, given in column B, with its related type of work or required result, found in column A, by putting each lettered item (column B) beside its corresponding numbered item (column A). NOTE: Each item in column B may be used once or more than once.

Column A	*Column B*
___ 1. Wide bead.	a. DC-SP.
___ 2. Deep penetration.	b. DC-RP.
___ 3. Weld magnesium.	c. AC.
___ 4. Use high frequency.	
___ 5. Break up oxide film.	
___ 6. Weld copper.	

2. When TIG welding aluminum, which is the preferred electrode, one with a green mark or one with a red mark? What is this electrode?

3. Indicate in the spaces provided whether argon or helium shielding gas should be used:
___ a. Weld magnesium with DC-SP.
___ b. Weld aluminum.
___ c. Weld stainless steel.
___ d. Weld with high frequency.
___ e. Weld medium alloy steel by MIG.

4. Indicate in the space provided the size gas cup used for welding with:
___ a. 90 amps DC-SP.
___ b. 1/16-inch-diameter electrode, 20 amps AC.
___ c. above 150 amps DC-SP.
___ d. 50 amps DC-RP.

TIG Welding

TUNGSTEN-INERT-GAS (TIG) welding is used extensively for aircraft repair and on light gage materials. It has also been proven to be a very effective means of joining heat and corrosion-resitance ferrous alloys, such as aluminum and magnesium.

6-1. Joints of Heat-and Corrosion-Resistant Ferrous Alloys

There are several types of joints used when welding heatand corrosion-resistant ferrous alloys. These consist of edge, butt, lap, and tee and corner joints.

In this section, we will discuss the preparation for and welding of the joints just mentioned by referring to the most common heat-and corrosion-resistant ferrous alloy—stainless steel. Let's start our discussion with some factors that will affect our successful welding of stainless steel.

A23. Cite operational factors affecting stainless steel welding.

Inert gas-shielded welding is preferred for the welding of corrosion-resistant steels. This process is used extensively for the fabrication and repair of hospital and kitchen parts, because it produces a minimum of warpage, prevents oxidation, and maintains the maximum of corrosion resistance in the welded part. The use of special fixtures, the application of certain techniques, and the close control of current settings and welding speed will help you produce welds of high quality.

As the coefficient of expansion for stainless steel is approximately 60 percent greater than that for carbon steels, special precautions are necessary. To keep the metal from warping during welding, you must correctly align and properly space the joint edges. Space tack welds closely in accordance with metal thickness. Thin gage meetals have less resistance to warpage from the heat of welding, and you must tack weld them at closer intervals.

Carbide precipitation is another important factor to consider in welding stainless steel. You can reduce it to a minimum by confining the arc or heat to as small an area as possible and still obtain proper fusion. Smaller electrodes, higher amperages, and faster welding speeds are helpful. Inert-gas-shielded welding is adaptable, since the tungsten electrode has a very high melting point, permitting the use of high amperages with smaller diameter electrodes. This results in higher welding speeds, a narrow heat-affected zone, and more rapid cooling.

On some gas-shielded welding applications, the joint edges should be backed up to obtain the best results. On light gage material, backing is usually used to protect the underside of the weld from atmospheric contamination, which would result in possible weld porosity or poor surface appearance. In addition, weld backup on heavier metals prevents the weld from melting through by conducting some of the heat away from the joint edges. Three methods of backing up welds to protect the undersides of the welds are:(1) introduce an inert gas on the underside of the weld, (2) use a combination of backup olate and an inert gas, and (3) brush flux on the underside of the joint. Flat metal backup plates may be used only on joints of the flange type, as shown in figure 6–1. If the plate comes in contact with the underside of the weld, the penetration will be rough and uneven. On square edge butt joints, the backup plate is grooved directly below the joint edges, as shown in figure 6–2. This groove permits the weld metal to penetrate uniformly through the joint. When the weld must conform to extremely rigid specifications, you must take extra care to exclude all atmospheric oxygen from the weld. Do this by introducing the shielding gas into the relief groove of the backing plate. When the design of the assembly prohibits using a backing plate, you can direct a series of hydrogen flames on the underside of the joint to exclude the atmosphere from the weld.

Exercises (A23):

1. How can carbide precipitation be reduced to a minimum?

2. Why is inert-gas-shielded welding used extensively for fabricating and repairing kitchen parts?

3. How does the coefficient of expansion for stainless steel compare with that for carbon steel?

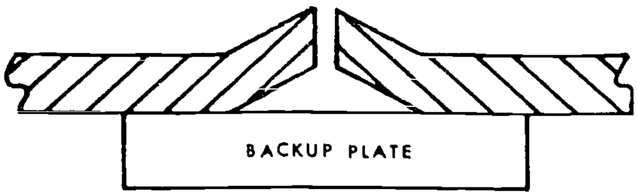


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Figure 6-1. Backup plate used on a flage-type joint.

4. List three methods of backing up welds to protect their undersides.

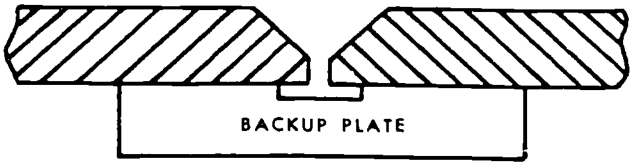
A24. State key functional features of the preparatory procedures and welding application for edge joints of stainless steel.

Edge Joint. The edge joint, one of the easiest joints to weld, is used primarily on light gage metal. It is not a strong joint and may fail at the root under relatively low stress loads. It should therefore not be used if direct tension or bending stresses will be applied to the finished joint.

Metal preparation and setup. The preparation of the edge joint is simple. Clean the edges thoroughly to remove all foreign material. Make sure that the edges fit together evenly and that all burrs have been removed. A very close fit-up is necessary for the edges to fuse together without the use of filler rod.

Machine setting and equipment adjustment. For metal thicknesses from .030 to .051 inch, you may alter the setting slightly to fit the thickness of the metal. Set the current for 15 to 30 ampere DC-SP. Adjust the flowmeter to allow 8 to 10 liters of gas flow per minute. Use a tungsten electrode with a diameter from .040 to 3/32 inch adjusted to extend 1/4 to 5/16 inch beyond the edge of the gas-shielding cup. With a water-cooled torch, the water flow should be approximately 1 pint per minute.

Welding application. At the weld starting point, strike and hold an arc until a molten pool develops. Hold the electrode as nearly vertical to the joint as possible and regulate the speed of travel to produce a uniform bead. A slow welding speed will cause molten metal to roll off the edge of the metal. Irregular or rapid speed of travel will produce a rough or an uneven surface. To terminate the weld, swing the foot control to the low position to break the arc and permit the shielding gas to flow over the weld area until it has cooled to a black heat.



53-912

Figure 6-2. Backup plate used on a square edge butt joint.

Exercises (A24):

1. Under what circumstances should an edge joint not be used?

2. What current is used for welding 3/64-inch-thick stainless steel edge joints?

3. How should you terminate the weld?

4. Why is a very close joint fit-up necessary when preparing an edge joint?

5. Irregular or rapid welding speed when welding edge joints will produce what type of surface?

A25. Identify functional features involved in completing butt joints.

Butt Joints. Stainless steel butt welds made by inert-gas-shielded welding may be made narrow and, therefore, may not have to be reinforced. The reason is that the shielding results in a weld that has high ductility and high tensile strength. Because of the high amperage carried by the small electrode, a narrow weld can be made that has fusion quality equal to that of a wider weld made with the oxyacetylene or metallic arc welding processes.

The square edge butt joint is easy to prepare and can be welded with or without filler metal, depending upon the thickness of the pieces being welded. When you weld light gage metal without adding filler metal, be extremely careful to avoid low spots and burn-through. The heavier thicknesses will generally require filler metal to provide adequate reinforcement.

Metal preparation and setup. Light gage sheet stock to be butt welded must be accurately sheared and free of burrs, and the edges must be thoroughly cleaned of all foreign matter. When you weld butt joints, align the joint edges parallel, allowing a space approximately the thickness of the metal, and tack weld, as shown in figure 6-3.

Machine settings and equipment adjustment. For metal thicknesses from .030 to .051 inch, you may alter slightly the current settings to fit the thickness of the metal. The welding unit is adjusted to DC-SP and set at 15 to 30 amperes, and the argon flow is from 4 to 6 liters

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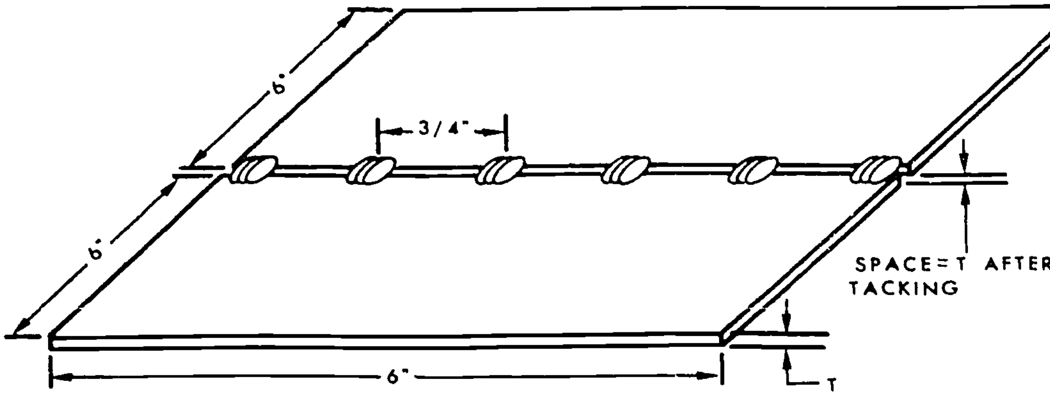

Figure 6-3. Proper tack welding of stainless steel. 53-914

per minute. Select a tungsten electrode .040 to 3/32 inch in diameter, and adjust it to extend 1/4 to 5/16 inch beyond the edge of the gas-shielding cup. If the torch is water cooled, adjust the water flow to approximately 1 pint per minute.

Welding application. Strike an arc on a copper plate with the foot control rheostat set in the high position. Immediately upon establishing the arc, swing the foot control toward the low position and back again toward high, fluctuating the current to steady the characteristics of the arc. Move arc to the joint edges and travel steadily along (fo. hand), holding the electrode as nearly vertical to the joint as possible. Add filler rod at the forward edge of the molten pool to prevent contaminating the tungsten electrode and to aid in weld control.

To terminate the weld, swing the foot control to the low position to break the arc, permitting the shielding gas to flow over the weld area until it has cooled to a black heat. In order to avoid overlap in restarting a weld, strike the arc ahead of the terminated weld (approximately 1/4 inch) and then move the arc back to the end of the weld, bringing the weld to a molten state before adding filler rod.

The completed weld should have penetration slightly in excess of 100 percent. Reinforcement for light gage stainless steel can vary from 5 to 30 percent of T (thickness) with the width of the bead varying from 2 to 3 T. The surface appearance of the completed weld should be dark bronze or light purple.

Exercises (A25):

1. Why is the filler rod added to the forward edge of the molten pool?

2. What is the minimum penetration allowed on .050-inch-thick stainless steel butt joints?

3. Describe briefly the appearance of a properly made butt weld of stainless steel.

A26. Supply operational factors and identify the specific welding procedures involved in preparing and welding lap, tee, and corner joints.

Lap Joints. Lap joints are used to join two overlapping sheets so that one sheet is welded to the surface of the other. When the joint design does not permit welding from both sides, the joint may be welded from one side only. For some applications, such as tubular splices, a single welded lap is satisfactory; however, a single welded lap joint in sheet metal will not develop the full strength of the base metal. Lap joints are used extensively in the repair of weldable jet and conventional aircraft parts because of the ease of preparation and welding. Stainless steel and inconel lap welds made by the inert gas-shielded process in light gage metals up to .0625 inch in thickness can be set up and welded without adding filler rod. Direct the arc to melt the upper edge of the joint to make a smooth, slightly convex weld bead.

Metal preparation and setup. Shear the pieces to be lap welded to leave a square edge free of burrs and warping. Clean the edges thoroughly to remove all foreign materials. You may use steel wool for this purpose.

Machine setting and equipment adjustment. The machine and equipment settings for welding lap joints are the same as those for butt welds, except that the amperage is set slightly higher—20 to 40 amperes.

Welding application. After the arc is struck and stabilized on a copper plate, move the arc to the joint edge and travel steadily along (forehand), melting back approximately 1 to 2 thicknesses of the top sheet. Failure to melt back the top sheet will result in a concave undercut bead. Weaving of the torch is not necessary to lap weld light gage stainless steel sheets. Tilt the torch head slightly toward the root of the joint

and in the direction of travel. Take particular care to insure that penetration at the root of the weld is 15 to 85 percent of T. The reinforcement should not extend above the thickness of the upper sheet. The contour of the bead should be slightly convex. The weld metal should taper smoothly into the base metal with no overlap, and the width of the bead should be from 2 to 3 times T. The surface appearance should be dark bronze or light purpose.

Tee and Corner Joints. Tee and corner joints are used to join two plates whose surfaces are at an angle of approximately 90° to each other. Welding can be done from one or both sides, depending upon the position, type of joint, and strength required.

Metal preparation and setup. Shear the stainless steel sheet stock to be tee or corner welded to leave a square edge free of burrs and warpage. Thoroughly clean the joint edges. For metal up to .0625 inch in thickness, no edge preparation other than cleaning and square shearing is necessary. Metal over .0625 inch thick is sometimes prepared for a single V-tee or a double V-tee when the joint can only be welded from one side or when maximum strength is necessary. Do not space tee or corner joints for inert-gas-shielded arc welding, because the concentrated heat of the arc permits obtaining proper fusion and penetration without spacing. Fluxing the back side of tee joints and underside of corner joints is recommended.

Machine setting and equipment adjustment. The machine and equipment settings for welding tee and corner joints are the same as for butt welds, except that the argon flow for corner joints should be adjusted to 8 to 10 liters per minute, and for tee joints, the electrode should extend 3/8 to 1/2 inch beyond the edge of the gas-shielding cup.

Welding application. Strike and hold an arc on a piece of copper plate, using the foot control rheostat to establish a stable arc of the approximate required heat. Tack-weld the edges of the joint about 1½ inches apart. Hold the torch so that it will bisect the included angle made by the two pieces being welded and as nearly perpendicular to the areas of the weld as practical. To weld sheets of unequal thickness, preheat the heavy sheet with a long arc and direct most of the heat on the heavy sheet during the actual welding operation. Add the filler rod at the root of the joint and the forward edge of the molten pool. Protect the molten pool and end of the filler rod with the shielding gas during the entire welding operation. The angle of the torch, heat input, and speed of travel must be exact in welding the tee joint to insure adequate penetration at the root of the weld without burning through the vertical sheet. To terminate the weld, swing the foot control to the low position to break the arc and permit the shielding gas to flow over the weld area until it has cooled to a black heat. The upper and lower legs of the tee weld should equal 1½ T. The upper and lower legs of the corner joint should equal T. The throat of the weld for both tee and corner welds should equal approximately T. Tee welds should have a face contour varying from slightly concave to slightly convex, while corner welds should have a convex face to insure the proper depth of throat. Surfaces of the welds must be free of pinholes and excessive oxidation.

Exercises (A26):

1. Name the type of welding operations in which lap joints are used extensively and give the reason for this?

2. What will occur if the top sheet (lap joint) is not melted back approximately 1 to 2 thicknesses?

3. Explain briefly the edge preparation necessary for welding corner joints of stainless steel using TIG.

4. Describe briefly how filler rod is added to a stainless steel tee joint using TIG.

6-2. Joints of Aluminum and Magnesium

In this day and age when talk of space travel is common, things developed for space are finding their way into industry and civil engineering. More and more aluminum and magnesium alloys are being installed in Air Force facilities. In this situation who is granted the privilege of repairing and maintaining these Air Force facilities? That's right, you and I. Accordingly, in this section we will discuss steps that will lead to successful welding.

A27. Identify welding applications, purposes, and specifications applicable to joints of aluminum and magnesium.

Aluminum and aluminum alloys that can be welded by the TIG welding process include 1100, 3003, 3004, 5005, 5050, 5052, 5083, 5154, 6061, 6062, and 6063 alloys. Welding work-hardened, nonheat-treatable alloys reduces their strength. Heat-treated alloys in the 'as-welded condition' can be expected to develop 40 to 60 percent of their strength.

Welding Setup and Application. The weld should be supported by a backup bar or plate when possible, except when welding is done from both sides. The backup bar may be copper, steel, or aluminum. Copper and steel backups should be removable. When an aluminum backup bar or plate is used, it should be compatible with the parent metal. Backup plates are recommended to control weld penetration and to permit faster welding speeds. Inert gas backup can be used when high-quality welding is necessary.

The metal should be clamped for alignment and spacing. Good joint fit-up makes welding easier. Adjust the current setting and argon flow for the thickness of the metal being welded. Start the arc by bringing the tungsten electrode close to the work surface. The electrode does not have to touch the work surface, because the high-frequency current forms a path to the work plate. Adjust the arc to the desired length, between 1/8 to 3/16 inch. Hold the arc at the starting point until the metal liquifies and a molten pool is established. Add the filler rod manually to the front edge of the molten pool, melting a small amount and withdrawing the rod. Point the torch in the direction of travel at a 10° to 20° angle from the vertical position. Hold the filler rod fairly flat to the work surface between 15° to 30° from the horizontal position. Advance steadily along the line of weld, keeping a uniform bead with evenly spaced ripples. To terminate the weld, depress the foot switch, keeping the torch directed onto the molten pool. Gas and water will continue to flow for a few seconds, cooling the weld and preventing contamination and cracking of the metal. Cracking can be minimized during welding by using the steps shown in figure 6-4.

Weld Specifications. The weld specifications for butt joints are slightly over 100 percent penetration, bead width of 2 to 3 T, and reinforcement of approximately 5 to 30 percent T. The weld specifications for a tee joint are penetration from 15 to 85 percent of T, bead width 2 to 3 T, upper and lower legs equal to 1½ T, and face slightly concave or convex.

Exercises (A27):

1. What produces an arc without the electrode touching the metal?

2. Why does the gas continue to flow for a few seconds after the welding is completed?

3. What is the purpose of a backup bar?

4. What is used when high-quality aluminum welding is necessary?

5. Weld specifications call for slightly ____________ ____________ percent penetration for butt joints.

A28. Identify functional procedures and factors involved in the welding of magnesium alloys.

Welding Magnesium Alloys. Magnesium has been largely responsible for the development of the

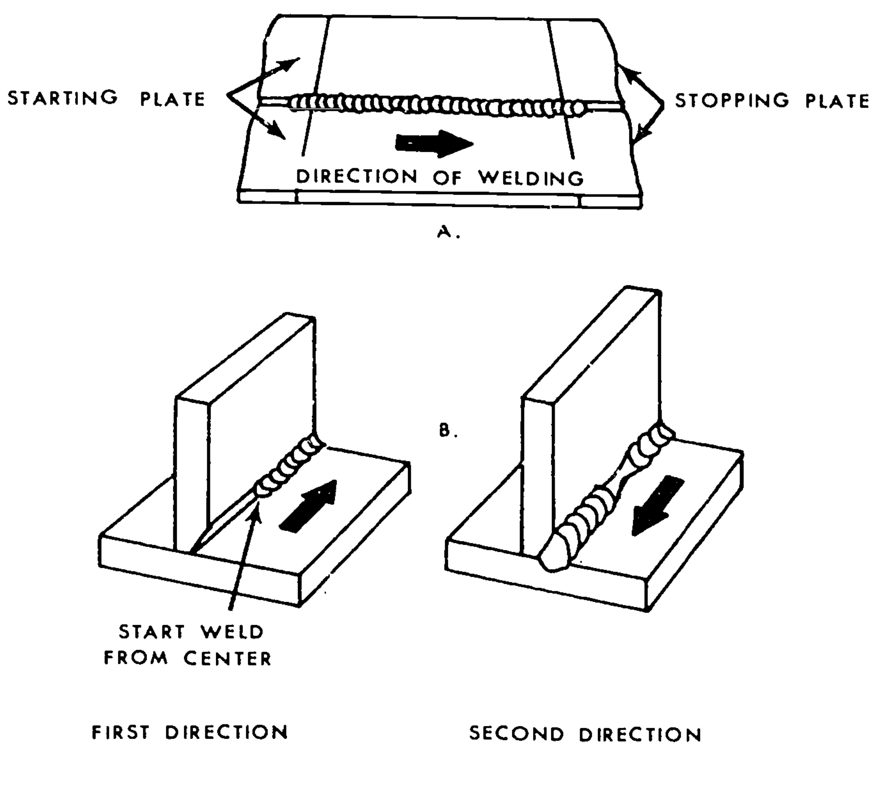

Figure 6-4. Minimizing cracking during welding.

gas-shielded welding process. This is virtually the only process that can be successfully used to weld magnesium. Magnesium alloys can be welded with either AC or DC. If DC machines are used, use reverse polarity current with helium gas for shielding. When AC machines with high-frequency stabilization are used, use argon as the shielding gas. The welding itself will be perform using the "inert-gas-tungsten arc" process.

Cleaning. An oil coating or chrome pickle finish is usually provided on magnesium alloys for surface protection during shipment and storage. The oil, together with other foreign matter and metal oxides, must be removed from the surface before welding. Chemical cleaning is preferred, because it is faster and more uniform in its action. However, mechanical cleaning may be used if chemical cleaning facilities are not available. A final bright chrome pickle finish is recommended for parts that are to be arc welded. Grease should be removed by the vapor degreasing method, in which trichloroethylene is used; or a hot alkaline cleaning compound may be used. Grease may also be removed by dipping small parts in drycleaning solvent or mineral spirits paint thinner. Mechanical cleaning can be done satisfactorily with 160 to 240 grit aluminum oxide, abrasive cloth, stainless steel wool, or by wire brushing. Immediately after the grease, oil, and other foreign materials have been removed from the surface, dip the metal for 3 minutes in a hot solution of the following composition:

Chromic acid	24 ounces
Sodium nitrate	4 ounces
Calcium or magnesium fluoride	1/8 ounces
Water	1 gallon

Operate the bath at the 70° to 90° F. Remove the work from the solution, thoroughly rinse it with hot water, and air dry. Welding rod should also be cleaned of contaminating agents, as oil or oxides.

Joint preparation. Edges that are to be welded must be smooth and free of loose pieces and contaminating agents, such as oil or oxides.

Safety precautions. Goggles, gloves, and other equipment designed to protect the eyes and skin of the welder should be worn. The possibility of fire caused by welding magnesium is very remote, because the temperature of incipient fusion must be reached before solid magnesium will ignite, and sustained burning occurs only if this temperature is maintained. Fine magnesium particles, such as grinding dust, filings, shavings, borings, and chips, present a fire hazard, since they ignite readily if proper precautions are not taken. Magnesium scrap of this type is not common in welding operations. If a megnesium fire does start, it can be extinguished with dry sand. The preferred extinguishing agent for magnesium fires is graphite base powder.

Welding setup and application. The welding setup and application for welding magnesium is the same as that for aluminum, with minor deviations. To weld either the butt joint or tee joint you should set the current low (40 to 50 amperes), using high-frequency alternating current. Clean the edges of the joint, making certain that no loose particles are on the edges. Adjust the gas-shielding rate from 6 to 12 cubic feet per hour. It is advisable to have backup gas (3 cubic feet per hour) for the butt joint. The torch angle should be 10° to 25° from the vertical. The weld specifications for magnesium are identical to those for aluminum.

Exercises (A28):

1. What is virtually the only process that can be successfully used to weld magnesium?

2. How should grease be removed from magnesium parts before welding?

3. What is the preferred way to extinguish a magnesium fire?

4. To what are the weld specifications for magnesium welding identical?

6-3. Titanium and Titanium Alloys

Titanium is produced in pure form as well as in various alloys. Pure titanium can be cast, formed, joined, and machined with relative ease as compared to the various alloy grades. Unalloyed titanium cannot be heat treated. Therefore, its uses are limited to end items not requiring the higher strengths obtained from the heat-treatable alloys. Titanium is a very active metal and readily dissolves carbon, oxygen, and nitrogen. For this reason, heating must be performed in a closely controlled atmosphere to prevent the absorption of oxygen and nitrogen, which cause brittleness.

A29. Identify characteristics of titanium.

Physical Properties. Titanium in the commercially pure form is silvery gray in appearance, resembling unpolished stainless steel but with slightly more luster. It is nonferrous and nonmagnetic. It weighs 0.163 pound per cubic inch compared to 0.283 pound per cubic inch for steel. It grinds very slowly and gives off bright white sparks with traces ending in brilliant white bursts. About 90 percent of these traces terminate in bushy bursts within 10 inches of the grinding wheel. The remaining 10 percent may reach a distance of 6 feet, depending upon the wheel speed and pressure

applied against the wheel. This spark color and behavior is unique and, therefore, reliable as a quick, easy shop test. Titanium is also identified by the manufacturer's code and specifications numbers stamped on sheet, bar, plate, and tubing stock. Aircraft parts fabricated of titanium are identified by the word "titanium" etched or stamped in a conspicuous place.

Limited physical properties are available on titanium compositions covered by existing military specifications. The melting point of titanium is higher than that of any of the other construction metals currently in use. The density of titanium is between that of aluminum and steel. The electrical resistivity of titanium is similar to that of corrosion-resistant steel. The modulus of elasticity is somewhat more than half that of the alloy steels, and the coefficient of expansion is less than half that of austenitic stainless steels.

Mechanical Properties. As we pointed out previously, titanium is a very active metal and readily dissolves carbon, oxygen, and nitrogen. All three elements tend to harden the metal; oxygen and nitrogen have the most pronounced effect. The control of these elements causes considerable difficulty in obtaining correct mechanical properties during fabrication. This variation in mechanical properties causes difficulty in the fabrication of parts, since the absorption of small amounts of oxygen or nitrogen makes vast changes in the characteristics of this metal during welding, heat treating, or any application of heat in excess of 800° F. Operations involving titanium requiring the application of heat in excess of 800° F. must be performed in a closely controlled atmosphere.

Welding Titanium. Titanium can be welded by the open fusion method, provided that the molten titanium can be protected from air and foreign materials. Thus, titanium is fusion welded by inert

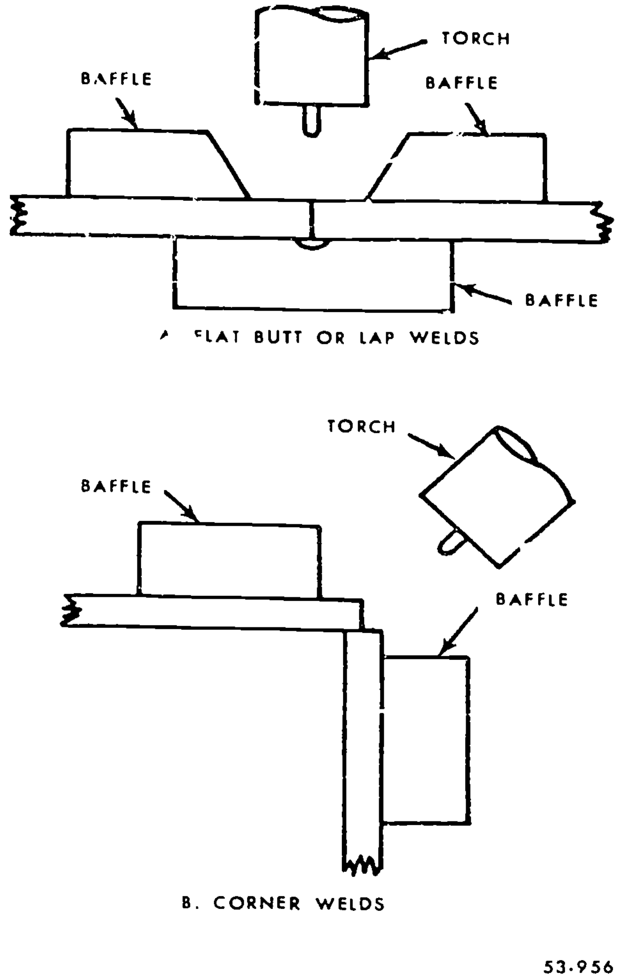

Figure 6 5. Baffle arrangements for improving shielding.

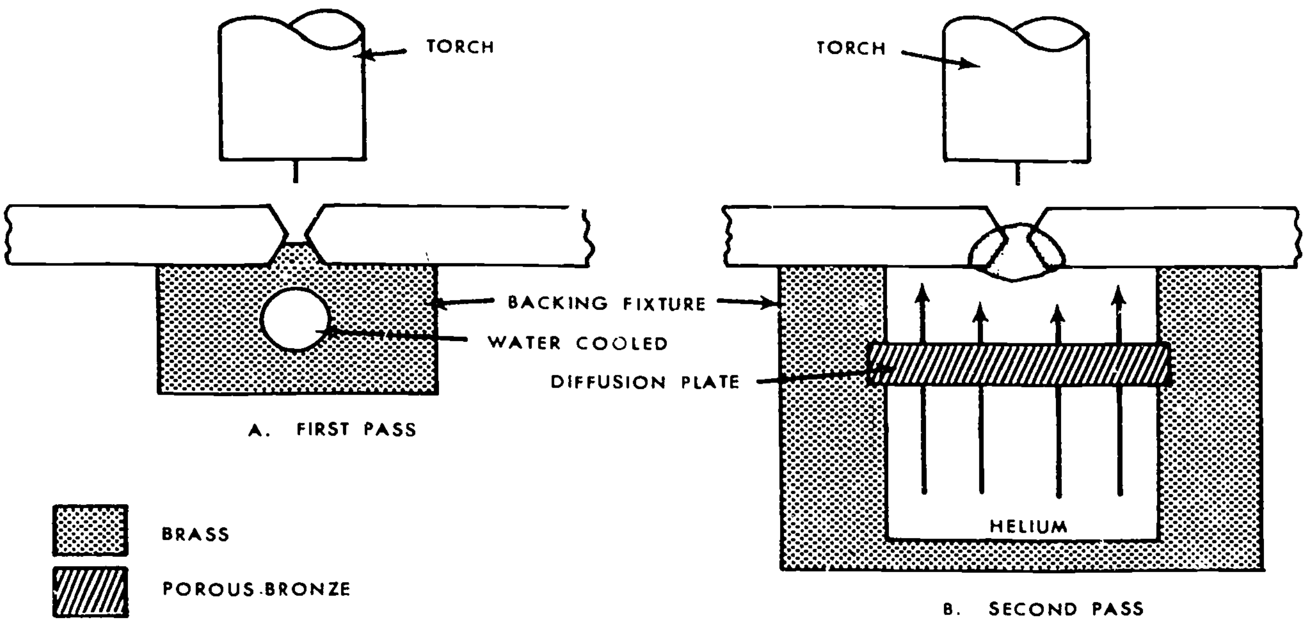

Figure 6 6. Backing fixture for heavy titanium plate.

gas-shielded arc welding, which includes both the nonconsumable (TIG) and consumable (MIG) electrode processes. Welding titanium by either process requires a sufficient quantity of argon or helium, or a 50/50 mixture of both, to shield the weld zone. Figure 6-5 illustrates the use of baffles to help shield the face of the weld by retaining the inert atmosphere in a smaller area. A better protection for the weld is using backing fixtures as shown in figure 6-6. However, under ideal conditions, the welding should take place in an inert gas chamber fitted with observation windows, and the welder should wear shoulder length rubber access gloves. The gas chamber can be constructed of ordinary steel.

A satisfactorily protected weld has a bright silver color. Any sign of brown or powdery gray scale indicates insufficient shielding and must be corrected immediately.

Exercises (A29):

1. Briefly describe the appearance of titanium.

2. The electrical resistivity of titanium is similar to that of what other metal?

3. Name the elements that tend to harden titanium.

4. What indicates sufficient shielding when welding titanium?

6-4. Welding Super Alloys

Most of the metals being used in the fabrication of the latest jet engines are made from various compositions of metals and are known as *super alloys.* They may be divided into these three groups: (1) iron base, (2) nickel base, and (3) cobalt base.

A30. Identify characteristics of iron base, nickel base, and cobalt base super alloys.

Iron Base Group. The iron base metals are able to withstand more than 10,000 pounds per square inch of stress (rupture) for 100 hours at temperatures from 1200° to 2000° F. They are able to retain their strength at temperatures up to 1400° F. The alloys which have the highest stress rupture strength at high temperatures are generally vacuum melted to improve their ductility and fabrication.

Alloy A-286. A 286 is one of the iron base metals which includes the iron-chromium-nickel austenitic stainless steels that are work hardenable. This super alloy is austenitic and nonmagnetic and develops hardness by titanium (1.95 percent) precipitation. Molybdenum (1.25 percent) also produces a hardening effect. A-286 may be received in both the solution condition, which is used in the fabrication of parts, and in a solution-treated aged condition. The metal in the solution condition can be formed, pressed, machined, or welded into various shapes or parts. After a part has been welded, it must be stress relieved by heating slowly to 1650° F. for 1 hour, followed by air cooling.

The chemical composition of A-286 follows:

Carbon (C)	0.08 percent max
Manganese (Mn)	1.00 to 2.00 percent
Silicon (Si)	0.40 to 1.00 percent
Chromium (Cr)	13.50 to 16.00 percent
Nickel (Ni)	24.00 to 27.00 percent
Molybdenum (Mo)	1.00 to 1.50 percent
Iron (Fe)	Balance
Titanium (Ti)	1.90 to 2.15 percent
Vanadium (V)	0.10 to 0.50 percent
Aluminum (Al)	0.35 percent max
Sulfur (S)	0.40 percent max
Phosphorus (P)	0.40 percent max
Boron (B)	.0010 to 0.010 percent

Chromoloy. Chromoloy is a new steel alloy which is manufactured by the electric furnace process. It must be free from all defects, such as laps, seams, scale, porosity, cracks, hard spots, excessive nonmetallic inclusions, and segregations. This alloy meets the medium-high temperature service requirements for jet engine turbine sections. This metal is processed in the annealed condition; and after a part has been fabricated by welding, it is normalized at 1725° F. for 2 hours and then air cooled. This produces a hardness of approximately RC36-40. If it is tempered at 1200° F. for 2 hours and air cooled, the minimum hardness should be approximately RC30. Since chromology is a new alloy, you should become familiar with its properties and characteristics, and the welding procedures used to repair it. The technique used to weld chromoloy should present no problem for the skilled welder. Chromoloy is one of the easiest of the new alloys to weld.

The chemical composition of chromoloy follows:

Carbon (C)	.18 to .23 percent
Manganese (Mn)	.04 to .60 percent
Silicon (Si)	.06 to .90 percent
Phosphorus (P)	.040 percent max
Iron (Fe)	Balance
Sulfur (S)	.040 percent max
Chromium (Cr)	.80 to 1.20 percent
Molybdenum (Mo)	.80 to 1.20 percent
Vanadium (V)	.08 to .15 percent

Nickel Base Group. Nickel base alloys have attained wide acceptance in aircraft application, largely as a result of their suitability at temperatures above 1400°

F. In general, the nickel base alloys are intended for use in a temperature range " 1400° to 1800° F. The alloys contain 50 to 70 percent nickel, about 20 percent carbon, up to 10 percent molybdenum, up to 20 percent cobalt, and small amounts of titanium and aluminum. The alloys containing titanium and aluminum are hardened by a single or double aging treatment after being cooled from a temperature range of 1950° to 2150° F.

Rene 41. Rene 41 is a vacuum-melted precipitation hardening nickel base alloy designed for highly stressed parts operating between 1200° and 1800° F. Its applications include afterburner parts, turbine casings, wheels, buckets, and high-temperature bolts and fasteners. Rene 41 is available in sheet, bar, and forgings. It work hardens very rapidly, and frequent anneals are required; to anneal, heat it rapidly to 1950° F., soak it for 30 minutes, then and quench it. Rene 41 can be satisfactorily welded in the solution-treated condition. After welding, the parts should be solution treated for stress relief.

Hastelloy-X. Hastelloy-X is a nickel base alloy used for burner liner parts, turbine exhaust weldments, afterburner parts, and other parts requiring oxidation resistance and moderately high strength above 1450° F. It is used in the solution treated (annealed) condition. Hastelloy-X is available in all of the usual mill forms. It is somewhat hard to forge; forging should be started at 2150° to 2200° F. and continued as long as the metal flows freely. It should be in the annealed condition for optimum cold forming, and severely formed detail parts should be solution treated at 2150° F. For 7 to 10 minutes and cooled rapidly after forming. Hastelloy-X can be resistance or fusion welded or brazed. Large or complex fusion weldments require stress relieving at 1600° F. for 1 hour.

Cobalt Base Alloys. The cobalt base alloys are designed for use for moderately and highly stressed parts operating between 1000° and 1900° F.

N-155 alloy. N-155 alloy, also known as *multiimet*, is designed for applications involving high stress up to 1500° F. It has good oxidation properties and good ductility and can be fabricated readily by conventional methods. This alloy has been used in aircraft applications, including afterburner parts, combustion chambers, exhaust assemblies, turbine parts, and bolts. It is easily cold formed by conventional methods; intermediate anneals may be required to restore its ductility. This alloy is machinable in all conditions. Low cutting speeds and ample flow of coolant are required. The weldability of N-155 is comparable to that of austenitic stainless steels.

N-155 alloy has the following composition:

Chromium (Cr)	20.0 to 22.5 percent
Nickel (Ni)	19.0 to 21.0 percent
Molybdenum (Mo)	2.5 to 3.5 percent
Cobalt (Co)	18.5 to 21.0 percent
Iron (Fe)	Balance

L-605 alloy. L-605 alloy, also known as Haynes alloy-25 and *crucible alloy WF-11*, is a corrosion- and heat-resistant cobalt base alloy used for moderately stressed parts operating between 1000° and 1900° F. Its applications include gas turbine blades and rotors, combustion chambers, and afterburner parts. L-605 is not hardenable, except by cold working, and is usually used in the annealed condition. It is available in all of the usual mill forms. In the annealed condition, it has excellent formability at room temperature; severely formed parts should be annealed at 2225° F. For 7 to 10 minutes. It is difficult to machine. Its toughness and capacity for work hardening necessitate the use of sharp tools and low cutting speeds; high-speed steel or carbide cutting tools are recommended. L-605 can be fusion or resistance welded or brazed; large or complex fusion weldments should be stress relieved at 1300° F. for 2 hours.

The composition of L-605 is as follows:

Chromium (Cr)	19.00 to 21.00 percent
Manganese (Mn)	1.00 to 2.00 percent
Wolfram (tungsten) (W)	13.50 to 16.00 percent
Silicon (Si)	1.00 percent max
Sulfur (S)	.03 percent max
Nickel (N)	9.00 to 11.0 percent
Iron (Fe)	2.00 percent max
Cobalt (Co)	Balance

Exercises (A30):

Indicate in the blank spaces provided before each of the follow statements whether it is true or false.

___ 1. The iron base metals are able to retain their strength at temperatures up to 1700° F.

___ 2. A-286 is austenitic and nonmagnetic, and develops hardness by titanium (1.95 percent) precipitation.

___ 3. Chromoloy is one of the most difficult of the new alloys to weld.

___ 4. Nickel base alloys contain a greater percentage of molybdenum than of carbon.

___ 5. The cobalt base alloys are designed for use for moderately and highly stressed parts operating up to 1000° F.

___ 6. N-155 alloy is not machinable.

___ 7. L-605 alloy is not hardenable except by cold working and is generally used in the annealed condition.

8. Provide the missing word or words for each of the following statements about super alloys:

a. Molybdemum (________ percent) produces an ________ effect in alloy A-28G.

b. Chromoloy is processed in the ________ condition; and after a part has been fabricated by welding; it is normalized at ____° F. for 2 hours and air cooled.

c. To anneal Rene 41, heat it rapidly to ________° F.soak it for ________ minutes, and quench it.

d. Also known as ____________, N-155 alloy is designed for applications involving high stress up to ____________° F.

e. L-605 alloy is also known as __________ __________ __________ and is __________ to machine. (One of the two answers, not both, follow "known as.")

A31. State procedures and operational features related to welding the super alloys A-286 and chromology.

Welding A-286 Alloy. This alloy is somewhat hard to weld correctly until you master the techniques. The weld requirements of this metal are very critical. Tungsten-inert gas, metal arc welding is a good fusion welding process for repairing and welding this alloy. Argon gas shielding is desirable for welding light gage metal. Use helium on the heavier metal thicknesses. The welding of this alloy requires more care than does the welding of stainless steel, because there is greater danger of cracking if the weld burns through. The proper use of either a shielding gas or copper backup block is necessary to eliminate the causes of weld cracking. For most inert-gas, metal arc welding operations, argon is cheaper to use than helium, because less of it is used.

Welding equipment and materials. The following information about equipment and material will help you to produce quality welds. The welding machine should be an AC-DC rectifier type with a foot control rheostat. Use a lightweight inert-gas welding torch with a 2-percent thoriated tungsten electrode. For metal thickness up to .090, use argon for the shielding gas; use helium gas for metals over .090 thick. Welding lens number 8 or 10 can be used. Do not use lenses over 10 for welding A-286 alloy. Wear lightweight leather gloves to avoid burns. The filler material should be Hastelloy-W or A-286 sheared stock.

Welding requirements. To produce sound welds that meet full strength requirements, you must maintain the proper penetration and reinforcement of the base metal. There is great danger that the weld will crack if shielding does not protect the weld before solidification. When the weld burns through the metal, the part must be rejected. The weld specifications for the butt, lap, and tee joints follows:

- Butt joint—100 percent penetration and 50 percent reinforcement.
- Lap joint—fused into the root of the weld and 35 to 65 percent penetration into each sheet.
- Tee joint—fused into the root of the weld and 35 to 65 percent penetration into each sheet.

Weld preparation and applications. The welding machine should be set for DC straight polarity and the current adjusted for the thickness of the material to be welded. All sharp edges and burrs should be removed and the weld area cleaned, using stainless steel brush or wool. If emery cloth is used, remove the dust before welding. To avoid distortion, use copper or argon backup shields whenever possible. The spacing of the joint should be .020 inch. Use 3 cubic feet per hour of backup gas and 12 cubic feet per hour of shielding gas. Grind a needle point on the electrode and extend it approximately 3/16 to 1/4 inch beyond the gas cup. The torch angle should be slanted no more than 25° from vertical. Sheets heavier than .060 inch should have the edges beveled to 50 percent of T. The width of the bead for butt joints should be approximately 3 to 4 T. Leg lengths for fillet welds should be 1½ T.

Welding Chromology. The welding equipment, welding requirements, and welding preparation are the same as those for welding A-286; however, the welding current may be set slightly higher (45 to 55 amperes), and the filler metal should be copper-coated chromoloy filler wire or sheared stock from chromoloy sheet. After the completion of a weld on a chromoloy part, stress relieve the area immediately, since its temperature is approximately at the preheat temperature. Use an oxyacetylene torch with a slightly reducing flame. The size of the tip should be approximately number 4, depending upon the type. The oxygen and acetylene pressure should be 6 psi. As a result of stress relieving the weld area, the parent metal and weld area will regain most of the original strength. The strength of the repair will depend upon the proper control of heating time and temperature.

The maximum linear distance of individual localized heating should not exceed 2 inches at a time. The initial heating should be controlled in such a manner that the weld and the weld-affected zones in both members joined by the weld are raised uniformly to the stress-relieving temperature. Heating should be intermittent to bring thee temperature slowly to 1200° F. in 1 minute. Use a stopwatch to check the time. Use tempilstiks of 1150°, 1200°, and 1250° F. to determine the temperature of the metal during stress relieving. Maintain a temperature between 1150° and 1250° for 5 minutes, controlling the time with a stopwatch. Time begins when the repair weld area and heat-affected zones have reached 1200° F. Remove heat after 5 minutes and permit the heated area to cool down to room temperature. Remove the scale and tempilstik residue from the stress-relieved area, using a wire brush of the stainless steel type. Inspect the repaired area, using the dye penetrant method.

Exercises (A31):

1. What is needed to eliminate the causes of weld cracking?

2. What type of welding machine is used to weld A-286 alloy?

3. When welding chromology, what shade of welding lens can be used?

4. What are the weld specifications for a la, oint of ..-286 alloy?

5. What should be done upon completing the welding of a chromoloy part?

6.20

Pipe Welding

IN THIS CHAPTER, we will discuss the laying out, preparing, and welding of carbon steel, stainless steel, and aluminum alloy pipe. Pipe is used for many types of construction jobs, such as frames, platforms, jigs, and fuel and oil lines. Missile weapon systems use a particular kind of pipe for liquid oxygen facilities. The advantages of arc welding pipe include permanently tight connections, great strength and rigidity, less resistance to flow by eliminating projections inside the pipe, and easier and cheaper construction without the use of mechanical attachments or fittings. A high degree of skill and dexterity is required to weld pipe in all postions.

7-1. Welding Carbon Steel Pipe

Pipe to be welded is usually supplied with a single V-bevel of 32½° with a 1/16-inch-root face for pipe thickness up to 3/4 inch. A single U-groove is used for heavier pipe. If the pipe has not been properly beveled and prepared or if it has been cut in the field, it must be beveled and prepared before welding.

A32. Identify joint and backing ring types and functional factors involved in welding butt joints of carbon steel pipe.

Butt Joint. The most common type of joint used in the fabrication of welding pipe systems is the *butt joint.* It is the most satisfactory from the standpoint of stress distribution. When the wall thickness of the pipe is 3/16 inch or greater, the ends of the pipe are beveled to an angle of 20° to 37½° to within 1/16 inch of the inside wall of the pipe, as shown in figure 7-1

When you join pipe of large diameter that will be subjected to severe service conditions, use a backing ring. A backing ring is a ring-shaped metal strap which is fitted on the inside surface of the pipe at the joint before welding. It helps in securing complete penetration of the deposited weld metal to the inside surface of the pipe without burn through. The backing ring prevents globules of splattered weld metal and slag from entering the pipe. You can use it to assist in aligning the pipe ends. There are several types of backing rings: the plain flat strip rolled to fit the inside of the joint, the forged or pressed type (with or without projections), the circumferential rib which spaces the pipe ends to the proper distance apart, and the machined ring. All shapes of backing rings may be of the continuous or split type. Several kinds of backing rings are illustrated in figure 7-2. These rings should be made from metal that is readily weldable. Those used in welding steel pipe are usually of low carbon steel.

Edge preparation. Use the oxyacetylene cutting torch to bevel heavy walled pipe and the pedestal grinder for thin walled (up to 3/16 inch) pipe. After beveling, remove all rust, dirt, scale, or other foreign matter from the outside of the pipe in the vicinity of the weld with a file, wire brush, grinding disc, or other type of abrasive. If the bevels are made by oxyacetylene cutting, the oxide formed must be entirely removed. The inside of the pipe in the vicinity of the weld may be cleaned by sandblasting, by tapping with a hammer, with an airblast followup, or by any other suitable method, depending upon the inside diameter of the pipe. The scarf faces should be thoroughly cleaned.

Welding setup. Before welding, align the pipe carefully. A pipe lineup clamp, used to align and securely hold the pipe ends for tack welding, and a spacing tool made from an automobile spring are shown in figure 7-3. The spacing will depend upon the side of the electrode used for the root pass. If a lineup clamp is not available, set the pipe sections in a jig so that their centerlines coincide and the spacing of the pipe ends are uniform before tack welding. An angle iron, figure 7-4, will serve as a jig for small diameter pipe, while a section of channel or I-beam is satisfactory for larger pipe.

When you weld to a backing ring, the spacing should not be less than the diameter of the electrode used for the root pass. When you do not weld to a backing ring, the spacing should be 3/32 inch maximum, but it varies from this maximum to zero, as figure 7-5 shows, depending upon whether a small or large angle of bevel is used. When you have properly aligned the pipe ends, make four tack welds, one-half the thickness of the pipe and equally spaced around the pipe. The tack welds must be strong enough to maintain the joint alignment and to permit the removal of any external fastenings that were used to maintain alignment. Tack welding permits handling the pipe after setting it up and before welding.

Welding procedure. Pipe and other circular shapes involve no new welding principles. The main difference between welding straight joints and pipe joints is that the position of the work or the welder must change constantly because of the circular shape of the work.

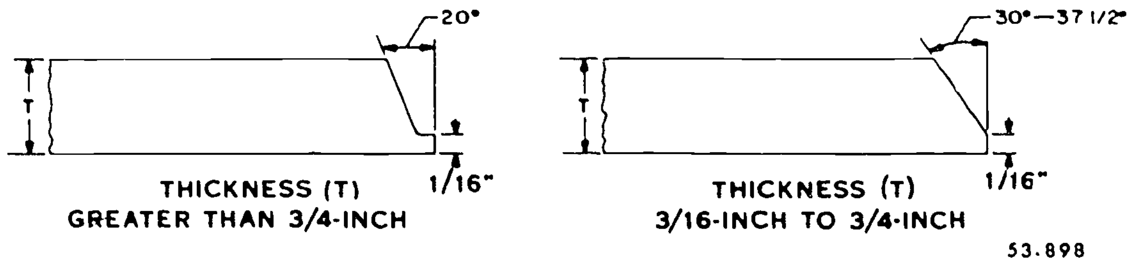

Figure 7-1. Forms of bevels for butt welded joints.

There is no definite direction specified for welding pipe in a fixed horizontal position. In metal arc welding, the preferred direction of travel is from the bottom upward (the forehand method); however, the direction in some welding, especially that of pipe of thin or medium wall thickness, is downward (the backhand method). More metal is deposited in welding upward, and complete grain refinement is easier to achieve. Downward welding requires a higher degree of manual skill to secure adequate fusion with the walls and to avoid trapping slag.

The number of passes required for making a pipe weld varies with the wall thickness of the pipe, the welding position, the size of the electrode, and the welding current. In general, however, it is one pass for each 1/8 inch of pipe thickness. When you are welding in the horizontal or rolled position, the number of layers is usually increased 25 to 30 percent, and smaller

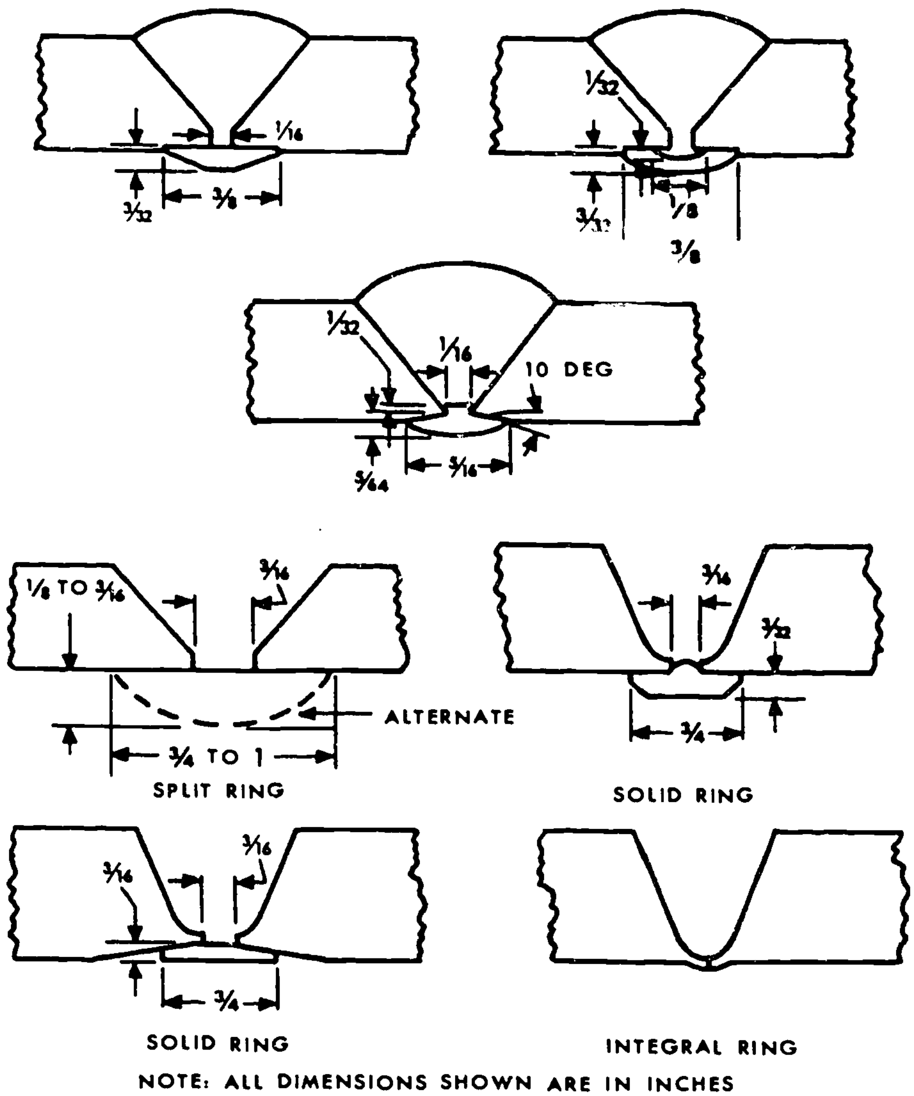

Figure 7-2. Types of backing rings. 53.899

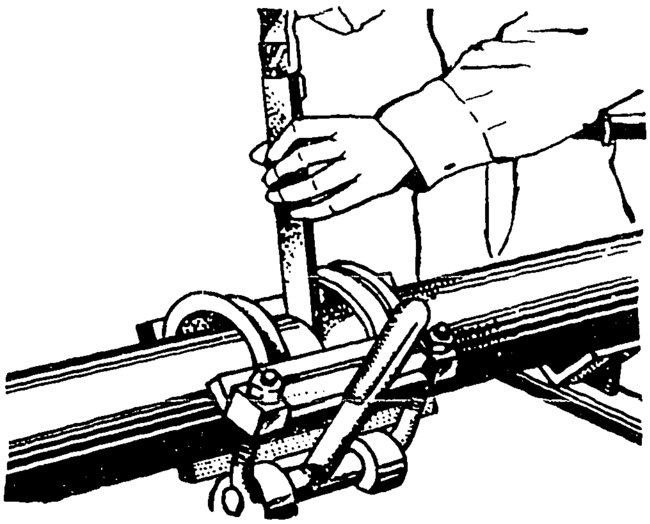

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Figure 7 3. Pipe lineup clamp and spacing tool.

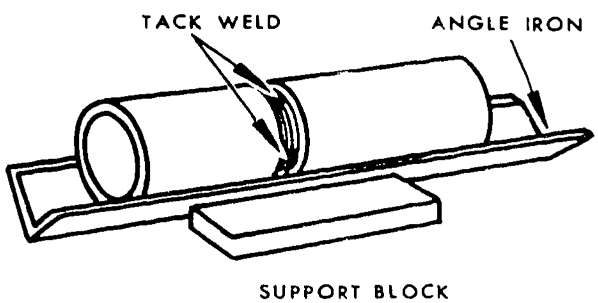

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Figure 7 4. Angle iron pipe welding jib.

electrodes are used to lessen the heat concentration and to insure complete grain refinement of the weld metal. The sizes of the electrodes are from 1/8 to 5/32 inch diameter for the first pass, 5/32 inch diameter for the intermediate passes, and up to 1/4 inch for the top passes and reinforcement. Deposit a layer of metal across the full width of the welding groove during each pass.

When the pipe is in a fixed vertical position, deposit the filler metal in a series of overlapping string beads, using 1/8 inch (maximum) electrodes, and allowing 25 to 30 beads per square inch of weld area. Clean each layer of deposited weld metal before depositing the following layers. Chip with a slag hammer and wire brush to remove the slag deposited by coated electrodes. When you repair a weld, you should first remove the defect by chipping, machining, flame gouging, or flame cutting. After removing the defect, shape and clean the surfaces upon which the repair weld is to be made.

Exercises (A32):

1. What is the most common type of joint used in the fabrication of welded pipe systems?

2. Indicate briefly the functions or uses of backing rings.

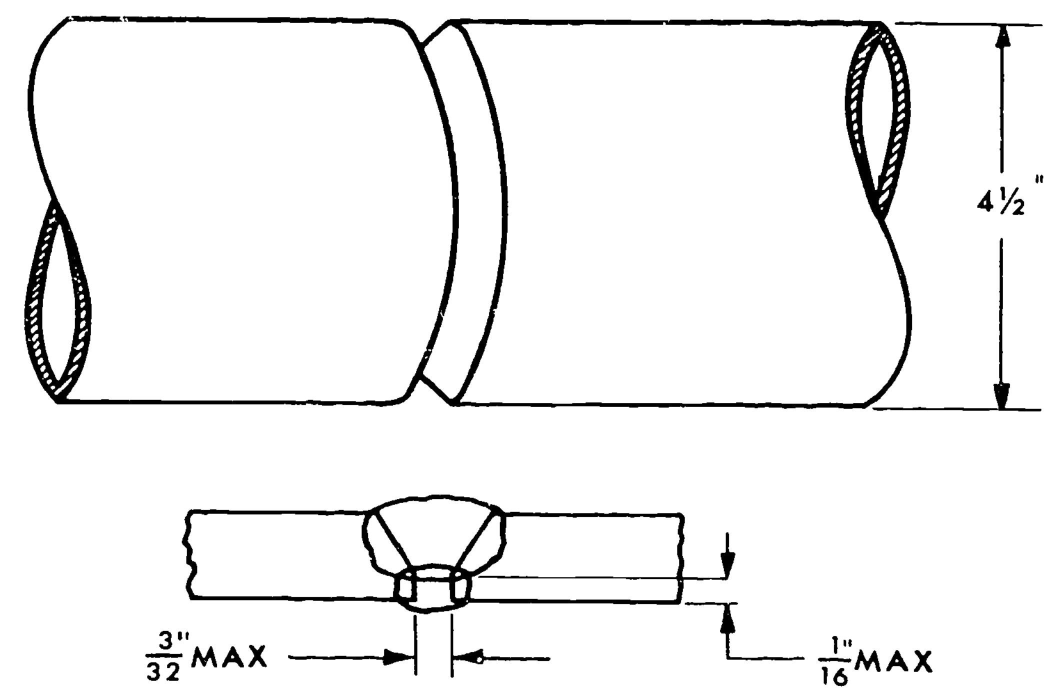

Figure 7 5. Butt weld in pipe.

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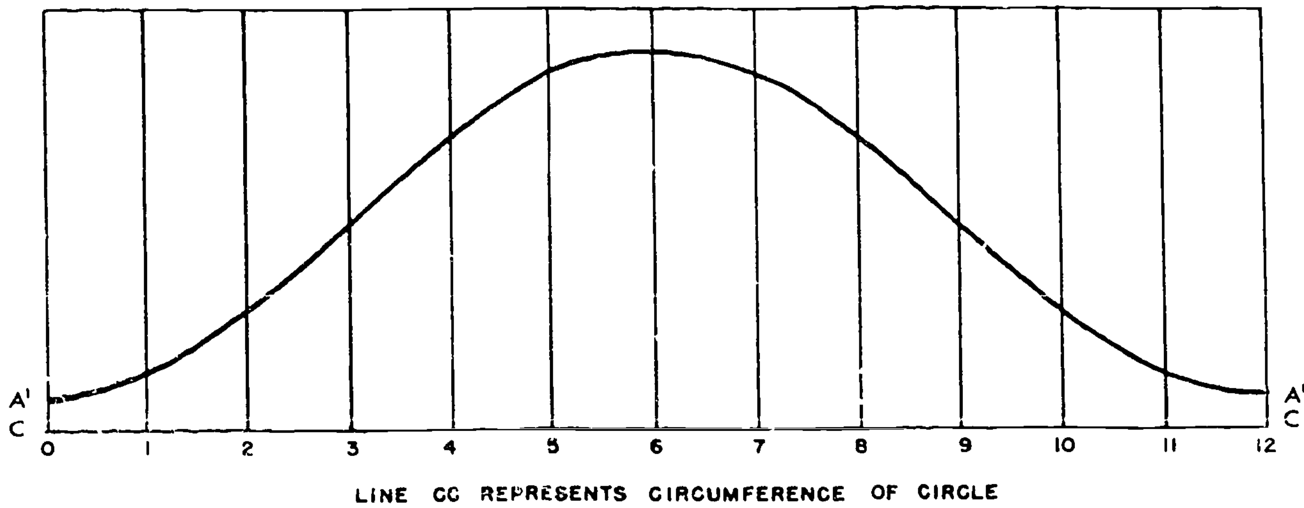

Figure 7-6. Pattern for a 90° bend. 53.947

3. Name four types of backing rings used in the fabrication of welded pipe systems.

4. What is used to bevel heavy walled pipe before welding?

5. When you weld to a backing ring, what should the spacing be?

6. How many passes are required when making a pipe weld?

A33. State procedures, for welding pipe joints and other butt joints.

Joining pipe when one member forms an angle with another presents the problem of preparing one pipe to fit the other, or preparing both to fit each other. Remember the sheet metal patterns you made way back in an earlier volume? Well now we will do it again, only this time we will use pattern only to mark the pipe. The rest of the work will be with the pipe sections. Remember a good fit-up is a *must*, and the only way to get a good fit-up is to make an accurate pattern. If you need a slight refresher course, look back to the layout section.

90° Bend. In preparing to lay out a pattern for a 90° bend, as shown in figure 7-6, first determine the size of the pipe and then proceed to lay out the pipe joint in actual size. Use the outside lines of the pipe to represent the outside diameter, as shown in figure 7-7. Next, inscribe a circle and divide it into 12 equal parts, numbering them beginning with zero. Extend these points over to line AA and number the intersections, as shown in figure 7-8. Draw the line BB at a right angle to the pipe, starting it 3 inches from the corner pipe. This completes the preliminary details before the actual pattern is made.

Now, lay the stretch out, line CC, which represents thee circumference of the circle, as shown in figure 7-6. Divide this line into as many equal parts as the circle was divided into, and number them, beginning at the left with zero. Construct perpendiculars at these

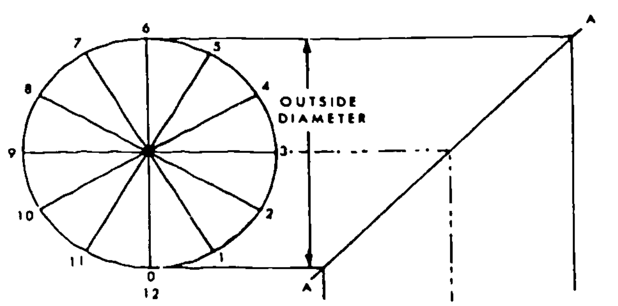

Figure 7-7. Layout plan view. 53.945

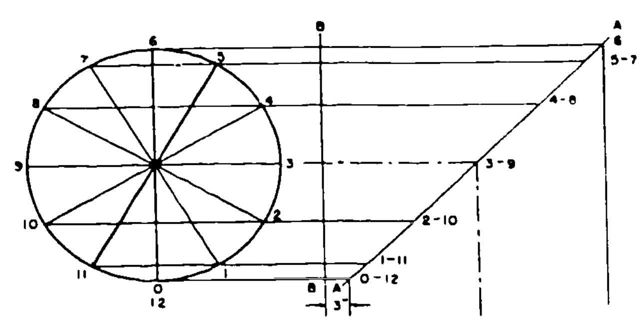

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Figure 7-8. Layout of the true length lines.

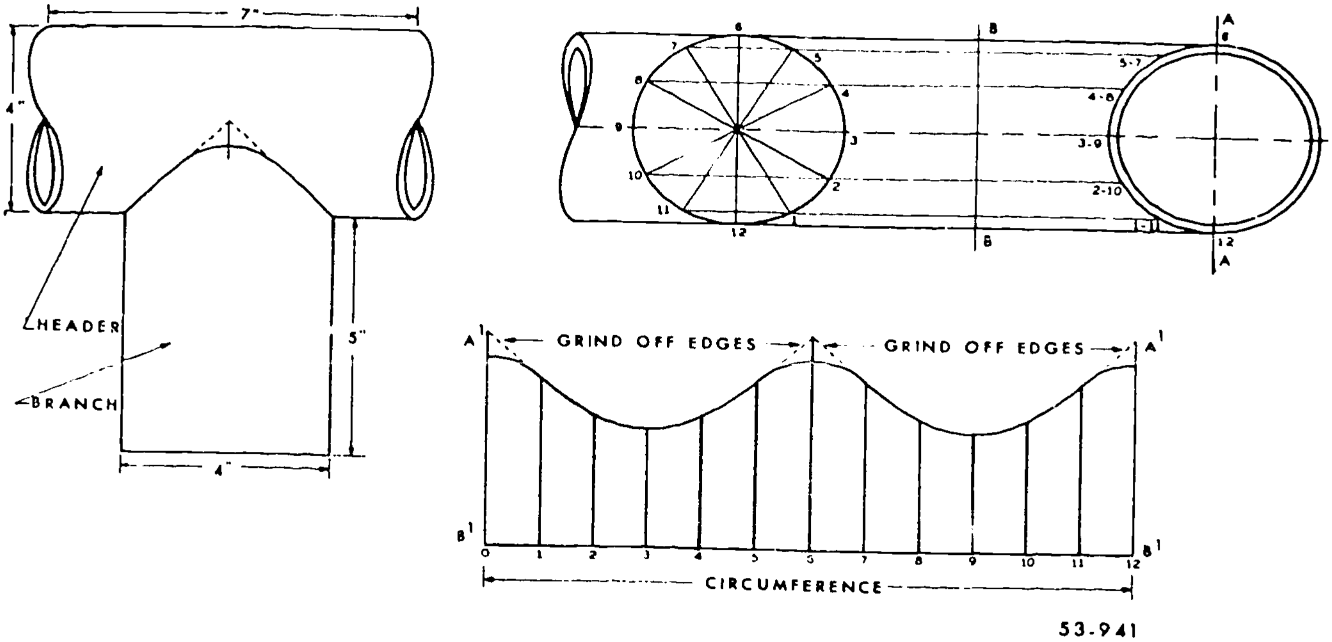

Figure 7-9. Layout pattern for a tee.

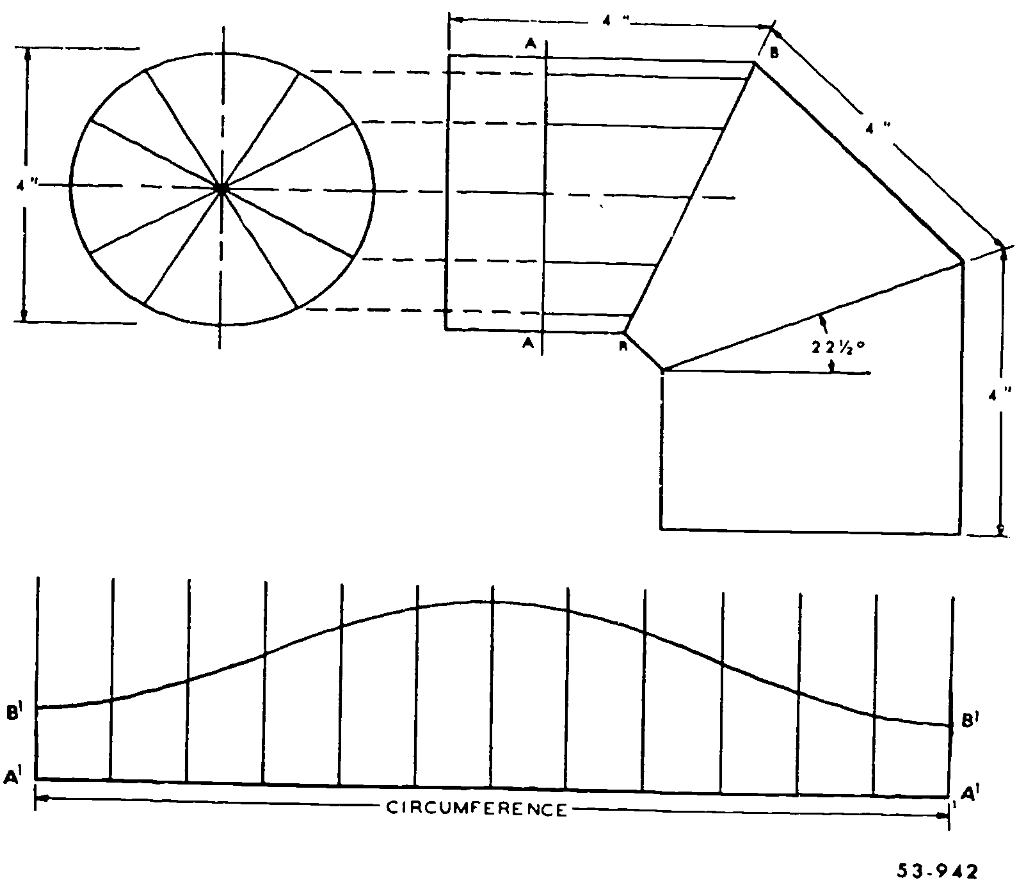

Figure 7-10. Layout of three-gore elbow pattern.

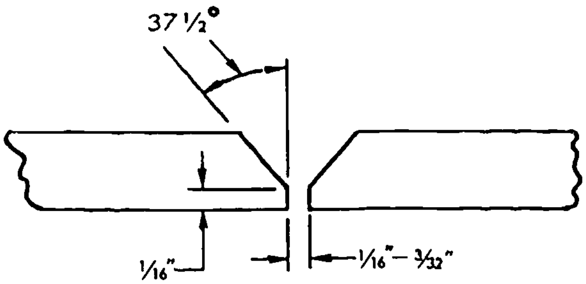

Figure 7-11. Standard vee joint.

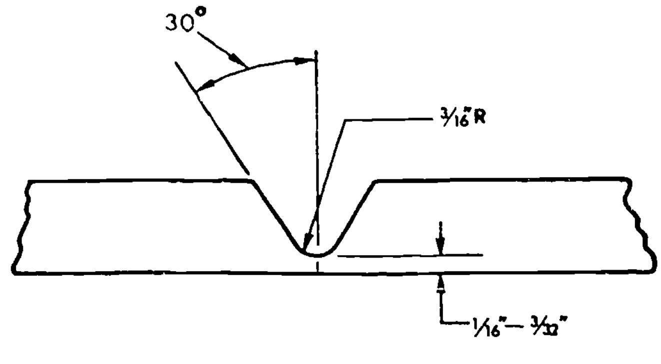

Figure 7-13. U-grooved joint.

points. Next set off the true lengths and connect these points, forming the curved line A'Asl. Check to insure accuracy and cut out the pattern.

The pattern is then wrapped around the pipe in the desired position and marked on the pipe with soapstone following the line A'A'. This is the cutting edge. Cutting two pieces of pipe on line A'A'and butting them together results in a 90° bend which should require no trimming other than beveling of the edges.

Tee and Elbow. If a pattern must be made for a pipe tee, the joint would be laid out as shown in figure 7-9. The same procedure, as outlined for a sheet metal pipe can be applied The patterns would then be wrapped around the pipes, marked, and cut to form the tee joint.

After the branch line is cut, it is placed in position on the header. The header is then marked and cut.

To fabricate a multigore elbow, follow the procedure for a 90° elbow. Be careful of the 22½°! Why? Because the angle of the miter line, as shown in figure 7-10, will change with the number of gores in the elbow.

Welding Procedures. After the pipe has been laid out and cut, you are almost ready to weld. First, you must clean the edge thoroughly and remove all burrs. All metal that is to be fused during welding must be absolutely clean. Avoid sharp corners or sudden changes in size or contour, since they might lead to concentrations of stress. Maintain joint alignment by the use of jigs and fixtures or by adequate tack welds. When tack welds are used for alignment and holding, they should be of sufficient size to support the joint throughout the welding operation. The spacing between the parts to be joined should be carefully considered. The edges should fit snugly. The root opening between the welding edges for a given wall thickness of pipe must permit the gap to be bridged without difficulty.

Welding application. The welding application for this joint is similar to that for the lap joint. When welding joints of unequal thickness, direct the arc in such a manner that both pipes being welded are heated to the same temperature. When joints require multilayer welding, stagger the starting and stopping points of successive passes. Each layer should be not more than 1/8 inch thick; deposit the several layers in succession, completing and cleaning each layer before starting the next.

Weld specifications. All fillet welds on pipes should have leg dimensions not less than 1.8 times the wall thickness of the lighter of the two pipes being welded. Penetration at the root of the weld should be 15 to 85 percent of the wall thickness.

Exercises (A33):

1. What is the first step to a good fit-up?

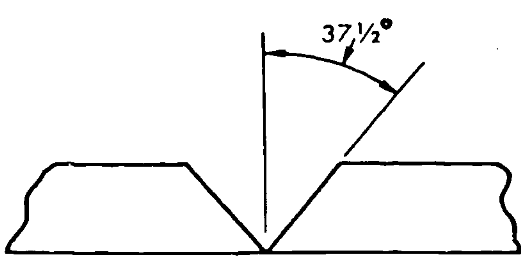

Figure 7-12. Sharp vee joint.

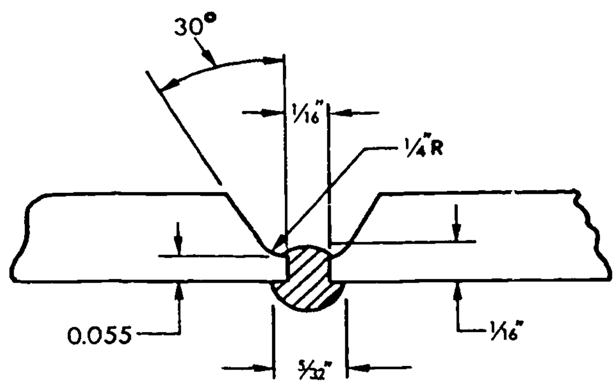

Figure 7-14. Consumable insert joint.

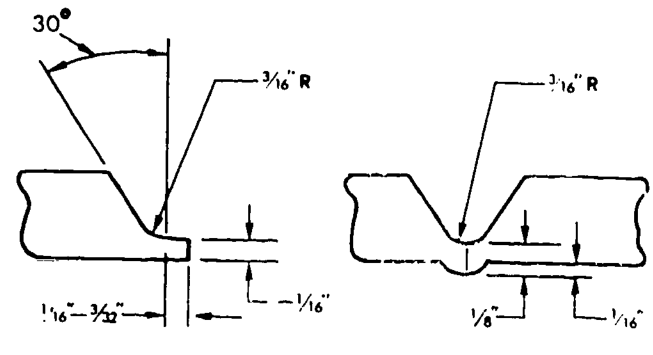

Figure 7-15. Rolled edge joint.

2. Once the pipe has been laid out and cut, what must be done before welding is begun?

3. How is the alignment of pipe joints maintained?

7-2. Welding Stainless Steel Pipe

Metallic arc welding *can* be used for stainless steel pipe, but inert-gas-shielded welding has been found to be the best method. High quality welds with uniform penetration are made at a lower cost than arc welds made with either oxyacetylene or metallic arc welding.

A34. Concerning pipe welding, state how best to weld stainless steel pipe, why pipe weld joints need thorough cleaning after tack welding, and the most common types of pipe welding joints.

Pipe welding isn't done in only one position, but rather in a combination of all positions because of the constant change due to the circular form of the pipe. However, the pipe itself can be fixed in either a vertical or an overhead position. The preparation for each position is the same.

Joint Designs. Five joint designs have been developed for pipe welding using the heliarc process. These joints are satisfactory for welding rolled pipe, as well as for welding pipe in fixed positions. All pipe with a wall thickness greater than approximately 1/8 inch should be beveled for heliarc welding. Wall thickness less than 1/8 inch may be beveled if the filler rod is used.

The vee groove joint illustrated in figure 7-11 has been widely accepted as a standard joint design for pipe welding. The standard vee joint may be butted together and welded without filler rod on the root pass. However, for higher quality welds, filler rod is required.

The vee joint illustrated in figure 7-12 is called a *sharp vee joint* to distinguish it from the *standard vee*. The sharp vee joint is adaptable to field erection of pipe.

The joint illustrated in figure 7-13 is recommended when more uniform welds and higher weld quality are required than could be obtained with the vee groove joint. Penetration is uniform with this design, and weld "sink in" in the vertical position is minimized.

Consumable inserts are available and will produce the highest weld quality and the strongest inside weld reinforce ment. Figure 7-14 illustrates the *consumable insert joint* design, as well as the insert. The joint preparation requires close tolerances, and fitting the insert into the joint is time consuming; but since the composition of the insert may be selected to vary the composition of the weld, the weld results may be superior.

Another method of obtaining inside weld reinforcement is the *rolled edge joint*. The left-hand section of figure 7-15 shows the first stage in preparing this joint, while the right-section of the same figure shows the finished joint. The rolled edge joint is recommended for nickel alloy or stainless steels. It is less costly than the consumable insert joint, and the fit-up is less critical.

Joint Preparation. The two most common types of joints encountered in pipe welding are butt and tee joints.

Butt joint. Butt joints are the most common type of pipe joint. This joint can be fit-up, using any one of the five joint designs. The edges of the pipes must be cleaned, aligned, and tack welded at 90° intervals. The joint should be cleaned again after tack welding to insure an oxide-free weld.

Tee joints. Tee joints must be fitted by fishmouthing the branch and cutting a hole in the header in the manner discussed for metallic arc earlier in this chapter. The pipe edges must then be prepared by beveling to one of the five joint designs. Clean the edges, tack weld at 90° intervals, and then reclean the joint.

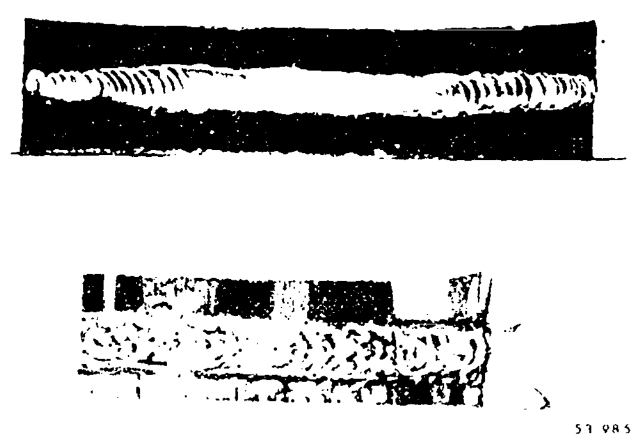

Figure 7-16. Weld made with argon (upper) and without argon (lower).

Purging. Pipe should be purged before the weld is started, and the purging should be maintained throughout the entire welding operation. When conditions permit, the purging gas should be introduced at the lowest point in the pipe or system and vented out at the high point. Oxidation of weld deposits and/or base metal must not occur.

A comparison is made in figure 7-16 of welds made with an argon backing (upper) and without an argon backing (lower).

Exercises (A34):

1. What has been found to be the best method of welding stainless steel pipe?

2. Why should pipe weld joints be cleaned thoroughly after tack welding?

3. What are the two most common types of pipe welding joints?

A35. Regarding butt and tee joints, cite the appearance of finished weld contours, the penetration required at the weld root when tee-joint welding stainless steel pipe, and the surface appearance of a completed stainless steel weld.

The welding procedure for pipe is nothing new to us. As has been stated in earlier chapters of this volume, it is merely a combination of all position welding. It does require more skill of the welder because of the constant changing positions.

Butt Joints. Butt welds should be made in one pass for each 1/8 inch of pipe wall thickness with a minimum of two passes. Butt welds should be flush with the inside of the pipe. When grinding is not possible, allow an inside protrusion of 1/32 inch for pipe up to 2 inches in diameter and an inside protrusion of 1/16 inch for pipe 2½ inches in diameter and over.

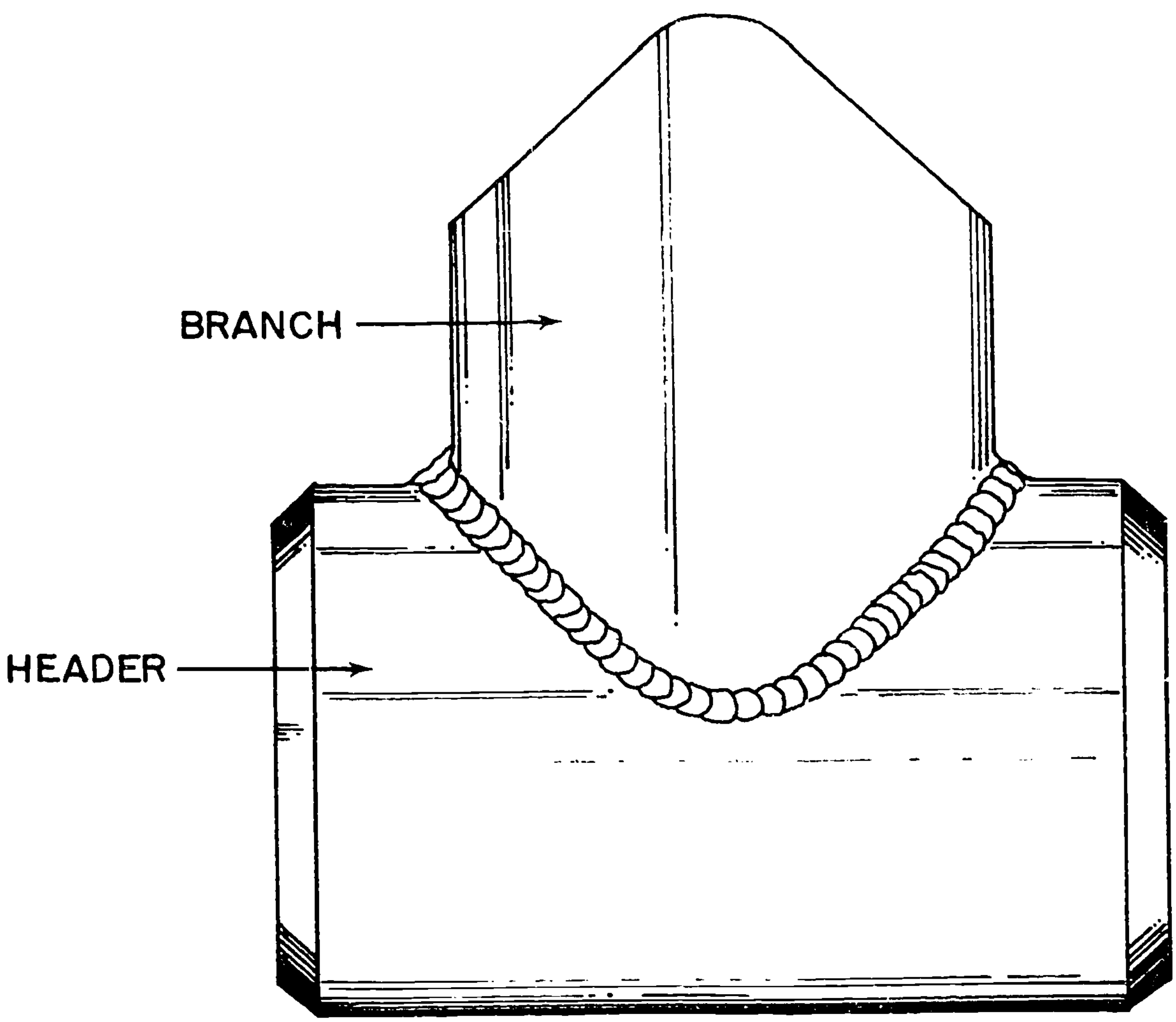

Figure 7-17. Stainless steel tee joint.

The reinforcement for butt welds should not be less than 1/16 inch nor more than 3/32 inch above the surface of the base material. The reinforcement should be built up uniformly from the base metal to a maximum at the center of the weld and should blend smoothly and gradually with the base metal. The finished weld contours should be uniform and free from depressions below the surface of the base metal. Butt welds should have a finished bead width of approximately 1/16 inch on each side of the bevel. Under no circumstances are wide welds to be used to cover poor fit-ups.

Tee Joints. Tee welds must be fitted up carefully. The edges must be thoroughly cleaned and all burrs removed to prevent unequal spacing around the joint. The edges should fit snugly and should be evenly spaced to allow for proper penetration and to prevent burn through. Tilt the torch head slightly toward the root of the joint and in the direction of travel. Take particular care to insure that penetration at the root of the weld is 15 to 85 percent of the pipe wall thickness (T). The reinforcement should not exceed the thickness of the pipe wall. The contour of the bead should be slightly convex. The weld metal should taper smoothly into each pipe with no overlap, and the width of the bead should be from 2 to 3 times the wall thickness. The surface appearance should be dark bronze or light purple. A completed tee joint is shown in figure 7-17.

Exercises (A35):

1. Describe briefly how the finished weld contours should appear.

2. When tee-joint welding stainless steel pipe, what is the required penetration at the root of the weld?

3. What is the surface appearance of a completed stainless steel weld?

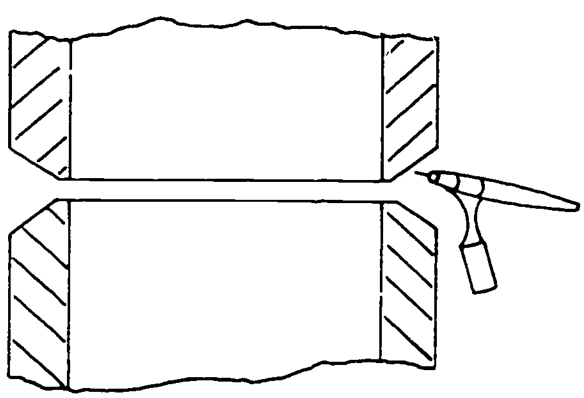

Figure 7-18. Torch position for welding pipe in the vertical position.

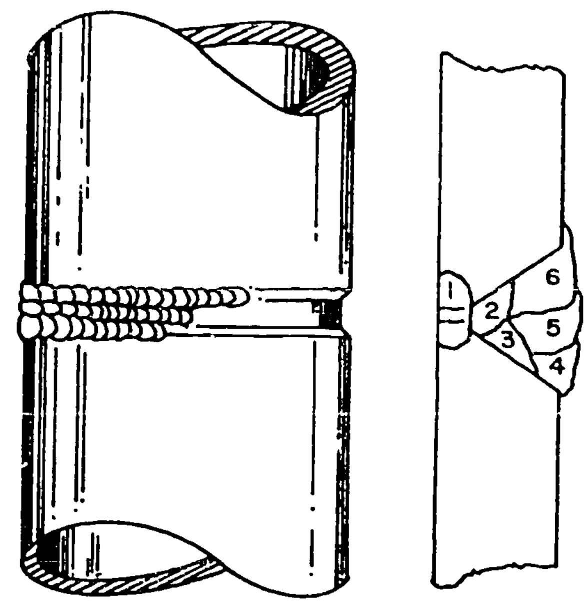

Figure 7-19. Multipass stringer beads (left) and welding sequence (right).

A36. State the purposes, operational techniques and applications of welding stainless steel pipe joints in the fixed vertical and overhead positions.

Vertical Welding Position. When pipe sections are in the vertical fixed position and may not be rotated, the welding is performed in the horizontal position.

Welding technique. Special techniques are required to compensate for the sagging of the puddle due to gravity. Consequently, position the torch as shown in figure 7-18 and form the weld puddle on the upper side of the joint, keeping it slightly above the centerline of the joint. Move the torch in small circles, from the top of the puddle around the puddle to the bottom, and then up the other side to the top. Do not permit it to dwell longer on the top of the weld. This circular motion will insure fusion of the bottom of the joint with the filler rod but will not undercut the upper side of the weld bead.

Welding application. Whenever possible, start the arc by using a high-frequency arc starter attachment. The high-frequency current should be sufficient to start the arc without touching the electrode to the work piece. When joints require multilayer welding, stagger the starting and stopping points of successive passes, as shown in figure 7-19. Each layer should be not more than 1/8 inch thick; deposit the several layers in succession and complete each layer before starting the next. The preferred method for breaking the arc is to gradually decrease the welding current with the foot-operated current control until the arc is extinguished. If the foot-operated current control is not available, increase the rate of travel to a speed at which the arc will travel without fusing the base metal; then break the arc. A finished horizontal weld bead of stainless steel pipe is shown in figure 7-20.

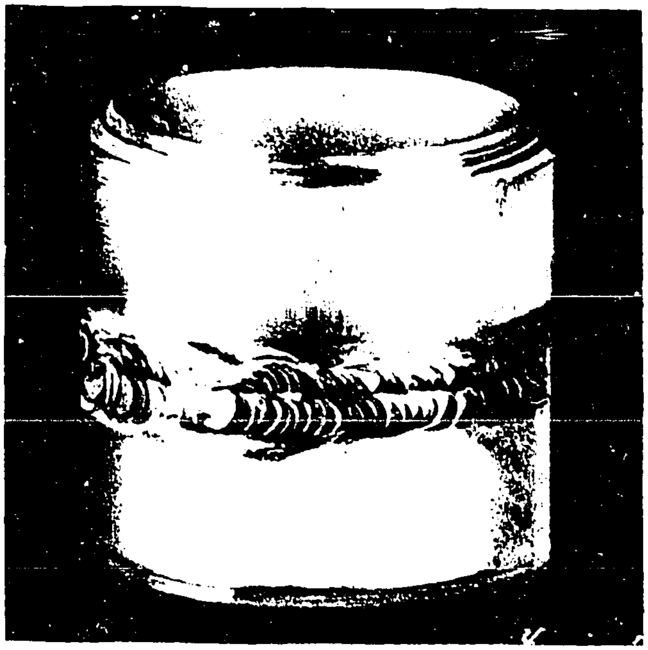

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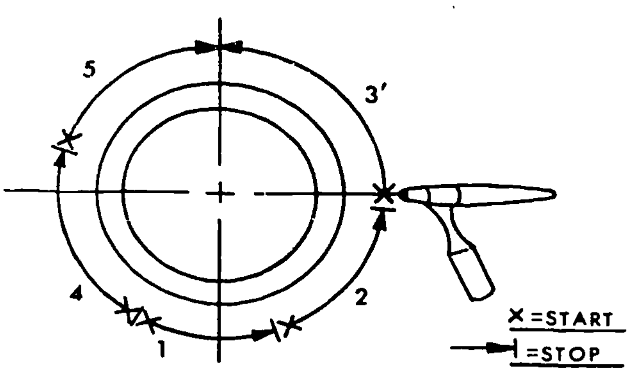
Figure 7-20. Finished horizontal weld bead.

Overhead Welding Position. When you weld in the overhead welding position, make the entire weld with the work at or above eye level. Set the pipe so that the centerline is approximately horizontal. Figure 7-21 shows the correct welding sequence.

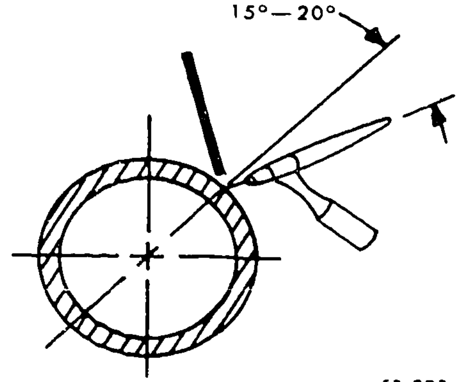
Welding technique. After properly tacking the joint, strike an arc on the side of the joint and carry it to the bottom of the joint. Let the arc dwell on the bottom of the joint until a small weld puddle forms on each side of the vee. Then, add the filler rod to the front edge of the weld puddle until the puddle bridges the joint opening. Do not insert the filler rod directly into the arc. When you add the filler rod, hold it almost tangent to the pipe surface and slant the heliarc torch about 15° to 20° toward the rod with the arc length about 1/16 inch, as shown in figure 7-22.

When the puddle increases to about 1/8 inch in thickness, remove the rod and hold the torch



53-922

Figure 7-21. Welding sequence for pipe.



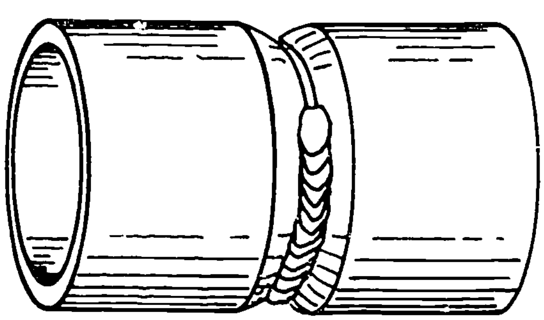
53-923

Figure 7-22. Torch and filler rod position relative to pipe.

stationary. The weld puddle will now begin to flatten out in front, forming a thin front edge, and will take a wedge shape with rounded corners extending to the bottom of the joint. The wedge shape indicates that penetration is complete. Figure 7-23 illustrates the correct puddle shape for complete penetration of the joint. As soon penetration is complete, as shown by the puddle shape, add the filler rod and advance the heliarc torch at the same time. Keep advancing the correct puddle shape to complete the pass. When you have mastered the technique, you will be able to keep the eight of the puddle even and about 1/8 inch in thickness.

If the welding speed is too slow, you will have excessive penetration inside the pipe. The weld puddle will then have a rounded opening at the front edge of the puuddle which will be wider than the joint opening (keyhole shape). A keyhole shape for a spaced joint indicates excessive penetration, since too much of the edges are being melted back. To overcome excessive penetration, add more filler rod to the puddle, slant the torch sharply toward the filler rod so that more rod is melted, and increase the welding speed. The effect will be to direct more heat onto the filler rod and less onto the pipe. This will close the enlarged opening at the front of the puddle.

Welding application. Strike and hold an arc near the joint edges. If the tungsten electrode becomes contaminated, strike the arc on a piece of copper plate



53-924

Figure 7-23. Correct puddle shape.

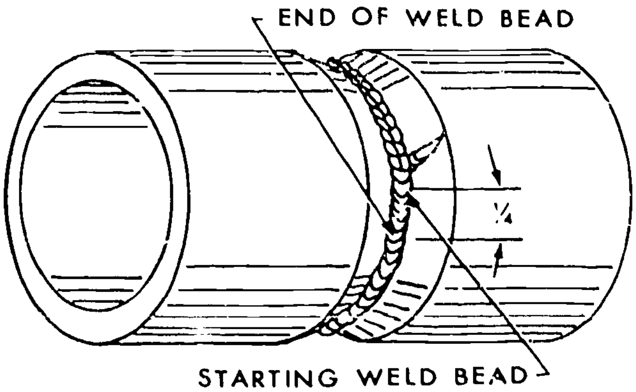


Figure 7-24. Starting and stopping a weld bead.

until the erratic action of the arc smooths out. Use the foot control rheostat to adjust the arc to the approximate desired heat. Move the arc to the joint edges and travel steadily along (forehand), holding the electrode as nearly vertical to the joint as possible. Add the filler rod at the forward edge of the pool. Manipulating the torch is not necessary in order to obtain the proper width of weld in light gage metals. To terminate the weld, swing the foot control to the low position to break the arc and permit the shielding gas to flow over the weld area until it has cooled to a black heat. To avoid overlap in restarting a weld, strike the arc ahead of the terminated weld (approximately 1/4 inch), as shown in figure 7-24, and then move the arc back to the end of the weld and bring it to a molten state before adding the filler rod. The weld specification of the penetration bead is shown in figure 7-25. These specifications are approximations of acceptable variations for stainless steel welds.

Exercises (A36):

1. What is the purpose of using a circular motion when welding stainless steel pipe in a fixed vertical position?

2. Describe briefly the preferred method of breaking the arc when welding pipe.

3. What is indicated by a keyhole shape for a spaced joint, and why is this so?

4. How do you overcome excessive penetration, and why?

5. What should you do if the tungsten electrode becomes contaminated?

7-3. Welding Aluminum Alloy Pipe

In this last section we will discuss types of aluminum pipe, equipment, preparation, and technique of welding aluminum alloy pipe.

A37. Cite three aluminum alloys produced in pipe form, the solvents used to clean aluminum alloy joints before welding, flow rate for inert gas when welding aluminum pipe, and how aluminum steel joints are prepared and welded.

For many years, aluminum pipe was generally joined with threaded fittings. Today, welded pipe is widely used. Only three aluminum alloys are produced in pipe form. Of these, alloy 3005-H12 is a nonheat-treatable alloy containing manganese. It provides adequate strength for many applications and resistance to corrosion. Alloy 6063-T6, a heat-treated aluminum magnesium silicate type alloy, provides higher strength and equal resistance to corrosion. Alloy 6061-T6 is similar to 6063-T6, but it has higher strength. In most environments, its resistance to corrosion is equal to that of the other two alloys already discussed.

Equipment Setup. The current setting for welding aluminum alloy pipe will vary with the skill of the welder, but the types of current, shielding gas, and electrode remain the same. Alternating current with superimposed high frequency or direct current (straight polarity) is used to weld aluminum alloy pipe. When you use AC high frequency, the tungsten electrode may be either of pure tungsten or of 2 percent thoriated tungsten. The shielding gas should be argon. With DC straight polarity, the electrode should be pure tungsten and the shielding gas helium.

Preparation of Edges. All butt joints must be melted through their full thickness to obtain a complete penetration weld. This can be done by using two of the joints we have discussed for stainless steel pipe welding—the standard vee joint and the sharp vee

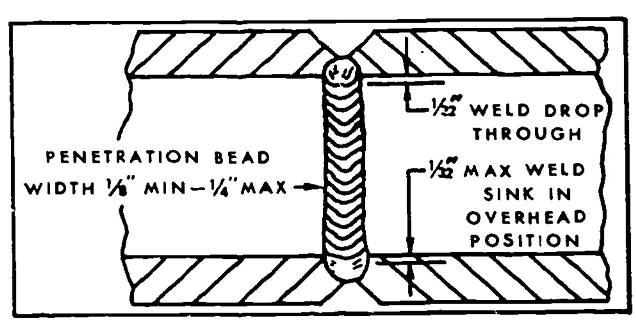


Figure 7-25. Typical weld dimensions.

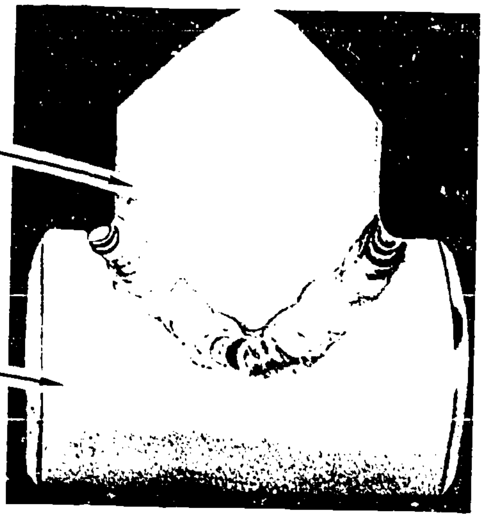


Figure 7 26. Aluminum tee joint.

joint. These joints must be thoroughly cleaned to remove all foreign substances before welding. Oil, grease, dirt, paint, and other substances will burn in the arc and generate gases which will contaminate the inert gas and interfere with the clean, smooth flow of weld metal. They can also cause porosity, incomplete fusion, inadequate penetration, and undercutting, in addition to rough welds of poor appearance. Joint edges can be cleaned with solvent-soaked rags to remove surface oil, grease, and dirt. This should be sufficient cleaning for most joints. Suitable solvents include naphtha, alcohol. and acetone. When solvent-soaked rags will not remove imbedded dirt, you must use files, chisels, wire brushes, or metal scrapers. These should be clean and free from oil.

Welding Technique. After the edges have been cleaned, assemble the joint. When the joint has been properly aligned, tack weld at three or more locations. The tack welds should fully penetrated and rather flat, and they should not be more than 1 inch long. Three such welds at equal distances around the joint will usually maintain alignment.

To weld pipe, point the electrode toward the center of the pipe. This is more satisfactory than trying to modify the anngle of the electrode along the length of the weld. Maintain the arc at a controllable length, usually about 1/4 inch or just enough to prevent contamination of the electrode when you add the welding rod. Short arcs do not contribute to ease of application or improvement of weld soundness or appearance. Adjust the inert gas to flow at a rate which will produce good cleaning. When you are welding on the bottom section of a joint in the horizontal fixed position, increase the gas in order to obtain freedom from porosity. Use a welding rod for all passes and use it in such a manner that it does not interfere with the stability of the arc. The best method is introduce the welding rod nearly tangent to the pipe at the location of the arc, making certain that the first contact is between the end of the welding rod and the leading edge of the pool. A smooth, uniform, forward motion of the arc as you add the filler rod will produce the best results. In contrast, jerky movements will result in inclusions, rough appearance, nonuniform penetration, and difficulty in application.

When you apply a weld with the pipe in the vertical position, all passes should be applied as stringer beads. When you are welding pipe in the horizontal fixed position, the welding should be performed without pipe rotation. Start the welding at the bottom of the joint and progress upward to the top; under no circumstance should welding be performed in the reverse order.

Tee Joints. Fillet-type (tee) joints of aluminum are prepared and welded in the same manner as the fillet-type joints made of stainless steel. An example of a finished fillet-type joint of aluminum is shown in figure 7-26.

Exercises (A37):

1. Name the three aluminum alloys that are produced in pipe form.

2. What solvents should be used to clean joints of aluminum alloys before welding?

3. What is the rate of flow for the inert gas when welding aluminum pipe?

4. What is the result of short, jerky movements of the arc?

5. Indicated how fillet-type (tee) joints of aluminum are prepared and welded.

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NOTE: None of the items listed in the bibliography are available through ECI. If you cannot borrow them from local sources, such as your base library or local library, you may request one item at a time on a loan basis from the AU Library, Maxwell AFB AL 36112, ATTN: ECI Bibliographic Assistant. However, the AU Library generally lends only books and a limited number of AFMs. TOs, classified publications, and other types of publications are *not* available. Refer to current indexes for the latest revisions of and changes to the official publications listed in the bibliography.

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

A01 - 1. a. An electric current must have a complete conducting path in order to flow. This path is called a *circuit.*
b. The push which electricity needs in order to move through a circuit is supplied by the electromotive force commonly known as *voltage.*
c. An *ampere* tells the amount of electricity flowing per second past a given point.
d. The amount of current flowing in a circuit is determined by the amount of resistance in the circuit. This resistance is measured by a unit known as an *ohm.*

A01 - 2. Because with a long arc, much heat is lost by radiation to the atmosphere.
A01 - 3. Straight polarity.
A01 - 4. (1) Gravity, (2) gas expansion, (3) electromagnetic, (4) electric, and (5) surface tension.
A01 - 5. A magnetic field set up in the work by the flow of the welding current.

A02 - 1. Generator, rectifier.
A02 - 2. Transformer and rotating-type machines.
A02 - 3. Because of low initial cost, low operating cost, and low maintenance cost.
A02 - 4. Powerline; welding cables.
A02 - 5. (1) Motor-generator, (2) frequency changer, (3) phase changer, and (4) combination types.
A02 - 6. The size of these cables depends on the normal welding current and the length of the cable.
A02 - 7. It is attached to one of the welding cables, which has a clamping device for holding the electrode.

A03 - 1. In the 34W4 series TOs.
A03 - 2. Give them a coat of shellac.
A03 - 3. (1) Brushes, (2) commutator, (3) contact points, and bearings.
A03 - 4. At 4- to 6-month intervals, depending upon the number of operating hours.

CHAPTER 2

A04 - 1. That the electrode (E) has a tensile strength of 120,000 psi, can be used in any position, and should be used with alternating current.
A04 - 2. Class A.
A04 - 3. a. True.
b. True.
c. False.
d. False.
e. True.
A04 - 4. a. Black end, orange spot, and green group.
b. White spot only.
c. Black end and black spot.
d. No color codes (only a manufacturer's trademark (11018).

A05 - 1. The shielded arc or heavy-coated electrode.
A05 - 2. a. Heavy-coated.
b. Bare or light-coated.
c. Bare.
d. Heavy-coated.
e. Heavy-coated.
f. Bare.
g. Light-coated.
h. Heavy-coated.
i. Heavy-coated.
j. Heavy-coated.

A06 - 1. (1) Type of work, (2) type of machine, (3) type of electrode, (4) the current, and (5) safety factors.
A06 - 2. In hot weather, when you are perspiring.
A06 - 3. You should be sure that the lens is suited to your eyes.
A06 - 4. Wear leather gloves of the gauntlet type to protect them from the heat and injurious rays emitted by the arc.

CHAPTER 3

A07 - 1. Those are: the very hot section next to the molten filler metal, the annealed section next to the heated base metal, and the zone adjacent to the cold base metal.
A07 - 2. The heat-affected area is increased when the speed is decreased, and increasing the speed decreases the affected area.
A07 - 3. The hardness from arc welding is greater.
A07 - 4. The longer the arc length, the greater the heat-area.
A07 - 5. No, because penetration applies to depth and not width, so the heat-affected area should not increase.

A08 - 1. A bare electrode should be held at a 90° angle to the base metal. A heavy-coated electrode should be tilted 5° to 15° in the direction of travel.
A08 - 2. 1/16 inch.
A08 - 3. The proportions of the bead desired, current value, and size of the electrode used.
A08 - 4. So that the stringer beads may be ended with less difficulty.
A08 - 5. At right angles to each other.
A08 - 6. Make sure you have a clean working surface—free of oil, dirt, and other foreign matter.

A09 - 1. 3/4 inch.
A09 - 2. a. True.
b. False.
c. False.
d. True.
e. True.
f. False.
g. True.
h. True.

A10 - 1. A *butt joint* is the welding of two plates having surfaces in approximately the same plane.
A10 - 2. By flame cutting, shearing, flame grooving, machining, chipping, and grinding.
A10 - 3. Clean the edges without any special preparation.

A10 - 4. 100 percent.
A10 - 5. (1) Angle iron and clamps, (2) special jigs and clamps, or (3) a wedge.
A10 - 6. 1/8 inch.
A10 - 7. 30° to 35° for single bevel; 60° to 75° for single "V."
A10 - 8. a. buckling.
b. single weld; multiple-pass.
c. thickness; shoulder.
d. thickness.

A11 - 1. The electrode is held at a 45° angle to the plate surfaces and inclined approximately 15° in the direction of the weld.
A11 - 2. By using chain intermittent or staggered intermittent welds.
A11 - 3. Three.
A11 - 4. Position two plates at approximately right angle to form an inverted T.

A12 - 1. Two overlapping plates; fillet weld.
A12 - 2. To insure good fusion and to prevent undercutting.
A12 - 3. To prevent undercutting of that edge.

A13 - 1. Gravity. Do this by using smaller diameter electrodes at lower current settings and maintaining a smaller molten pool to permit surface tension.
A13 - 2. Reverse polarity.
A13 - 3. Vertical-up weave bead.
A13 - 4. Vertical-down.
A13 - 5. Current settings for vertical should be lower than those used for flat welding.

A14 - 1. You must hold a short arc and control its motion.
A14 - 2. Shift the electrode away from the crater quickly without breaking the arc.
A14 - 3. Vertical-up.
A14 - 4. 90° to the plate.

A15 - 1. The horizontal plate.
A15 - 2. Too fluid.
A15 - 3. By removing all slag and oxides from the surface of each pass by chipping or wire brushing before applying additional beads in the joint.
A15 - 4. The joints are prepared for overhead welding in the same way that they are prepared for flat welding.
A15 - 5. 3/16 inch diameter.

CHAPTER 4

A16 - 1. (1) The strength of the parent metal, (2) the corrosion resistance, and (3) the appearance of the stainless steel surface must be protected.
A16 - 2. Austentite.
A16 - 3. Loss of corrosion resistance, excessive strains would be induced, and undesirable grain growth would be promoted.
A16 - 4. MIL-E-6844.
A16 - 5. DC reverse polarity for light gage, and DC straight polarity for heavy gage.
A16 - 6. 1) Heat conductivity, (2) metal thickness, (3) mass, (4) type of stainless steel, and (5) skill of the welder.

A17 - 1. The removal of all dirt, grease, and other foreign substances by washing with a suitable cleaning agent.
A17 - 2. By striking the arc in the vee rather than on the surface of the base metal.
A17 - 3. The cast iron may crack just back of the line of fusion.
A17 - 4. Peening forges the metal and relieves the cooling strains.
A17 - 5. Mild steel electrodes, stainless steel electrodes Monel electrodes, and cast iron electrodes.

A18 - 1. a. Chipping.
b. Machining.
c. Grinding.
A18 - 2. To prevent overheating the base metal.
A18 - 3. Anneal heat-treating the base metal.
A18 - 4. Water quenching will crack hard surfacing.
A18 - 5. 1/16 inch; 1/4 inch.
A18 - 6. To insure that impact or shock loads may be transmitted through the hard-surfacing metal into the tougher base metal.
A18 - 7. This reduces spatter loss, insures good penetration, prevents oxidation of the deposited metal, and helps to stabilize the arc.

A19 - 1. a. Oxy arc cutting.
b. Metallic arc cutting.
c. Carbon arc cutting.
d. Metallic arc cutting.
e. Oxy arc cutting.
f. Metallic arc cutting.
g. Oxy arc cutting.
A19 - 2. In metallic arc cutting, a low carbon steel electrode with a heavy nonconducting coating is used; in carbon arc cutting, a carbon electrode is used; while and in oxy arc cutting, a steel or conducting ceramic type hollow electrode is used.

CHAPTER 5

A20 - 1. The inert gas prevents the air, which causes the formation of harmful oxides and nitrides, from coming into contact with the molten weld metal.
A20 - 2. TIG uses a nonconsumable tungsten electrode, while MIG uses a consumable alloy wire with about the same composition as that of the metal being welded.
A20 - 3. a. TIG.
b. MIG.
c. MIG.
d. TIG.
A20 - 4. They are stronger, more ductile, and more corrosion resistant.

A21 - 1. (1) A welding generator, (2) a DC rectifier, or (3) an AC transformer.
A21 - 2. It permits starting the arc without contact between the electrode and the work.
A21 - 3. For one, you can use a higher current, and for another, there is no danger of overheating as long as the water flows.
A21 - 4. (1) Excessively high water pressure, (2) mistreatment of equipment, and (3) improperly sealed hose connections.
A21 - 5. An "inert gas" is one that is chemically inactive and which will not combine with any other element.
A21 - 6. 10.6 cubic feet per hour.
A21 - 7. 14.
A21 - 8. a. True.
b. False.
c. True.
d. False.

A22 - 1. 1. b.
2. a.
3. c.
4. c.
5. b.
6. a.
A22 - 2. Use the one with the red mark. It is a 2-percent thoriated tungsten electrode.
A22 - 3. a. Helium.
b. Argon.
c. Helium.
d. Argon.
e. Helium.
A22 - 4. a. 6-7-8.
b. 6.
c. 7-8.
d. 7-8.

CHAPTER 6

A23 - 1. y confining the arc of heat to as small an area as possible while still obtaining proper fusion.
A23 - 2. Because it produces a minimum of warpage, prevent oxidation, and maintains the maximum of corrosion resistance in the welded part.
A23 - 3. The coefficient for stainless steel is approximately 60 percent greater than that for carbon steel.
A23 - 4. (1) Use inert gas backing, (2) use a combination of backup late and an inert gas, and (3) brush flux on the underside of the joint.

A24 - 1. If direct tension or bending stresses will be applied to the finished product.
A24 - 2. 15 to 30 amps DC SP.
A24 - 3. Swing the foot control to the low position to break the arc and permit the shielding gas to flow over the weld area until it has cooled to a black heat.
A24 - 4. To allow the edges to fuse together without the use of a filler rod.
A24 - 5. A rough or an uneven surface.

A25 - 1. To prevent contaminating the tungsten electrode and to aid in weld control.
A25 - 2. .050 inch or slightly in excess of 100 percent.
A25 - 3. The completed weld should have penetration slightly in excess of 100 percent. Reinforcement for light gage stainless steel can vary from 5 to 30 percent of T with the width of the bead varying from 2 to 3T. The surface appearance of the weld should be a dark bronze or light purple.

A26 - 1. Lap joints are used extensively in the repair of welded jet and conventional aircraft parts, because of the ease of preparation and welding.
A26 - 2. Failure to melt it back will result in a concave undercut bead.
A26 - 3. Shear the stainless steel sheet stock to leave a square edge free of burrs and warpage.
A26 - 4. It is added at the root of the joint and the forward edge of the molten pool.
A26 - 5. To insure adequate penetration at the root of the weld without burning through the vertical sheet.

A27 - 1. High frequency current.
A27 - 2. To prevent oxidation
A27 - 3. To support the weld.
A27 - 4. Inert gas backup.
A27 - 5. Over 100.

A28 - 1. The gas-shielded welding process.
A28 - 2. By the vapor degreasing method, in which trichlroethylene is used; or a hot alkaline cleaning compound may be used.
A28 - 3. The preferred agent is graphite base powder.
A28 - 4. To those for aluminum.

A29 - 1. In the commercially pure form, it is silvery gray, resembling unpolished stainless steel but with slightly more luster.
A29 - 2. Corrosion-resistant steel.
A29 - 3. Carbon, oxygen, and nitrogen.
A29 - 4. Any sign of brown or powdery gray scale.

A30 - 1. False.
A30 - 2. True.
A30 - 3. False.
A30 - 4. False.
A30 - 5. False.
A30 - 6. False.
A30 - 7. True.
A30 - 8. a. 1.25; hardening.
b. Annealed, 1725.
c. 1950; 30.
d. Multimet; 1500.
e. Hayne alloy 25 (or crucible alloy WF 11); difficult.

A31 - 1. The proper use of either a shielding gas or copper backup block.
A31 - 2. An AC DC rectifier type with a foot control rheostat.
A31 - 3. Lens number 8 or 10 can be used.
A31 - 4. Fused into the root of the weld and 35 to 65 percent penetration into each sheet.
A31 - 5. Stress relieve the area immediately.

CHAPTER 7

A32 - 1. The butt joint.
A32 - 2. They help to secure complete penetration of the deposited weld metal to the inside of the pipe without burn through, prevent globules of splattered weld metal and slag from entering the pipe, and can be used to assist in aligning the pipe ends.
A32 - 3. (1) Plain flat strip type, (2) the forged or pressed type, (3) the circumferential rib type, and (4) the machined ring type
A32 - 4. he oxyacetylene cutting torch.
A32 - 5. Not less than the diameter of the electrode used for the root pass.
A32 - 6. The number varies with the wall thickness of the pipe, the welding position, the size of the electrode, and the welding current.

A33 - 1. Make accurate patterns.
A33 - 2. The edges should be cleaned thoroughly, and all burrs should be removed.
A33 - 3. By the use of jigs and fixtures or by adequate tack welds.
A33 - 4. Determine the size of the pipe involved.

A34 - 1. Inert gas-shielded welding.
A34 - 2. To insure an oxide-free weld.
A34 - 3. Butt and tee joints.

A35 - 1. They should be uniform and free from depressions below the surfaces of the base metal.
A35 - 2. 15 to 85 percent of the pipe wall thickness.
A35 - 3. Dark bronze or light purple.

A36 - 1. The circular motion will insure fusion of the bottom of the joint with the filler rod but will not undercut the upper side of the weld bead.
A36 - 2. Gradually decrease the welding current with the foot-operated current control until the arc is extinguished.
A36 - 3. Excessive penetration, since too much of the edges are being melted back.
A36 - 4. Add more filler rod to the puddle, slant the torch sharply toward the filler rod so that nore rod is melted, and increase the welding speed. The effect will be to direct more heat onto the filler rod and less onto the pipe. This will close the enlarged opening at the front of the puddle.
A36 - 5. Strike the arc on a piece of copper plate until the erratic action of the arc smooths out.

A37 - 1. Alloy 3005 H12, alloy 6063 T6, and alloy 6061 T6.
A37 - 2. Naphtha, alcohol, and acetone.
A37 - 3. Adjust the inert gas to flow at a rate which will produce good cleaning.
A37 - 4. Short, jerky movements will result in inclusions rough appearance, nonuniform penetration, and difficulty in application.
A37 - 5. This is done in the same manner as for fillet-type joints made of stainless steel.

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ELECTRODE IDENTIFICATION AND OPERATING DATA

COATING COLOR	IDENTIFICATION MARKING (E) END	(S) SPOT	(G) GROUP	(L) SPECIAL	AWS CLASS	POLARITY DC (+) = "REVERSE" DC (−) = "STRAIGHT"	SIZES AND CURRENT RANGES (Amps.) (electrodes are manufactured in those sizes for which current ranges are given) 5/64" SIZE	3/32" SIZE	1/8" SIZE	5/32" SIZE	3/16" SIZE	7/32" SIZE	1/4" SIZE	5/16" SIZE
MILD STEEL														
White					E6010	DC (+)			75-130	90-175	140-225	20	250-325	280-400
Brick Red					E6010	DC (+)			75-130	90-175	140-225			
Tan		White			E6012	DC (−) AC		55-80 60-90	80-130 90-140	120-180 130-200	180-250 200-275	210-280 230-310	250-315 280-350	320-410 350-450
Gray		White			E6012	DC (−) AC			90-135 100-150	120-190 130-210	150-265 165-290	225-300 250-325	250-340 275-375	315-405 350-450
White		Blue			E6011	AC DC (+)		40-75 35-70	75-120 70-110	90-160 80-145	120-200 110-180	150-260 135-235	180-300 170-270	
Dark Tan		Brown		Green	E6013	AC DC (−)	4. 35-65	75-100 60-90	90-140 80-125	140-200 125-180	200-260 180-235			
Gray-Brown	Black	Brown			E7014 E6014	AC DC (−)			110-160 100-145	150-225 135-200	200-280 180-250	260-340 235-305	315-425 285-380	370-500 330-450
Tan					—	DC (−) AC				175-250 160-225	230-350 210-315	300-450 275-410		
Tan		White		Green	E6012	DC (−) AC			80-135 90-150	110-180 120-200	155-250 170-275	225-295 250-325	245-325 275-360	
Brown		Blue			E5011	AC DC (+)		40-90 40-80	60-120 55-110	115-150 105-135	160-210 145-190			
Dark Gray	Black	Yellow			E7024 E6024	AC DC (+)			130-190 120-180	190-250 180-230	240-300 220-280	300-380 280-360	360-440 330-400	
Red Brown		Silver			E6027	AC DC (+)				190-240 175-215	250-300 230-270	300-380 270-340	350-450 315-405	475-600
Gray	Black	Yellow		Green	E7024 E6024	AC DC (±)		65-120 60-110	115-175 100-160	180-240 160-215	240-300 215-270	300-380 270-340	350-450 315-405	450-600
Gray	Black	Orange	Green		E7018 E6018	DC (+) AC		70-100 80-120	95-155 115-165	120-200 145-230	160-280 200-310	190-310 240-350	230-360 290-410	375-475 400-500
Gray-Brown	Black	Black			E7028 E6028	AC DC (+)				180-270 170-240	240-330 210-300	275-410 260-380	360-520	
LOW ALLOY, HIGH TENSILE STEEL														
Pink	Blue	White			E7010-A1	DC (+)		50-90	75-130	90-175	140-225		190-325	
Pink	Blue			Green	E7010-G	DC (+)					140-225			
Pink					—	DC (+)			75-130	90-175	140-175			
Dark Red	Blue	Yellow	Silver		E7020-A1	AC DC (+)				190-240 175-215	250-300 230-270	275-375 250-320	350-450 330-370	
Gray				9018	E9018-G	DC (+) AC			90-150 110-160	110-200 140-230	160-280 200-310			
Gray				11018	E11018-G	DC (+) AC			95-155 115-165	120-200 145-230	160-280 200-310	190-310 240-350	230-360 290-410	
STAINLESS STEEL														
Pale Green	Yellow		Black	308-15	E308-15	DC (+)	20-55	30-70	50-100	75-130	95-165		150-225	
Gray	Yellow		Yellow	308-16	E308-16	DC (+); AC	20-45	30-60	55-95	80-135	115-185		200-275	
Gray	Brown		Yellow	308L-16	E308L-16	DC (+); AC		30-65	55-100	80-140	115-190		200-285	
Pale Green	Red		Black	310-15	E310-15	DC (+)		30-70	45-95	80-135	100-165		140-225	
Gray	Red		Yellow	310-16	E310-16	DC (+); AC		30-65	55-100	80-140	120-185		200-275	
Gray	Brown	White	Yellow	316L-16	E316L-16	DC (+); AC		30-65	55-100	80-140	115-190		200-285	
Pale Green	Yellow	Green	Black	318-15	E318-15	DC (+)		30-75	45-95	80-135	100-165			
Pale Green	Yellow	Blue	Black	347-15	E347-15	DC (+)	20-55	30-70	50-100	75-130	95-165		150-225	
Gray	Yellow	Blue	Yellow	347-16	E347-16	DC (+); AC		30-60	55-95	80-135	115-185			
BRONZE & ALUMINUM														
Peach	Yellow	Blue	Blue		E-CuSn-C	DC (+)			50-125	70-170	90-220			
Peach					Al-43	DC (+)		20-55	45-125	60-170	85-235		125-360	
CAST IRON														
Light Tan	Orange				ESt	DC (+); AC			80-100					
Black	Orange	Blue	White		ENi	DC (+) AC			60-110 65-120	100-135 110-150				
HARDSURFACING														
Black						DC (+) AC			40-150 50-165	75-200 80-220	110-250 120-275		150-375 165-410	
Slate	Yellow					DC (+); AC					60-150			145-350
Slate	Pink					DC (+); AC					60-150			145-350
Gray						DC (+); AC				115-225	200-290		255-375	
Bare Wire						DC (+)					130-170		170-225	
Dark Gray	Orange	Red				DC (+) AC				125-210 135-230	150-260 165-285		200-350 220-385	
Slate						DC (−); AC		40-85	65-130					
Gray						DC (+)			65-100					
Dark Gray						DC (+) AC					110-275 125-275		150-400 200-400	

Foldout 1. Electrode identifiction and operating data.

STOP - 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

55252 06 22

ELECTRIC WELDING, METALLIC ARC EQUIPMENT

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (A01) What is the force that moves electricity through a circuit?

   a. Ohm.
   b. Ampere.
   c. Voltage.
   d. Current.

2. (A01) Select the term used to measure the flow of electricity.

   a. Ohm.
   b. Voltage.
   c. Current.
   d. Ampere.

3. (A02) A transformer type of arc welding machine is capable of producing

   a. alternating current (AC).
   b. direct current (DC) with reverse polarity.
   c. direct current (DC) with straight polarity.
   d. any of the above.

4. (A02) The size of electrode holders for arc welding machines is determined by the

   a. type of welding.
   b. voltage control.
   c. amperage capacity.
   d. type of current used.

5. (A03) Dust should be cleaned out of an arc welding machine

   a. with soap and water.
   b. with dry compressed air.
   c. carbon tetrachloride.
   d. by dismantling and soaking it.

6. (A03) What determines how often moving parts of welding machines are lubricated?

   a. Type of machine.
   b. Dust in the area.
   c. Age of the machine.
   d. Number of operating hours.

7. (A04) In a four-digit number electrode, what does the third digit designate?

   a. Recommended position
   b. Type of current.
   c. Tensil strength.
   d. Ampere rating.

8. (A04) What is the number of the digit which indicates that an electrode can be used for welding in any position?

   a. Four.
   b. Three.
   c. Two.
   d. One.

9. (A05) What are the three types of coatings on electrodes?

   a. Bare, dipped, and shielded.
   b. Bare, heavy-coated, and shielded.
   c. Shielded arc, light-coated, and bare.
   d. Shielded arc, light-coated, and heavy-coated.

10. (A05) An electrode that produces a gaseous shielding of the molten metal is a

    a. bare electrode.
    b. flux coated electrode.
    c. mineral coated electrode.
    d. cellulose coated electrode.

11. (A06) What is the most important safety equipment used in arc welding?

    a. Clothing.
    b. Leather gloves.
    c. Welding helmet.
    d. Electrode holder.

12. (A06) The type and size of electrode for deep penetration on thick plate affect

a. the voltage.
b. the current.
c. type of machine.
d. all of the above.

13. (A07) When welding plate, the rate of hardness increases as the

a. percent of carbon increases.
b. percent of carbon decreases.
c. electrode coating increases.
d. electrode coating decreases.

14. (A07) The heat affected area in arc welding will increase if the current is constant and the

a. arc length increases.
b. arc length decreases.
c. welding speed increases.
d. voltage decreases.

15. (A08) When you and padding with multilayer beads, the part should be

a. allowed to cool slowly between layers.
b. quenched only after completely padded.
c. cleaned and quenched after each layer.
d. quenched often enough to eliminate excessive heat.

16. (A08) How should you reduce the possibility of crater cracks at the edges of the work when padding?

a. Quench each bead immediately.
b. Encircle the edges with beads.
c. Weld from both edges to the center.
d. Post heat after padding is completed.

17. (A09) At the start of an arc on lap joints, it is important to

a. weld toward the edge.
b. guard against undercutting.
c. hold a long arc to insure penetration.
d. hold a short arc to ensure penetration.

18. (A09) Stress can be concentrated at points in lap joint welding when you

a. create a flat weld face.
b. undercut the toe of the weld.
c. overlap the edge of the weld.
d. do all of the above.

19. (A10) When using multiple-pass welds, what does reheating of the lower layer of weld permit?

a. Grain refinement.
b. Formation of stresses.
c. Formation of hard spots.
d. All of the above.

20. (A10) Penetration can be obtained at the beginning of a butt joint by

a. backwelding.
b. holding a long arc momentarily.
c. striking the arc and decreasing the arc length as quickly as possible.
d. preheating the edge.

21. (A11) How is the electrode held when welding tee joints in the horizontal position?

a. At a 30 degree angle to the plates.
b. At a 45 degree angle to the weld bead.
c. At a 45 degree angle to the plate surface.
d. Inclined 20 degrees in the direction of travel.

22. (A12) How can you prevent overheating or undercutting the edge of a thinner plate in a vertical lap joint?

a. Use a weave band.
b. Reduce the current flow to 60 amps.
c. Hold the electrode at 90 degrees to the plate.
d. Wash the molten metal to the edge of the plage.

23. (A13) Which type of electrode is best suited for vertical position welding?

a. AC.
b. AC-high frequency.
c. Heavy-coated and reverse-polarity.
d. Heavy-coated and straight-polarity.

24. (A13) To weld vertical-up, the electrode is held

a. 15 degrees down (arc end).
b. 30 degrees to horizontal.
c. 45 degrees up (arc end).
d. 90 degrees to surface.

25. (A14) What technique aids in control of molten metal when making a fillet weld in the vertical-down position?

a. 15 degrees up and hold a short arc.
b. 15 degrees up and move in a triangular motion.
c. 90 degrees from plate and short arc.
d. 90 degrees from plate and slow speed.

26. (A14) How is an electrode moved to weld a lap joint in the vertical position?

a. Whipping motion.
b. Triangular motion.
c. Rectangular motion.
d. Semicircular motion.

27. (A15) A large pool of weld deposit, which is hard to control, is caused by

a. excessive weaving.
b. slow motion.
c. excessive current.
d. all of the above.

28. (A16) Stainless steels that only contain chromium are undesirable when welded because of the lack of

a. ductility.
b. corrosion resistance.
c. tensile strength.
d. yield strength.

29. (A16) The composition of electrodes used for arc welding stainless steel affects corrosion resistance and

a. shear strength.
b. tensile strength.
c. impact strength.
d. color appearance.

30. (A17) Which procedure is used to relieve strains developed when welded cast iron joints are cooling?

a. Peening.
b. Still air cooling.
c. Quenching quickly in oil.
d. Post heating operations.

31. (A17) Which of the following procedures should you use to protect against overheating the joint when welding cast iron?

a. Skip procedure.
b. Back step procedure.
c. Intermittent, short stringer beads.
d. All of the above.

32. (A18) When it becomes necessary to quench hard-surfaced deposits, what should you use as the quenching media?

a. Brine.
b. Oil.
c. Water.
d. Alcohol.

33. (A18) Before heat-treated steels can be hard-surfaced, they must be

a. studded.
b. beveled.
c. annealed.
d. heat-treated.

34. (A19) Direct current, straight polarity is used for metallic and carbon arc cutting, because

a. it develops a higher heat at the base metal.
b. the arc is easier to start, maintain, and control.
c. a higher current can be used.
d. there is less chance of electrical shock to the operator.

35. (A19) What is the greatest advantage of using arc air cutting operation to groove a heavy plate?

a. The side angle can be adjusted.
b. The joint does not need grind nor chip.
c. The operation required only single phase power.
d. All of the above

36. (A20) What is the difference between tungsten-inert gas (TIG) and metal-inert gas (MIG) welding processes?

a. MIG uses a consumable electrode.
b. A filler rod may be used with TIG.
c. TIG is designed for light-walled objects.
d. All of the above.

37. (A20) What is the purpose of the inert gas in the gas shield welding process?

a. To provide a fluxing agent.
b. To form a protective blanket.
c. To protect the weld and fluxed area.
d. To provide better fusion and penetration.

38. (A20) What inert gases are used as shielding gases in TIG and MIG welding.

a. Argon and helium.
b. Argon and hydrogen.
c. Agron and nitrogen.
d. Helium and hydrogen.

39. (A21) Select the characteristic of helium that makes it undesirable for welding thin material.

a. Impurities in it.
b. High heat per ampere.
c. Reduced penetration.
d. Cloudiness produced when welding.

40. (A22) The type and size of ceramic tile cup depends upon the

a. voltage used.
b. amperage used.
c. alloy of the electrode.
d. diameter of the electrode.

41. (A22) Which of the following should be used to obtain a weld with deep penetration and a narrow bead?

a. Alternating current.
b. Direct current with straight polarity.
c. Alternating current with high frequency.
d. Direct current with reverse polarity.

42. (A23) One important factor while welding stainless steel is to obtain proper fusion and a reduction of

a. warpage.
b. welding speed.
c. number of tacwelds.
d. carbide precipitation.

43. (A23) W[illegible] is inert gas-shielded welding preferred to the oxyacetylene welding of stainless steel?

a. Wa[illegible]ing and oxidation are less with inert gas-shielded welding.
b. Oxyacetylene welds do not produce the desired color.
c. Faster welding speeds are used with the inert gas-shielde[illegible] welding.
d. Less heat is required with inert gas-shielding welding.

44. (A24) When setting a TIG machine for welding .040-inch steel with a water-cooled torch, the electrode

a. extends 1/4 - 5/16 inch past the cup.
b. must be cut sharp and clear.
c. extends .040 inches past the cup.
d. should be vertical.

45. (A24) When welding an edge joint stainless steel, the shielding gas is allowed to flow over the welded joint until

a. the color changes.
b. the weld is irritated.
c. a black heat is obtained.
d. carbide precipitates.

46. (A25) Where should you strike the arc to avoid overlap when restarting a weld on a stainless steel butt joint using the TIG process?

a. Behind the terminated weld.
b. Ahead of the terminated weld.
c. At the beginning of the weld.
d. Where welding was terminated.

47. (A25) Where is the arc struck when making a butt joint on stainless steel with a TIG torch?

a. On a copper plate.
b. On a tack weld.
c. At the edge of the joint.
d. Near center and moved to the edge.

48. (A26) When TIG welding a corner joint in stainless steel, what must you do to obtain proper fusion and penetration?

a. Use extra long arc.
b. Do not space the joint.
c. Shear the edges.
d. Prepare the edges properly.

49. (A26) How should stainless steel be prepared for a lap joint using TIG welding?

a. V groove the top edge only.
b. Square the edges and remove burrs.
c. Square top edge only and remove burrs.
d. V-groove the edges for better penetration.

50. (A26) When high-quality weld is necessary on TIG welded aluminum alloy, use

a. inert gas backup.
b. steel heat sink.
c. the flat position only.
d. all of the above.

51. (A27) While TIG welding on aluminum, the filler rod is added to the

a. electrode.
b. bottom of the arc.
c. front edge of the molten pool.
d. uphill side of the molten pool.

52. (A28) What is the preferred extinguishing agent for magnesium fires?

a. Water.
b. Dry sand.
c. Sodium nitrate.
d. Graphite base powder.

53. (A29) Under ideal conditions, the welding of titanium should take place

a. in an inert gas chamber.
b. using the proper backing fixtures.
c. in a controlled shop atmosphere
d. in a controlled flight line situation.

54. (A29) What causes vast characteristic changes in titanium during a welding project?

a. Rapid heating and cooling.
b. Absorbtion of oxygen or nitrogen.
c. Any temperature above 800 degrees F.
d. Oxidation causes harness at the edges.

55. (A30) Name the three groups of super alloys.

a. Iron base, cobalt base, and nickel base
b. Carbon base, silicon base, and iron base.
c. Nickel base, chromium base, and iron base.
d. Steel base, copper base, and magnesium base.

56. (A30) What super alloy is used for burner liner parts, turbine exhaust weldments, and other parts requiring oxidation resistance?

a. Chromoloy.
b. Hastelloy-X.
c. Alloy A-286.
d. N-155 alloy.

57. (A31) To weld on A-286 alloy of 1/4-inch thickness, what type inert gas would be used?

a. Argon.
b. Helium.
c. Argon-helium.
d. Tungsten-inert.

58. (A31) After welding, an item made from chromoloy must be post heated immediately to

a. relieve stress.
b. increase strength.
c. normalize fusion at the weld area.
d. prevent quick solidification.

59. (A32) What is the primary tool used to align pipe sections for a butt weld?

a. Angle iron.
b. Channel iron.
c. Straight edge.
d. Pipe lineup clamp.

60. (A32) Which of the following is the specified direction for butt welding pipe in a fixed horizontal position?

a. Backhand method only.
b. Forehand method only.
c. Downward method.
d. Any of the above.

61. (A33) When multilayer welds are required on a pipe weld, the starting and ending points of each pass should be

a. staggered.
b. passed over.
c. in line (stacked up).
d. located at or near the top.

62. (A33) When welding joints or pipe with unequal thickness, you must direct the arc so

a. the thicker piece melts and fuses with the thinner piece.
b. the thin piece melts onto the thicker piece.
c. that it heats the thick piece to a temperature sufficient to melt the thin piece on contact.
d. both pieces being welded are heated to the same temperature.

63. (A34) What type of welded joint is recommended for stainless steel?

a. Sharp vee joint.
b. Vee groove joint.
c. Rolled edge joint.
d. Consumable insert joint

64. (A34) Besides a thorough cleaning of joint edges, what else should be accomplished prior to welding pipe?

a. The pipe should be purged.
b. The edges should be fluxed thoroughly.
c. The edges should be dipped in an acetic acid compound.
d. The pipe should be preheated.

65. (A35) The purpose of a snug fit of the edges of stainless steel pipe when tee joint welding is to

a. allow for more thorough cleaning.
b. produce a concave weld bead for better hold.
c. allow for proper penetration and prevent burn through.
d. accomplish all of the above.

66. (A35) The contour of the reinforcement of the pipe weld should be

a. convex and not wider than the wall thickness.
b. concave with a width of twice the wall thickness.
c. flat (smooth with pipe) for a good looking joint.
d. concave with a slight overlap.

67. (A36) While welding stainless steel in the vertical position, you must use special technique to

a. add filler rod correctly.
b. compensate for gravity.
c. ensure fusion at the root.
d. avoid under cut and overlap.

68. (A36) When welding stainless steel pipe in the overhead position, how is a "too slow" welding speed indicated?

a. Excessive buildup on top of the pipe.
b. Excessive penetration inside the pipe.
c. Reduced carbon smoke emitted from the weld area.
d. Excessive buildup on top and reduced penetration on inside of the pipe.

69. (A37) What solvents can be used to clean aluminum pipe joints before welding?

a. Naptha, acetone, or MEK.
b. Acetone, alcohol, or MEK.
c. Alcohol, naptha, or acetone.
d. Naptha, water, or chromic acid.

70. (A37) When using direct current straight polarity for welding aluminum alloy pipe, what type of electrode and shielding gas should be used?

a. Pure tungsten electrode and helium shielding gas.
b. Two percent thoriated tungsten electrode and helium shielding gas.
c. Pure tungsten electrode and argon shielding gas.
d. Pure tungsten or two percent thoriated tungsten electrode and argon shielding gas.

END OF EXERCISE

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ATC/ECI SURVEY

The [illegible] questions (125-135) are not part of the Volume Review Exercise (VRE). These questions are a voluntary ATC/ECI survey. Using a number 2 pencil, indicate what you consider to be the appropriate response to each survey question on your answer sheet (ECI Form 35), beginning with answer number 125. [illegible] respond to questions that do not apply to you. Your cooperation in completing this survey is greatly [illegible]ated by ATC and ECI. (AU SCN 100)

PRIVACY ACT STATEMENT

A. Authority. 5 U.S.C. 301, *Departmental Regulations*.

B. Principal Purpose: To gather preliminary data evaluating the ATC/ECI Career Development Course (CDC) Program.

C. Routine Uses: Determine the requirement for comprehensive evaluations in support of CDC program improvement.

D. Whether Disclosure is Mandatory or Voluntary: Participation in this survey is entirely voluntary.

E. Effect on the Individual of not Providing Information: No adverse action will be taken against any individual who elects not to participate in any or all parts of this survey.

QUESTIONS

125. If you have contacted ECI for any reason during your enrollment, how would you describe the service provided to you?

a. Excellent.
b. Satisfactory.
c. Unsatisfactory.
d. Did not contact ECI.

126. My ECI course materials were received within a reasonable period of time.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

127. The condition of the course materials I received from ECI was:

a. A complete set of well-packaged materials.
b. An incomplete set of well-packaged materials.
c. A complete set of poorly packaged materials.
d. An incomplete set of poorly packaged materials.

128. The reading level of the material in the course was too difficult for me.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

129. The technical material in the course was too difficult for me at my present level of training.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

130. The illustrations in the course helped clarify the information for me.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

131. Approximately how much information in the course provides general information about your AFSC?

a. Between 80 and 99%.
b. Between 60 and 79%.
c. Between 40 and 59%.
d. Between 20 and 39%.

132. Approximately how much information in this course was current?

a. Between 80 and 99%.
b. Between 60 and 79%.
c. Between 40 and 59%.
d. Between 20 and 39%.

133. The format of the text (objective followed by narrative and exercises) helped me study.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

134. The volume review exercise(s) helped me review information in the course.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

135. Check the rating which most nearly describes the usefulness of the information in this CDC in your upgrade training program.

a. Excellent.
b. Satisfactory.
c. Marginal.
d. Unsatisfactory.

NOTE: If you know this CDC contains outdated information or does not provide the knowledge that the current specialty training standard requires you have for upgrade training, contact your OJT advisor and fill out an AF Form 1284, Training Quality Report.

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STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 10 USC 8012 and EO 9397. PRINCIPAL PURPOSES: To provide student assistance as requested by individual [illegible] ROUTINE [illegible] This form is shipped with ECI course package. It is utilized by the student, as needed, to place an inquiry with ECI [illegible] The information requested on this form is needed for expeditious handling of the student's need. Failure to provide all information [illegible] slower action or inability to provide assistance to the student.

SECTION I CORRECTED OR LATEST ENROLLMENT DATA: *(Mail to: ECI, Gunter AFS AL 36118)*

1. THIS REQUEST CONCERNS COURSE (1-6)	2. TODAY'S DATE	3. ENROLLMENT DATE	4. AUTOVON NUMBER

5. SOCIAL SECURITY NUMBER (7-15)	6. GRADE/RANK	7. NAME *(First initial, second initial, last name)* (17) (18) (19-32)
– –		

8. ADDRESS *(OJT Enrollees – Address of unit training office with zip code. All others – current mailing address with zip code.)*	(33-53)
	(54-75)

9. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE	10. TEST CONTROL OFFICE ZIP CODE/SHRED (33-39)

SECTION II: REQUEST FOR MATERIALS, RECORDS, OR SERVICE

(Place an "X" through number in box to left of service requested.)

		FOR ECI USE ONLY	
1	Request address change as indicated in Section I.	16	
2	Request Test Control Office change as indicated in Section I.		17
3	Request name change/correction (Provide Old or Incorrect data)	G	
4	Request Grade/Rank change/correction.	K	Vol 33-35 CR 36-38
5	Correct SSAN. (List incorrect SSAN here) (Correct SSAN should be shown in Section I)		33-34 35-40
6	Extend course completion date. (Justify in REMARKS)	M	33-38
7	Request enrollment cancellation.	N	
8	Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 Originals were: [ ] Not received [ ] Lost [ ] Misused		Vol 33-35 TC 36-37
9	Send course materials. (Specify in REMARKS) [ ] Not received [ ] Lost [ ] Damaged	P	33-34 Volume 35-37
10	Course exam not yet received. Final VRE submitted for grading on ______ (date).	Q	QQ
11	Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 not yet received. Answer sheet(s) submitted ______ (date).	38 1	39-42
12	Results for CE not yet received. Answer sheet submitted to ECI on ______ (date).	2	39-42
13	Previous inquiry ([ ] ECI Fm 17, [ ] Ltr, [ ] Msg) sent to ECI on ______ (date).	3	39-42
14	Give instructional assistance as requested on reverse.	16	
15	Other (Explain fully in REMARKS)		

REMARKS *(Continue on Reverse)*

OJT STUDENTS must have their OJT Administrator certify this request. ALL OTHER STUDENTS may certify their own requests.	I certify that the information on this form is accurate and that this request cannot be answered at this station. *(Signature)*

ECI FORM 17, OCT 82 (PREVIOUS EDITIONS MAY BE USED)

SECTION III: REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of subject matter should be forwarded directly to preparing agency. For an immediate response to these questions, call or write the course author directly, using the AUTOVON number or address in the preface of each volume. All other inquiries concerning the course should be forwarded to ECI.

VRE Item Questioned:

Course No ______

Volume No ______

VRE Form No ______

VRE Item No ______

Answer You Chose ______ (Letter)

Has VRE Answer Sheet been submitted for grading?

[ ] Yes [ ] No

REFERENCE

(Textual reference for the answer I chose can be found as shown below)

In Volume No ______

On Page No ______

In [ ] left [ ] right column

Lines ______ Through ______

MY QUESTION IS:

REMARKS

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. Course workbooks have a Form 17 printed on the last page.

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CDC 55252

METAL FABRICATING SPECIALIST

(AFSC 55252)

Volume 7

General Contingency Responsibilities

Extension Course Institute
Air University

651

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Preface

THIS VOLUME provides you with the knowledge about the following subjects: first aid techniques, field hygiene and sanitation, work party security, and convoy techniques.

Code numbers appearing on figures are for preparing agency identification only and should be of no concern to the student.

Direct your questions or comments relating to the accuracy or currency of this volume to the course author: 3770 TCHTG/TTGIC, ATTN: MSgt Arnold D. Ringstad, Sheppard AFB TX 67311. If you need an immediate response, call the author, AUTOVON 736-2879, between 0800 and 1600 (CST), Monday through Friday. *(NOTE: Do not use the suggestion program to submit changes or corrections for this course.)*

If you have any questions on course enrollment or administration, or any of ECI's instructional aids (Your Key to a Successful Course, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If this person cannot answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 18 hours (6 points).

Material is this volume is technically accurate, adequate, and current as of July 1982.

Contents

NOTE: In this volume, the subject matter is developed by a series of student-centered objectives. Each of these carries a three-digit alphanumeric number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see whether your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

First Aid Techniques

SOMEDAY YOU may save someone's life—possibly your own—if you know how to give first aid. You've heard similar statements many times before, but don't take such statements lightly. A little effort on your part right now could mean that one of your buddies will not lose a finger, a leg, or his life later.

1-1. Responsibilities

Since your job takes you to so many remote locations around the base, you may be the only one at the scene of an accident or another emergency. One of your first obligations is to render aid to those who are injured. Your actions in treating a casualty must be immediate, thorough, and correct.

C01. State your responsibilities as a first-aider.

Fundamentals of First Aid.
As an airman, you have important reasons for learning first aid. Proper first aid may mean a vital mission accomplished, rather than mission not accomplished. Learn how to give first aid; you can't afford not to.

You can easily learn the fundamentals of first aid. Highly technical, involved study is not necessary to become a capable first-aider. You can improve your handling of emergencies just by acquainting yourself with the procedures of first aid.

You should discuss the procedures outlined in this chapter with other airmen. You should use the "buddy method" to practice the various steps outlined. You can learn a lot more by actually applying a splint to an arm than you can by just reading about it.

You should familiarize yourself in first aid measures for injuries such as fractures and chest wounds, for emergencies such as drowning and electric shock, and for common emergencies such as minor wounds and unconsciousness. You should learn as much as you can about first aid measures for sickness and injury resulting from industrial toxic substances.

Very important are procedures dealing with assuring breathing, preventing or treating shock, first aid for electric shock or drowning, poisonous plants, the effects of heat, and the effects of cold. While studying these topics, keep in mind that skin color changes may be too subtle to recognize if the patient is darkly pigmented. Therefore, it is necessary to carefully observe the injured for these changes on the palms, soles, nail beds, mucous membranes of the lips and mouth, and mucous membrane which lines the eyelids and is reflected onto the eyeball.

As you know, first aid refers to the treatment given the sick and injured before a trained individual can administer regular medical or surgical treatment. Personnel in the Air Force medical service have the finest medical equipment available, and they are trained in the most modern methods of saving lives and easing pain. But they can't be everywhere at once, so in an emergency you may have to depend upon your own knowledge of first aid.

The good first-aider deals with the whole situation—the person as well as the injury. When giving first aid, a person who lacks sufficient knowledge could possibly cause even further injury to an injured person. Anyone attempting first aid must use care and skill.

In practicing first aid, your primary duty is to know what to do and what not to do. You must keep calm, use appropriate first aid measures, and seek medical help as soon as possible. Never attempt treatment that is beyond your skill, and never move an injured person unless absolutely necessary.

Exercises (C01):

1. As a first-aider, what areas should you familiarize yourself with?

2. What are alternate methods of determining skin color changes?

3. What is your primary responsibility when practicing first aid?

1-2. Lifesaving Steps of First Aid

When you treat a victim, you must carry out four lifesaving steps. Memorize these steps and learn the simple methods of carrying them out. Bear in mind that prompt and correct first aid not only speeds healing but may also save a life.

C02. Name the four lifesaving steps of first aid, and state why cutting or tearing is usually the best way to remove clothing from the area near a wound.

Four Lifesaving Steps. To treat an injured person, you should carry out what is known as the four lifesaving steps. These steps are: assure breathing, stop the bleeding, protect the wound, and prevent or treat shock. You should memorize these four lifesaving steps and learn the simple methods of carrying them out. Now is the time to learn how to do this. Prompt and correct first aid not only speeds healing but, as emphasized before, may save a life.

To treat a wound, begin by looking carefully at it—but don't touch it. Look to see if there is more than one wound. If the patient has been hit by a flying fragment or other missile, check to see if the missile came out the other side, a condition which would require treatment of a second area.

You must see all of the wound to find out exactly where it is, how large it is, and how much it is bleeding. Usually the best way to remove clothing is by cutting or tearing. Pulling clothing over the wound increases the danger of infection, and moving the wounded part may make the wound worse, as well as cause needless pain.

If possible, cover the wound to prevent further contamination and then treat for shock.

Exercises (C02):

1. What are the four lifesaving steps?

2. Why is cutting or tearing usually the best way to remove clothing from the area near a wound?

C03. From a list of statements about assuring breathing, identify the true statements, and state briefly why the others are false.

Assure Breathing. When a victim can't breathe, any other action you take is of little value because a lack of air can quickly cause a victim's death. Thus, you must see whether the air passageway (airway) is blocked; if it is, you must clear it and keep it clear.

Check for airway obstructions. There are three main causes for airway obstructions. The first is foreign matter, such as false teeth or liquids, in the mouth or throat. The second is caused by relaxation of the jaw. When the victim is unconscious, the jaw muscles relax and sometimes allow the tongue to roll backward and block the throat. This is commonly called swallowing the tongue. The third cause of airway obstruction is the victim's neck position. For example, when a victim's chin is close to the chest, the neck is bent in a manner which "kinks" the throat, thus preventing the passage of air. You must be sure the casualty is able to get air to the lungs. If necessary, you must clear the airway.

Clear the airway. Clear the airway quickly by sweeping your fingers deep into the victim's mouth to remove froth, debris, or any other obstructing matter. Grasp the tongue with your fingers and pull it forward so that it doesn't obstruct breathing. Usually, you have to drive your fingernails into the tongue in order to hold it firmly. Then, look into the mouth to see whether any broken teeth, splintered bone, or other particles are clogging the throat. If so, remove them by any means available: your fingers, a twig, etc. Don't be slow and careful now—the victim's life is ebbiing out. Scratches you might make in the throat are not going to kill the person, and the scratches can always be treated at the hospital. What matters is to get the airway cleared immediately. Anything else is less important at this time.

In some instances, it may be necessary for you to "tie" a victim's tongue in the forward position with a clamping device. For example, if you were alone and had to restore a victim's breathing and heartbeat, you could not possibly hold his or her tongue at the same time. One clamping device you can use is the clip that holds your canteen to your web belt. Another is a safety pin. Clamp the victim's tongue to the lower lip as shown in figure 1-1. When the victim's airway is cleared, it must remain clear.

Keep the Airway Open. You can keep the airway open by placing the victim's head in a position that stretches the

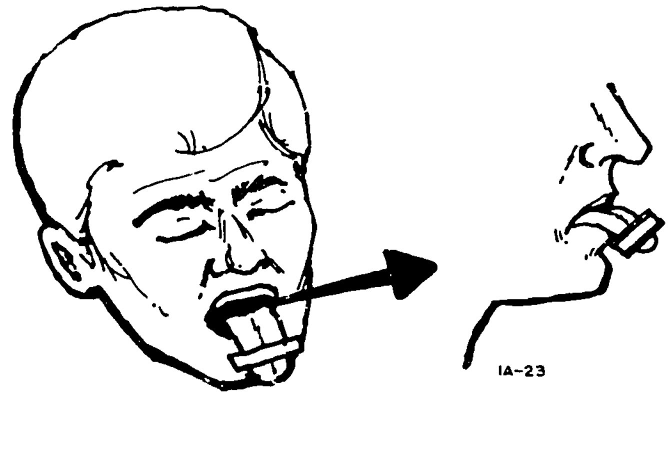

Figure 1-1. Clamping the tongue.

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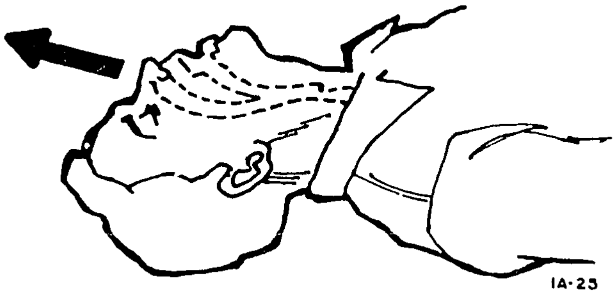


Figure 1–2. Sword swallowing position.

throat to what is called the sword-swallowing position (see fig. 1-2). Use the thumb jaw lift method or the two-hand jaw lift method that figure 1-3 illustrates. Even if the victim is on his or her stomach or side, place his or her head so that the throat is stretched away from the chest to allow air to pass to the lungs (see fig. 1-4). When someone stops breathing, establish and maintain an open airway at once.

Exercises (C03):

Identify each true statement by writing "true" in the space provided; briefly explain why the others are false.

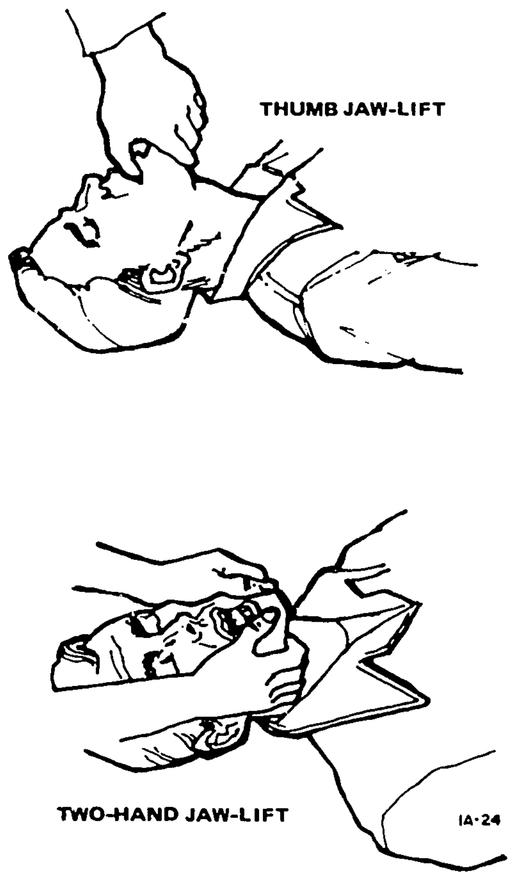


Figure 1–3. Thumb and two hand jaw-lift.

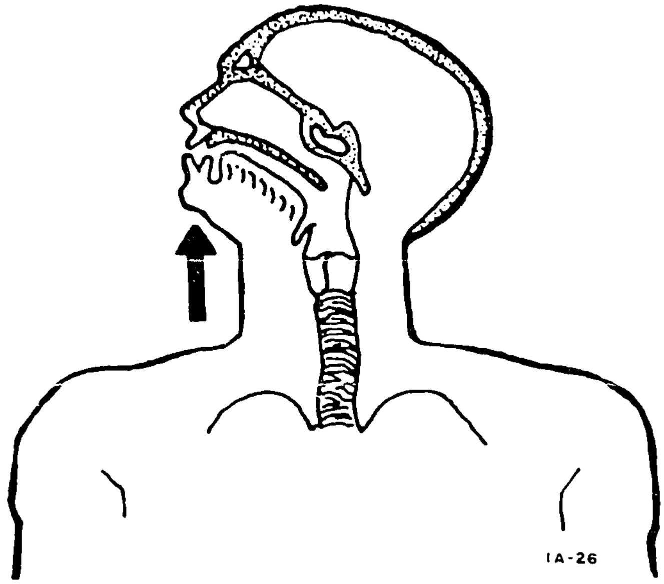


Figure 1–4. Stretch the neck.

____ 1. A victim who can't breathe will undoubtedly die in a short period of time.

____ 2. The main causes of airway blockage in a victim are tongue swallowing, neck bending, and foreign matter in the mouth or throat.

____ 3. Of more importance than how you clear a blocked airway is the fact that it is cleared.

____ 4. In some situations, a victim's tongue must be held in the forward position by mechanical means, such as safety pin or shoe string.

____ 5. Placing a victim's head in the sword-swallowing position means placing his chin close to his chest.

____ 6. There are two variations of stretching the victim's neck: the thumb jaw-lift and two-hand jaw-lift methods.

____ 7. Checking for obstructions and opening and maintaining an open airway are the primary steps of assuring breathing.

C04. Given statements about a bleeding victim, identify the type of bleeding and the best method to control the bleeding in each situation.

Stop Any Bleeding. Similar to the need for assuring that a victim can breathe is the need to stop any bleeding—the victim's life is at stake. A person's uncontrolled bleeding can result in severe shock and death. To control or stop any bleeding, you must first know the three main types of bleeding.

Types of bleeding. Types of bleeding are classified by the kind of blood vessel that has been cut. Therefore, they are called arterial, venous, and capillary bleeding. In arterial bleeding, the most dangerous kind, you see a large amount of bright red blood and a spurting or pumping action as the blood leaves the wound. When a vein has been cut, causing venous bleeding, a large amount of dark red blood flows from the wound without the spurting action which characterizes arterial bleeding. In capillary bleeding, the blood oozes or flows very slowly from the wound. Remember these signs. Your doing so may help you select the best method to stop the bleeding of a victim.

Controlling bleeding. Before you treat a bleeding victim, first check to see whether there is more than one wound. It would be senseless to take great pains to stop bleeding from one wound while the victim's life was draining away from another wound. To stop bleeding, you first apply direct pressure to the wound. Preferably, use a surgical dressing from a first aid pack; but if one is not available, use anything you have. Obviously, you want to be sure the dressing is as clean as possible. Place the dressing directly over the wound and press firmly. Continue this pressure as long as necessary, and use additional dressings if required. If the wound is on the arm or leg. you can place the victim on his or her back and elevate the limb. The elevation tends to reduce circulation to that limb and, thus, slow down the flow of blood. However, do not attempt to do this if the victim has other injuries on that limb (for example, broken bones), because moving that limb could cause further injuries and unnecessary pain and increase the danger of shock.

Pressure points. In addition to applying pressure directly on the wound and elevating the wound, you can apply pressure at one of several pressure points. Figure 1-5 shows the location of these point. Place your finger lightly where you think the pressure point is. If you feel a pulse beat similar to a throbbing, you are right on it. Then, use the heel of your hand or fingertips your to press hard. Continue this pressure until any blood gushing from the wound ceases. If you release pressure and bleeding starts again, reapply the pressure. One warning about pressure points: in cases of head wounds, where pressure points are commonly used, be sure NOT to press on both neck pressure points at the same time.To do so will block the flow of blood to the victim's brain and eventually result in death.

Tourniquet. Use a tourniquet only as a last resort, and only after all other methods of controlling the bleeding have failed. Usually, tourniquets are applied only in cases of extreme arterial bleeding. Apply a tourniquet only when you assume that there has been a great loss of blood and that any further loss, even in a small quantity, will be fatal. In other words, act on the assumption that it is better for a victim to lose a limb than a life. As soon as possible after you have applied a tourniquet, get the victim to a hospital. Under no circumstances should the tourniquet be loosened by anyone except a physician, who can stop the bleeding by surgical methods.

When you apply a tourniquet, always place it near the joint (knee, elbow) closest to the wound and between the wound and the heart because the gushing arterial blood is coming directly from the heart. Tighten your tourniquet only as much as needed to stop the spurting blood flow. Place it as close as possible to the wound but above it, except in cases of bleeding below the knee or elbow. In these cases, place a tourniquet just above the knee or elbow. When possible, protect the victim's skin by placing the tourniquet over a smooth sleeve or trouser leg. Figure 1-6 shows the exact procedure for applying tourniquets. If at all possible, stay with the victim, and check the tourniquet frequently to see whether it has slipped and whether there is any sign of further bleeding. Should the bleeding resume, or the tourniquet slip out of place, tighten or readjust it as necessary. In cold weather, because there is a very real possibility of cold injury to a victim's injured limb, protect the limb with anything available: a blanket, jacket, etc.

Again, be sure that the victim gets qualified medical treatment as soon as possible. You must also be certain that medical personnel can see that a tourniquet has been applied. To do this, you could write the information on a piece of paper and attach it to the victim's clothing, or you could write the information on the victim's forehead, face, or other readily seen body part.

Exercises (C04):

1. Match the statements in column A with the types of bleeding in column B, and with the best method to control that bleeding in column C, by writing the column B and column C letters in the space provided. Each item in columns B and C may be used more than once.

	Column A	*Column B*	*Column C*
____	(1) A victim has blood spurting from a lower leg wound.	a. Arterial.	A. Direct pressure.
____	(2) A victim has dark red blood coming from a cut on the forehead.	b. Venous.	B. Pressure point.
____	(3) A victim with a wound on the upper right arm is pumping blood past the bone fragments sticking out.	c. Capillary.	C. Tourniquet.
____	(4) Blood is rapidly flowing from a cut at the left side of a victim's head. Your efforts at direct pressure have failed.		
____	(5) A victim has a large, ugly open wound in the leg, and blood is slowly coming from the wound.		
____	(6) A victim has stepped on a board with a nail in it, and the wounded foot has blood oozing out of it.		
____	(7) Dismounting from the bed of a pickup, an airman slipped and hit his/her		

Column A

chin on the tailgate. There is a deep cut on the chin, and blood is flowing from the wound.

____ (8) An accident victim has been cut on the left shoulder by a piece of glass, and the blood is flowing slowly from the wound.

____ (9) A CE construction worker has severed three fingers, and blood is vigorously flowing from the wound.

____ (10) You are late for work. While shaving you make a deep cut on your cheek. The blood is running smoothly from your cheek.

C05. State the purpose for protecting wounds, and define "dressing" and "bandage."

Protect the Wound. Protecting a wound from infection and from further injury constitutes the third lifesaver step. You must, of course, keep this important first aid measure in mind throughout the treatment of any victim.

A dressing is a pack or padding placed directly on the wound. A bandage is used to hold the dressing in place or create pressure to stop the flow of blood. Bandages should never be placed directly on the wound. Always try to use sterile dressings from a first aid pack; and only as a last resort use other material such as strips torn from a shirt. While dressing a wound, avoid touching it with your hands and do not handle the side of the dressing that goes next to the wound. Do not pull clothing over the area to be treated because it could infect the wound further. Instead, tear or cut

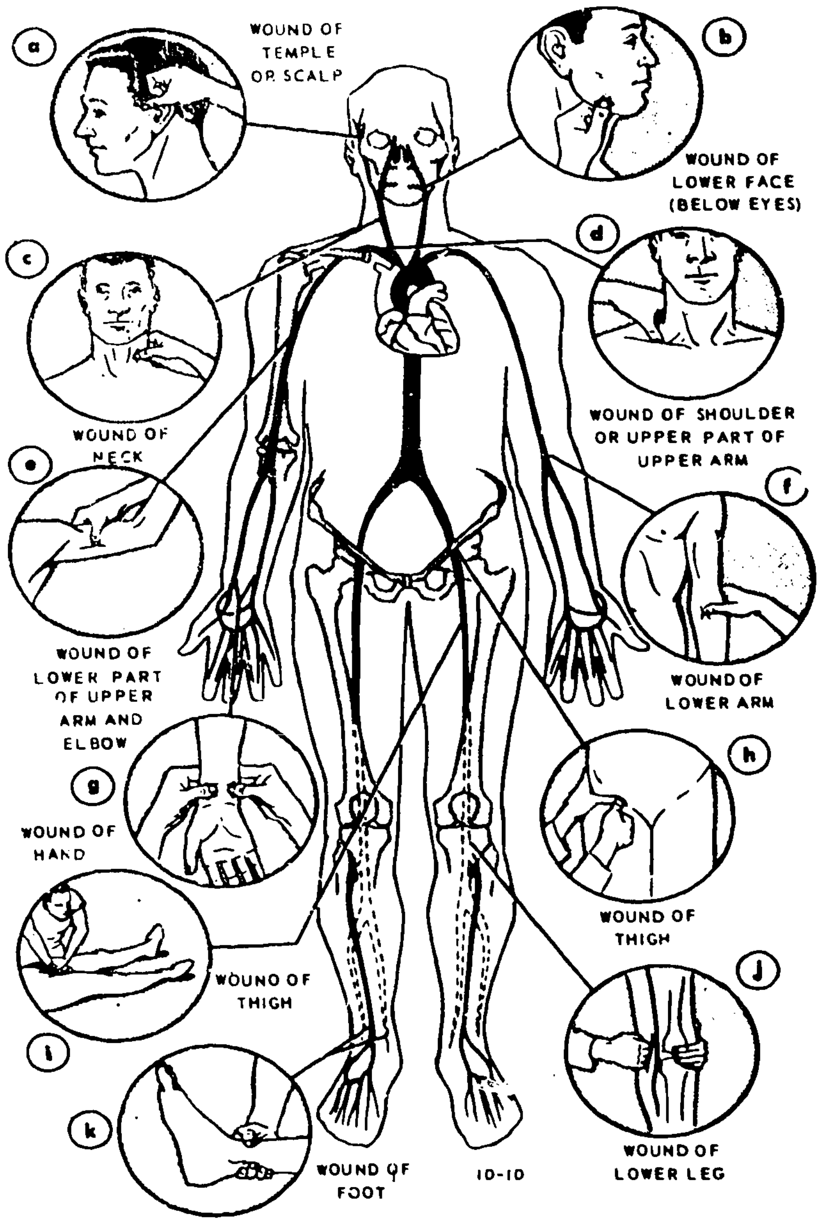


Figure 1-5. Pressure points.

clothing away from the injured area. If you have a regular first aid wound pack available, follow the instructions printed on the back of the package.

Remember, when bleeding is severe, immediately carry out measures to stop the bleeding; protect the victim from infection and further injury by applying dressings and bandages; and prevent or treat shock in all casualty situations.

Exercises (C05):

1. What is the purpose of dressing a wound?

2. What is a dressing?

3. What is a bandage?

C06. Specify whether given statements correctly define shock and shock treatment; if any statement is incorrect, briefly state why.

Prevent or Treat Shock. Although treatment of shock is listed as the fourth of the lifesaver steps, you actually begin treating for shock simultaneously with stopping bleeding. Shock exists in several forms, the least dangerous of which is the temporary shock caused by pain, fright, horror, or the sight of blood of other severely injured persons. Such temporary shock may result in fainting, and the victim recovers quickly with no further effects. Far more dangerous is the type of shock caused by severe injuries or bleeding. Unless treated properly and promptly, this type shock is most often fatal. Normally, the severity of shock corresponds to the severity of the injury. Also, delayed shock is not uncommon and may set in several hours after an injury has occurred. Don't be overly concerned with determining the type of shock; just follow the golden rule: treat for shock with any injury. You never hurt a victim by treating for shock, and even if they show no symptoms whatsoever, you have no way of knowing whether delayed shock may set in.

Symptoms of shock. A victim feels shock as a great weakness of the body. The outward symptoms are cold and clammy skin, shallow breathing, lackluster eyes, and apprehension or restlessness. Also, the victim may be excessively thirsty, retching, vomiting, or hiccupping, and be dry around the mouth and lips. The victim is probably going to be pale and wet with perspiration and may gasp for air and lose consciousness. In the final stages, most victims become listless and apathetic and die in deep shock.

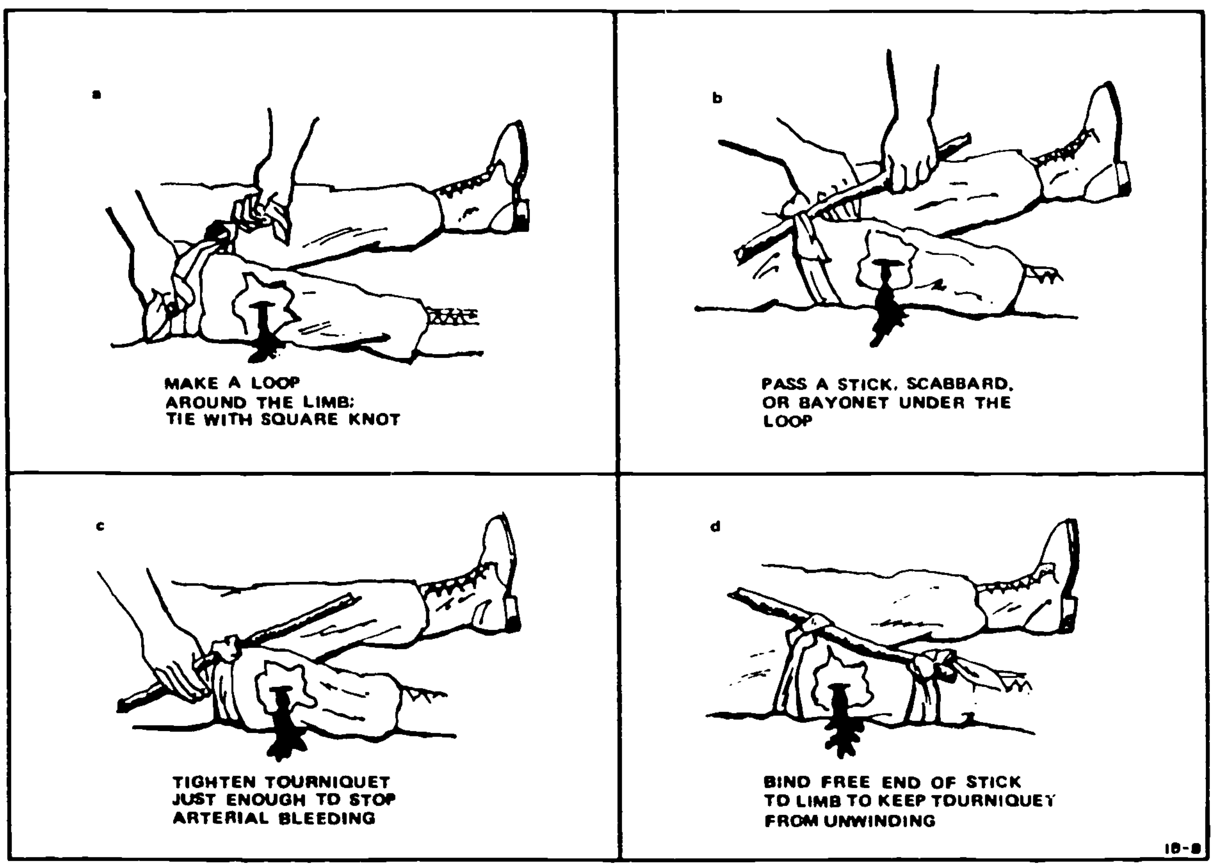


Figure 1–6. Applying a tourniquet.

Action to take. In case of severe injury, it is imperative that treatment for shock be started immediately. The first steps in shock prevention and treatment are to reassure the injured person and make him or her as comfortable as possible. Place the victim flat on his or her back on a blanket or any other material available. Handle the victim gently, remove all bulky items from his or her pockets, and loosen the belt and clothing. Move the victim as little as possible. You can reassure a victim by being gentle and calm. Nervousness on your part transmits itself to the victim and may increase the degree of shock. Also, do not let the victim see his or her injuries or the injuries of others involved in the same accident. Give the victim as much water to drink as he or she wants, except when he or she has a stomach wound. However, do not give alcohol in any form. When a victim has a stomach wound, you may moisten his or her lips with a damp cloth. An unconscious victim should be placed on his or her stomach, face turned to one side to prevent choking should he or she vomit. This placement is called the shock position. Keep the victim warm by covering him or her with anything available, and be sure to place something under the victim as protection because the ground may be wet or cold. In a hot climate, place the person in the shade, with his or her face away from direct sunlight. Finally, remember that shock is a serious condition and that you should get qualified medical help as soon as possible. You treat for shock in all cases of injury or disaster.

When you have assured the breathing, stopped the bleeding, protected the wound, and treated for shock, you have completed the four lifesaver steps. Your job is not done, however. You must continue to watch the victim, insuring as best as you can that he or she stays alive to be treated by medical personnel. Remember the four lifesaver steps; they are the basis of all your other actions in first aid.

Exercises (C06):

For each of the following statements which is correct, write "true" in the space provided. For each statement which is incorrect, briefly state why.

_____ 1. Shock must be treated immediately.

_____ 2. When you treat victims for shock when they aren't really experiencing it, you cause little or no additional injury or emotional trauma.

_____ 3. Hot, dry skin is indicative of shock.

_____ 4. Unconsciousness can be a good indicator that a person is in shock.

_____ 5. A victim who is undergoing shock can be given water, or wine with little or no side effect.

_____ 6. Any injured person should be protected from the elements of weather and kept warm, particularly if shock is suspected.

_____ 7. The shock position means the victim is on his or her stomach with his or her head turned to the side.

_____ 8. You begin treating a person for shock after you have assured breathing, stopped the bleeding, and protected the wound.

1-3. Moving and Transporting Injured Personnel

Frequently, a seriously injured person must be moved immediately. Knowing how to move a casualty is one of the most important parts of your first aid treatment. Careless or rough movement can increase an injurt and may cause the victim's death. Unless there is a good reason for immediately moving casualties, such as removing them from a burning aircraft, do not move or transport them until medical help arrives. On the other hand, since there may be situations where you have to move a person yourself, you must know the different ways of moving them. You already know that you always give any necessary first aid, including splinting fractures, before you move a victim. What you must learn now are methods of constructing improvised litters and executing manual carriers. Because movement by litter is most desirable, the section begins with it.

C07. Given hypothetical situations, select the most appropriate methods of transporting injured personnel.

Litters. Transporting of victims is a critical point in evacuating them from the field to medical facilities. Since this movement is critical, you should use a litter (stretcher) whenever possible. Using a litter not only makes it easier for you to carry a victim but also makes the journey safer and more comfortable for the injured. Remember that back and neck fracture casualties must not be moved except on a litter. Basically, there are two types of litters with which you must be familiar: standard and improvised.

Standard litter. A standard litter consists of a frame, a cover, and accessories, such as poles, legs, and securing straps. Generally, such litters as those shown in figure 1-7 are readily available and suited for moving any victim. When a standard litter is available, use it. In situations where no litter is available, you must construct one.

Improvised litter. An improvised litter is simply a substitute for a standard litter. It is constructed from

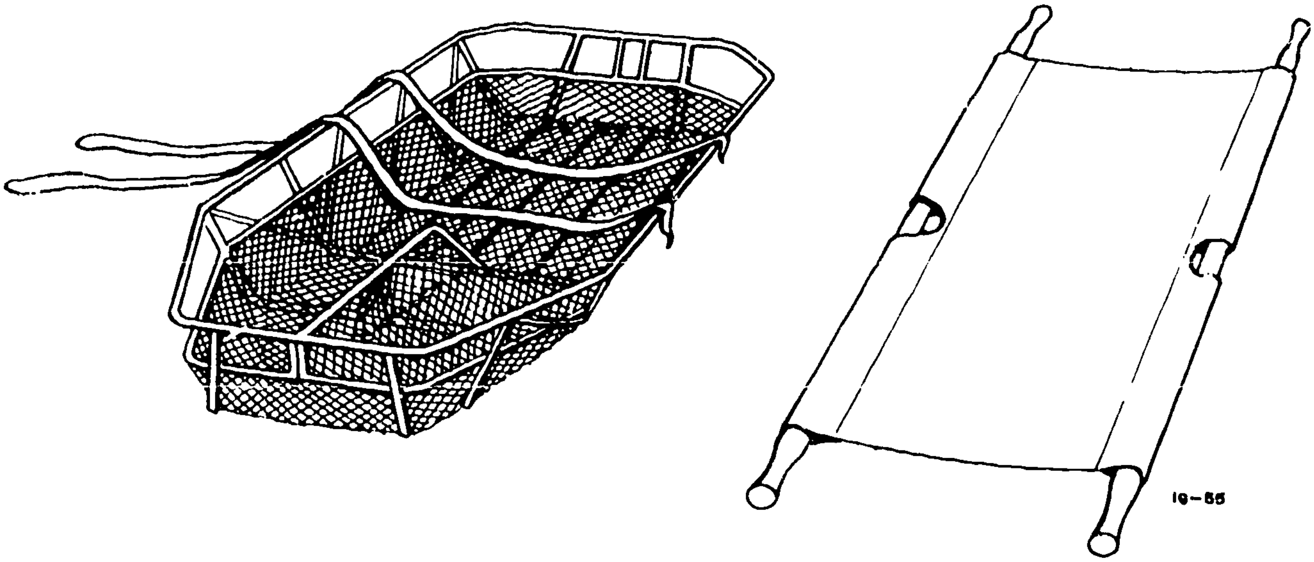


Figure 1-7. Standard litters.

whatever materials are available. Here are four improvised litters that you can construct very easily:

a. Pole and blanket litter. A blanket, poncho, shelter half, tarpaulin, or other material can be used for the bed of a pole and blanket litter. The poles can be made from such objects as strong branches, tentpoles, rifles, etc. Figure 1-8 is a good example of this type of litter. It would be best not to transport back or neck fracture victims on this type of litter unless they are face down.

b. Pole and jacket litter. Illustrated in figure 1-9 is an example of how you can use two or three shirts or field jackets to make a pole and jacket litter. Button up the jackets and turn them inside out so that the lining is outside and the sleeves are inside. Then slide the poles through the sleeves. Again, it's best not to use this for transporting back and neck fracture casualties unless they are face down.

c. Door or board litter. To make a door litter, you use any flat surfaced object of a suitable size, such as cots, window shutters, doors, benches, ladders, boards, or poles tied together. Even the hood, door, or windshield from a vehicle will work. You should pad this litter if possible. When you can, use this improvised litter to transport neck and back fracture victims.

d. Blanket roll litter. When you can't find poles or material to make a door litter, you can roll a blanket, shelter half, or poncho from both sides to the center, as shown by figure

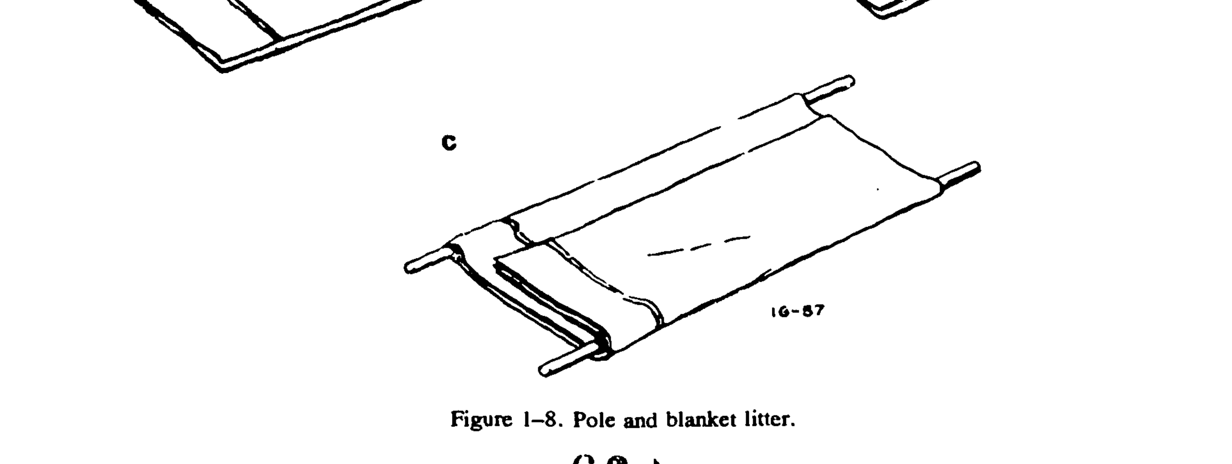


Figure 1-8. Pole and blanket litter.

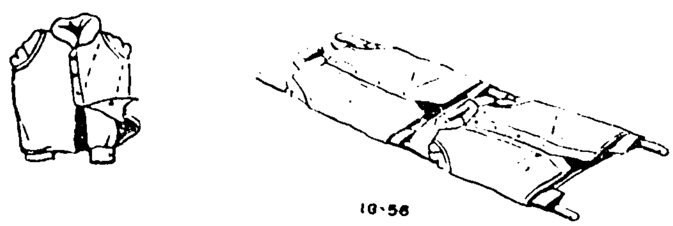


Figure 1-9. Pole and jacket litter.

1-10. Use the rolled material as grips when carrying the injured. You can use this litter with all victims.

Putting the Injured on the Litter. At this point, you know how to make and use a litter, and, obviously, you know that at least two people should carry a litter. As a minimum, two people are needed to place the victim on a litter. You and another person could move a victim from the ground to a litter (See fig. 1-11) in this way:

a. You and your assistant kneel on one knee on the same side of the victim.

b. You then slide your arms under the victim. Note that one of you slides your arms under the victim's hips and legs and that the other slides his or her arms under the victim's shoulders and back.

c. In a joint effort, you lift the victim to a height even with your knees. Use care, insuring that the victim's head doesn't drop, and keep the victim as straight as possible.

d. The final step is to place the victim on the litter. To do this, you lower the person to the litter by reversing the procedure you used to pick the person up.

Manual Carries. Manual carriers are tiring for the carrier and involve the risk of increasing the seriousness of the victim's injury. The methods of manual carry that are explained here can be used for conscious and unconscious victims. Bear in mind that a victim should be transferred to litter movement as soon as possible and that back and neck fracture injuries must be transported only by litter.

Two-man arm carry. Remember the technique we used to move a victim from the ground to a litter? The first three steps of that technique are the same for the two-man arm carry (fig. 1-12). Once you have the victim at a height equal to your knees, you and your assistant rise to your feet in a smooth, joint effort. As you rise, lift the victim and, by pulling your arms in, roll the individual toward your chest. You can use this technique with just about all types of injuries.

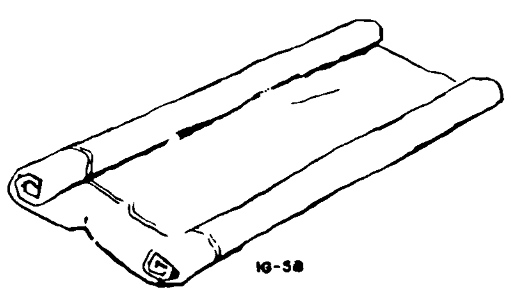


Figure 1-10. Blanket role litter.

Two-hand carry. This method is ideally suited for for carrying victims with injuries of the head or feet, and it may not be as tiring for the carriers as the two-man arm-carry:

a. With the victim lying on his or her back, you and your assistant kneel on opposite sides of the victim's hips.

b. You both slide your arms under the casualty--one arm goes under the thighs and the other under the arms and behind the back. As you reach through, you and your assistant grasp wrists as shown in figure 1-13.

c. You and your assistant rise together and lift the injured person.

Fireman's carry. This technique is ideal when you must move a victim by yourself and you are not exposed to enemy

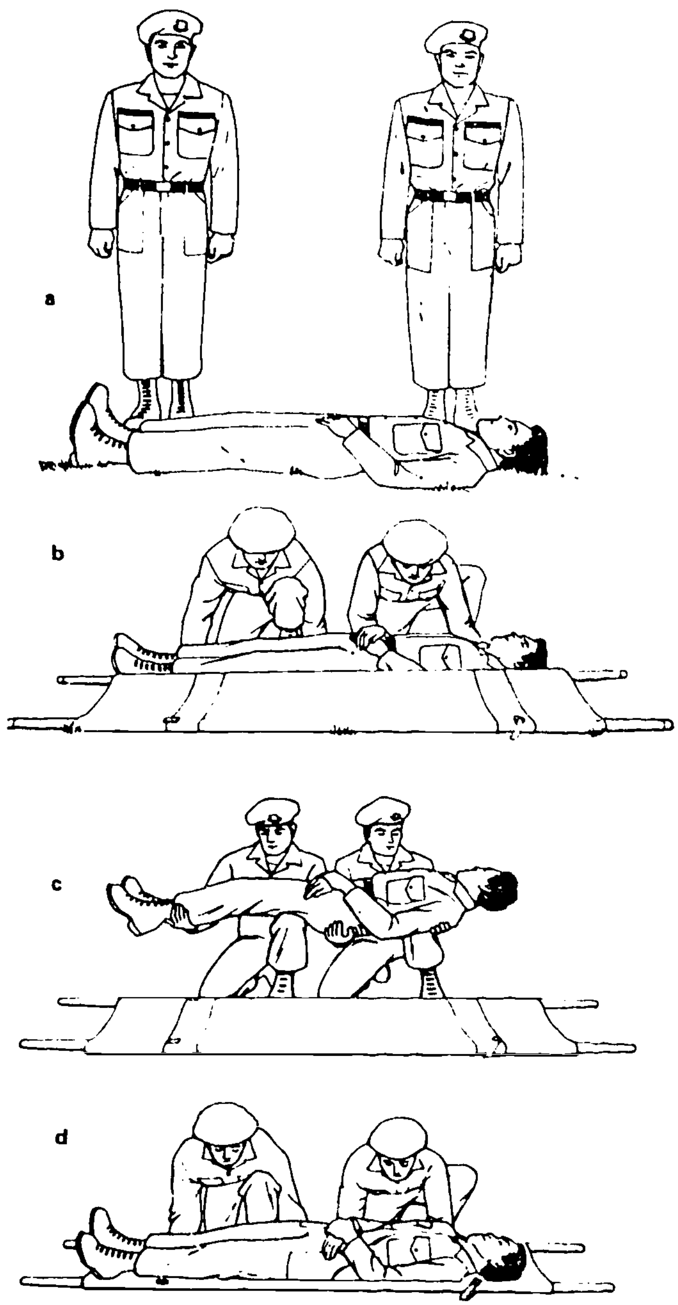


Figure 1-11. Two person litter lift.

gunfire. To use it, follow the steps shown in fig. 1-14.

a. Begin by turning the victim face down on the ground. Stand at his or her head and kneel on one knee with his or her head between your legs.

b. Place both hands under the victim's armpits and slide your hands down the his or her side so that they meet at the small of his or her back. This acton raises his or her head to your shoulders.

c. From this position, you now grasp or hug the victim and pull him or her to the kneeling position.

d. Once the victim is in the kneeling position, take a firmer grip across his or her back and lift him or her to the standing position.

e. Once the victim is standing, you support him or her by placing one arm around the waist. You then grasp the wrist farthest away from you and fold the victim's arm across his or her midsection.

f. You are now ready to load the victim to the carry position. Keep your grip on the victims waist and wrist and move slightly to the front. As you move, bend at the waist and pull the wrist you are holding around the back of your neck. Release the victims waist, and with your arm encirc' his or her leg.

g. At this point, you must use caution not to strain yourself by lifting. Remember to lift with your legs as you return to the standing position. You maintain your grip on the victims wrist and leg as you lift.

h. After you reach the standing position, you can carry the victim easier by grasping his or her wrist with your hand which encircles his or her legs.

Pistol-belt drag. This method (see fig. 1-15), although only useful for short distances, is ideal to move a victim to a location which offers cover and concealment so that you can use the fireman's carry. To use the pistol-belt drag, follow these steps:

a. Extend two pistol belts to their fullest length. Join them together and lay them on the ground in a straight line next to the victim.

b. Roll the victim to his or her back so that he or she is lying at about the middle of the extended pistol belts.

c. Reach across the victims chest, grasp the free end of the pistol belt, and, by pulling it to you, join the open pistol belts

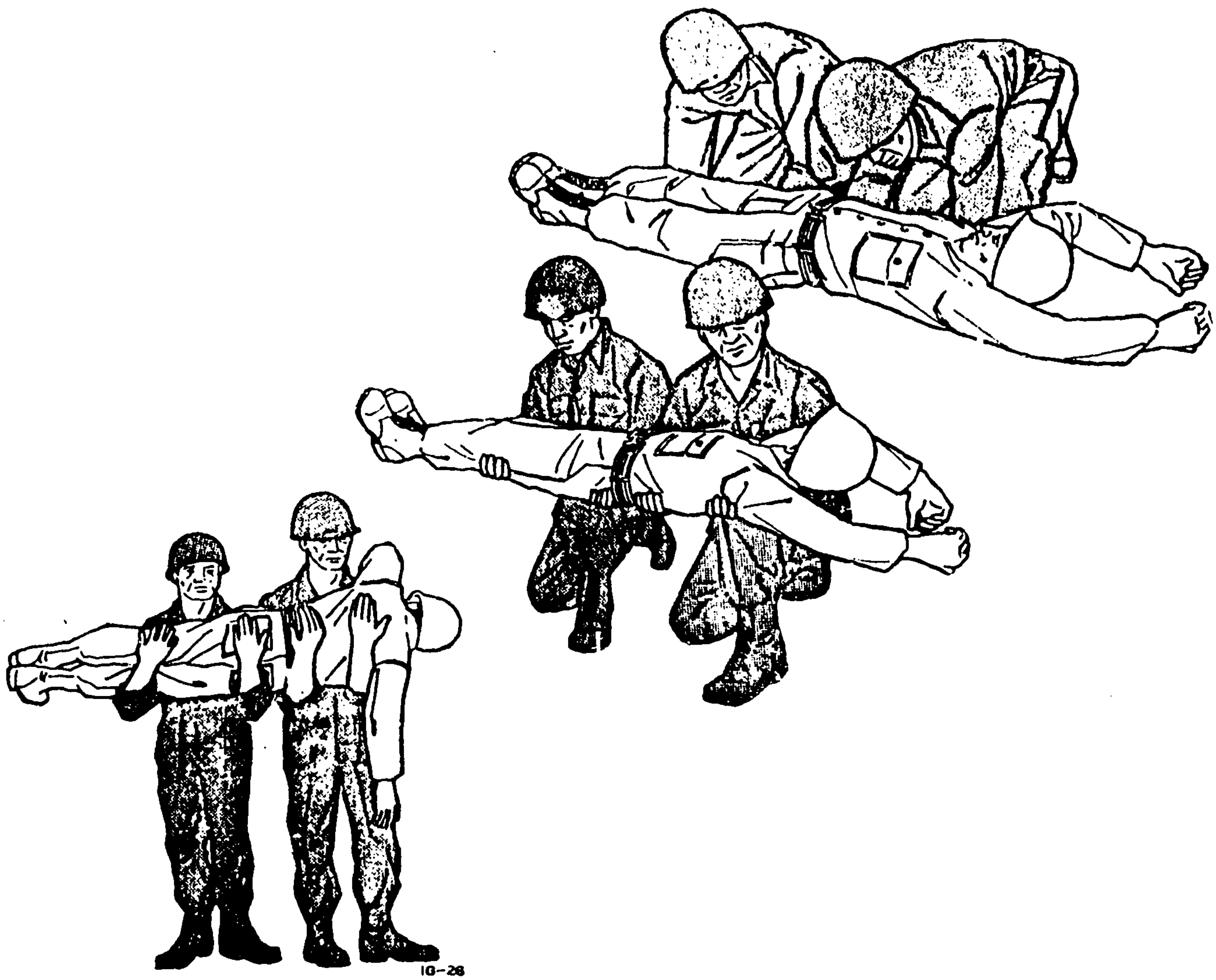


Figure 1-12. Two-man-arm carr

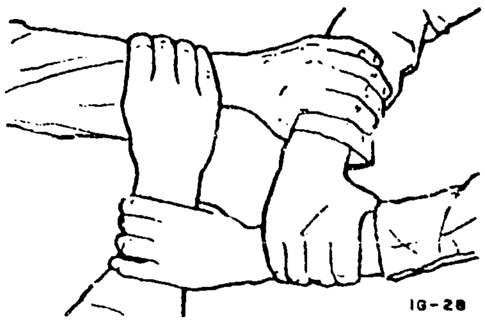


Figure 1–13. Front view two hand carry.

together to form one, large, continuous loop around the victim's chest and back. Be certain the belt goes under his or her armpits.

d. Lying on your side with your back to the victim, slip your upper shoulder through the loop. Roll away from the victim to your stomach. Then crawl away dragging the victim with you.

When transporting the sick and wounded, move a victim as little as possible. You must always be sure to treat any injury before you try to move a victim. Remember your four lifesaving steps throughout the period of movement, and treat symptoms as they occur.

Exercises (C07):

1. Match each hypothetical situation in column A with the best method of transportation in column B by writing the column B letter in the space provided. Column B items may be used only once.

Column A	*Column B*
____ (1) During a severe windstorm at your base, a CE maintenance man is blown off the side of a building. He is lying on his stomach, on the ground next to the building.	a. Standard litter.
____ (2) On a camping trip, one of the two friends that accompanied you falls and break his legs. It is nearly 5 miles to the nearest road.	b. Improvised litter.
____ (3) During a base defense exercise, a security police vehicle overturns on the base perimeter. The driver was thrown from the vehicle and landed with his back against a concrete drain. The two passengers are both shaken up but otherwise uninjured. The vehicle is burning, and the driver must be moved quickly to prevent being burned.	c. Two-man arm-carry.
____ (4) In a raid on a missile launch facility terrorists have wounded your team member. The victim is lying on the open about 10 feet from the culvert you are hiding in.	d. Fireman's carry.
	e. Pistol-belt drag.

1-4. Extreme Weather Protection

The very nature of your duties exposes you to the extremes of weather. Regardless of where you are now stationed, you undoubtedly have heard how miserable the heat or cold can make a tour of duty. Unfortunately, either of these weather elements can also cause you a very severe injury. In this section, you are presented the actions to take when confronted with an injury caused by the heat or cold.

C08. Given statements about treating conditions caused by heat, identify the true statements, and correct any false statements.

Heat Conditions. Heat cramps, heat exhaustion, and heatstroke are the most prevalent conditions resulting from exposure to heat. These conditions are your body's reaction to both internal and external factors. The harmful effects they create take place because your body becomes overheated and cannot dispose of the excess heat. All three of these reactions are associated with your body's loss of large amounts of

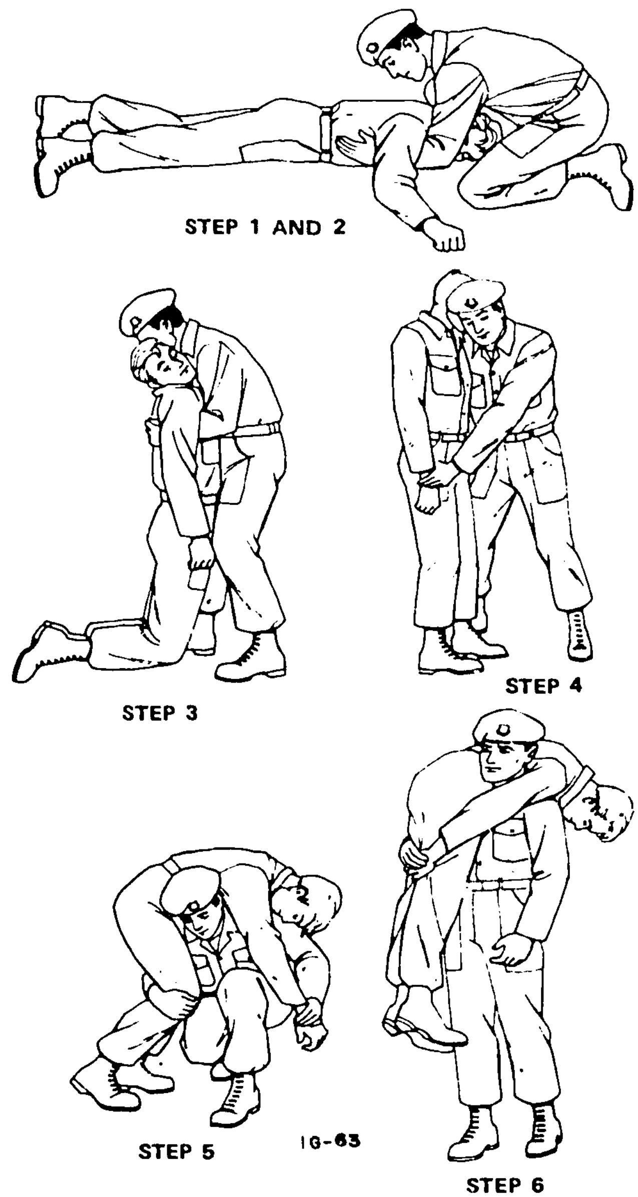


Figure 1–14. Fireman's carry.

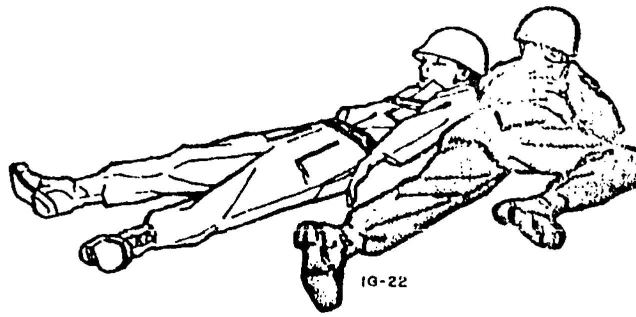


Figure 1–15. Pistol belt drag.

water and salt as a result of very heavy perspiration, for instance, vigorous athletic competition, manual labor, or strenuous exercise in a hot atmosphere.

Heat cramps. These are involuntary, painful muscle spasms and pains, similar to those you would experience with a "charley horse." Heat cramps are primarily the result of your body's loss of salt or an insufficient intake of salt. Heat cramps may often be a compounding factor to heat exhaustion; thus, you must watch for their telltale signs and take appropriate first aid measures:

a. Symptoms. Heat cramps most often affect the muscles in the legs and stomach first. A sudden, violent cramp is the main indication.

b. Aid. To relieve the pain of a heat cramp, you take either of the following actions:

(1) Exert firm pressure on the affected area with your hand.

(2) Gently massage the muscle spasm.

When the spasm has reduced, give the victim sips of water containing 1 teaspoonful of salt per 4 ounces of water. This treatment is continued for about an hours.

Heat exhaustion. This condition is a fainting or body weakness due to drinking an inadequate amount of water to replace that which your body loses through perspiration. Heat exhaustion is more severe than heat cr ıps. Therefore, immediate recognition and treatment are needed:

a. Symptoms. The symptoms of heat exhaustion are headache, excessive sweating, dizziness, and muscle cramps. Also, the skin is pale, cool, moist, and clammy. Heat exhaustion may come on gradually or suddenly.

b. Aid. Give a victim of heat exhaustion the following first aid, immediately:

(1) Lay the victim in a cool, shaded area and loosen his or her clothing.

(2) If the victim is conscious, give the victim cool salt water to drink. Prepare the salt water by dissolving two crushed salt tablets (1/4 teaspoonful of table salt) in a canteen (quart) of cool water. The victim should drink 3 to 5 canteenfuls during a period of 12 hours.

Heatstroke. Heatstroke can be fatal. It is your body's violent reaction to extremely high temperatures and malfunction of the ability to sweat. Heatstroke is the most severe heat condition. Immediate recognition and treatment are essential to life:

a. Symptoms. The first sign of heatstroke may be stoppage of sweating. This causes the skin to feel hot and dry. Collapse and unconsciousness may come suddenly or may be preceded by headache, dizziness, fast pulse, nausea, vomiting, and mental confusion. It is necessary to work fast to save the life of a heatstroke victim. The heat regulators of the body have been damaged, and the body temperature may rise quickly as high as 108° F.

b. Aid. Take the following first aid measures for a heatstroke victim, immediately:

(1) Immerse the victim in the coldest water available. If ice is available, add it to the water.

(2) If a cold water bath is not possible, get the victim into the shade, remove his or her clothing, and keep the entire body wet by pouring water over it. Cool further by fanning the wet body.

(3) Transport the victim to the nearest medical treatment facility at once, and continue to cool the body on the way.

(4) When the victim becomes conscious, give him or her cool salt water to drink in the same manner as you would to a heat exhaustion victim.

Exercises (C08):

If one of the following statements about treating heat conditions is true, mark it true in the space provided. If a statement is false, correct it.

____ 1. Heat cramp victims should be treated quickly to reduce pain.

____ 2. A gentle squeezing action on the contracted muscle of a heat cramp victim should alleviate the cramp.

____ 3. A victim suffering from heat exhaustion may first exhibit signs indicative of heat cramps.

____ 4. A person exhibiting signs of profuse sweating and cool skin should be treated as a victim of heatstroke.

____ 5. Treating a heat exhaustion victim is simply a matter of reducing the body exposure to heat and replacing body fluids and chemicals lost through perspiration.

____ 6. A heat exhaustion victim should drink 96 to 160 ounces of mild salt water in the 6 hours following the onset of the condition.

____ 7. A heatstroke victim is in critical condition and must be treated immediately to prevent death.

____ 8. Immediate aid for a heatstroke victim could include attempting to reduce body heat by placing the victim in the nearest water or spraying the victim with water from a garden hose.

____ 9. A victim of heatstroke should be transported to a medical aid facility when he or she regains consciousness, and treatment should be continued en route.

C09. Given statements about treating cold weather injuries, identify the true statements and correct any false statements.

Cold Conditions. The extent or severity of an injury caused by exposure to extreme cold weather generally varies with such factors as temperature, humidity, wind velocity, and wind type. Of the conditions presented here, frostbite is

usually considered most severe and most common. Nevertheless, trenchfoot, immersion foot, and snow blindness are not mild conditions.

Trenchfoot. Trenchfoot is an injury that results from fairly long exposure of the feet to cold, wet conditions. Generally this happens at temperatures from freezing to 50° F. If you are also inactive (such as when standing in one spot on your post), the possibility of developing trenchfoot is even greater. Trenchfoot can be very serious; it can lead to a loss of the toes or parts of the feet. A frequent symptom of trenchfoot is numbness. There may also be a tingling or aching sensation or cramping pain. If exposure of the feet has been prolonged and severe, they may swell so tightly that pressure closes the blood vessels and cuts off the circulation. Should you develop trenchfoot, dry your feet thoroughly and get to a medical treatment facility by the fastest means possible. If transportation is available, avoid walking.

Immersion foot. Immersion foot is similar to trenchfoot. It results from immersing the feet in water or constant wetness of the feet for a long time—usually in excess of 12 hours. Immersion foot develops more rapidly if the water is below 50° F. It can occur, however, when the feet are exposed to warm water for a period exceeding 24 hours. In immersion foot, the soles of the feet become wrinkled and white; standing or walking becomes extremely painful. Other portions of the body also may be similarly affected. Should you develop immersion foot, dry your feet thoroughly and get to a medical treatment facility. You should observe the same walking precaution as is observed for trenchfoot.

Snow blindness. Snow blindness is the effect that glare from an icefield or snowfield has on the eyes. For instance, the parking ramp or launch facility may produce such a glare. This condition can occur even in cloudy weather. In fact, it is more likely to occur in hazy, cloudy weather than when the sun is shining. You can recognize the early stages of snow blindness by a scratchy feeling in the eyes when the eyelids are closed. Should you develop snow blindness, cover your eyes with a dark cloth to shut out all light. Then, have someone take you to a medical treatment facility at once.

Frostbite. Frostbite is the injury of skin tissue caused by exposure to cold. The body parts most easily frostbitten are cheeks, nose, ears, chin, forehead, wrist, hands, and feet. Frostbite may involve only the skin, or it may extend to a depth below the skin. Deep frostbite, which is much more serious than skin frostbite, requires different first aid to avoid or minimize the loss of parts of the fingers, toes, hands, or feet. Frostbitten skin is whitish, stiff, and numb, rather than painful. For this reason, you must watch one another's face and hands for signs of frostbite. If a body part has been numb for only a short time, the frostbite probably involves only the skin; otherwise, assume it to be deep:

a. Frostbite of the skin. Take the following actions whenever frostbite of the skin occurs: (NOTE: DO NOT warm or rewarm frostbitten parts by such measures as massage, exposure to open flame, cold water soaks, or rubbing with snow.)

(1) Parts of the face. Cover the frostbitten part with your warm hands until pain returns.

(2) Hands. Place your hands next to your skin in opposite armpits.

(3) Feet. In the most sheltered area available, place your bare feet under the clothing and against the abdomen of another person.

b. Deep frostbite. As we stated earlier, if your body part has been numb for only a short period (5 to 10 minutes), you treat yourself for skin frostbite. Otherwise, take the following actions:

(1) Get to a medical treatment facility by the fastest means possible. If transportation is available, avoid walking.

(2) Protect the frostbitten body part from additional injury, but do NOT attempt to treat it or thaw it in any way.

Thawing increases the possibilities of infection, further damage, and gangrene (rotting skin). There is less danger of walking on your feet while they are frozen than after they have been thawed. Thawing may occur spontaneously during transportation to the medical facility, but this cannot be avoided because your body in general must be kept warm.

Exercises (C09):

Identify the true statements in the following list, and correct any false statements.

____ 1. Drying your feet and seeking medical aid are about the only measures a first aider can take for trenchfoot or immersion foot.

____ 2. Trenchfoot is caused by prolonged exposure of the feet to moisture and cool weather.

____ 3. Snow blindness treatment consists of covering the eyes and seeking medical aid.

____ 4. Frostbitten skin is whitish, stiff, and numb, rather than painful.

____ 5. A deep frostbite victim should be protected from further exposure, without thawing the affected body part, and taken to medical aid.

Field Hygiene and Sanitation

PERSONAL HYGIENE and sanitation are of real importance when an organizational unit is working in the field. When you live in the field apart from modern cleaning facilities, you must give extra care and attention to hygiene activities.

You should already know that untreated psychological injuries can have a serious impact on the effectiveness of an individual and a unit. Lack of personal hygiene and sanitation can have a similar impact on individual and unit effectiveness.

2-1. Hygiene and Health

An efficient military unit is a carefully planned, well-organized, well-trained fighting team. It is a team that carries no substitutes. When any team member is absent or sick, teamwork suffers. Carelessness of one member of the unit in regard to his personal hygiene can lead to disease which incapacitates the entire unit.

C10. Indicate whether given statements concerning personal hygiene are true.

Meaning of Personal Hygiene. Personal hygiene is the practice of health rules by the individual to safeguard his or her own health and the health of others. Personal hygiene is often thought of as being the same as personal cleanliness, but cleanliness of the body is only one of many aspects of all personal hygiene. All personnel actions directed toward maintaining personal health are a part of personal hygiene.

Health. You belong to a group whose physical condition is as carefully guarded as the most vital weapons system. The purpose of this concern is to maintain your effectiveness. Remember—this is group protection. The Air Force can go just so far. Your personal health and welfare still depend upon your own good care and good sense.

Anytime you do not feel perfectly well, or when you believe that you have a disease of any kind, you should report to sick call. Don't wait to see whether the symptoms get worse. Diseases are most readily spread in their early stages. Often, before you feel really sick, you may be a source of infection to your friends. Don't try to treat yourself. Nearly all medicines may be harmful in unskilled hands.

If you have a cold, a headache, diarrhea (loose bowels), sore eyes, a body rash, or a fever, report to sick call immediately.

Diet. Physically, man is the product of what he eats. Great care is exercised to make sure that balanced menus are provided to keep you in good health. An interesting point to understand here is that the C-ration issued to you in most field operations is a balanced, nourishing, and adequate menu. It is your responsibility to eat enough of the various food items to maintain your health and vigor. Proper variety in food is essential to your health. You should know the variety of foods necessary for physical well-being. The human body requires nutrition from each of seven food groups:

- Milk and milk products.
- Leafy green and yellow vegetables.
- Butter or fortified margarine.
- Bread and other cereal products.
- Meat, fish, poultry, and eggs.
- Oranges, tomatoes, and grapefruits.
- Potatoes and other vegetables and fruits.

When possible, you should eat foods from each of these seven food groups daily. This diet should help you to keep alert, healthy, and vigorous. (Eat everything edible in the C-ration for field operations.) Proper diet is extremely important to your body under normal conditions. When you are in the field, proper diet is even more important to maintaining health, because a properly balanced diet helps your body increase resistance to infection.

Mental Health. Mental disorders may be as disabling as are physical diseases. When you are incapacitated by combat fatigue, you are as much a casualty as is the individual with malaria. Both mental health and physical health make up your total health. A sense of well-being, the absence of overpowering fears and anxieties, and a wholesome attitude toward life are essentials of total health.

Exercises (C10):

Indicate whether each of the following statements is true or false.

____ 1. Personal hygiene includes cleanliness, physical and mental health, and seeking medical treatment when ill.

____ 2. Maintaining personal hygiene is actually the action of staying clean and healthy.

____ 3. Personal hygiene could be defined as the everyday personal actions you must take to safeguard your health and the health of others.

____ 4. Diet can be a major factor in an individual's personal hygiene.

C11. Define "infection"; and list, in order of most to least vulnerable, the body's natural defenses against infection.

Infection (Disease). As you recall, even though you may not feel sick yourself, you may be a source of infection to others. Infection occurs when micro-organisms invade the body, multiply, and produce injury or disease. Micro-organisms which enter the body range from those that produce disease (pathogens) to those that do not produce disease. To understand infection, you must know how the micro-organisms enter the body.

Portals of entry. The principal portals of entry for micro-organisms are abrasions of your skin, mucous membranes of your respiratory system or gastrointestinal and genitourinary tracts, and your eyes. Nevertheless, unbroken skin and mucous membranes are natural defensive barriers against an invasion by pathogenic organisms. Certain organisms require specific routes to infect; others can invade by several routes. Most respiratory diseases are contracted by the inhalation of droplets of contaminated moisture or dust. Intestinal infections usually are produced by the ingestion of contaminated food or drink.

Some organisms invade by penetrating the skin through hair follicles, sweat gland ducts, or abrasions; other organisms must enter through wounds in order to establish themselves. Tetanus spores, for example, may be swallowed without causing harm; but if they are introduced into an open wound, tetanus (lockjaw) may develop. What takes place in your body when these organisms enter is very similar to a battle. If your body has a good defense and wins, you suffer no ill effects. When the pathogens win, you're in trouble—infection has occurred, and you have a disease. Fortunately, your body is usually a tuned fighting machine.

Bodily defense against infection. The ability of your body to fight off or overcome infection is known as resistance. You can better understand this ability when you compare your body's resistance to an active ground defense action using the three-component system and defense in depth:

a. Early warning. Your body's early warning system alerts you to the fact that something is wrong by displaying symptoms. For instance, a sore throat, headache, fever, or sore that won't heal are early warnings to you that your body has been infected.

b. Tactical defense. Your body's first line of defense is provided by the skin and the mucous membranes of your gastrointestinal, tract, respiratory system, and genitourinary tract, along with their secretions. These help to prevent entrance of micro-organisms into the deeper tissues that have little ability to ward off invasion.

c.. Reaction. The second line of defense (blocking force), of which the lymphatic system is a part, is a cellular one not as susceptible to infection as your skin. This defense comes into play when the migrating cells of your body attack and destroy invading organisms. The third line of defense is presented by your blood. Your blood contains neutralizing bodies (counterattacking force) which push the organisms to the liver and spleen where they are destroyed or inactivated. Your blood is about your least vulnerable body defense.

Body preparation. Obviously your body can't employ an active intelligence gathering network. However, because you know your body's enemy is infection, you can take action to prepare (plan) your body in case the pathogens launch a surprise attack.

Your body uses active and passive defensive measures against infection. You have learned the active measures your body uses. The passive defense, like the intelligence capability, must be exercised by you. You can insure that your body has a more then even chance by following these tips:

a. Avoid exposure. Stay away from any person who you know has a disease, or who you think might have a disease, unless it is your assigned duty to take care of him or her. Ask your friends to stay away from you when you think you are becoming ill.

b. Eat properly, and form the habit of having your bowels move regularly.

c. Drink plenty of water at intervals. Depending on climatic conditions, drink three or four full canteens per day.

d. Change wet clothes and shoes for dry ones as quickly as possible.

e. Never borrow cups, pipes, or other personal items that your associates put in their mouths.

f. Keep insects away from food, and don't handle pets before eating.

g. Don't borrow handkerchiefs, towels, shaving brushes, razors, or combs.

h. Take salt as directed to avoid fatigue and heat prostration.

i. Regularly get the proper amount of sleep whenever possible.

Exercises (C11):

1. What is infection?

2. In order of most vulnerable to least vulnerable, what are your body's three natural defenses against infection?

2-2. Personal Cleanliness and Foot Care

This section covers techniques of personal cleanliness as well as measures you can take to have healthy feet.

C12. Given statements about techniques of personal cleanliness, identify the true statements and briefly state why the others are false.

Personal Cleanliness Techniques. Probably no other single habit of hygiene is as important as being clean. An unclean body is not only offensive, it can also be a source of infection to you and your friends.

Clothing. Clothing easily becomes contaminated with disease agents as a result of contact with agents present in stool, urine, and surface garbage. Change your underclothing daily, if possible. If you can't change it daily, rinse your underwear in clean water, and lay it in the sun to dry. The sun's rays act as a purifying agent. Wash outer

clothing when it becomes excessively dirty. When it is absolutely impossible to wash your outer clothing, shaking it out and airing and sunning for two hours can greatly reduce the number of disease germs. Any shaking of clothes should always be done out of doors, not in tents or dwellings.

Bathing. It is virtually impossible to take a complete bath while living under field conditions, but even the limited bathing possibilities available to you may make the difference between poor health and keeping fit. Daily washing of your armpits, ears, feet, and crotch with soap and water is a most important part of field hygiene. You should shave every day if possible. If possible, you should wash your hair at least once a week with soap and water. Your helmet can be used as a wash basin. Fill it with water, wash your body, and then shave. You can build simple bathing devices, such as those shown in figure 2-1, if you are going to be in one location for a long time.

Oral hygiene. Regular and proper cleansing of your mouth and teeth prevent tooth decay and gum disease, both of which can cause severe pain and loss of teeth. The most healthful oral hygiene, which should be practiced whenever possible, is to cleanse your mouth and teeth thoroughly and correctly after each meal with a toothbrush and fluoride dentifrice. However, when the situation makes this activity impractical, you should thoroughly cleanse your mouth and teeth at least once each day, using improvised devices if necessary. If a dentifrice is not available, use your toothbrush without one, or use salt. In the absence of a toothbrush, you can use twigs cut from a tree and frayed on the ends to resemble toothbrush bristles. Twigs can also be cut in the form of toothpicks for use in removing material caught between your teeth. If necessary, pieces of clean cloth can be used to wipe away food debris which has collected on your teeth. Rubbing your gum tissue vigorously with a clean finger also stimulates them to better health.

Bedding. At least once a week change your bedsheets. Air and sun the blankets, pillows, and mattresses the same as you do you clothing.

Hands. Keep your fingernails closely trimmed and clean. Wash your hands (with soap and warm water if available) after any dirty work, after each visit to the latrine, and before touching food or food utensils. As shown in figure 2-2, effective hand-washing devices can be improvised. Such habits as nose-picking, nail biting, and unnecessary scratching can cause contamination of your hands and of the things that you touch later. These habits, which are unpleasant to see and unhealthy for you, should be broken. Coughs and sneezes should be smothered in a tissue or

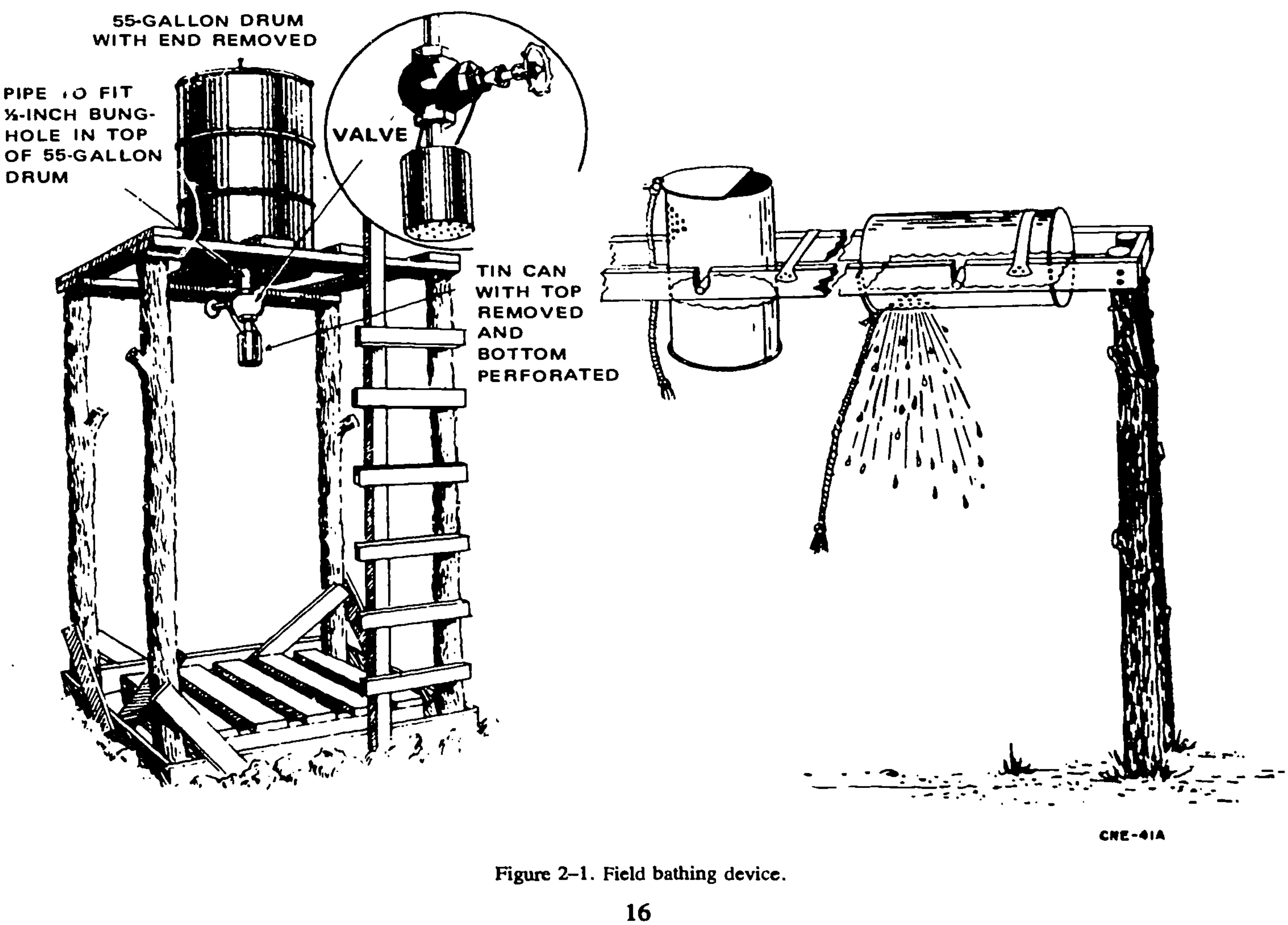


Figure 2–1. Field bathing device.

handkerchief or at least directed away from other persons. Keep your fingers and other contaminated objects out of your mouth.

Exercises (C12):

Indicate whether each of the following statements about the techniques of personal cleanliness is true or false. Correct any false statements.

____ 1. An unclean body can be a source of pathogenic organisms to yourself and other members of your unit.

____ 2. You should change your underwear at least daily.

____ 3. Exterior clothing that can't be washed can be partially cleaned by shaking, sunning, and airing.

____ 4. When total bathing isn't possible, offensive body odors can be reduced and your health promoted by daily washing of your body creases with soap and water.

____ 5. In the absence of a commercial dentifrice, toothpaste can be used to brush your teeth.

____ 6. When a toothbrush isn't available in the field, a clean cloth can be used to brush your teeth.

____ 7. An individual who practices the techniques of cleanliness in the field should remain relatively disease free.

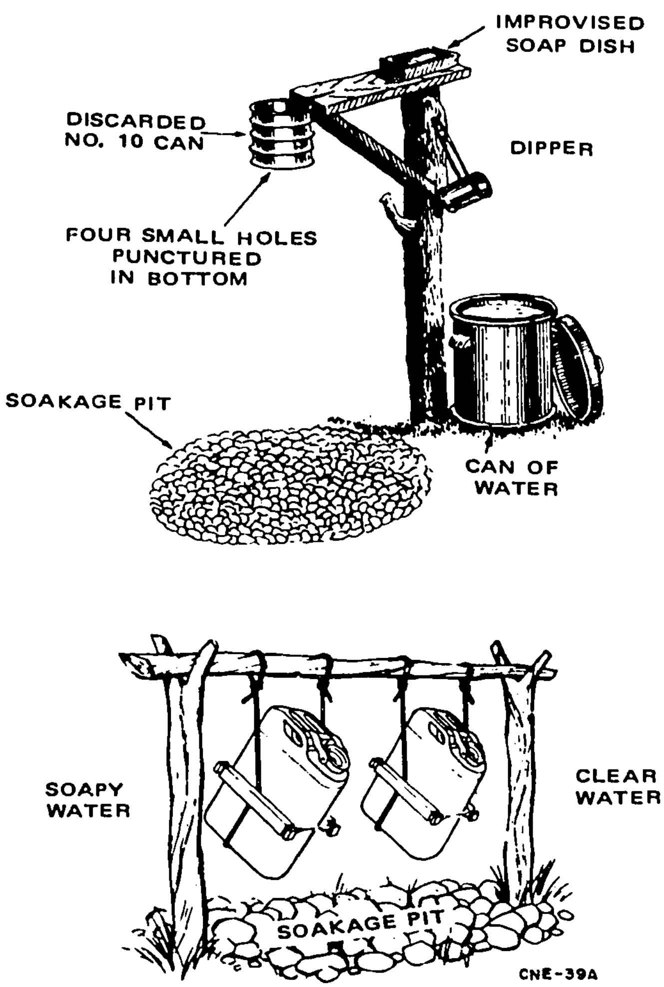


Figure 2-2. Hand-washing device.

C13. Associate common foot ailments with their symptoms and the actions needed to correct or prevent these ailments.

Care of the Feet. During sustained field operations, one of the biggest casualty inflictors, and a prime cause for pain, is poor foot care. Proper foot care is essential to the maintenance of physical fitness. Serious foot trouble usually can be prevented by observance of the following simple rules.

Foot hygiene. You should wash your feet daily and dry them thoroughly, especially between the toes. Persons whose feet perspire freely should apply an antifungus foot powder lightly and evenly twice a day. This powder helps retard the growth of some fungi.

Properly fitted shoes. In field operations, only footgear issued for field purposes should be worn. Expert fitting at the time of issue is absolutely essential. There should be no binding or pressure spots; neither should the footgear be so large that it permits your foot to slide forward and backward when you are walking.

Clean, fitted socks. Socks should be changed and washed daily. They should be large enough to allow your toes to move freely but not so loose that they wrinkle. Woolen socks should be at least one size larger than cotton socks to allow for shrinkage. Socks with holes or poorly darned socks may cause blisters. Different types of socks are provided for various footgear; learn their proper uses at the time they are issued to you.

Common Foot Ailments. Blisters, corns, bunions, ingrown toenails, and fungus infections are the most common causes of foot trouble.

Blisters. You can usually prevent blisters by wearing properly fitted shoes and socks. Shoes should be broken in slowly, and socks should be clean and free of holes. If a blister does develop, treat it as shown in figure 2-3.

Bunions and corns. Bunions and corns are painful growths on your feet. Similar to blisters, they are caused by irritation of the foot tissue, such as pinching shoes or rubbing socks. These ailments need medical attention.

Ingrown toenails. Ingrown toenails develop when nails are improperly cut. You should trim your toenails straight across rather than following the contour of your toes. If tenderness develops in the nailbed or along the edge of the nail, report to the medical officer.

Athlete's foot. Athlete's foot is a cracking of the skin between and under the toes, or a general itching of the foot. Athlete's foot is really a misnomer. Generally any fungus that concentrates in the area of the foot is called athlete's foot, which is caused by a fungus that thrives on the warm, moist atmosphere offered in your boots, particularly when you have had them on for a prolonged period. The most appropriate treatment for athlete's foot is to seek medical aid. The reason for this is that the various fungus infections of the feet usually respond differently to treatment. Athlete's foot can be very serious and painful. Don't try to treat yourself.

Immersion foot and trenchfoot. You learned about these ailments earlier. Seek medical aid when you suspect you are suffering from one of these ailments.

Exercises (C13):

1. Match the column A foot ailment symptoms with the types of ailments in column B and the preventive or first aid measures in column C by writing the column B and C letters in the spaces provided. Column B and C items may be used once or not at all.

Column A	*Column B*	*Column C*
____ (1) Cracked skin and itching on sole of foot.	a. Ingrown toenail.	A. Properly sized footwear.
____ (2) Extreme pain and tenderness on top side of corner of toe.	b. Blister.	B. Keep feet dry.
____ (3) Fluid-filled spot on heel of foot.	c. Fungus infection.	C. Powder feet.
____ (4) Painful bump on your little toe.	d. Bunion or corn.	D. Puncture at lower edge and bandage.
	e. Immersion foot or trenchfoot.	E. Correct cutting.

Figure 2–3. First aid for blister.

2-3. Field Sanitation

As you have learned, personal hygiene is your observance of the rules of good health and cleanliness. Even though you follow these rules and maintain perfect health, your body c[illegible] cope only with a limited number of disease agents.

Under field conditions, unless you and every other member of your outfit follow some basic sanitation rules, practicing personal hygiene is only a temporary stopgap against infection. Three areas of sanitation that must be strictly observed in the field are water, food, and waste sanitation.

C14. Arrange in sequence, of most to least desirable, given statements about water sanitation; state the procedures for purifying water.

Water Sanitation. Impure water may be a means of transmitting such diseases as cholera, dysentery, typhoid fever, paratyphoid fever, and snail fever. All of these can assume epidemic proportions and disable large numbers of people. Getting, purifying, and providing water in the field are usually the responsibilities of base engineer personnel. Nevertheless, we must all be aware of the danger of impure water and must know simple purification procedures to use in field situations. All water must be treated or certified as safe by medical personnel. Water containing organisms that cause disease is contaminated. Water containing substances that are undesirable or that render it unfit for drinking or domestic use is polluted. Water that is free of both contamination and pollution is potable; that is, you can drink it.

Selection of water sources. Water may be obtained in the field from surface water sources (lakes, rivers, streams, ponds), from ground water sources (wells and springs), and sometimes from public water supplies. Public water supplies free from unusual impurities are the best source for drinking water during field operations. In combat, advantage must be taken of whatever water is available if it can be purified with the materials on hand. Whe[illegible]d situation permit, a wider search for a better s[illegible] may be made. In some locations, it may be necessary to use rainwater, seawater (which must be distilled for drinking), or melted ice or snow.

Individual water purification. When good sources of potable water are not available, you may produce potable

water by mixing water purification tablets (iodine) or calcium hypochlorite ampules and water in your canteen. Normally, one iodine tablet is used per canteen of clear water, and two iodine tablets per canteen of cloudy water. You must wait 20 minutes after purifying to drink this water. When using calcium hypochlorite ampules, you should take the following actions:

a. Put one ampule in a canteen of water. Leave a small airspace in the canteen and dissolve the ampule by shaking the canteen thoroughly.

b. Allow the water to stand at least 30 minutes before drinking.

Exercises (C14):

1. Number the following statements about water sanitation in sequence of most to least desirable by writing numbers in the spaces provided.

____ a. Using polluted water from a rain puddle in an open field.
____ b. Using certified water from a livestock drinking trough.
____ c. Using existing potable water supply.
____ d. Obtaining uncontaminated water from small, covered, ground sources.

2. Complete the following statements.
   a. Potable water can be produced by using __________ __________ or __________ __________
   b. To purify a quart of unclear water, you would use one ampule.
   c. Water purified with iodine is not considered potable until __________ __________ after mixing.
   d. One iodine tablet is used to purify __________ __________ of clear water.

C15. Given statements about food sanitation, select the true statements; if any statements are false, correct them.

Food Sanitation. Food, even the most appetizing, can cause illness if it has become contaminated with disease germs through improper handling or storage. Outbreaks of food poisoning, dysentery, and typhoid fever may result from unsanitary practices in kitchens and dining halls. Thus, persons who handle food must maintain the highest standards of personal hygiene and sanitation.

Stored food must be protected from the sun, heat, dust, insects, rodents, and any other agent that might cause contamination or the growth of disease germs. In operations where you are issued C-rations, you must be alert for signs of possible contamination. You must also prevent your food from being contaminated after you open it. Here are some very basic rules to prevent eating contaminated rations:

a. Look at the metal containers for signs of bulging or leaking. Do not eat the contents if these signs are present.

b. Wipe the top of the cans off with a clean cloth before you open them.

c. Use your own eating utensils, and keep them clean.

d. Do not open the metal containers and let them stand uneaten for long periods.

e. If an unusual odor or color is present after you open the can, do not eat the food.

f. Wash your hands before you eat.

Exercises (C15):

Indicate whether the following statements about food sanitation are true or false. Correct any false statements.

____ 1. Improper handling and storage of food can lead to unit-wide sickness.

____ 2. Canned and sealed food is not susceptible to contamination in storage.

____ 3. C-rations that have been opened and left standing for long periods are suitable for eating.

____ 4. Unclean eating utensils can also be a source of contamination of food.

____ 5. Food that is not within a reasonable range of its normal color or aroma should be thrown away.

C16. Associate given situations involving waste to the methods best suited for sanitary disposal.

In war or field conditions, all Air Force personnel are expected to know how to live in the field and how to maintain excellent health and mission efficiency. It is essential, therefore, that you understand the methods of constructing, maintaining, and using field sanitation devices, with emphasis upon the disposal of human and kitchen wastes.

Human Waste. Human waste can cause widespread dysentery and diarrhea among personnel if it is not properly managed. These diseases have cost our airmen more lost time from duty than any other disease. The common method of disposing of human waste in the field is to bury the waste in pit latrines or to burn the latrine contents. Three types of latrines are commonly used in the field: the oil drum latrine, the straddle trench latrine, and the deep pit latrine.

Oil drum. The oil drum latrine, similar to that shown in figure 2-4, is considered the ideal type of latrine for use by small USAF units in the field. To construct an oil drum latrine, you remove the top from a 55-gallon oil drum and fix a flyproof seat with a self-closing lid over the top of the drum. Where the water table is low and the area drains rapidly, the bottom of the drum may be perforated and the latrine set into a flyproof soakage pit. This latrine is intended for long time use; the contents are burned daily, and the resulting ashes are buried.

Straddle trench. The straddle trench latrine (see fig. 2-5) consists of a trench 1 foot wide, 2½ feet deep, and

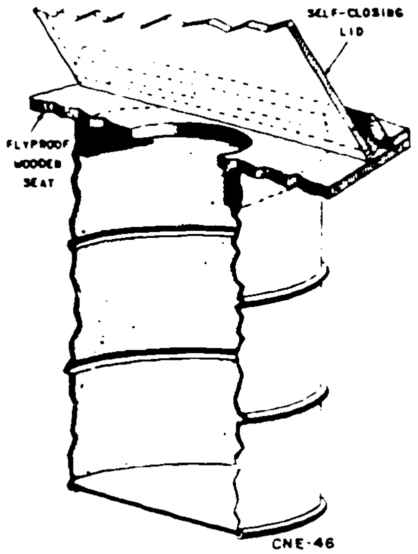


Figure 2–4. Oildrum latrine.

approximately 4 feet long. If available, boards should be placed alongside to provide secure footing. Toilet paper should be placed at the end of the pit and protected from the rain with a wooden covering or tin can. Earth removed from the trench should be piled at each end, and a paddle or shovel should be provided with which each person can immediately cover his excretion and the used toilet paper. This latrine is considered to be inadequate for other than temporary use. It must be closed when abandoned or when filled to within 1 foot of ground level. When this stage is reached, earth should be piled over the pit and tightly packed down. If the soil is sandy, it should be mixed with waste motor oil. The site should be marked with a sign reading "Closed Latrine (date)."

Deep pit. The deep pit latrine is intended for use with a standard latrine box. It is adequate when the water table is low. To construct, you dig a pit approximately 4-foot deep and fit the dimensions to the latrine box. The pit should be surrounded with drainage ditches to direct rainwater away from the latrine box. This type of field latrine is intended for use by large units (squadrons, groups, etc.) that remain in one location for relatively long periods of time. The closing provisions are the same as for the straddle trench.

Kitchen Waste (Garbage). Kitchen waste, if not properly disposed of, becomes the breeding ground for rodents and insects that transmit disease. Consequently, great emphasis must be placed on sanitary disposal of garbage when you are in the field.

There are two classifications of garbage: that which is suitable for animal food and that which is not. Burial is the best method of nonedible garbage disposal in the field where there are areas with low water tables. Incineration is best to dispose of nonedible garbage when units or more than 30 people plan to remain in one location for a period longer than 1 week.

Garbage pits and filled trenches should not be located within 100 yards of any source of drinking or cooking water.

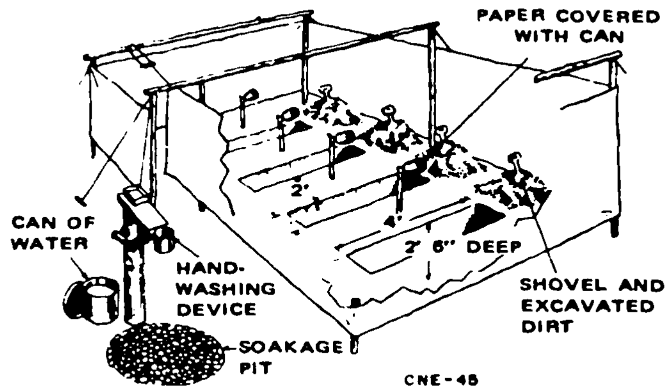


Figure 2–5. Straddle trench latrine.

They must be located within easy walking distance of kitchens and eating areas, in order to facilitate dumping of garbage. When filled and ready to be abandoned, garbage fills should be marked to indicate the date of closure with a sign reading "Closed Garbage Fill (date)."

What all this means to you is that during field operations you must use the established facilities to dispose of waste. If there are none established, make your own. To neglect personal sanitation or personal hygiene when you are in the field can be as fatal as standing up when you come under enemy fire. When you give pathogens a place to grow, it's only a matter of time until your body's defense system loses the battle.

Exercises (C16):

1. Match the column A statements about waste with the best method of disposal in column B by writing the column B items in the space provided. Column B items may be used once or not at all.

Column A	*Column B*
____ 1. Human waste of a deployed wing during a 20-day field deployment.	a. Burial.
____ 2. Nonedible garbage from a large unit planning to remain in one location.	b. Straddle trench latrine.
____ 3. Waste accumulated from cooking and eating during an overnight stop where there is a low-water table.	c. Deep pit latrine.
____ 4. Human waste from four personnel deployed to an off-base plane crash site for 25 days.	d. Incineration.
	e. Oil drum latrine.

2-4. Disease and Pestilence Countermeasures

Cleanliness of the body and clothing is the first line of defense against body parasites and pestilence. In certain situations, special measures must be used to control disease. We will discuss some of these measures.

C17. State how louse-borne diseases are transmitted and indicate the procedures for counteracting them.

Louse-borne Diseases. The louse-borne diseases are typhus fever and relapsing fever. Of these, epidemic typhus is the most important. Relapsing fever is usually present whenever typhus occurs; cases occurred among American troops in World War II, Korea, and Vietnam. These diseases, which are spread from man to man by lice, occur in epidemics. Since they are serious infections, they are a special threat to all personnel. A good vaccine against typhus is available, but none is yet available for relapsing fever.

Disease is seldom transmitted by the actual bite of a louse. The germs within the louse are passed out with the droppings. Louse bites itch and cause scratching, during which these droppings are rubbed into the skin abrasions. Scratching also may crush the louse and rub the germs into the wound.

The three species of lice which are of medical importance are the body louse, the head louse, and the crab louse. They live on human blood. If they are unable to feed, they will die in a relatively short time. In the higher temperatures, lice require more food and die even more quickly if they are deprived of it. Lice are spread by contact with infested persons or with things onto which adult lice or eggs have dropped, such as straw, debris, blankets, clothing, or latrine seats.

Preventive measures. In every military campaign, there are provisions to combat lice, especially body lice, that must be made in advance. Head and crab lice present individual problems, but from the standpoint of disease they are of no great importance. When troops are located in areas where the civilian population is lousy, they should use louse powder on their clothes routinely as a preventive measure. They should also be warned to stay away from the natives. In spite of precautionary measures, the troops may become infested, particularly if bathing facilities and changes of clothing are not available. Under such conditions frequent inspections must be made. Lice are not easy to find and may become quite numerous before they are noticed. Whenever a person's skin shows evidence of itching or of insect bites, he or she should carefully examine his or her clothing for lice, especially at the seams, where eggs and young lice are most likely to be found. When one infested person is found, all other personnel in that particular unit should also be examined.

Selecting delousing procedures. If the troops are found to be infested upon inspection of a unit, the entire unit should be dusted, using mass delousing procedures. In this case, assistance should be requested through command channels from a preventive medicine unit. If the troops are lousy, the infested individuals and the remaining troops in the unit should be required to dust themselves. Weekly inspections should be made by the medical officer to determine the effectiveness of the operation.

Insecticides for louse prevention. In 1951 the strain of lice in Korea was found to be resistant to louse powder; hence a substitute powder was made available. Louse powders are effective against all three forms of lice.

Individual Louse Control Procedure for Clothing. An individual can treat his or her own clothing for delousing or louse prevention purposes. If possible, the individual should take a bath before putting on the treated clothing. The clothing should be dusted as follows:

(1) Apply the powder inside of the hat.

(2) Spread the coat, with sleeves turned inside out, on a table so that all of the inside can be seen; then powder the inside, taking special care to apply the powder along the shoulder, armpit, and arm seams.

(3) Turn the trousers inside out and lay them with the seat uppermost on top of the coat; then powder all seams, particularly at the crotch and down both legs.

(4) Next, spread and powder the shirt in the same way as the coat.

(5) Turn the underwear inside out and powder it thoroughly, again giving special attention to the seams.

(6) Fold the entire pile of clothing together and pound it several times to fluff the powder.

(7) Before putting on each change of clean clothing, repeat the procedure. The shoes are not ordinarily powdered.

Individual Control Procedure for Head and Crab Lice. When an individual knows or suspects that he/she has become lousy, he/she doesn't have to wait on unit action. He/she can take the following steps.

(1) Using the insecticide powder, dust the head and hairy portions of the body.

(2) One week from the initial application, apply the powder again to kill lice which may have hatched in the meantime. Withhold bath and shampoo for one day after this dusting.

(3) Examine the head and hairy parts of the body closely to be sure that no living lice are present. If the hair is cut short, lice can be seen more easily; short hair is also easier to powder effectively. Delousing procedures for an individual are shown in figure 2-6.

Individual control procedure for extra clothing and bedding. Since body lice are most often found in the seams of clothing, particular attention must be given to the neck, armpits, waist, shirttail, and crotch of clothing.

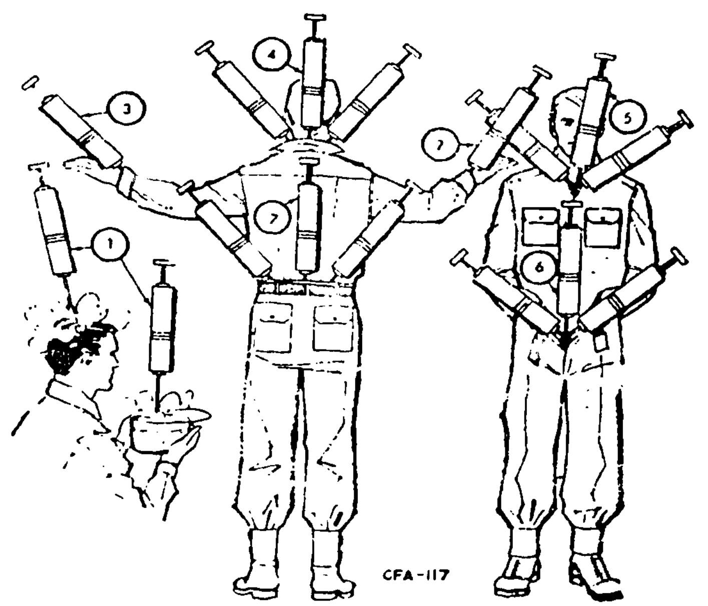


Figure 2-6. Delousing procedure.

Although 99 percent of all lice are found on a person's body or on the clothes he or she is wearing, extra clothing and bedding may be infested and cause reinfestations.

When delousing extra clothing and bedding, place the powder between the layers of clothing in order to speed the job and avoid wasting powder. If mattress covers are not in use, place a blanket over the mattress and apply the powder between the two items, taking care to reach the sides and seams. Blankets are deloused by spreading one on top of another and dusting between every two of them or by folding each blanket once and dusting between the two layers. The folded blanket may be placed on a flat surface, hung over a line, or held by two other persons.

When a duster is not available, apply the powder with a sifter can. As each blanket is spread, the powder is shaken onto it. The surface of one blanket will then spread the powder onto th[illegible]ace of the next. After a number of blankets have be[illegible]d, pound or fluff them lightly to distribute powder evenly. Canvas packs, dufflebags, boxes, footlockers, and similar items may also need dusting.

Exercises (C17):

Fill in the blanks to the following statements.

1. Disease is seldom transmitted by the actual __________ of the louse.
2. The three species of lice which are of medical importance are the __________ louse, the __________ louse, and the crab louse.
3. Since body lice are most often found in the __________ of clothing, particular attention must be given to the __________ , armpits, __________ , shirttail, and crotch of clothing.
4. When a duster is not available, apply the powder with a __________ can.

C18. Given statements regarding fly-borne diseases, identify each as either correct or incorrect.

Fly-Borne Diseases. Ho[illegible] flies are found all over the world, but they are m[illegible] [illegible]undant in warm climates. Houseflies, which comprise the majority of all flies found in messes, are the most important of the nonbiting species in the transmission of diseases.

The medical history of past wars indicates that the health of troops has been seriously affected by flies. They carry the germs which cause dysentery and may carry those which cause cholera, typhoid, and other diseases. In the tropics, various skin and eye diseases may be spread by flies.

Flies transmit disease organisms on the tiny hairs of their bodies and feet and in their feces and vomitus. they may bring the disease germs directly from manure, garbage, and human feces to food and water.

Characteristics. Flies have mouthparts which allow them only to sponge up their food. To dissolve solid food, they vomit some of their stomach contents onto the food and then sponge it up. By this method flies sample all manner of filth and waste matter and may easily swallow disease germs or pick them up on their feet and bodies. Knowledge of the following characteristics and habits of houseflies will serve as a useful guide to effective fly control.

a. Houseflies breed in manure, human waste, and decaying vegetable or other organic matter.

b. For growth, larvae or maggots require suitable food, moisture, and warmth.

c. Larvae move from the breeding material to a dried place to pupate.

d. Adult flies are attracted by food odors.

e. In the temperate areas of the world, flies are most abundant in late summer and early fall.

f. In warm climates, flies breed throughout the year.

Control. Flies may be controlled through proper sanitation, thus eliminating their breeding places; by the screening of living quarters; and by the use of chemicals to kill both adults and larvae. The elimination of breeding through proper sanitation is the most effective fly control measure.

Elimination of breeding [illegible] flies requires that all human waste, animal m[illegible] garbage be covered, disposed of, or treated p[illegible]d effectively.

All food-handling places should be properly screened to protect food against infestation by flies. The screens should be constructed of 18-mesh wire to bar mosquitoes as well as the flies. Food-handling places should also be equipped with self-closing doors which fit snuggly and open outward.

While the use of chemicals is an important aid to fly control, it should never be adopted as a substitute for sanitation. In places where sanitation is difficult, chemicals may be used to control fly breeding or to prevent new adults from leaving their breeding places.

Insecticide may be used to kill flies quickly. When correctly applied, it is very effective. Windows and doors should be closed before the insecticide is sprayed. Since some of the organic insecticides are highly toxic to humans, only approved formulations may be used.

Exercises (C18):

Place a C mark beside each correct statement, and an X beside each incorrect statement.

_____ 1. Houseflies are found all over the world.
_____ 2. Flies transmit disease organisms [illegible]n the tiny hairs on their bodies and feet.
_____ 3. Flies have teeth and chew th[illegible] [illegible]ood.
_____ 4. Proper sanitation is the most effective fly control measure.
_____ 5. Chemicals are a substitute for sanitation.

C19. Indicate whether given statements correctly reflect the procedures that effectively counteract flea-borne diseases.

Flea-borne Diseases. Fleas are medically important because they produce irritating bites and because they transmit diseases to man. The fleas which attack man live chiefly on cats, dogs, and rodents. When man lives and works in close association with these animals, conditions are ideal for the occurrence of flea-borne diseases. Although fleas have certain host preferences, they will transfer to and feed on different animals, including man.

Individual protective measures. Individual protective measures should be used in flea-infested areas. This is

especially important for those persons who perform flea and rodent control work where plague and typhus fever (murine) are present. Clothing, particularly the trouser leg, should be impregnated with approved insect repellent. The repellent should be applied to the boots, socks, and lower parts of the trouser legs. The sleeves should be kept rolled down, and the trouser legs should be tucked into the boots.

Control methods. Fleas are controlled by applying approved insecticides to the animal hosts and to the infested areas. Insecticide powder is applied to animals. Powder or liquid insecticide may be applied to the infested areas; however, powder is preferred for treating rodent burrows, as it can be distributed more thoroughly than a spray. All insecticides must be approved by medical personnel before using for any kind of pestilence control in the Air Force.

Except for cats, rabbits, and other animals which clean themselves by licking, powder is the insecticide ordinarily used to control fleas on animals. Merely dusting the animals, however, will not control the fleas, as flea eggs and larvae are in the debris about the areas where the animals rest. Unless these areas are properly treated, reinfestation will take place.

Treatment of infested areas. In the treatment of areas infested with fleas and flea larvae, such as rodent nests, burrows, runways, and places where other animals rest, insecticide is effective. It should be approved by medical personnel only. Should a plague epidemic occur, the operation to kill the fleas must always be accomplished before the rat-poisoning operations are started; otherwise, the fleas will leave the dead rodents and attack man.

When rats or other flea-infested animals enter buildings, the fleas may leave the host and infest the cracks and crevices in the floors. These fleas may deposit eggs that hatch into larvae, which continue to live and develop in the cracks and crevices of the floor. Good cleaning practices will do much to eliminate or prevent such infestations.

Rodent fleas are responsible for the transmission of plague and typhus fever (murine). Various rodents, principally rats and ground squirrels, are sources of infection from which fleas pick up the disease germs and transmit them to man. When the normal rodent hosts are unavailable, rodent fleas will readily attack man. Other fleas (chigoe or jigger fleas) attack the bare feet, usually between the toes and on the soles of the feet, where they cause painful swelling and inflammation.

Fleas become infected with plague germs when they feed on a rodent that has plague. Plague is then transmitted to human through the bite of the infected flea. People can also become infected with plague when they breathe the plague germs coughed out of the lungs of a person who has pneumonic plague. Typhus fever (murine) is transmitted when flea feces or crushed fleas are scratched into the skin. This may happen when a person scratches a fleabite.

Exercises (C19):

Place a T before each true statement and an F before each false statement.

____ 1. Flea-borne diseases are medically important because they produce irritating bites and because they transmit disease to man.

____ 2. Individual protection measures should not be used in flea-infested areas.

____ 3. Rodent fleas are responsible for the transmission of plaque and typhus fever.

____ 4. Fleas become infected with plague germs when they feed on rodents that have plague.

C20. State the procedures for effectively counteracting tick-borne and mite-borne diseases.

Tick- and Mite-Borne Diseases. Ticks and mites are commonly called insects. Technically, however, they belong to the class Arachnida; true insects belong to the class Insecta.

Ticks occur throughout the world but are less common in the arctic and subarctic zones. They are divided into two groups: the hard ticks and the soft ticks. The hard tick has a hard shield on its back (see fig. 2-7,A). The soft tick does not have a hard shield on its back, and it has a leather-like appearance (see fig. 2-7,B).

Tick control. Controlling vast areas of tick-infested land is a major operation done by either a preventive medicine unit or by other trained personnel. A certain degree of control can be maintained by clearing away brush and vegetation and keeping animals out of the area. Ticks in buildings can be controlled by spraying or dusting such insecticides as malathion, chlordane, or lindane on walls and in cracks and corners. These insecticides may also be used to spray or dust the vegetation and the ground in tick-infested areas. Effective control of ticks is greatly dependent upon knowledge of the species present.

Individual protective measures. Impregnating clothing with an insecticide clothing repellent gives excellent protection against ticks. Proper wearing of the uniform will also reduce tick bites. The bottoms of trousers should be tucked inside the boots without blousing rubbers. Blousing boots make it possible for ticks as well as mites to slip unharmed between the top of the boots and the treated cloth.

Removal of ticks. It may require some time for ticks to infect a person after they attach to his body. Persons in tick-infested areas should examine themselves and each other at least every 2 hours for the presence of ticks. This will often prevent the transmission of disease. In the removal of an imbedded tick, care must be taken not to crush it or to leave its mouthparts imbedded in the skin. A tick can be removed most effectively by using small forceps to grasp it as close to its mouthpart as possible and then carefully pulling it off. The tick should not be grasped by its abdomen, since disease germs may be injected into the person due to pressure in this area. After a tick is removed, the area where it had attached itself should be treated with a suitable antiseptic.

Mites. Mites are found throughout most of the world and in practically all climates. Many mites feed on plants, but some feed on humans and animal. Mites lay eggs which hatch into six-legged larval mites. Certain mites feed on humans and animal only in this larval stage; these are commonly called chiggers. Larval mites develop into nymphs; and these, in turn, develop into adult mites (see fig. 2-8). Both nymphs and adults have eight legs.

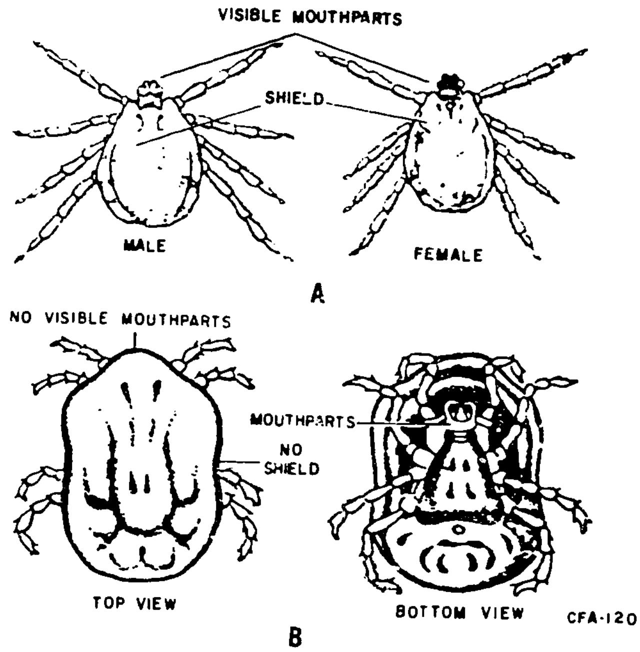


Figure 2–7. Hard ticks and soft ticks.

The scabies itch mite burrows and lives in the skin of humans, causing a condition called scabies, or the seven year itch. This condition is not fatal but may cause much discomfort due to intense itching, especially at night. Scabies is often found among people who do not or cannot practice good personal hygiene. Scabies mites are transferred from person to person by intimate personal contact.

In permanent or semi-permanent camps located in scrub-typhus areas, it is desirable to remove all surrounding growth with bulldozers, to burn the collected debris, and to place tents 2 or 3 feet off the ground. Application of insecticide to the ground in the camp area and in training areas will aid in mite control. Insecticides are effective. Control of rodents is also helpful in reducing the number of chiggers. Mite-infested areas should, if possible, be avoided.

If mite-infested areas cannot be avoided, the troops should apply individual protective measures as follows:

(1) All personnel operating in chigger-borne disease areas should wear clothing which has been impregnated with the prescribed insect repellent. All clothing except the underwear and the socks should be treated. Furthermore, blankets and sleeping bag covers should be treated whenever bivouac in mite-infested areas is planned. The impregnation instructions printed on the container should be followed.

(2) The uniform should be worn with the trouser legs tucked into the boots without blousing rubbers and with the sleeves and collar buttoned.

(3) The insecticide should be applied to the exposed skin and to all openings of the uniform, including the collar, shirt front, waistband, sleeve cuffs, and boot tops. And remember that the insecticide must be approved before use.

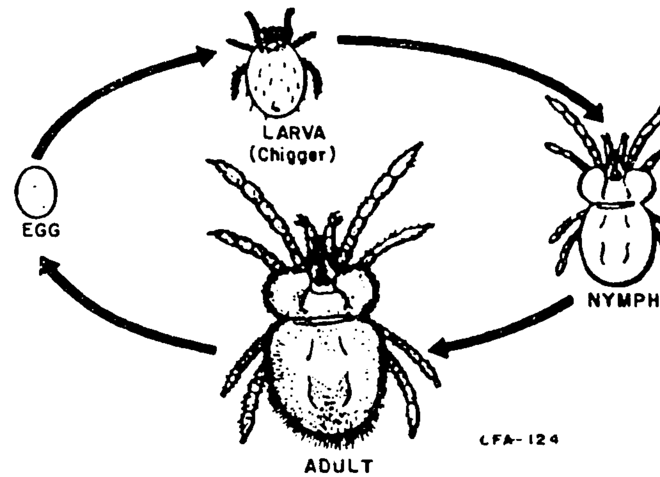


Figure 2–8. Life cycle of the mite.

Exercises (C20):

Fill in the blank spaces in the following statements.

1. Ticks and mites are commonly called __________ .
2. A certain degree of tick control can be maintained by clearing away __________ and __________ and keeping __________ out of the area.
3. In the removal of an imbedded tick, care must be taken not to __________ it or to leave its __________ imbedded in the skin.
4. Mites are found throughout most of the __________ in practically all __________ .
5. Scabies mites are transferred from __________ to person by intimate __________ contact.
6. Control of __________ is also helpful in reducing the number of chiggers.

C21. State countermeasures for controlling disease and pestilence.

Rodent-Borne Diseases. Rats contaminate and destroy food supplies, damage buildings, and cause fires by gnawing the insulation of electric wires and conduits. Rodents are carriers of several human diseases. Most of these diseases are transmitted through an insect vector, but with few exceptions they can also be transmitted by direct contact.

Plague. Plague ranks first in importance among rodent-borne diseases. It is found world-wide. Primarily a disease of rats and of other wild rodents, plague may be transmitted to man by the bite or the feces of [illegible] which has previously fed on an infected rodent. Control of plague is accomplished through the control of rodent fleas with the use of various insecticides.

Rocky Mountain Spotted Fever. Rodents and other animals are the natural reservoirs of this disease. It is transmitted to man by infected ticks.

Tularemia. This is a serious disease which may be contacted from the handling of infected rabbits or other rodents or from the bite of ticks or deerflies. It is widely distributed throughout the United States and has also been reported in Russia, Japan, Central Europe, Scandinavia, and Canada.

Salmonellosis. This is one form of food poisoning. Although the major sources of such poisoning are food handlers and poultry products, the germs may come from infected rats and mice. The germs may be transmitted to man by food which has been contaminated with rat feces and urine.

Trichinosis. This is a disease of rats and pigs. Man becomes infected through the consumption of infected pork which has not been cooked sufficiently. Pigs contract the disease by eating infected pork scraps in garbage and sometimes by eating infected rodent carcasses.

Control of Rodents. Rodents are nocturnal. They do not move about much during the day; they prefer the cover of darkness for food and water. They move in narrow runs along buildings, walls, pipes, and overhead beams. Rodents gnaw through materials to obtain food and harborage. Wood is not a barrier, as they have very sharp teeth which cut [illegible] They are spoilers. For example, they will [illegible] bite from many potatoes instead of eating one, sample every bag of flour, and eat from every piece of meat, thus contaminating all of them. These pests damage far more food than they eat.

Environmental control. The most effective rodent control is to prevent the infestation of rodents by making food and places for harborage inaccessible and by surveying the area regularly for signs of rodents. The commander should utilize the field sanitation team to maintain environmental control of rodents.

Food and harborage can be made inaccessible by ratproofing all buildings as well as the food storage areas inside buildings. Mess personnel should be required to store open packages of food in tightly covered metal containers. Furthermore, personnel should be required to store any personal food in tightly covered containers such as cake tins. All garbage and rubbish, which are food and harborage for rodents, should be removed.

Surveys for signs of rodents should be made by the field sanitation team regularly in order to detect the presence of rodents early. All airmen should be oriented to report observations of rodent signs. The following signs indicate not only the presence of rodents but also the type of rodents, the approximate number, and their location.

(1) Sounds. Rodents can be heard scurrying about at night or during the day when the part of the building which they inhabit is dark.

(2) Burrows in the ground. Burrows may be found inside a building with dirt floors, outside with the tunnel leading inside a building, around rubbish or woodpiles, and around stacks of supplies [illegible] side.

(3) [illegible] ntainers and walls. Rats gnaw [illegible] for food and harborage.

(4) Smudges along beams, pipes, or floors close to walls. Like most animals, rats create paths or runs in which they travel. A run has a smudgy, greasy appearance.

(5) Droppings. Rats drop pelletlike excreta along the runs or on the floor under the runs. This sign is very helpful in determining the extent to which rodents have infested the area.

(6) Dead rodents. In the absence of chemical and mechanical control measures, dead rodents may indicate the presence of plague.

Mechanical control. Mechanical control, which is achieved through the use of traps, is the method of choice in any area where food is handled or stored because of the hazards created in using a poisonous chemical around food. A large number of traps should be used because a catch of one rodent per ten traps is considered good. Various types of mechanical traps are available. The type used most frequently is the snap trap, which kills the rodent. Rodents ordinarily prefer foods that are prominent in the diet of people around whom they live. Good baits are oily foods such as bacon and peanut butter; cereals such as oatmeal and cream of wheat; and fresh fruits and vegetables such as apples, bananas, lettuce, and carrots.

Chemical control. Chemical control, which is achieved through the use of poisonous bait stations, may be the method of choice except in the areas where food is handled or stored. Unit personnel, including the field sanitation team, must never use poisonous bait in food areas. If this becomes necessary, the work should be performed by personnel who have had specialized training.

Disposal of dead rodents. All traps and bait stations must be checked early each morning for dead rodents. The dead rodents should be destroyed by the field sanitation team.

Up to now, we have covered just some of the diseases and pestilences that an airman may come in contact with during a contingency operation. But be assured that we have not covered all of them. We only gave you a general idea of what you may encounter in an operation.

Exercises (C21):

Fill in the blanks in the following statements.

1. Rodents are carriers of several __________ diseases.
2. Plague ranks first in importance among __________-__________ diseases.
3. The most effective rodent control is to prevent the __________ of rodents by making __________ and places __________ for rodents inaccessible.
4. Personnel should be required to store any personal food in tightly covered __________ .
5. __________ control is the method of choice in any area where food is handled.
6. All __________ and __________ stations must be checked early each morning for dead rodents.

C22. Given statements dealing with mosquito-borne diseases, identify each statement as either true or false.

Mosquito-Borne Diseases. Mosquitoes are found all over the world. In the tropics and subtropics they breed throughout the year; even in the subarctic regions they appear in great numbers during the brief summer months. Most of the disease-carrying mosquitoes are found in the milder climates and in the tropics. Different types of mosquitoes transmit different types of diseases.

There are many diseases transmitted by mosquitoes. Some of the more important ones are malaria, yellow fever, dengue fever, encephalitis, and filariasis. Of these diseases, malaria is the greatest threat to military operations. It is important to know that anti-mosquito measures are the major weapons against this group of diseases. Also available are excellent

drugs for the suppression and cure of malaria and an excellent vaccine for the prevention of yellow fever.

Malaria. Although the occurrence of malaria is rare in the United States, it commonly occurs in most tropical, subtropical, and semitropical areas of the world. Malaria is caused by a microscopic parasite. This parasite destroys the blood cells and causes chills, fever, weakness, and anemia. Unless the disease is treated promptly and properly, it may cause death from damage to the brain. The only sure way of preventing malaria is to avoid the bites of infected mosquitoes. When complete mosquito control is difficult or even impossible, such as during periods of active combat, the prevention of malaria is dependent upon the application of individual protective measures and the use of anti-malarial drugs as prescribed.

Yellow fever. Yellow fever is a viral disease now confined to tropical Africa and tropical America. Yellow fever is characterized by fever, headache, backache, jaundice, and internal bleeding. The most important preventive measures include the administration of a highly effective vaccine and the application of individual protective measures.

Dengue Fever. The term dengue refers to a group of viral diseases which are widespread throughout the tropical areas of the world. Often the only symptom is a mild fever, but there may also be severe muscular pain. No vaccine is available for this disease. The best means for avoiding dengue fever is the prevention of mosquito bites by using individual protective measures.

Encephalitis (sleeping sickness). There are many forms of encephalitis throughout the world. Often these diseases are named after the geographical area in which they are first identified. They are viral diseases which usually affect the central nervous system (brain and spinal column). Some of the viruses are thought to be transmitted from birds to humans by mosquitoes. No vaccines are available; thus, individual protective measures are essential in the prevention of this group of diseases. These mosquito-borne types of sleeping sickness are not to be confused with African or American trypanosomiasis which is also known as sleeping sickness.

Breeding. Mosquitoes will breed in practically any collection of water which stands longer than 5 to 7 days, (see fig. 2-9). Those breeding in and around human dwelling places are called domestic mosquitoes. Different kinds of mosquitoes vary in their choice of breeding places. Some like sunlit places; others prefer the shade. Some prefer fresh water to stagnant water; others prefer the brackish water of salt marshes. C[illegible] sites are pond[illegible] [illegible]amps an[illegible] ditches, rain barrels, road gutters, pit latrines, an[illegible] [illegible]avation sites.

Mosqui[illegible] [illegible]rol. The unit commander is responsible for mosquito control in the unit area. He or she should employ the field sanitation team to take unit control measures and to supervise the application of protective measures that the individual must take.

Air Force medical department. The medical department conducts surveys to determine control requirements, advises the commander of effective control measures for a particular area or situation, and prescribes the anti-malarial drug program. This department also assists in the training of the unit field sanitation team appointed by the commander and supervises or conducts, as required, control operations beyond the capabilities of the field sanitation team.

Control of breeding sites. Since all mosquitoes require water for breeding, the control of water sites is the most effective means of eliminating mosquitoes. The unit field sanitation team accomplishes this by (1) insuring the proper disposal of discarded containers and the elimination of any holes, ruts, or other low areas in which water can collect and stand, and (2) applying an insecticide to the waterholes which cannot be eliminated, at sufficient intervals to kill the mosquito larvae. Insecticides for the control of larvae may be applied in various formulations. Only a small quantity of the actual chemical ingredient is necessary to attain control. Any large bodies of standing water in which mosquitoes are breeding should be reported so that such control measures as ditching, draining, and filling may be accomplished by units with the required capabilities.

Control of adult mosquitoes. Adult mosquitoes, as well as other insects, are controlled by clearing away such mosquito resting places as tall grass, bushes, and vines; by space spraying with an insecticide; and by applying a residual insecticide to quarters or shelters, mess areas, and latrines. Adult mosquitoes are further controlled by the application of individual protective measures prescribed to protect troops against mosquito bites. The troops must be taught the proper application of the protective measures which they are to use individually.

Insecticides. A residual insecticide is one that is applied to surfaces from which insects may later get a toxic dose. A residual spray may remain toxic to certain insects for a few days to several months after application. A residual spray is applied to the interior surfaces of walls and ceilings where mosquitoes usually rest when not feeding. Under certain conditions, a residual spray is applied to shrubbery and other vegetation outside to form a protective barrier or zone between the breeding areas and human habitations. Insecticides are used and controlled by qualified medical personnel.

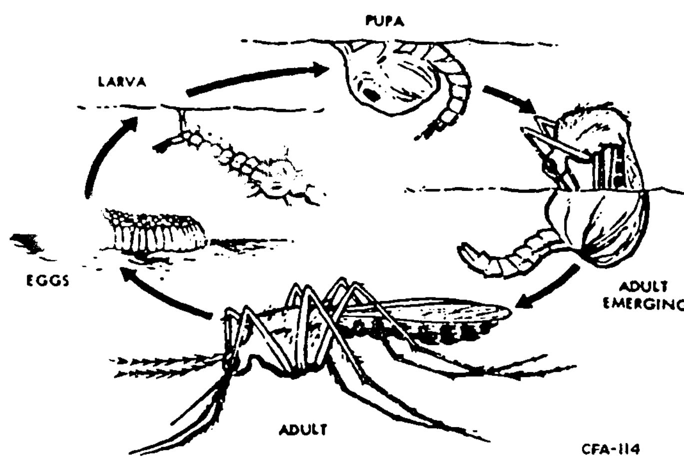


Figure 2-9. Life cycle of the mosquito.

Exercises (C22):

Place a T in the blank provided for each true statement and an X in the blank for each incorrect statement.

____ 1. Yellow fever is a viral disease.

____ 2. The only sure way of preventing malaria is to avoid the bites of infected mosquitoes.

____ 3. Vaccines are the only available protective measures for encephalitis.

____ 4. Mosquitoes will breed in practically any collection of damp sand which stands longer than five to seven days.

____ 5. The control of water sites is the most effective means of eliminating mosquitoes.

____ 6. Adult mosquitoes can be controlled by clearing away grass, bushes, and vines.

Work Party Security

THE RESPONSIBILITY for the defense of an air base rests with those security police specialists assigned to the base ground defense force. As you know, this force comes into being only as a result of hostile actions, as in case of general or limited war actions, or in some cases as the result of a terrorist group's attempt to attack and overcome the base security force. Regardless of the reason for activation, you undoubtedly will become an integral part of the defense force.

Before you can be an effective member of the ground defense force, you must possess and apply certain individual and group defensive skills. These skills can help you close with and capture or eliminate an enemy force. These same skills can also reduce the probability of your being detected by an enemy force. These skills are particularly valuable should the situation be such that you must remain undetected until a significant event occurs. Camouflage, movement, fire control, and field fortification are discussed in this chapter.

3-1. Camouflage Techniques

Camouflage is a French word meaning disguise; it is used to describe actions taken to mislead the enemy by misrepresenting the true identify of an installation, an activity, or an item of equipment. Camouflage, as an element of military deception, permits you to approach unseen and to remain hidden within striking distance of an enemy. It also affords protective concealment for a firing position, materiel, and personnel. Camouflage permits you to see without being seen, thereby enabling you to strike first and at minimum cost.

Although camouflage may be easily described, good camouflage is not easy to attain. Many factors must be considered and remembered. This section addresses the purpose of camouflage, describes the three methods of camouflage, and discusses how you can attain good camouflage for yourself, your equipment, and your position.

C23. Specify the purpose, methods, and factors of camouflage.

Camouflage Objectives. Of a human's five perceptive senses, sight is by far the most useful to the enemy; hearing is second; smell is of only occasional importance. The comparative usefulness of the perceptive senses is primarily a matter of range. For this reason, basic camouflage stresses visual concealment that is relatively long range and protects from direct or indirect observation.

Direct observation. Direct observation is the process whereby the observer looks directly at the object itself, with or without the use of telescopes, fieldglasses, or sniperscopes. Direct observation can be made from ground or air. Direct aerial observation becomes more and more important because of rapid changes in the tactical situation due to greater mobility of troops, weapons, and possible use of guided missiles by enemy forces. Reconnaissance airplanes over enemy lines report locations of troops, vehicles, and installations seen from the air to the ground control stations. Immediate fire can then be brought to bear on targets thus found and reported.

The principal advantage of direct observation is that the observer can readily see movement of troops or equipment in the observed area, and observation can be maintained over relatively long periods of time. The main disadvantage lies in human frailty—that is, the physical condition of the observer can affect his power of observation.

Indirect observation. Indirect observation is the use or study of a photograph or an image of the subject. Photography, radar, and television are examples of indirect observation. Indirect observation is becoming increasingly more varied and rapid, and it may be used from either manned or unmanned positions.

Indirect observation has many advantages: it can be far-reaching, cover large areas, and can be very accurate. It also produces a record of the area observed so that the recorded picture can be studied in detail, compared, to other pictures,and evaluated. The principal disadvantage is that a photograph rarely allows detection movement. However, this disadvantage can be overcome partially by taking pictures of the same area at different times and comparing them for changes.

Camouflage Methods. There are three basic ways of concealing yourself, your equipmment, and your activity. The following paragraphs describe what you must strive to achieve with each method.

Hiding. Hiding is the complete concealment of an object. You must master the act of hiding. You can do this easily if you remember the childhood game of hide-and-seek. Where did you always look first? In the most obvious location, of course. An enemy force will do the same when looking for your position.

Blending. Blending is the arrangement of camouflage materials on, over, and around an object so that it appears to be part of the background. The aim is to prevent detection of the object caused by a change in the natural appearance of the position. Because the works of man are usually geometric in

form, they present easily recognized outlines and rectangular shapes and shadows that are very unlike the average terrain features. Blending distinctive, man-made objects into the normal terrain pattern requires that you restore and simulate the normal and natural appearance of the terrain.

Deceiving. Deceiving simulates an object or situation, or disguises it so that it appears to be something else. Deception is intended to mislead an enemy into false identification of strengths, activity, or intentions.

Camouflage Requirements. For camouflage to be successful, three fundamental requirements must be observed; namely, choice of position, camouflage discipline, and camouflage construction. These requirements, and factors inherent in meeting these requirements, are presented in the following narrative.

Choice of position. When choosing a position to gain concealment, a background is chosen that visually absorbs the elements of the position (see fig. 3-1). The appearance of the background must be changed as little as possible by the presence of individuals, weapons, and equipment. Finally, the position selected must not hinder the accomplishment of the mission. With these factors foremost in mind, a natural position is located; that is, a position that can be used almost as it is, such as a natural cover. Isolated landmarks such as individual trees, haystacks, or a house should be avoided because they attract attention to themselves. At times, by making use of background, complete concealment against visual and photographic detection may be gained with no construction. In terrain where natural cover is plentiful, this is a simple task. By taking advantage of terrain irregularities, even though natural cover is scarce, you may gain complete concealment without added camouflage construction.

Camouflage discipline. Camouflage discipline is the avoidance of activity that changes the appearance of an area or reveals military objects to the enemy. A well-camouflaged position is only secure as long as it is well maintained.

a. Daytime. Concealment is worthless if obvious tracks point like directional arrows to the heart of the location or if signs of occupancy are permitted to appear in the vicinity. Tracks, spoil (leftover construction material), and debris are the most common signs of military activity that indicate cor[illegible]led objects. Therefore, existing tracks, paths, roads, or natural lines in the terrain should be used. Exposed routes should not end at a position, but rather, extend to another

Figure 3–1. Choice of position.

logical termination point. If practical, exposed tracks are camouflaged by brushing them out, by covering them with material, or, where time permits, by planting local vegetation. Spoil and debris are covered or placed to blend with the surrounding terrain. Smoke from fires must be controlled and dispersed.

b. Nighttime. Concealment at night is less necessary than in the daytime. Therefore, the enemy can use the cover of darkness to their advantage. They can do this much easier than they can in daylight if given clues to guide them. Camouflage discipline thus becomes doubly important at night. For example, aerial photos taken at night (by light furnished by flares dropped from planes) can pick up breaches of camouflage discipline that are more likely to occur at night than during the day. Consequently, light discipline is very important at night. Sound discipline is always important. Nosies seem magnified at night; clanking gear or snoring may prove fatal. Calling to one another and talking, even whispering, should be kept to a minimum. However, by far the most important phase of night discipline is light discipline. Necessary work lights must be shielded by using them inside an enclosure, such as a lightproof tent or bunker. Even on the darkest nights, your eyes grow accustomed to the lack of light in approximately 30 minutes. Every time a match is lit or a flashlight is used, your eyes must go through the complete process of getting adjusted to the darkness again. Smoking must also be prohibited at night in areas close to the enemy because the light is impossible to conceal. A cigarette light aggravates the situation by creating a reflection that completely illuminates your face.

c. Lessening sound. Sound can be lessened by precautionary measures. Loud orders, talking, calling, and sneezing must be avoided. Walking on hard surfaces should be avoided and full use should be made of soft ground for digging. Hand signals or signs should be used when possible. Individual equipment should be padded and fastened in such a manner as to prevent banging noises. Loading and unloading of vehicles must be accomplished in complete silence; every piece must be carefully lifted and gently set down; and straw, wood shavings, or other muffling agents should be used for packaging. It may even become necessary for you to disconnect vehicle horns and shut off engines. Remember, the noise of engines and tracked vehicles cannot be diminished while they are in movement.

Camouflage construction. Camouflage construction is used for a camouflaged position that requires additional concealment. Camouflage construction is the use of artificial and natural materials to help blend personnel and equipment with the surrounding terrain. Artificial materials are manmade; they and include such items as paint, wire, burlap, chicken wire, fiberglass, garnished nets of various types and sizes, and osnaburg (a cotton cloth more closely woven than burlap).

If artificial materials are used, they must be arranged to blend with the surrounding terrain and must be capable of withstanding local weather conditions. Seasonal changes may require gradual alternation in the color or kind of material used.

Exercises (C23):

1. What purpose is served by camouflage?

2. If you wanted to completely screen a position from enemy observation, which camouflage method should you use?

3. What camouflage method would lead an enemy observer to believe there were more people in a position than there actually were?

4. When using camouflage, what three requirements must be strictly adhered to?

5. What two elements of camouflage discipline are especially important at night?

C24. In given situations, determine what type of camouflage to use.

Individual Camouflage. Individual camouflage is the personal concealment you use to surprise or deceive an enemy. To achieve individual camouflage, you must remember the purpose of camouflage and decide upon the camouflage method to use. The following narrative presents important considerations in camouflage of the individual.

Uniform. Your utility uniform (fatigues) is designed to be as inconspicuous as possible. However, there are occasions when your uniform's appearance or color must be altered to help you blend with the terrain—for instance, for wear on a snow-covered mountain.

Skin tonedown. The contrast in tone between the skin of your face and hands and that of the surrounding foliage and other background must be reduced. Your skin must be made lighter or darker, as necessary, to blend with the surrounding natural tones. The issue facestick may be used whenever natural materials are not available. The facial shine areas are the forehead, cheekbones, nose, and chin; these areas should have a dark color. The shadow areas around your eyes, under your nose, and under your chin should have a light color, as shown in figure 3-2. Your hands, arms, and any other exposed areas of skin must also be toned down to blend with the surroundings. Burnt cork, charcoal, lampblack, and mud can all be used as toning materials. Because soils contain harmful bacteria, a medical officer should determine which soils are safe for use. A mesh mosquito face net, properly toned down, is an effective method of breaking up the outlines of your face and ears. Such a net can be dyed in strong coffee when manufactured dye is not available.

Helmet. The outline of your helmet is a striking characteristic of your equipment. Its curved shape is familiar to the enemy. One of the first steps in individual camouflage is to disrupt the shape of your helmet and thereby eliminate the strong, straight-lined shadow that it casts. The following ways of disrupting the shape of the helmet and reducing its shine or contrast can be used (see fig. 3-3). The choice of method depends on the tactical situation and time and materials available.

a. Paint. A disruptive paint pattern can be used on the helmet. Care must be taken to carry the pattern across the curved lines to the helmet edges, especially those seen from the front.

b. Bands. Rubberbands can be used as holders for garnish of natural materials. A band cut from a discarded inner tube makes a good substitute for the issue band, as do strips of cloth. Bands should not be placed too high on the helmet. When natural materials are not available or not advisable for garnish, the shape of your helmet can also be disrupted with bow ties made of burlap or osnaburg. They should be small enough so that they do not readily catch in bushes or branches and large enough to disrupt the form of the helmet.

c. Helmet covers. An improvised cover can be made for your helmet from a circular piece of osnaburg, burlap, or other coarse-weave cloth. Burlap is best; it helps to tone down the color of the helmet, disrupts its shape, and eliminates shine. The circular piece should be 20 inches in diameter. A 2-inch hem is sewn around the edge, a tape or drawstring is pulled through the hem, and the cover is pulled loosely onto the helmet. It should be painted or smeared with mud to break up the continuous tone. Slits must be cut in the cover to allow for the insertion of foliage. No matter what kind of helmet cover is used, it is incomplete if the shadow underneath the helmet is not broken up by arranging bits of foliage or other garnish so that pieces of it hang over the rim

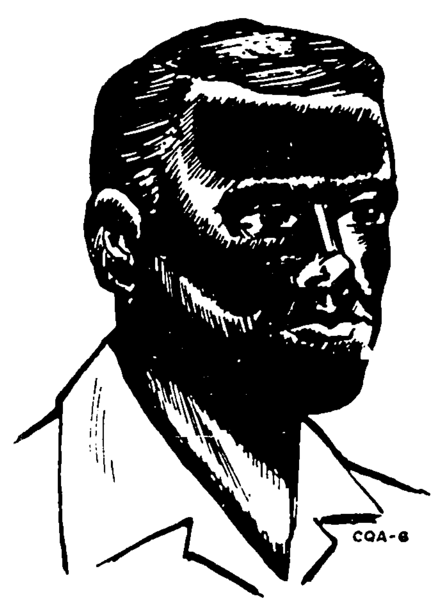
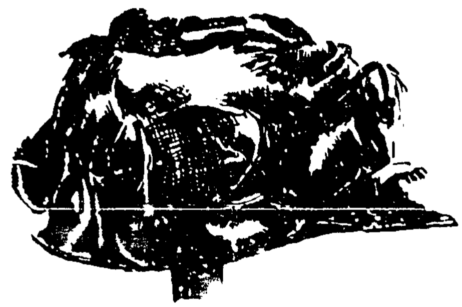
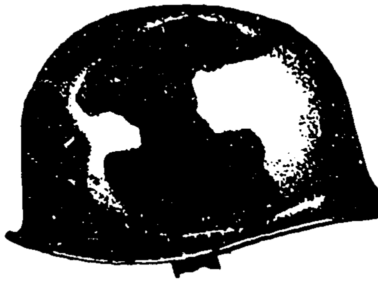


Figure 3-2. Skin tone down.



BOW TIE

NATURAL MATERIAL HELD IN PLACE BY RUBBER BAND.



CQA-5

DISRUPTIVE PAINTING

Figure 3–3. Helmet camouflage.

Figure 3–4. Silhouette.

of the helmet. Small irregular fringes of cloth, similarly arranged, can accomplish the same purpose and at the same time keep gnats and mosquitoes away from your face and neck.

Canvas gear. Clean canvas equipment is great for inspections, but in a combat situation such equipment violates the principles of camouflage. Patches of lighter or darker color are easily spotted. One of the first tasks in dressing for the job of fighting is to reduce the tone contrast between your equipment and the surroundings. This requires darkening your equipment in some instances and making it lighter in tone in others. Reducing tone contrast can be done with paint, cloth, mud, charcoal, or any other suitable substance that is available.

Silhouette. Although the airman shown in figure 3-4 blends with the ground, he is sharply silhouetted against the sky. Such clearly defined edges must be avoided. The correct way to look over the bank is from the midst of objects that are irregular in shape and that can conceal. In the illustration, the base of the tree would be a good location to reduce silhouette.

Action at night. As in the daytime, silhouette and background are vital elements in concealment. A silhouette is always black against a night sky. You must take care at night, as in the daytime, to stay away from the skyline (horizontal plane where sky and earth appear to join). On bright moonlit nights, you must use the same precautions as for daylight. You should also remember that the position of an enemy force, not the topographic crest of a hill, fixes the skyline. At night, sound seems amplified and is revealing. Thus, your movement must be careful, quiet, and close to the ground. On the other hand, should you hear the pop of a flare before it illuminates the area, drop to the ground and remain motionless. If you are surprised by the light from a flare, freeze in place, with your face pointed down toward the ground.

Position Camouflage. Proper site selection is the most important consideration in planning field fortifications. However, to serve in their fullest capacity, field fortifications and obstacles must be camouflaged in such a manner that they are a complete surprise to the enemy. The camouflage task is made easier by proper site selection.

Field fortifications are sited to take advantage of the terrain and, at the same time, permit camouflage that is vital for their security and stability. A position should be selected that does not require a change in the appearance of the terrain. Consideration of the camouflage aspect saves time and labor in effecting good concealment. To reduce ground observation, a position should be located with a good background so that occupants are not silhouetted. When proper advantage is taken of the terrain, positions can be inconspicuous from ground observation. To reduce the possibility of aerial observation, regular geometric layouts of positions must be avoided, and decoys and dummies should be used to confuse the enemy. Positions should be located under trees, under bushes, or in dark areas of the terrain, although your locations should not be isolated to the extent of being a landmark or an aiming point.

Postponing erection and construction of field fortifications is often the best way to camouflage a position. However, where the enemy has nuclear employment capabilities, the erection or construction must not be postponed.

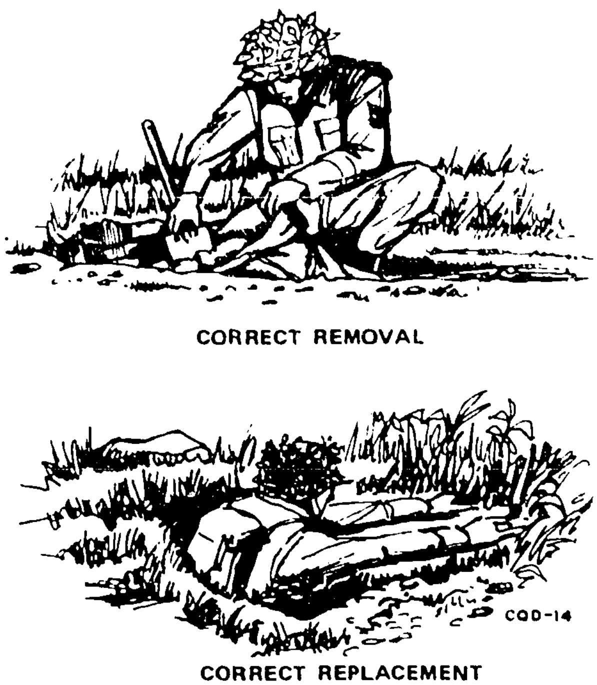


Figure 3–5. Concealing construction spoil.

Construction. Before any excavation is started, all natural materials for camouflage construction such as turf, sod, leaves, forest humus, or snow, must be removed. This material is placed or scraped aside so as to not interfere with the digging of the position. It is replaced over the site when the work is completed (see fig. 3-5). Soil (spoil) that is not used must be carried away and dumped in a concealed place, such as under bushes and low trees. Concealment is vital during camouflage construction. To prevent detection of camouflage construction that has little or no overhead cover, camouflage nets can be suspended above the position. The nets are placed so as to permit unhampered excavation work. Workers must then confine their activities to the area beneath the camouflage.

Covers. Camouflage covers are essential for positions that cannot be sited under natural concealment. They are also a valuable aid in preventing detection of the position. Natural materials native to the site must be used to a good advantage. Artificial or manufactured material may be used if garnished or pattern-painted to match terrain features. Covers made from these natural or artificial materials for hasty field fortifications should be light in weight to permit easy removal.

Weapon camouflage. Your individual weapon must be concealed to complete the camouflage of a position. Weapon outline and shiny surfaces are the two factors involved in concealment of the weapon by camouflage. An M–16 rifle, shotgun, machinegun, and recoilless and antitank weapons have distinctive outlines that are easily identifiable. Concealment of the weapon by digging it in to present a low silhouette and by using nets and natural cover are excellent methods. However, the tactical situation does not always permit sufficient time for these methods. One of the simplest ways to distort the outline of the weapon is to wrap it with standard burlap garnishing or strips of cloth (see fig. 3-6) dyed to match the surrounding terrain. Foliage placed on various parts of the weapon is another field expedient; however, this is difficult to maintain when the weapon is operational.

Painting. Pattern painting of a weapon (fig. 3-6), using colors that blend with terrain features, is another excellent method of camouflage used to distort the outline of the weapon. Any type of camouflage used must not interfere with the tactical effectiveness of the weapon.

Other methods. Shiny surfaces of a weapon can be concealed by various field expedients. For instance, cloth and paint, mentioned previously, not only distort outline but can also be used to cover the shiny surfaces of the weapon. Mud or lampblack can also be used to cover these surfaces. The mud used must dry to the desired color. Care must be exercised in application of mud to prevent interference with sighting and firing of the weapon.

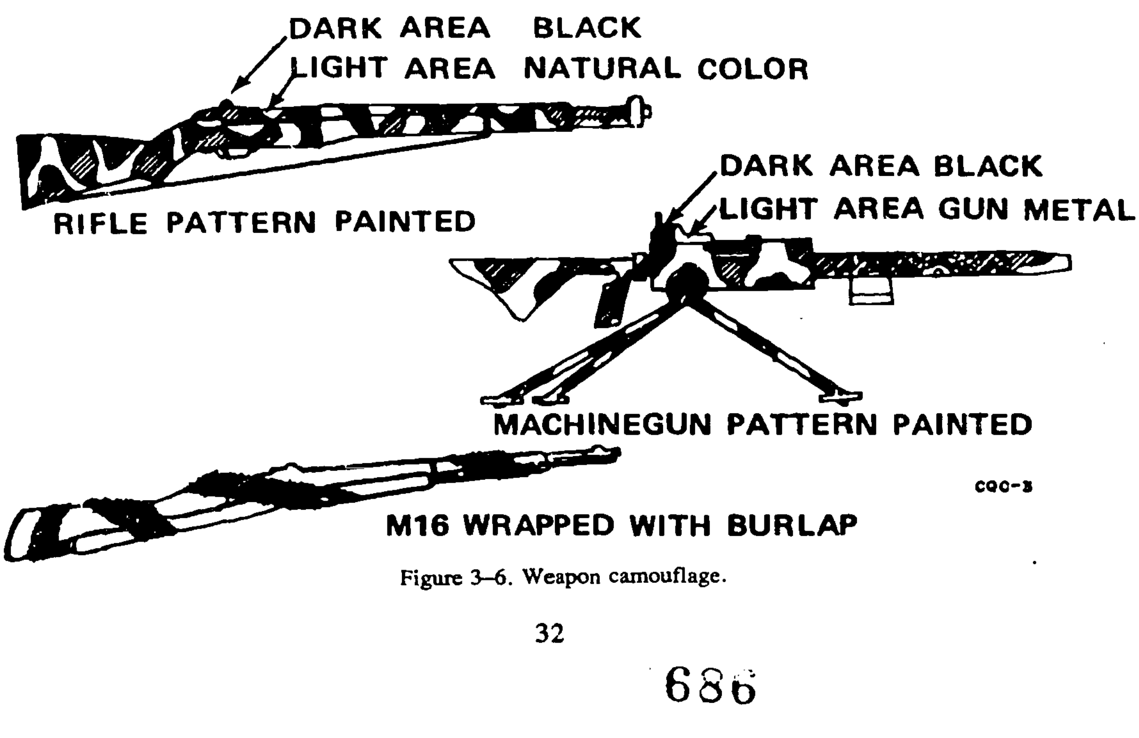


Figure 3–6. Weapon camouflage.

Camouflage of other equipment. In a hostile situation, your ability to camouflage yourself and your personal equipment (fig. 3-7) may be excellent. However, even if these efforts are completely successful, their effect can be nullified. This happens when you forget to camouflage other support equipment; for example, vehicles, cooking areas, and sleeping areas. Generally, you do not bear the responsibility for these actions. However, guess who gets smoked when an enemy force has detected your position because of the sunlight shining on a vehicle window? You must do something to prevent this from happening. The same rules apply to camouflaging support equipment that apply to your personal camouflage. Every item in the vicinity of your area must be camouflaged. You can cover equipment with natural or manmade camouflage. The point is that you should cover it, alter the geometrical shape, reduce or eliminate shine, or do whatever else is needed to conceal the equipment.

Exercises (C24):

1. What are some common materials used for skin tone-down?

2. List three ways of disrupting the shape of a helmet and reducing its shine.

3. What fixes the skyline (as opposed to the topographic crest of a hill?

4. How is detection of camouflage construction prevented when there is no overhead cover?

C25. Determine whether cover or concealment is best suited to given circumstances.

Cover. Cover is protection from the fire of enemy weapons. It may be natural or artificial. Natural cover (ravines, hollows, reverse slopes) and artificial cover (foxholes, trenches, walls) protect you from flat trajectory fire and partially protect you from high-angle fire. Even the smallest depression or fold in the ground may provide some cover when you need it badly. As a member of a ground defense force, you should learn how to take advantage of every bit of cover available. You need to do this to achieve maximum protection from enemy fire. In a combat situation, you must learn to select temporary firing or observation positions that take advantage of available cover. Observing and firing around the side of an object, staying low to observe and fire, and selecting a good background when observing over the top of an object are examples of using cover to your advantage (see fig. 3-8).

Figure 3-7. Proper camouflage.

Concealment. Similar to camouflage, concealment is protection from enemy observation. It, too, may be natural (bushes, grass, shadows) or artificial (burlap, nets, camouflage made from natural materials). Concealment is not protection from enemy fire. Do not make the mistake of believing you are protected from enemy fire merely because you are concealed from enemy eyes. To conceal yourself:

a. Avoid unnecessary movement; movement attracts attention. Remember that movement against a stationary background causes you to clearly stand out.

b. Use all available concealment. Background is important; blend with it to prevent the enemy from detecting you. Select trees and bushes that blend with your uniform and absorb the outline of your figure. Shadows also help hide you.

c. Stay low to observe. Present a low silhouette, making it difficult for the enemy to see you.

d. Expose nothing that shines. Reflection of light on a shiny surface instantly attracts attention and can be seen for great distances.

e. Keep off the skyline. Figures on the skyline can be seen from a great distance, even at night, because a dark outline stands out against the lighter sky. The silhouette formed by your body makes a good target.

Exercises (C25):

1. As a member of a response force, you have been ordered to flank an enemy unit attempting to penetrate a restricted area. En route to the scene, you come under fire from a second force no one had reported. Do you use cover or concealment?

2. For the situation in exercise 1 above, what action may have precluded your coming under fire?

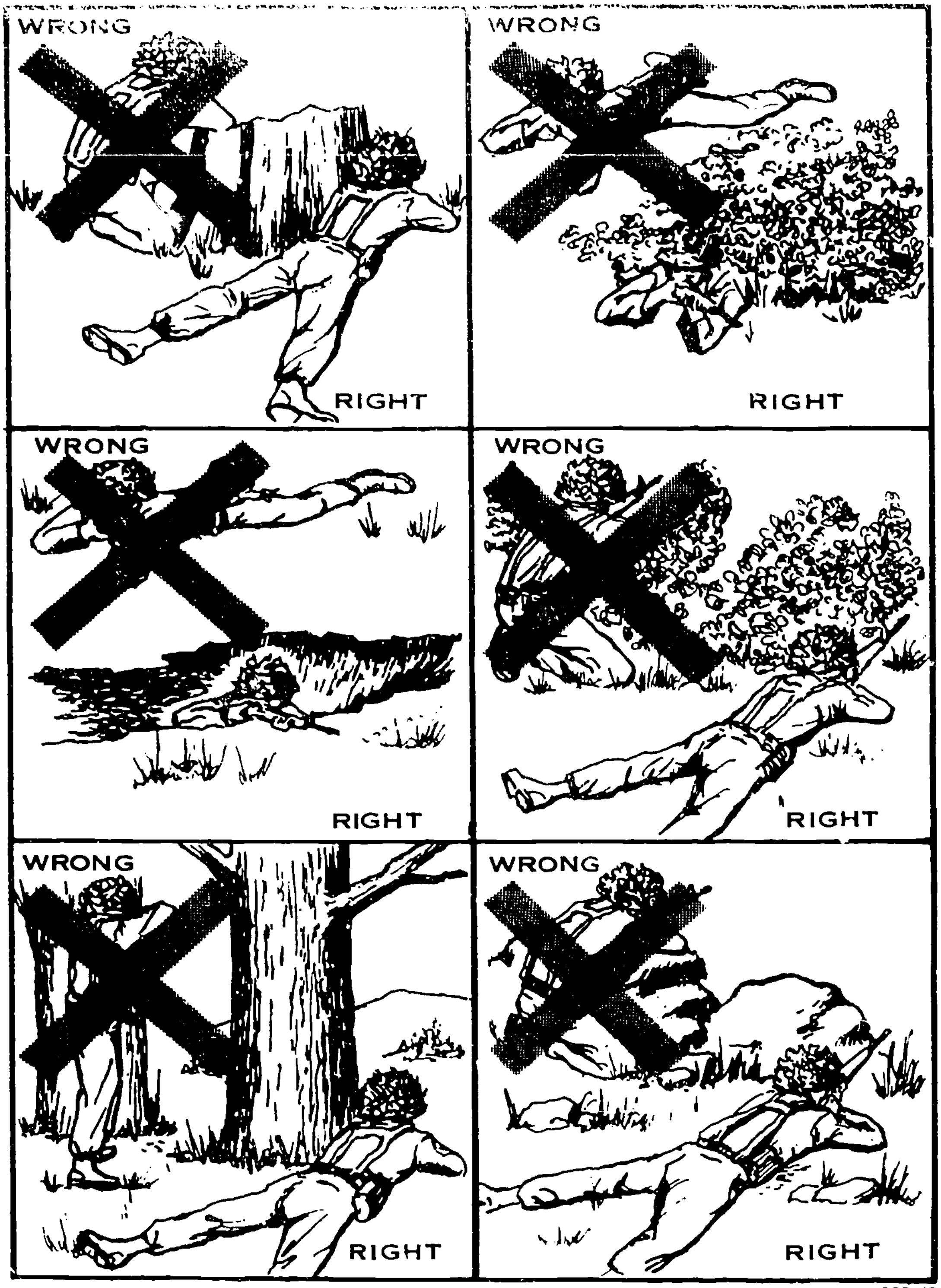


Figure 3–8. Use of cover and concealment.

3. As a member of a response force, you have been alerted to a possible armed attack and have been positioned in an area between your base's resources and its perimeter. Should you use cover or concealment to await the arrival of the reported enemy force?

3-2. Individual and Force Movement

Being camouflaged and standing still doesn't always get the job done. As you know, movement is necessary, but you must know how to protect yourself when you move.

C26. Specify the methods of individual movement used by a response force member.

Individual Movement. There are several ways of getting from one place to another when you deploy. Depending on the situation, you may decide to use one or more of the following methods.

Rushing. This is a technique for moving quickly from one place to another. You start either from a place of cover or the prone position. You then select the next spot that you want to move to. This new spot should offer you cover or, as a minimum, concealment from observation. To rush to your selected location, you get up quickly, run to the new location, and take cover. While moving, you should be sure to keep alert for enemy fire and for obstacles. You should rush in short bursts, a maximum of 15 meters. Don't try to cover great distances in one rush.

Low crawl. When you must move in on an enemy and there is little or no cover or concealment available, you must use the low crawl. To low crawl, you get into the prone position, lay the stock of your weapon on top of your arm, lay your head as close to the ground as you can, and pull and push yourself along the ground. (see fig. 3-9.)

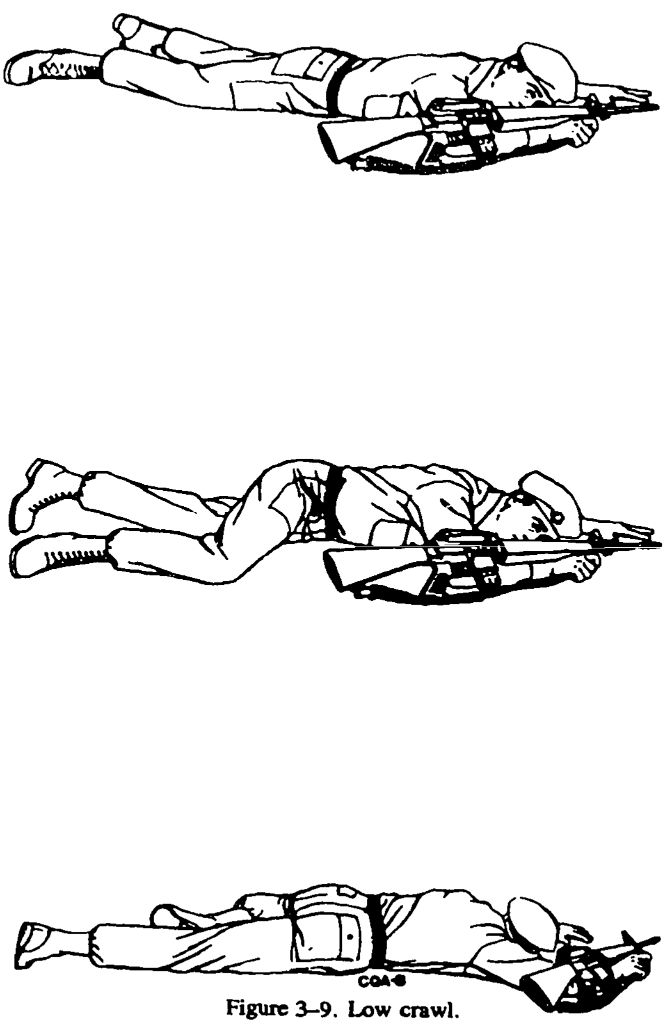


Figure 3–9. Low crawl.

High crawl. The high crawl shown in figure 3-10 is used when some cover and/or concealment is available. To high crawl, you lay your rifle across your arms in front of your body (prone position), and you push and pull yourself along. Your head should be slightly raised so that you can watch things ahead of you.

Walking at night. The darkness of night offers you some concealment. You can effectively walk at night without being detected by lifting your legs high and stepping down carefully on your toes, as illustrated in figure 3-11.

Stealth. Whenever you are moving, be it day or night, move as quietly and as inconspicuously as possible. When rushing or walking, avoid having loose equipment that bangs against your body; when crawling, don't drag your weapon on the ground or pavement. Silence is necessary to coneal your movement.

Exercises (C26):

1. What is the rushing technique of movement?

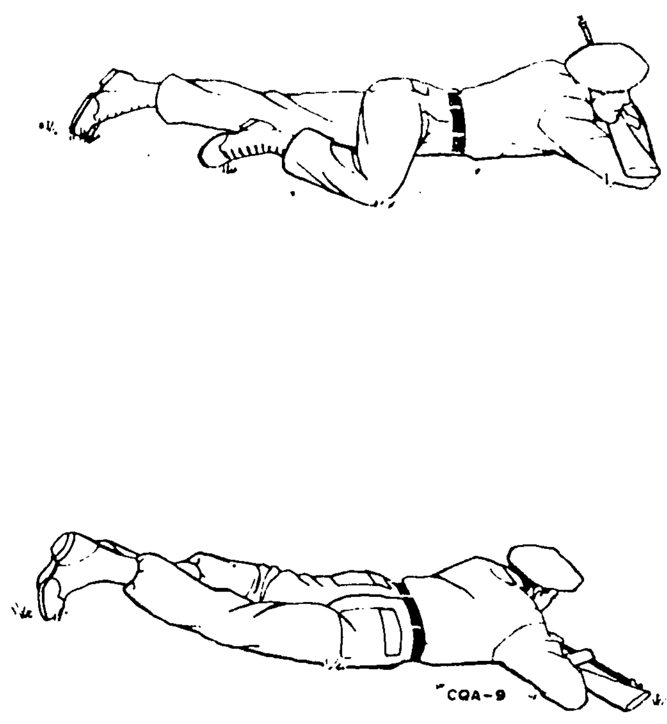


Figure 3–10. High crawl.

Figure 3–11. Walking at night.

2. What are the low and high crawls?

3. What is the best method of walking at night?

C27. Differentiate between the techniques of fire and movement for individuals and for fire teams.

Fire and Movement. Fire and movement is a tactic used for advancing a unit while it is under enemy gunfire. You do this by having a part of your force moving forward while the remainder of the force delivers covering fire to the enemy position.

The number of people who are moving and the manner in which they move depends on the size of your unit, the terrain, and the volume of fire being received.

Individual. Individual movement is usually the safest way for your people to advance under heavy fire. When moving as an individual member, you rush 10 to 15 meters forward to a point of cover. Trying to travel any further than this allows an enemy enough time to take aim with a weapon. After you take cover, you begin to deliver cover fire and another member of the unit begins to move. This leapfrog procedure goes on until all of your unit has reached the desired objective.

Team. The tactic of movement by fire team is similar to the procedure for individual movement. In the team situation, you have a portion of the unit move forward while the remainder of the squad or flight delivers cover fire. You use this type of movement when enemy fire is light. You may start out in individual movement and, as enemy fire decreases, convert to fire team movement.

Exercises (C27):

1. State the techniques of fire and movement.

2. What is the difference between individual and team fire and movement techniques?

C28. Identify the responsibilities of the base-of-fire and maneuver echelons during fire and maneuver.

Fire and Maneuver. Fire and maneuver is a combat tactic in which a squad or flight is divided a maneuver echelon and a base-of-fire echelon. The following narrative illustrates the use of the fire and maneuver tactic.

Let us assume that a hostile armed unit has taken up a position on your base. From this position, the hostile unit directs weapons fire on a number of alert aircraft. In this instance, your task as a member of a defense squad or flight would be to move to the hostile position and neutralize it as soon as possible. In order to do this, your unit would most likely use the fire and maneuver tactic. It is used to permit a portion of your squad or flight (called the maneuver echelon) to get close enough to the hostile force to conduct an assault.

To use fire and maneuver techniques, you divide the squad or flight into a maneuver echelon to advance on the hostile position and a base-of-fire echelon to deliver cover fire for the maneuver echelon. The division of the unit does not have to be equal. For instance, suppose that you find that you need a tremendous volume of fire from your base-of-fire echelon but require only a small maneuver echelon. In this case, you might assign two fire teams as the maneuver echelon and the remainder of the flight as your base-of-fire echelon. Your determination must depend on the situation. It is best to divide your unit so that you do not disrupt the integrity of its elements.

The maneuver echelon moves out under the base-of-fire echelon's cover fire. Depending on the conditions and situation, the maneuver echelon moves by crawling or rushing to a point called the final coordination line, such as that shown in figure 3-12. This point should be as near the enemy position as you can get without being dangerously exposed to friendly gunfire. The base-of-fire echelon may advance its position toward the enemy, providing there is no loss of cover fire.

Often, when long distances must be covered, the maneuver echelon moves to a point midway between its point of departure and the final coordination line and lays down cover fire while the base-of-fire echelon moves forward. This allows the base-of-fire echelon to engage the target area more effectively, whereupon the maneuver echelon resumes their advance toward the final coordination line.

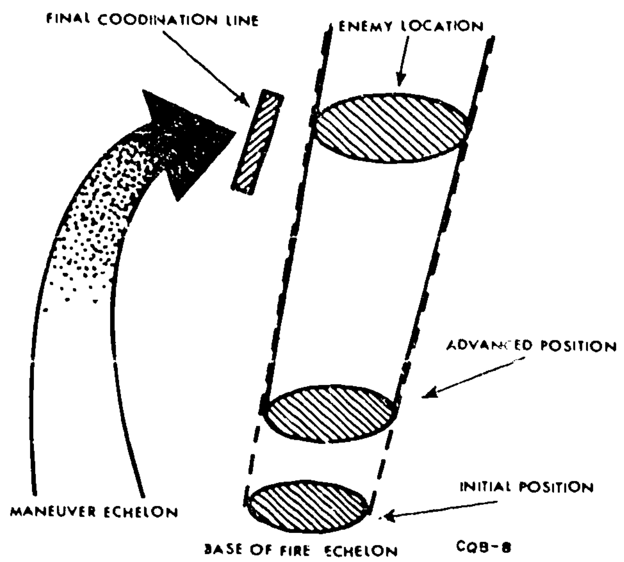


Figure 3–12. Fire and maneuver.

Exercises (C28):

1. What are the responsibilities of the maneuver echelon during fire and maneuver?

2. What are the responsibilities of the base-of-fire echelon during fire and maneuver?

C29. State the mission of each type of reconnaissance patrol, and identify features of each type.

Reconnaissance Patrols. The overall mission of all types of recon patrols is to gather intelligence information and to confirm or disprove the accuracy of previous information. There are three types of reconnaissance patrols, namely: area surveillance, area reconnaissance, and point reconnaissance. Each type has a specific intelligence-gathering function.

Area Surveillance. Your mission on an area surveillance patrol is to observe a large area, such as the area depicted by a grid square on your map, and locate enemy activity. You mark down enemy locations, places where you observe enemy movement, direction of enemy travel, and especially any changes such as new roads, and built-up areas that are not on your map. Area surveillance patrols provide us with the big picture.

Area Reconnaissance. Your mission on an area recon patrol is to move through an assigned area and locate specific enemy positions. You also confirm data reported by area surveillance patrols. There are many methods of conducting area recon patrols. Figure 3-13 illustrates these methods. Your imagination can produce other methods to use.

Point Reconnaissance. When you go on a point recon patrol, you go to observe one point: a fork in a road or stream, an enemy position, or any point your commander wants to know more about. The time you spend observing a given point is predetermined by your commander; it could be as brief as 15 minutes or as long as several days. Figure 3 14 represents several methods of point reconnaissance.

Exercises (C29):

1. What is the mission of:
   a. Area surveillance patrols?

   b. Area reconnaissance patrols?

   c. Point reconnaissance patrols?

2. Match the descriptions in column A with the types of reconnaissance patrols in column B by entering the column B letters in the spaces provided. If the description does not fit a type of reconnaissance patrol, enter 0 (zero).

Column A	*Column B*
____ (1) Locating enemy positions while moving from one place to another.	a. Point reconnaissance.
____ (2) Provides coverage of your route.	b. Area reconnaissance.
____ (3) Four-man teams observing movement in a valley.	c. Area surveillance.
____ (4) A patrol to deny the enemy control of an area.	
____ (5) A two-man team watching a road junction.	

C30. State the mission of each type of combat patrol, and identify features of each.

Combat Patrols. All combat patrols serve basically the same purpose: seek out and destroy, capture, or harass the enemy. They may provide security. They also collect and report information related and unrelated to their mission. There are five types of combat patrols, and each type has a specific goal.

Ambush patrols. Ambush patrols wait in hiding to attack and destroy a moving or temporarily halted target, such as a column of troops or vehicles. There are as many types of ambushes as there are imaginations. Figure 3-15 illustrates only a few of the many forms of ambush.

Raid patrols. When you go on a raid, your mission is to attack and destroy an enemy position and then withdraw. You want to hit the enemy where it hurts and then move on to strike again. Your force is not large enough to hold the position you raid, only strong enough to cause damage, and reduce or eliminate the position.

Search and clear patrols. The mission of a search and clear patrol is to move into an area, destroy the enemy or run them out, and hold that territory for our own use or for use by friendly forces.

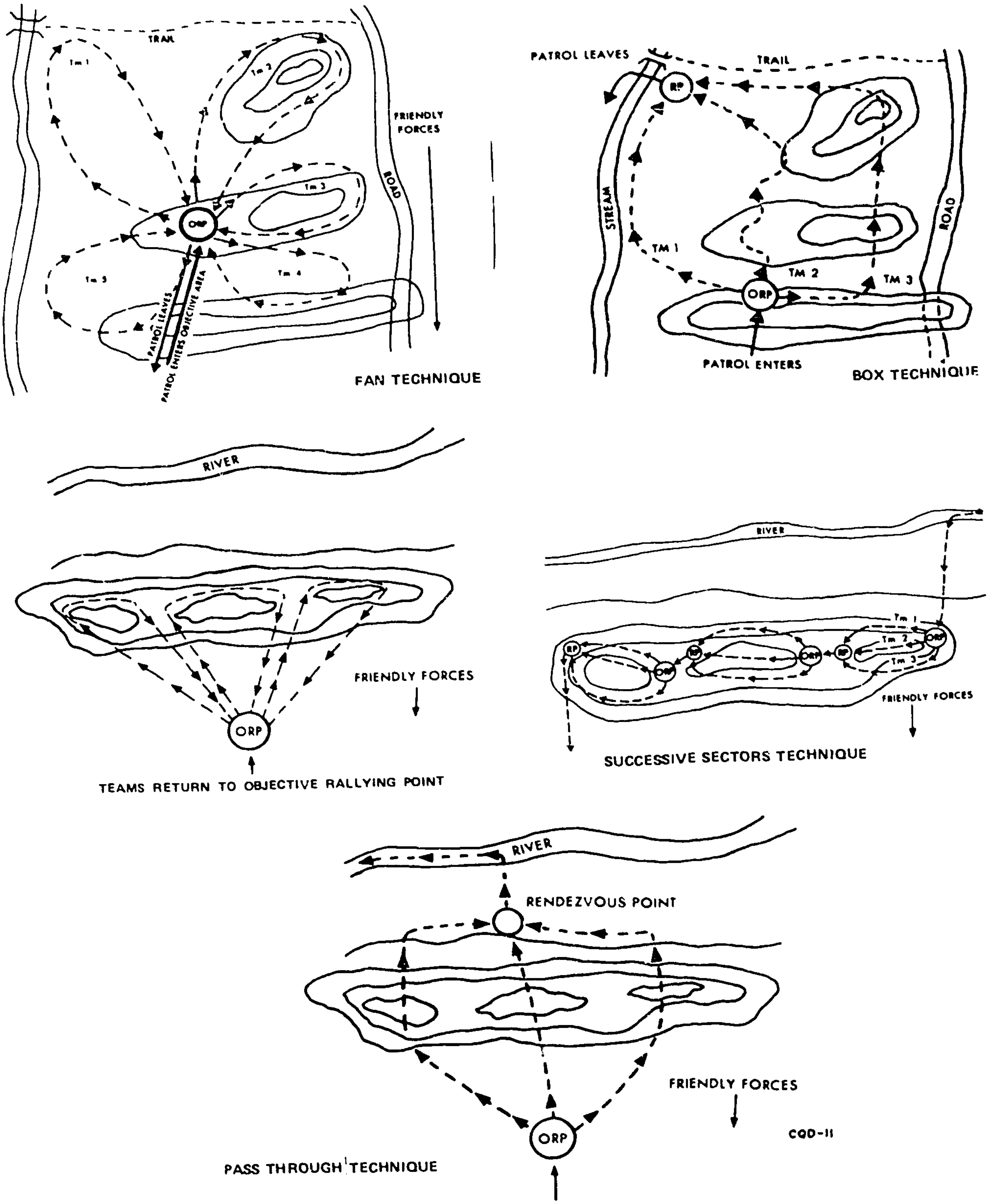


Figure 3–13. Area reconnaissance.

Security patrols. These patrols are designed to screen or cover the flanks of your position, area, or route. These screens prevent infiltration and surprise attack. During movements, security patrols prevent ambushes along the way.

Economy of force patrols. Your mission on an economy of force patrol may be to establish a roadblock that prevents enemy movement or reinforcement, seize key terrain to prevent enemy use, cover the withdrawal of a force by deception or delay, or act as a blocking force to allow a major effort to be made without interference at another location.

Exercises (C30):

1. What is the mission of:
   a. Ambush patrols?

   b. Raid patrols?

   c. Search and clear patrols?

   d. Security patrols?

   e. Economy of force patrols?

2. Match the descriptions in column A with the types of combat patrols in column B by entering the column B letters in the spaces provided. If the description does not fit a type of combat patrol, enter 0.

Column A	*Column B*
____ (1) Provides coverage for your route.	a. Ambush patrol.
____ (2) Surprise attack.	b. Raid patrol.
____ (3) Four-man team observing movement in a valley.	c. Search and clear patrol.
____ (4) Hit-and-run destruction of an enemy target.	d. Security patrol.
____ (5) A patrol to deny the enemy control of an area.	e. Economy of force patrol.
____ (6) Running an enemy out of an area for our own gain.	

3-3. Weapons Fire Control

Because our operations in a combat environment are generally defensive and our resources are often so inviting to an enemy, we sometimes seem to get more than our fair share of attack by hostile units.

No matter how strong your defense is, if the enemy wants your resources badly enough, they will try to get them. When this happens, your job can become a little bit hectic: you must block the attack before it gets to your resources and then counterattack to destroy the enemy. In this section, we discuss the principles of planning and conducting a counterattack against an attacking hostile force.

C31. Briefly define preparation, fire and manueuver, and assault as they relate to conducting a counterattack.

Preparation. The first step in conducting a counterattack is preparation. You can't just grab a rifle, yell, "Follow me, men," and charge a defended position. Those people in the position have real guns, with real bullets, and lack of preparation could be disastrous.

Plan. The enemy have a plan. If they didn't, they wouldn't be on your base holding one of your positions. And if they didn't want to fight, they wouldn't have come. Consequently, you must plan your actions carefully.

First of all, remember a basic rule of combat: meet force with superior force. To do this, you need to get a reliable estimate of (1) how many people you are facing, (2) how they are armed, and (3) how well protected they are. From this information, you can decide the size of the force you need, how to arm them, and what, if any, support you want to ask for. This support may range from artillery fire to the use of air-to-ground attack by combat aircraft. If that sounds a little heavy, remember that you are the one who has to peek into that position and hope that nobody is peeking back over a gunsight.

Next, plan your step-by-step actions through the point where you are again occupying the position. This planning includes two phases: (1) a fire and maneuver operation to get your assault force into the desired position and (2) the actual assault itself.

Assembly. To begin planning the fire and maneuver phase, you select an assembly area. This must be a safe area where final orders can be issued, final supply issue accomplished, and final planning conducted.

Route. Your next step is to carefully plan a route of travel that makes maximum use of all available cover, concealment, and supporting fire. Whenever possible, select a route that allows you to assault the enemy's flank or rear.

Departure Line. Next, you select a line of departure. This is a recognizable physical location that provides cover and that can be safely reached by the assault force (maneuver echelon). If a blocking force has not already established a position for your base-of-fire echelon, you also select that position.

Final Coordination Line. Now select your final coordination line. You must insure that everyone in the maneuver and base-of-fire echelons knows where this point is and knows the time when you plan to begin the actual assault.

Assault. The next step is to plan the assault. Now you must assig specific target areas to each member to avoid bunching your people toward the center of the enemy position. You designate one person as base, and instruct everyone else to stay abreast of the base and guide left or right with him in order to maintain proper spacing. You can then control the entire assault formation by adjusting the speed or direction of the base man. For large-scale operations, you may designate a base team or squad. Finally, you select a limit of advance. This is the point where your assault echelon stops after moving through the objective.

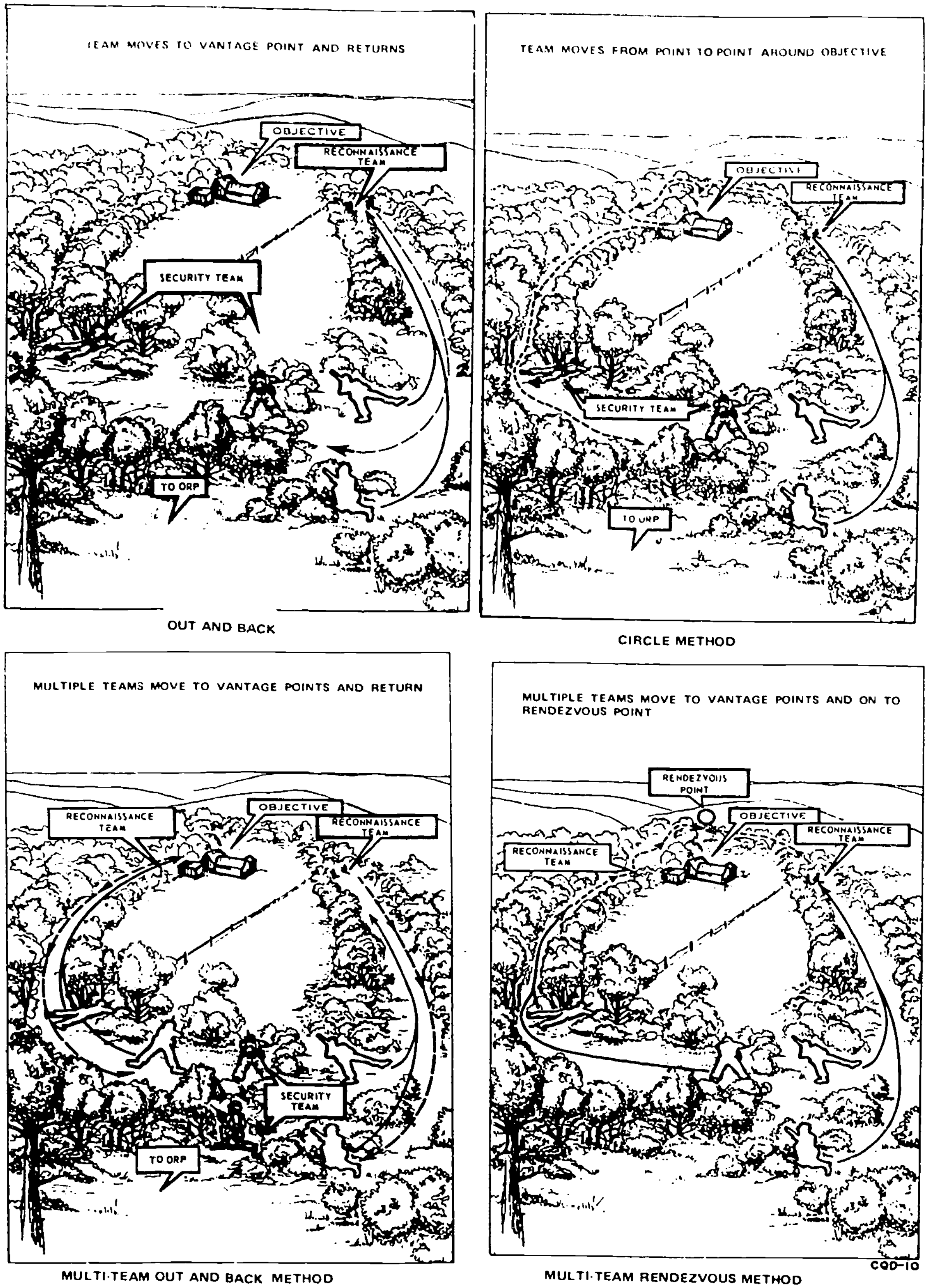


Figure 3–14. Point reconnaissance.

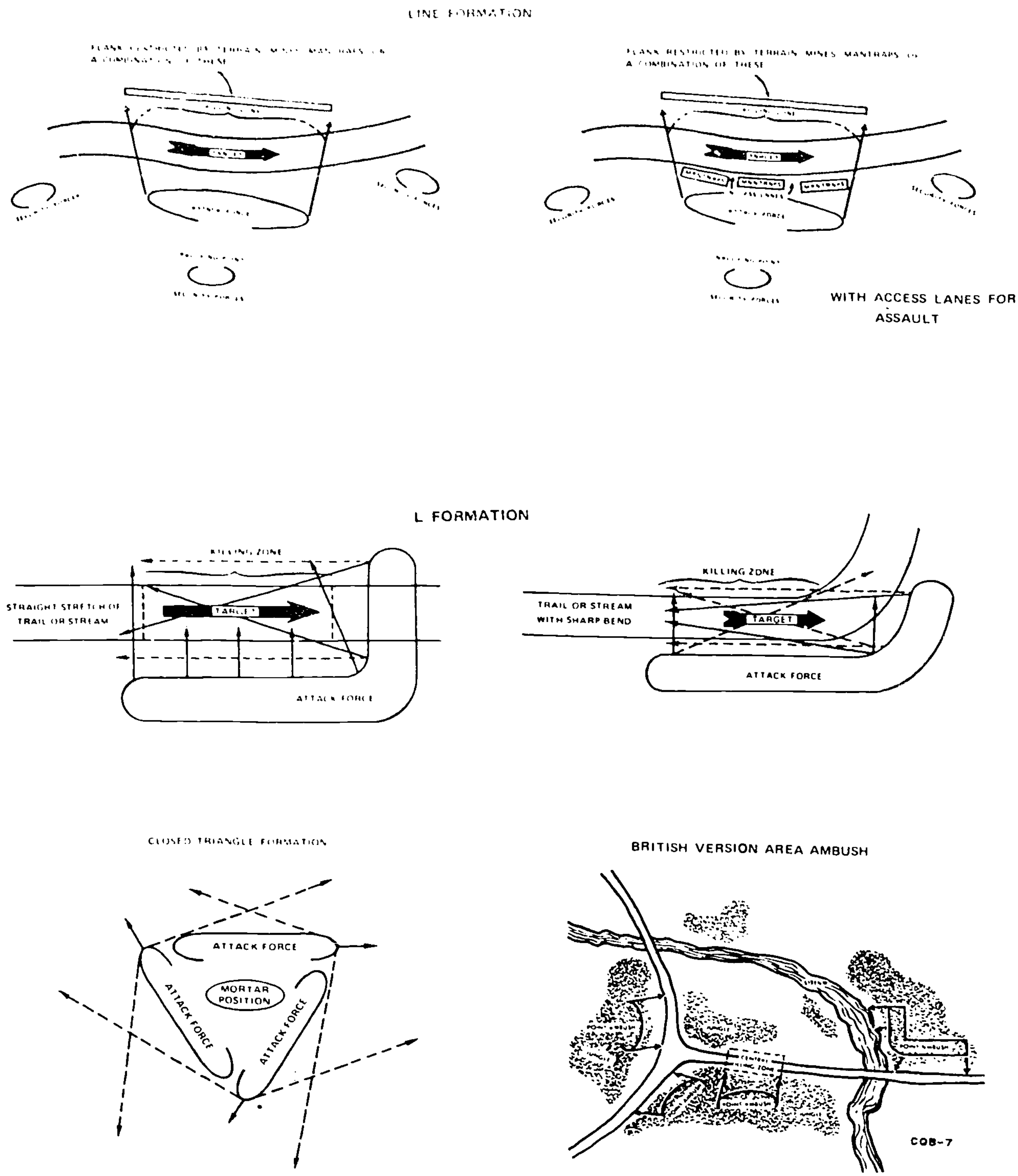


Figure 3–15. Harassing or destructive ambush.

You also designate a security element that returns to the objective, checks for boobytraps, and secures the area.

After completing the planning phase, you are ready to proceed to the line of departure. At this point, the base-of-fire echelon begins its suppressive fire. Any other fire support, such as mortar fire, artillery, or air support, is also employed at this time. As the support fire begins, your maneuver echelon starts to move toward the final coordination line. Upon arrival at the final coordination line, everyone reloads his weapon and prepares for the assault.

When the maneuver echelon is ready to begin the assault, the echelon leader gives a prearranged radio or visual signal to the echelon leader of the base-of-fire element. In turn, the base-of-fire leaders instruct their people to shift their fire to a direction different from where the assault will come from, or to cease fire. Now, the maneuver echelon, moving rapidly and maintaining alignment in the line formation, begins the assault. As your people move forward in the assault, riflemen and grenadiers fire a round or a short burst of rounds (as directed by the echelon leader) each time their left foot strikes the ground. To maintain a steady volume of firepower, machinegunners must fire as the right foot strikes the ground. No one in the formation should slow down or stop for anything. Reloading must be done rapidly as you move toward the objective.

When the assault echelon arrives at the objective, they continue moving in formation to your preestablished limit of advance. This is done to push the enemy force further from the objective and to reduce the possibility of a rapid counterattack or ambush.

Your unit then establishes all-around security, and your security element returns to the objective. They check for prisoners and boobytraps and secure the objective. Now your force can return to the objective and, if necessary, prepare to repel an enemy counterattack.

Exercises (C31):

1. Briefly define preparation, fire and maneuver, and assault as they relate to conducting a counterattack?

C32. State counter ambush actions during movement.

Counter Ambush Drills. If your unit is ambushed, you and your entire unit must act immediately with a preplanned course of action. This action, called the counter ambush drill, may vary, depending on whether you are caught in a near or far ambush. In each situation, the success of the counter ambush drill used depends upon being well trained in recognizing the nature of an ambush and well rehearsed in the proper reaction.

Near Ambush. A near ambush is one in which the enemy forces are located within a reasonable assaulting distance of the kill zone (50 meters or less as a guideline). In a near ambush, the kill zone is under very heavy, highly concentrated, close-range fire. There is little time or space for you to maneuver or seek cover. The longer you remain in the kill zone, the more certain your destruction. Therefore, if attacked by a near ambush, you should take the following actions (see fig. 3-16).

a. Those in the kill zone, without order or signal, immediately assault directly into the ambush position, occupy it, and continue the attack or break contact as directed by the squad or team leader. This action moves you out of the kill zone, prevents other ambush force elements from firing on the assault without firing on their own men, and provides you positions where you can take other actions.

b. Those not in the kill zone maneuver against the ambush force as directed by the squad or team leader.

c. The assault is continued until the ambush force is eliminated or the order is given to break contact.

Far Ambush. This is an ambush in which the enemy forces are located beyond a reasonable assaulting distance (more than 50 meters). Here, the kill zone is also under very heavy, highly concentrated fire, but from a greater range. This greater range provides those in the kill zone some space for maneuver and some opportunity to seek cover with a smaller risk of destruction. If attacked by a far ambush, you should take the following actions (see fig. 3-17).

a. Those in the kill zone, without order or signal, immediately return fire, take the best positions available, and continue firing until directed otherwise.

b. Those not in the kill zone maneuver as directed against the ambush force.

c. The attack is continued until the ambush force is destroyed or the order is given to break contact.

Exercises (C32):

1. What counter ambush actions do you take when caught in a near ambush?

2. What counter ambush actions do you take when caught in a far ambush?

C33. State the purpose and benefit of search and clear operations. Given hypothetical situations, identify actions taken to search and clear buildings and open areas.

Search and Clear Operation. Whenever a building or area is has been, or is suspected of being occupied by a hostile force, it must be searched and cleared. The operation is conducted before enemy-held real estate can be occupied by your own forces. This is an absolute must if you are to insure that all hostile forces have fled or been neutralized and that all boobytraps have been found and disarmed. Actions to search and clear a designated locale could take place within friendly or enemy territory.

Buildings. You would normally employ an entire squad to search a building. Two fire teams act as a security element. Their purpose is to seal off all avenues of escape and provide protective fire for the third fire team. The searching fire team is the search party that enters the building and conducts the

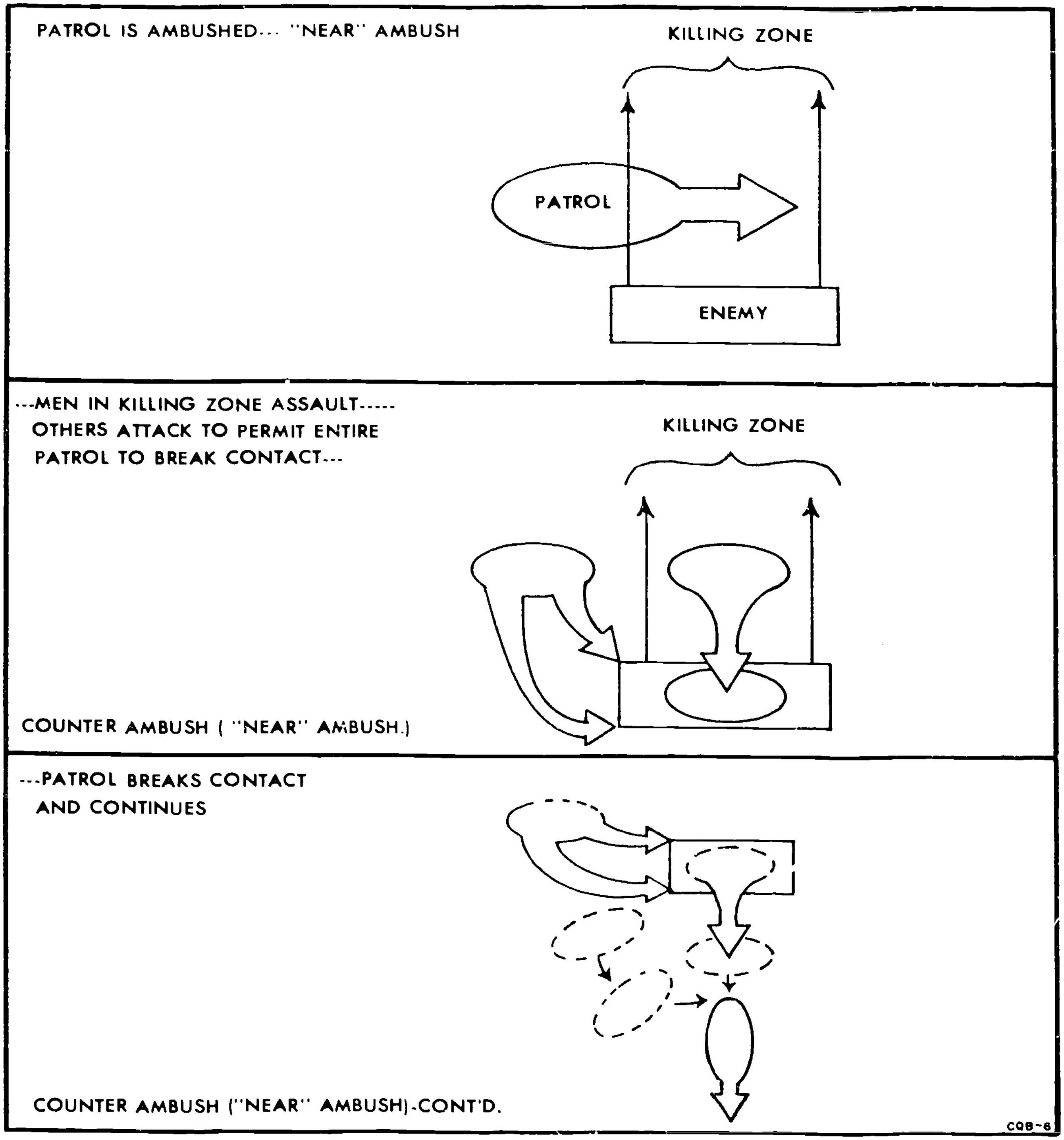


Figure 3–16. Counter ambush for near ambush.

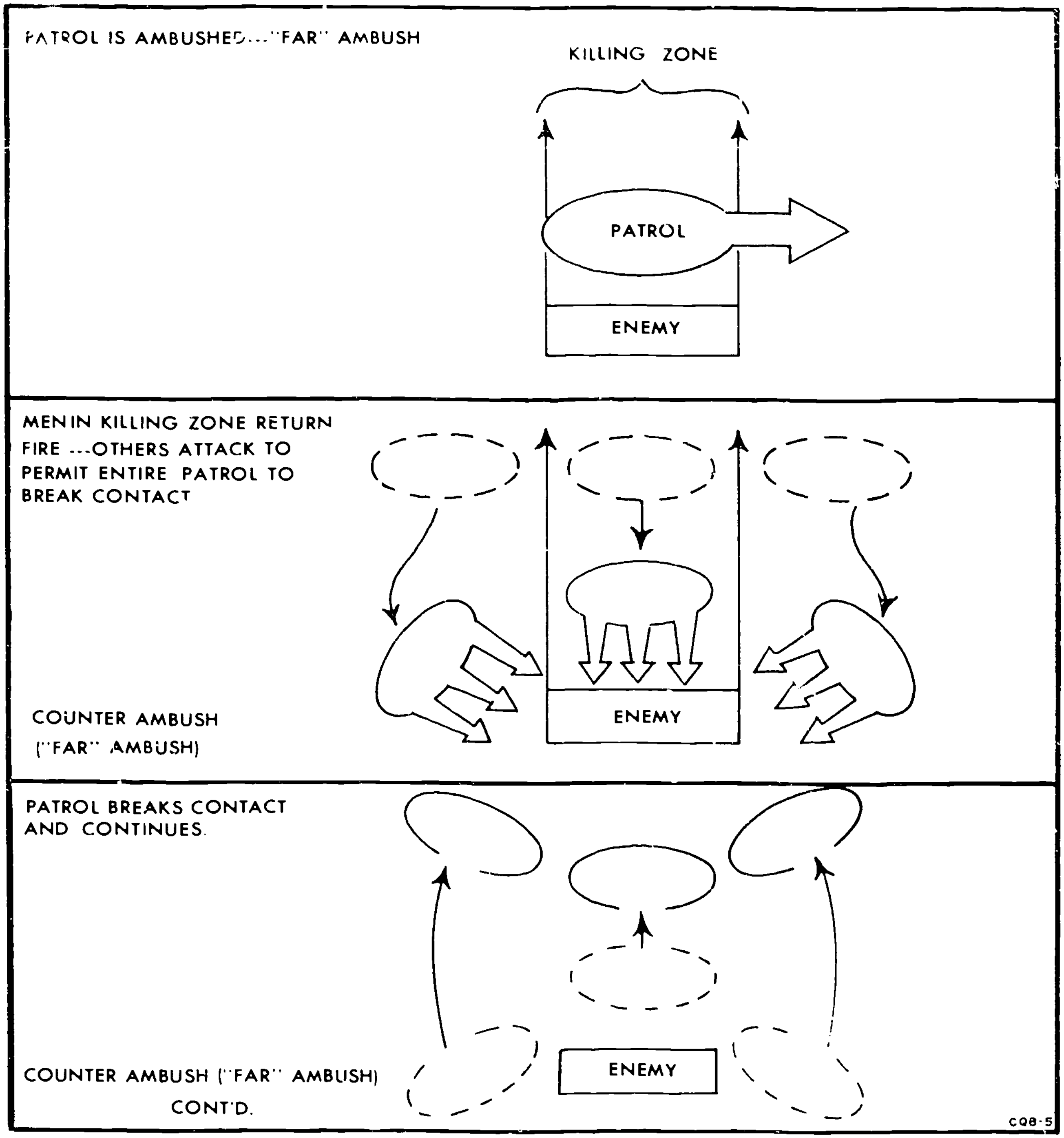


Figure 3–17. Counter ambush for far ambush.

search. There are three methods of entering and clearing buildings.

(1) Entry at the top. Whenever possible, you should enter and search a building from the top down. Enemies who are forced to the top of a building may be cornered and become physically violent, causing harm to you or forcing you to harm them. On the other hand, enemies who are forced downward to ground level may attempt to escape from the building, making themselves vulnerable to capture by the security element. You may use various means to gain entry to the top of a building; for example, ladders, drainpipes, toggle ropes, grappling hooks, roofs of adjoining buildings, or civil engineering utility vehicles designed for working at heights.

(2) Entry on the middle floor. In many cases, it may be impossible to enter a building at the top. In these instances, you must enter at the highest possible point, using the techniques previously described. Initially, you thoroughly search and secure the floor (level) you enter. Then you move to the top floor and search from the top down.

(3) Entry at the bottom. When you must enter a building at ground level, the security element must take every precaution to insure protection of the search element, up to point of actual building entry. When you have searched the ground floor, move to the top of the building and work down.

Rooms. To search individual rooms, a two-man team is normally used. Depending on the likelihood of an enemy presence in the room, one member may throw in a riot control or fragmentation grenade, wait for it to explode, then enter. After entry, you must place your back against the nearest wall. The second man then follows suit and searches the room in detail.

In an occupied building, when the enemy's location in a building is unknown, all rooms must be searched. In the case of quarters, attempt to have occupants submit voluntarily to the search. At the same time, question them in an attempt to pinpoint the enemy's location. If an occupant will not voluntarily submit and there is any cause to believe that an enemy is located in the room, conduct the search as described earlier.

In a building where the location of the enemy is known, proceed directly to the immediate vicinity of the enemy location. Then, carefully search the rooms near the location in case they have moved. When you pinpoint the enemy, employ riot control or fragmentation grenades in an attempt to force them into the open.

Open areas. The size of the unit you employ to search and clear an open area depends on the size and terrain of the area and size and strength of the enemy force you expect to encounter. Once again, the rule to follow is to meet force with superior force.

Search and clear operations in open areas usually take place outside the defended area of the base. They are really nothing more than the conduct of any of several types of patrolling operations; for instance, operations intended to harass guerrila or terrorist forces, keep them on the move and off balance, and hopefully destroy or capture them. Further, search and clear operations may include offensive tactics, such as raid and reconnaissance in force operations.

Raid. A raid is a swift, small-scale (squad or flight size) penetration of hostile territory. Your objective may be to secure information, harass the hostile force, or destroy their camp or base. A key feature of the raid is that, as soon as your mission is completed, you make an immediate planned withdrawal from the hostile territory.

Reconnaissance in force. A reconnaissance in force operation usually requires a flight-sized unit. Here your purpose is to develop intelligence, locate the hostile force, test their strength, and coordinate or conduct attack on the hostile force or their installation. This form of operation could be considered a large scale, thorough search of the hostile area.

Exercises (C33):

1. Why must an area be searched and cleared?

2. What benefit is realized by a search and clear operation?

Evaluate the situations given below and state the search and clear actions to be taken.

3. A sniper has gotten into a 3-story building just off of the perimeter and is firing at targets on the base. His location inside the building is unknown.

4. Same situation as in exercise 3, but there is no means of entry from the roof or top floor.

5. Intelligence sources indicate that a force of 45 heavily armed terrorists are camped in a densely wooded area somewhere close to your base. They have been harassing your perimeter frequently, and you have been directed to locate them, confirm their strength, and, if possible, attack their camp.

6. Same situation as in exercise 5, but with only 5 terrorists reported.

3-4. Field Fortifications

This section is designed to help you understand the advantages that can be gained through the correct use of field fortifications. Toward this end, we briefly discuss the various factors that must be considered when planning the use of, or building of weapon emplacements and tactical wire barriers. Included are the various types of emplacements and barriers commonly used by our combat forces. Also, we discuss how these fortifications should be used to

complement one another and to enhance your overall defense posture.

C34. Given hypothetical situations, determine whether field fortifications must be constructed.

Planning and Use. The opportunity to fight from prepared positions is an advantage that you must exploit. The degree of protection that field fortifications can give you depends on their construction and strength. This protection also depends on (1) how well you distribute them within the tactical defense, (2) how well you adapt them to the terrain, and (3) how well you conceal them from enemy observation. The following are some factors that you should consider when planning the use of, or building of, field fortifications.

Plans. Plans for fortifications not only provide for the desired degree of protection but also for bringing the enemy under the maximum volume of effective fire as early as possible. Fortification plans are usually based on progressive construction; that is, proceeding from open to covered emplacements and shelters. This is done in order to have the best protection possible under the circumstances.

On the offense. During offensive operations, periodic halts may be required to regroup, resupply, or consolidate positions gained. Where the enemy threat is known to include a counterattack capability (or probability), offensive units should seek available cover or should dig hasty emplacements as described later in this chapter.

On the defense. A defensive position is built around a series of organized and occupied tactical positions. Positions are selected for their natural defensive strength and the observation afforded. Fortification measures for these positions include clearing fields of fire, digging weapon emplacements and positions for personnel, strengthening natural obstacles, installing artificial obstacles, and providing camouflage.

Dispersion. The separation of units and individuals is a primary means of increasing protection. Clearly, a unit is less likely to be vulnerable to enemy weapon fire if the area the unit occupies is increased. Proper dispersion, then, can greatly reduce the need for a high level of protection from field fortifications. The extent to which a unit spreads out depends on the mission, the terrain, and the enemy situation. Fortifications, properly employed, can be used in lieu of, or to supplement, dispersion. For this reason, fortifications are particularly important for units that cannot disperse sufficiently to obtain adequate protection.

Alternate and dummy positions. When time and the situation permits, dummy and alternate positions should be built to deceive the enemy and to allow flexibility in your defense.

Exercises (C34):

State whether field fortifications must be constructed in each of the following situations by entering "yes" or "no" in the space provided.

____ 1. Your unit has just overrun an enemy position and halts to regroup and resupply before proceeding elsewhere on another mission. The decisiveness of your unit's victory assures that the enemy is incapable of mounting a counterattack before your unit leaves the area.

____ 2. After obtaining the resupply mentioned in exercise 1 above, your unit moves on to its second mission, and it again surmounts an enemy position. This time, however, in the face of your unit's superior strength, the enemy disengages contact and disperses before sustaining any significant casualties. Shortly thereafter, you receive an intelligence report indicating that an additional enemy unit, equal in size to the one that just retreated, is also somewhere in the area. Again, you must wait for resupplies before moving out of the area.

____ 3. Security forces in your sector recently repelled a ground attack against your base. This attack pointed out some possible weaknesses in your defenses. You find that to strengthen these weaknesses, you must add some weapons and relocate several of those already in place.

C35. Given hypothetical situations, determine the type of weapon emplacement to establish.

Types of Emplacements. Concerning the protection of our bases, we have the advantage of time to prepare defensive positions. As mentioned earlier, you must plan properly and concentrate your defense on what you expect the enemy to do. However, you must also learn to expect the unexpected and be ready to cope with it. Keep in mind that, as is usual with human nature, people do not always act or react as you expect. For this reason, you must be ready for the possibility of having to construct your own on-the-spot defensive position. This situation could arise, for example, when you are reacting as a member of the response force or when you are initially being posted during a ground defense operation. The emplacements you are most likely to use are presented in the following paragraphs.

Hasty emplacements. Hasty emplacements are dug when you have made contact with the enemy, and time and materials are limited. Their purpose is to provide immediate protection from direct fire. They are also used when there is no natural cover available. Examples of hasty emplacements are:

a. Shell crater. If you have time, try to find a crater that is 60- to 90-cm wide (2 to 3 feet). This size offers you immediate cover and concealment and can be quickly made into a hasty position. Any place where heavy weapons rounds have exploded can quickly be expanded to afford you some protection. These craters can later be developed into a foxhole if your stay in the area is extended.

b. Prone emplacements. Initially, you can start with a skirmish trench; this simply involves digging or scraping dirt into piles to place between you and the enemy. As time permits, you can expand this type of emplacement to conform to your body position and arm length. Once improved, you are better protected from small arms or direct fire weapons than if using a shell crater or your initial skirmish trench.

c. Other immediate alternatives. As a last resort, you can pile rocks, hard-packed snow, ice, and dirt in front of your

position. A minimum of 30 cm (12 inches) of this material can resist penetration of many small arm projectiles.

Foxholes. Foxholes are the basic defensive positions. They afford you good protection against most forms of enemy small arms fire. They can be developed by expanding the hasty positions discussed earlier, or you can start from scratch. As time permits, you can make improvements by revetting the sides, adding overhead cover, providing drainage, and excavating a grenade sump to dispose of handgrenades thrown into the hole by the enemy. When used in our concept of defense, the two-man foxhole is better than the one-man emplacement.

Machinegun emplacements. Machinegun emplacements should give maximum protection to the crew; however, the main consideration must be the effective use of the weapon. The positions described in the following paragraphs are designed for use in terrain that permits excavation.

a. Horseshoe. The horseshoe-shaped trench, about 3-feet deep, is a trench dug along the rear and sides to form a horseshoe. It has a chest-high shelf in the center to serve as the gun platform. The dirt from this trench is used to form a low protective wall (parapet). The wall should be at least 1-meter wide, and low enough to permit all-around fire. This type of emplacement permits you an easy traverse of the gun through an arc of 180°; but it does not allow you to fire effectively to the rear.

b. Two one-man foxholes. This emplacement consists of two one-man foxholes close to a gun position. The parapet is low enough for all-around fire and offers you good protection. Although 360° fire is possible from this position, fire to the front and rear is most effective because the M–60 machinegun is fed from the left side.

Drive-through fighting positions. In your defensive operation, drive-in revetments, with concealed approach routes, should be constructed on your main line of resistance (MLR). These positions should be as narrow and as short as your vehicle size permits. You can use sandbags or 55-gallon drums filled with sand to construct the drive-in revetments. Individual positions with overhead cover should also be constructed for deployed personnel. These individual positions serve to protect your drive-in positions; also, they give you direct fire support.

Concealment. Concealment is of prime importance in constructing your defensive positions. When and if time permits, you should make full use of all available natural materials; for example, trees, logs, and brush. Manufactured materials such as barbed wire, cement, lumber, sandbags, corrugated metal, and other material that you could use should be obtained from support organizations. To further conceal your positions, make maximum use of surrounding background to break up outlines. A more thorough coverage of camouflage techniques was presented earlier in this text.

Exercises (C35):

Match each situation in column A with the column B type of emplacement that should be constructed by writing the column B letter in the space provided. Column B items may be used once or not at all.

Column A	*Column B*
____ 1. You are in enemy contact and must seek immediate cover in an area devoid of natural cover and recently bombarded by heavy weapons.	a. Two one-man foxholes.
____ 2. You have the time to expand the initial hasty position you are lying in to make it fit the length.	b. Foxholes.
____ 3. After repelling an initial attack, your unit must hold its present position. You need to improve your present hasty emplacements for better protection against most forms of enemy small arms fire.	c. Prone emplacement.
____ 4. You must set up a machinegun emplacement that allows you a 180° arc of fire to the front. Firing to the rear is not needed.	d. Shell crater.
____ 5. You must set up a machinegun position that allows for all-around fire.	e. Horseshoe.
	f. Drive-through fighting position.

C36. Determine how tactical barriers are used, and state how they enhance defensive positions in given situations.

Tactical Barriers. Wire barriers (entanglements) are used to break up enemy formations and to hold the enemy in areas covered by your defensive fire. They also protect you by preventing close-in surprise attacks on your defensive positions. When you construct these barriers, place them close enough so that you can observe them both day and night. At the same time, however, be sure to place the barriers far enough from your position to keep the enemy beyond handgrenade throwing range.

As you can see, selecting the proper position for barriers is important. Equally as important, however, is selecting the proper type of barrier. To help you do this, barriers have been classified according to their use and their depth.

Use. Entanglements are classified by use as tactical, protective, or supplementary.

a. Tactical. Tactical wire entanglements are sited along and parallel to the friendly side of your final protective line. You use them to break up enemy attack formations and to hold or channel the enemy in areas covered by your most intense defensive fire. You can extend this type of entanglement across the entire front of your position. Remember, however, that it doesn't necessarily need to be continuous.

b. Protective. This type is located to prevent surprise assaults from points close to your defensive area. Remember to place it to keep the enemy beyond handgrenade range.

c. Supplementary. You can use this type to conceal the exact line of your tactical wire. Also, you can use it to inclose your defensive position by connecting protective wire entanglements. If used to break up the line of your tactical wire, it should be identical to the tactical wire entanglement and should be constructed at the same time.

Depth. The following are the three classifications of depth:

a. Belt. A belt is an entanglement that is one fence in depth.

b. Band. This consists of two or more belts with no intervals between them. You may construct a band by using different types of fences.

c. Zone. This is two or more bands or belts with intervals between them.

Types. Now that you are familiar with the classifications of entanglements, let us look at the types of barriers and their uses (see fig. 3-18).

a. Four-strand cattle fence. This fence may be used to designate the legal base boundary. It is also used as the center section of a double-apron fence.

b. Double-apron fence. This fence combines the four-strand cattle fence with aprons of barbed wire at the front and rear. Its effectiveness can be increased by installation of tripwires.

c. Standard concertina. The triple-strand concertina fence is usually a better obstacle than the double-apron fence. Concertina fences are held down by stakes placed at intervals of not more than 2 meters. These stakes are used on the single concertina fence and on the front strand of the double and triple types. There are three types of concertina fence you can use:

(1) Single. This single line of concertina is erected quickly and easily, but it is not an effective obstacle.

(2) Double. This consists of a double line of concertina with no interval between lines. The two lines are installed with staggered joints. Also, double concertina is less effective than a double-apron fence. It is used to supplement other obstacles in a band or zone.

(3) Triple strand. This consists of two lines of concertina serving as a base, with a third line resting on top. All lines are installed with staggered joints. Each line is completed before the next is started so that a partially completed concertina entanglement will present some obstruction. It is erected quickly and is difficult to cross or crawl through.

Portable barbed-wire obstacles. Concertina wire is an effective obstacle that can easily be moved, used to temporarily close gaps or lanes, or used for adding obstacles to already established barriers. Other portable barbed-wire obstacles you can use are:

a. Spirals of loose wire. By filling open spaces in and between your wire entanglements with spirals of loose wire, the obstacle effect is substantially increased. Men are tripped, entangled, and temporarily immobilized by the loose wire.

b. Knife rest. The knife rest is a portable wooden or metal frame strung with barbed wire. It is used when you need a readily removable barrier; for example, at lanes in wire obstacles or at roadblocks. Knife rests are normally constructed with 3 to 5 meters between crossmembers. They should be approximately 1 meter high, and the crossmembers must be firmly lashed to each horizontal member with plain wire. Insure that you firmly secure the knife rest in its position.

c. Tripwires. Immediately after a defensive positon is occupied, tripwires should be placed just beyond grenade range. The wires should stretch about 8 inches above the ground and be fastened to pickets at not more than 5-meter intervals. They can be concealed in long grass, or on a natural line, such as the side of a path or the edge of a field. Tripwires should be placed in depth, in an irregular pattern, to enhance their disguise.

d. Tanglefoot. Tanglefoot is used where concealment is possible. The obstacle should be used in a minimum depth of

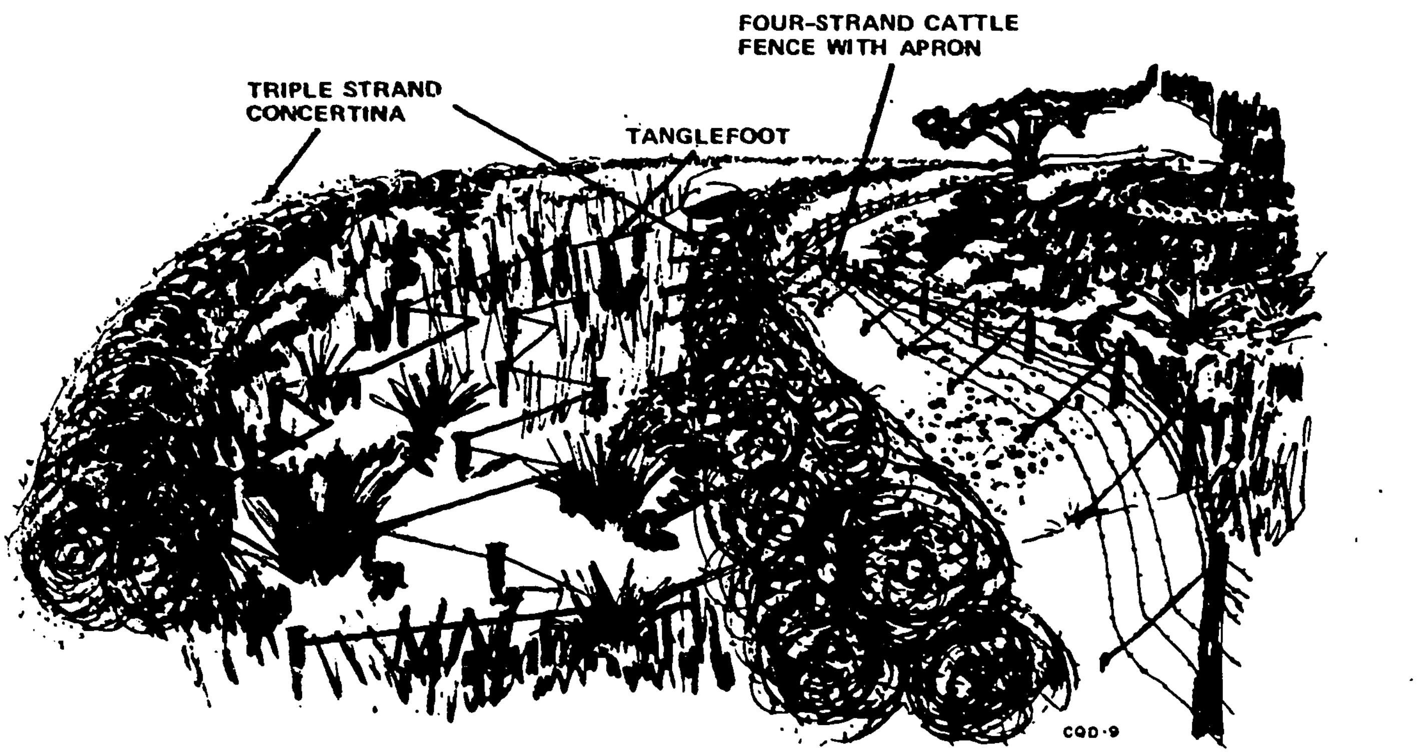


Figure 3–18. Entrapments.

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10 meters. Space your holddown pickets at irregular intervals from 1 to 3 meters, with the height of the barbed wire varying from 8 to 30 inches. Tanglefoot should be sited in scrub, if possible, using bushes as supports for part of the wire. In open ground, short pickets may be used.

Exercises (C36):

Determine how barbed-wire barriers are being used by matching the column A situations with the appropriate classification listed in column B by writing the column B letter in the space provided. Column B items may be used once or not at all. Briefly state how the barriers enhance your defensive positions.

Column A	*Column B*
____ 1. Barriers are positioned along and parallel to the friendly side of your final protective line.	a. Protective.
____ 2. Barriers are used to complement and/or join other wire barriers.	b. Tactical.
____ 3. Barriers are installed around your defensive positions at distances designed to keep the enemy beyond hand grenade throwing range.	c. Supplementary.

C37. Given hypothetical situations, determine how weapon emplacements and tactical barriers are used in base and sector defense.

Weapon Emplacements. Base and sector defense weapon emplacements are located to cover a selected area with fire, taking advantage of any natural cover and concealment. The most commonly used emplacements were discussed earlier in this chapter. One main point to keep in mind when planning or constructing weapon emplacements is that, in defensive firing positions, maximum fields of fire and observation in the direction of the enemy should not be sacrificed for elaborate overhead cover. Obviously, then, weapon emplacements must be built to coincide with your fire plans.

Fire plans. Fire plans must be prepared for each defended locality (whether occupied by a fire team, squad, or flight) and must be consolidated at sector level before coordination is attempted with adjacent sectors. Basically, a sector fire plan must provide for (1) placing long-range fire on enemy personnel as soon as they come under observation, (2) subjecting enemy personnel to an increasing volume of fire as they approach the tactical defenses, (3) breaking up the attacking force with close defensive fire, and (4) stopping an enemy assault with final protective fire.

Defense in depth, interlocking fires, and mutual support between defended localities and between defense sectors are essential. For instance, machineguns should be positioned to provide maximum grazing fire between the frontage of adjacent localities. Individual rifle positions are selected to support and protect machinegun positions, provide supplemental fire for the unit area, and add depth to the defense. Weapon emplacements, as we stated previously, must be built to directly support your fire plans.

Emplacement considerations. The following considerations affect the type and location of weapon emplacements:

a. Employment of weapons. Emplacements must permit effective use of the weapons for which they were designed. This requirement may limit the protection that can be provided and may influence the design and depth of adjacent shelters.

b. Protection. As far as possible, protection should be provided against all hazards except a direct hit by heavy artillery. This means that excavation should be as small as possible, consistent with space requirements, in order to obtain maximum protection from the walls against airbursts and to limit the effective target area for high trajectory weapons. Some of the main methods used to obtain this protection are presented later in this section.

c. Simplicity and economy. The emplacement or shelter should be strong and simple, require as little digging as possible, and be constructed, when possible, with materials that are immediately available.

d. Progressive development. Your plans for defensive work should allow for progressive development. This improves the usefulness of emplacements. You can develop emplacements in three steps:

(1) Digging in quickly where speed is the principal consideration, and no special tools or materials are required.

(2) Improvising with local materials.

(3) Refining, using stock materials.

e. Concealment. Weapon emplacements should be built so that the completed work can be concealed. It may not be practical to conceal a defensive position completely, but it should be concealed sufficiently to prevent the enemy from spotting the defensive position by casual ground observation. If possible, you should build dummy positions at the same time that the primary and alternate positions are built.

Protection. The most predominant hazard during ground defense operations is fire from conventional weapons. Therefore, the construction of weapon emplacements must be geared primarily toward obtaining protection against this hazard. This is done by digging in, providing overhead cover, and erecting standoff fencing.

a. Digging in. Protection against conventional weapons is best provided by constructing a thickness of earth and other materials. This is done by digging into the ground so that personnel and equipment can offer the smallest possible target. Digging in also provides some protection against artillery, infantry, heavy weapons, bombs, and other aerial weapons.

b. Overhead cover. Overhead protection is especially important in forward areas where the threat includes airburst shelling. Covered firing positions must be built for individual riflemen. Small, readily accessible shelters adjacent to weapon emplacements are also necessary. Available materials may be used, but cover must be kept low or the outline modified to blend with its surroundings.

c. Standoff fencing. Standoff fencing is intended to cause point detonating or inertial-impact-fused rounds to explode before hitting the defensive position. Chainlink fencing is used for this purpose, and it should be located 10 to 25 feet from the position.

Tactical Barriers. Basically, in base or sector ground defense operations, tactical barriers are used to complement

fire plans. They consist of a coordinated series of natural and artificial obstacles that are used to channel, restrict, delay, or stop enemy ground movement.

An important point to remember is that an obstacle may constitute either an advantage or a disadvantage. For example, an obstacle perpendicular to the direction of attack favors the defender; it slows or channels the attacker. Conversely, an obstacle that is parallel to the direction of the attack may help to protect the flank of an attacking force. For this reason, you must look at each obstacle or barrier closely, determine what you want it to do, and insure that this job is being done. Above all, make sure that each barrier is working for you, not against you.

Natural obstacles. Natural obstacles, such as ravines, streams, marshes, and forests, can be used to advantage in a barrier plan. These obstacles, when supported by artificial barriers (such as barbed wire), often make the most effective tactical barriers. For this reason, good use should be made of available natural or seminatural obstacles. For example, waterlogged ground and large watershed drains (pools or ponds), supported by wire entanglements, can present a formidable barrier to aggressors.

Perimeter barriers. Fences are used to delay the enemy and compound the problems they face in negotiating the perimeter. Vegetation, ravines, buildings, debris, and any other form of concealment should be removed or destroyed. Wire entanglements, roadblocks, and minefields can be used to cover likely avenues of approach and vulnerable parts of the base perimeter. Remember that no matter what fence system is used, it must have depth, the sentries maintaining surveillance over it must be alert, and it must be effectively covered by defensive fire.

Lighting. Lights should be installed to provide for maximum night visibility. Use of such lighting, however, depends on tactical considerations at the time. Additional devices, such as trip flares, antipersonnel mines, ground radar, and sensors, are also used to enhance the effectiveness of barriers.

Interior barriers. Tactical wire barriers are used within the perimeter to limit and channel penetrations by enemy groups or individuals. These interior barriers can be as simple as a single strand of wire, 3- to 4-foot high. Generally, they are placed in a manner that prevents a direct approach to vital areas.

Provisions must be made to cover these barriers by automatic weapons fire teams, by assignment as an alternate mission for such weapons teams. The barriers are constructed as inconspicuously as possible, and are relocated periodically to prevent counterplanning by the enemy.

It is important to insure that interior barriers do not preclude the reserve force's freedom of movement. For this reason, conterattacking forces, as well as all other personnel who work within areas reinforced with barriers, must be thoroughly familiar with the location of all barriers.

Lanes and gaps are provided for the passage of reserve forces, patrols, work parties, and counterattacking forces. When not in use, they are sealed by the use of portable obstacles covered by weapons fire. In barbed-wire zones, lanes and gaps are staggered in a zigzag pattern.

Exercises (C37):

You are tasked with evaluating weapon emplacements and tactical barriers on your base to insure that they effectively support fire plans and protect personnel. During your evaluation, you must insure that the specific criteria listed in column A are met. Match the column A item with the column B type of weapon emplacement, related protective action, or tactical barrier that would most likely achieve the result described by writing the column B letter in the space provided. Column B items may be used once or more than once.

Column A

____ 1. Provide grazing fire across the frontage of adjacent areas.
____ 2. Cause point detonating rounds to explode before hitting defensive positions.
____ 3. Should be covered by defensive fire.
____ 4. Should be relocated periodically to prevent counterplanning by the enemy.
____ 5. Provide the means for personnel and equipment to offer the smallest target possible.
____ 6. Must not hinder the movement of response forces.
____ 7. Provide supplementary fire for the unit area and add depth to the offense.
____ 8. Limit or channel the movement of enemy penetrators to areas covered by your most intensive fire.
____ 9. Provide protection of personnel against airburst shelling.
____ 10. Must be supported and protected by individual rifle positions.
____ 11. Increase the problems the enemy faces in trying to penetrate your outer defenses.

Column B

a. Overhead cover.
b. Perimeter barriers.
c. Machinegun emplacements.
d. Dug-in positions.
e. Interior barriers.
f. Individual rifle positions.
g. Standoff fencing.

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Convoy Techniques

A MILITARY FORCE must be able to get from one place to another with the necessary men and supplies if it is to perform its mission. The outstanding ability of U.S. Forces to do this today makes them the most mobile that the world has ever known. A great deal of this mobility depends upon the transportation of many people and large quantities of materials by military vehicles. This movement of people and material can be maintained only so long as vehicle operations personnel are qualified in all phases of motor transportation. One of these phases is convoy operation. This chapter provides you with knowledge of the kinds of convoys, coordination required with civil authorities, and planning and control of convoys.

4-1. Convoy Terms

The techniques of organization and management of convoys have been developed by the U.S. Army to a very high degree. This has been the result of the Arm's heavy reliance upon military vehicles for its ground transportation. Transportation within the Air Force has been directed toward the use of air transport whenever practical. However, Air Force motor transportation is particularly well-suited for short hauls and supply distribution. Another exceptionally useful advantage of motor transportation is its ability to reach an unlimited number of points which cannot be serviced otherwise. This makes it necessary for Air Force vehicle operations personnel to have a working knowledge of convoy techniques.

C38. Define terms used in convoy operations.

Convoy Defined. A convoy is the movement of a group of motor vehicles under the control of a designated individual. Its purpose is to facilitate the coordinated movement of personnel and materiel; it is also used for the practical training of personnel responsible for such operations. The individual designated to control the movement is the convoy commander. He may be either an airman or an officer—this depends on the size and purpose of the movement.

In many cases, a convoy is called a motor march. Actually, the two terms are synonymous and are used interchangeably. A motor march is quite formalized, with very rigid controls applied. Small convoys are more informal and controls are inclined to be more flexible.

Terms Used in Convoy Operation. There are several terms peculiar to convoy operation that you should know. The more commonly used terms are defined in the following paragraphs.

Control vehicle. The vehicle which precedes a convoy (motor column) or one of its elements (serial) and sets the pace or rate of march.

Fixed column. A motor column (convoy) in which a prescribed space between vehicles is maintained regardless of the speed.

Governed column. The spacing between vehicles is governed by a speedometer multiplier or by some other means.

Lead. The linear spacing between the heads of successive vehicles, march units, serials, or columns.

March graph. A time-distance diagram used in planning and controlling motor marches.

March unit. A subdivision of a serial which moves and halts on the command or signal of the march unit commander.

Rate of march. The average speed of a motor column over a period of time, including short, periodic halts.

Serial. A major subdivision of a motor column which consists of elements moving from one area to the same destination. These elements are grouped under a serial commander.

Speedometer multiplier (SM). Any number by which the speedometer reading in miles per hour is multipled to determine the vehicle distance in yards. At 20 mph, with an SM of 2, the distance between vehicles would be 40 yards.

Time-distance. The time required for a motor column, or one of its elements, to move from one point to another at a given rate of speed.

Traffic density. The number of vehicles that pass a given point within a given period of time; e.g., 500 vehicles per lane per hour. It can also be defined as the number of vehicles occupying a mile of roadway at any given time.

Types of Convoys. We can separate convoys into three kinds: normal convoys, hazardous convoys, and convoys transporting classified equipment.

Normal convoys. These are convoys consisting mainly of general-purpose vehicles that do not exceed legal limitations of maximum overall length, width, height, weight, or axle loadings permitted by the states through which the movement is made. They are also capable of maintaining normal speeds on the highway.

Hazardous convoys. These are convoys composed of large, bulky motorized equipment. One or more vehicles may be extra wide, having overhanging or projecting

obstacles to traffic; may be overlength; or may travel at unusually slow speeds. For all practical purposes, overweight vehicles can be put in this category, since most overweight vehicles have one or more of the preceding characteristics.

Convoys transporting classified equipment. These convoys may consist of normal transport vehicles or they may involve hazardous-type vehicles. Oversize vehicles are required for transporting specialized missile equipment. Usually, convoys with classified equipment are comparatively small and often have only one transport vehicle with the necessary escorts.

Exercises (C38):

1. Define the following terms.
   a. Fixed column.

   b. March graph.

   c. Serial.

   d. Speedometer multiplier (SM).

   e. Time-distance.

   f. Traffic density.

   g. Normal convoy.

   h. Hazardous convoy.

4-2. Planning and Coordination.

Consider for a moment the large number of interrelated factors that must be dealt with in moving troops and equipment through a war zone. Considerable planning must first take place and all plans must be coordinated at various levels of responsibility.

C39. State factors to be considered, sources and kinds of information, and the importance of route reconnaissance in planning convoy movements.

General Planning Factors. There are a number of factors that determine the amount of planning needed when a convoy movement is to be made. When convoy movements are being formulated, you must find out the purpose of the convoy, quantity and type of cargo to be hauled, loading point, destination, and arrival time. This information is usually obtainable from orders and instructions issued by higher authorities.

Next, determine the number and type of vehicles which are necessary. This can be decided after the amount and type of cargo are known. The number of personnel necessary depends to a great extent upon the number and type of vehicles needed.

Now, determine the supplies that are required. The number of vehicles, distance to travel, and personnel involved are the factors to be considered. When all this has been done, you should answer the following questions:

- What is the best route?
- What are the halts to be made?
- At what speed will the convoy travel?
- Where will fuel, oil, and other supplies be obtained?

However, if you are not familiar with the area of movement, do not attempt to answer these questions until you have made a route reconnaissance. You will then be able to answer the preceding questions regarding the route. After answering these questions, decide which type of march you will use and arrange the convoy accordingly. You must also arrange for convoy control.

Finally, most movements within the continental United States or its territories must be coordinated with the civil traffic authorities before they are started. Be sure to get all the necessary permits and clearances required from the civil authorities as early as possible.

Route Reconnaissance. Route reconnaissance simply means to survey a route over which a convoy movement will be made. This survey is used to gather needed information concerning the route and adjacent areas for planning the move. Reconnaissance should be made before and during any motor move.

You may obtain basic information from maps (either standard highway or military), personal knowledge, and reports furnished by engineers, state police, and weather forecasters. Within the continental limits of the United States and in most oversea areas, you will find well-marked routes and traffic personnel available. But even so, you may make a limited reconnaissance to prevent accidents or delays. In combat areas, you must make a more thorough reconnaissance—lack of information there may prove disastrous both to personnel and equipment.

If your reconnaissance is thorough, it should provide you with the following information:

a. The location and nature of major routes in the area.

b. The location and characteristics of major road junctions.

c. The location and characteristics of detours or bypasses.

d. The time and distance measurements between major points.

e. The types of road surface and the condition of roadway and shoulders.

f. The width of each roadway and the number of traffic lanes available for movement in each direction.

g. The maximum grades (percent).

h. Limiting physical features of the available routes (clearances, heights, loads, and widths).

i. Facilities providing fuel, repairs, rations, water, and other supplies.

j. Availability of medical facilities in the area.

k. The traffic density at critical points.

l. The variations in traffic density.

m. The location of critical points (bottlenecks, points needing traffic control, or highway regulation).

n. Availability and type of communications facilities.

o. Traffic control devices and their locations.

p. Types of traffic controls that are or can be used.

q. The locations of potential hazards (lack of roadways, ice and snow, steep grades, etc.).

r. The locations and characteristics of fords.

s. The routes which afford maximum protection from hostile ground or air attack.

t. Road and bridge construction that may be required.

u. Sites that may be adequate for dumps or depots.

Exercises (C39):

1. How are the number and type of vehicles determined in a convoy move?

2. Why is route reconnaissance important in a move?

3. What factor determines the number of personnel needed for a convoy?

4. Complete the following statements (one word in each blank): Basic information to be used in route reconnaissance may be obtained from highway __________, personal knowledge, and reports furnished by engineers, state police, and weather __________. A thorough reconnaissance usually reveals information concerning the location of __________ supply facilities and critical __________ en route.

C40. State responsibilities, procedures, and sources of information in the coordination and application of control measures, escort requirements, and permits for convoy movements.

Coordination/Escort Requirements for Normal Convoys. Normal convoy movements outside the local area consisting of 10 or more vehicles organized as a column are coordinated with civil traffic authorities by higher headquarters. This also applies to movements of 10 or more vehicles dispatched over the same route to the same destination during a 1-hour period. Arrangements with civil authorities for local movements are handled by the base transportation officer in coordination with the security police officer.

Special Procedures and Escort Requirements for Hazardous Convoys. Normal convoys are protected in both the front and the rear by escort vehicles. These escort vehicles should be equipped with red warning lights, flares, and other emergency equipment. These vehicles travel far enough in front of and behind the convoy to give adequate warning to all approaching traffic.

Hazardous convoys require special markings, red flags, and lights to make them readily identifiable and to reduce their danger to other traffic. Special markings and procedures also apply to all vehicles transporting explosives. Each truck carrying explosives or ammunition is properly marked with explosive warning signs. The word "explosives" or "dangerous," as determined by the class of explosives, is exhibited in letters at least 6-inches high on reflectorized placards. These placards are posted on the front, rear, and both sides of every vehicle. When 2 or more trucks carrying explosives are traveling together, a minimum distance of 300 feet is maintained between vehicles. Department of Transportation regulations govern the transportation of explosives on public highways. Specific safety precautions for the transportation of explosives are given in AFR 127–100, *Explosive Safety Standard*.

Escort vehicles lead and follow these convoys. Normally, escort vehicles are equipped with and display rotating red flashing beacons and also keep their headlights on. Suitable signs (preferably luminous) are displayed, indicating that a convoy follows or is ahead. Radio communications are used, when available, to facilitate normal communications and the immediate adoption of emergency procedures.

Other vehicles in the convoy will have headlights and running lights turned on at all times. All overhanging and projecting equipment is marked with red flags during daylight when visiblity is good; red and amber lights are used during periods of poor visibility and at night.

The vehicle operations officer and the convoy commander are responsible for insuring that these convoys are equipped for all conditions expected. The coordination with civil authorities for the movement of hazardous convoys is carried out by higher headquarters.

Special Procedures/Requirements for Classified Convoys. Small classified convoys of vehicles not exceeding legal limitations on size or weight can be coordinated locally. However, oversize classified equipment requires the same coordination as any other hazardous convoy.

Convoys with classified equipment are under the direct control of a security officer, who may also act as convoy commander. Also, escorts leading and following the convoy are security guards. The number of guards and their locations in the convoy are determined by the commander ordering the movement. Driver personnel must have security clearances.

Procedures in Coordination and Obtaining Permits for Convoys. The first thing is to determine whether or not the vehicle is oversize or overweight, thereby requiring a clearance. Each state has established its own limitations on vehicle widths, heights, lengths, weights, and axle loadings. Since these limitations vary considerably from state to state, you must be familiar with those for all the states in which your vehicles operate. You can get this information by checking state laws or by asking the appropriate highway officials. However, there is a simpler method. The American Trucking Association, Inc., publishes a consolidated chart that shows current information on vehicle sizes and weights and other related matters for highway carriers. This is not an

official Air Force publication but, it is used for military vehicle movements and commercial carriers.

The Director of Transportation and Supply of the appropriate air logistics center (ALC) is the representative designated to secure permits for military vehicle movements. The Director determines whether or not the movement by highway is essential to national security and, when appropriate, makes all the necessary requests and certifications to the authorities of the states involved.

In some cases, there is a recurring need for oversize, overweight, and special movements of military vehicles within a limited area. The director (mentioned above) coordinates and arranges for formal agreements with state and local civil authorities for such movements. Copies of these agreements are furnished to state officials, local military officials, and the Director of Transportation, Headquarters USAF. When a movement is to be made under an agreement, the local base transportation officer notifies the civil authorities of the move and obtains the necessary permits.

When an essential movement which is not covered by an agreement must be made, the local base transportation officer will request the appropriate ALC Director of Transportation and Supply to negotiate for the required permits. The request should be prepared on DD Form 1265, Request for Convoy Clearance, or on DD Form 1266, Request for Special Hauling Permit. T[illegible] furnish all the information normally needed fo[illegible]otiation. The information to be furnished for oversize or overweight vehicles includes, as a minimum, the following:

a. Type of equipment with the manufacturer's name, if available, and pertinent accessories; gross weight; axle or track loads and spacing; and the height, width, and length of the vehicle, both loaded and unloaded.

b. Origin and destination of the movement.

c. Proposed date and time of the movement.

d. Nature of the cargo (within security limitations).

In addition, reasons must be given why oversize or overweight vehicles or loads cannot be reduced. Also justification must be given as to why highway movement, as opposed to another mode of transportation, is essential.

In urgent cases, applications for permits can be made by electrical communications means. These message requests should give the required information in the numerical order given on the DD forms and should be confirmed through the submission of the applicable form.

Except in an emergency, all permits and clearances necessary for convoy movements should be obtained at least 24 hours before the movement. Also, if civil police escorts or traffic personnel are needed, arrangements for them must be made at least 24 hours ahead of time.

Exercises (C40):

1. You have a movement which involves 19 vehicles. All the vehicles will reach the same destination within a 1-hour period. Who is responsible for the initial coordination?

2. Who has the direct control of vehicles transporting classified equipment?

3. What is the best source for information pertaining to state laws concerning overweight or oversize vehicles for movement over highways?

4. Name the officials that are given a copy of a written formal agreement for oversize, overweight, and special movement of military vehicles.

5. What forms are used for requesting permits for essential oversize convoy movements not covered by formal agreements with appropriate civil authorities?

C41. Specify the chief difference, the advantages, and the disadvantages, in the three types of motor marches.

After gaining the necessary information concerning the route or routes, you should determine the type of motor march to use. Three general types of marches may be employed—close column, open column, and infiltration. The difference between these marches is largely vehicle spacing. Densities and speeds will vary with such factors as weather, tactical situation, enemy capability, condition and type of road, vehicular maintenance, types of vehicles, etc. The following descriptions are accepted values for average conditions.

Close Column March. Close column is the formation generally used in moves under blackout conditions or in movements through congested areas. For planning purposes, figure that vehicles move at a rate of 10 miles in the hour ("in the hour" refers to distance covered and not miles-per-hour speedometer readings) with a density of 67 vehicles per mile of road. In other words, elements of the column are grouped as compactly as possible to reduce road space to a minimum. Vehicles in close column follow each other at the minimum distance which safety, traffic conditions, and the tactical situation will permit.

Advantages. The full traffic capacity of the road, or traffic lane, can be used since road space is reduced to the minimum required for safe driving. Column control and intracolumn communications are better in such compact columns and fewer guides, escorts, and markers are needed.

Disadvantages. Close column formations do not provide dispersion for passive protection against enemy observation and attack. The strength and type of organization are readily apparent to hostile observation. Vehicles may arrive at loading and unloading terminals more rapidly than they can be handled. Careful scheduling and rigid control of traffic are necessary to avoid blocking intersections. Greater driver fatigue is generally experienced in close column than in other

marches. Use of the highway by other traffic is severely limited.

Open Column March. An open column march is generally used during daylight moves. The distance between vehicles is increased to gain a greater degree of protection from hostile action and to permit concurrent use of highways by other traffic. For planning purposes, figure that vehicles in open column move at the rate of 15 miles in the hour with a density of 20 vehicles per mile of roadway.

Advantages. Open column formations offer some passive protection from enemy observation and action, allow greater speeds with more safety, permit greater flexibility in planning moves, and reduce driver fatigue.

Disadvantages. In comparison with close columns, open columns are more difficult to command and control. Abnormal gaps make it hard for drivers to maintain prescribed spacing. Open column formations also permit less traffic volume on a road than more compact formations. In comparison with infiltration, open columns have less secrecy and are not as well adapted to passive defense.

Infiltration. Infiltration is used when maximum secrecy, deception, and dispersion are needed. This type of movement involves the dispatch of vehicles, individually or in small groups, to a predetermined destination over one or more routes, at irregular intervals and at irregular rates of march. To an observer, an infiltration move looks like ordinary casual traffic. Vehicles should normally be dispatched so as to produce an average density not to exceed eight vehicles per mile. It is suitable for daylight moves, movements in congested areas, and on routes which cross heavily traveled roads.

Advantages. Infiltration provides the best possible defense against hostile observation and attack. Under light traffic conditions, movement of the individual vehicle is not materially affected by other vehicles in the move but is limited only by orders, road capability, vehicle mobility, and the training, experience, and physical condition of the drivers. Higher speeds by individual vehicles may be used with this type of movement. Since traffic density is light, cross traffic may move without excessive interference. A unit may be moved by infiltration over a route on which traffic is too heavy to permit movement in a single unit or column.

Disadvantages. It takes longer for the vehicles in an infiltration march to complete a move than for those in any other movement formation. Thus, in spite of a higher rate of march, the total road clearance time for a move may be longer. More important, because of extended distances between vehicles, internal control of the column is difficult. Drivers are usually unable to regulate their movements by the vehicle ahead, and careful marking of the route is necessary to prevent drivers from getting lost. If drivers operate alone, a more detailed briefing is required. Maintenance, refueling, and messing are sometimes difficult to arrange. There is a danger that vehicles may bunch up. Due to relaxed control, tactical employment of the unit may be difficult until the march is completed.

Exercises (C41):

1. What is the main difference between the different types of marches?

2. In what type of march are fewer guides, escorts, and markers required?

3. Which type of march—open column or close column—offers passive protection from enemy observation?
4. Why is an infiltration march used when maximum secrecy is involved?

5. List three disadvantages of an infiltration march.

C42. Given a march graph, determine distance and time factors concerning a convoy movement.

March Graphs. A march graph is a time-distance diagram used in planning, controlling, and recording the progress of a convoy over a given route. It gives a visual picture of a movement and thus shows possible conflicts and congestion before they occur.

March graphs may be used for an individual vehicle, a small unit, or a large motor movement. They may show the movement of one or several columns traveling at different speeds over one or more routes.

Before preparing a march graph, determine the following information concerning the route and movement:

a. Distance from starting point to destination.

b. Route characteristics such as road surface, curves, populated areas, intersections, number of lanes, etc.

c. Reasonable speed for the convoy to travel.

d. Where halts will be made, and the time spent for each.

e. Checkpoints along the route.

f. Rate of march.

g. The time required to make the move by dividing the distance by the rate of march.

When you have the required information, you are ready to prepare a march graph. As we cover the preparation of a march graph, refer to figure 4-1 and check each item as we discuss it.

The first requirement is that the graph paper contain enough squares to plot the distance and time involved in the move. Across the bottom of the graph paper, starting at the left and progressing to the right, a time scale is inserted. A scale of distance, usually in miles, is then placed up the left side of the paper starting at the bottom.

After the time and distance scales are established, the selected route is added on the side of the graph. The names of towns, [illegible]ections, highway regulation points, and traffic

control posts along the route are shown at their proper locations on the route. This is done by the use of a diagrammatic strip map.

Next, the movement is plotted on the prepared graph. For example, in figure 4-1, a unit is to march from Mt. Royal to a point 5 miles beyond Travistock. Scheduled departure time is 0700, and the column is planned to proceed at the rate of 15 miles per hour.

A dot is placed on the graph at the point where the line representing the place of departure intersects the line representing the hour of departure. Another dot is placed on the graph at the point where the line representing the destination intersects the line representing the hour the head of the column is scheduled to arrive. A straight line is drawn to connect these two dots. This line represents the schedule on which the head of the column travels and indicates when it should reach any point en route.

In addition to scheduling the head of a column, the end of the column (the trail) may also be scheduled on a march graph. For example, in figure 4-1, the head of the column was scheduled to leave Mt. Royal at 0700 hours and the last vehicle of the convoy was scheduled to leave Mt. Royal at 0730.

After the head and trail of a column have been scheduled on a march graph, the length of the column can be determined. This is done by drawing a vertical line connecting the head and trail lines. This vertical line is measured and applied to the scale of miles, thereby giving the overall length of the column.

Exercises (C42):

Using the march graph in figure 4-1, determine the following planning (distance and time) factors.

1. What is the distance the convoy will travel?

2. When should the convoy head arrive?

3. When should the convoy trail arrive?

4. How long (miles) is the convoy column?

5. Where should the convoy head be at 0930?

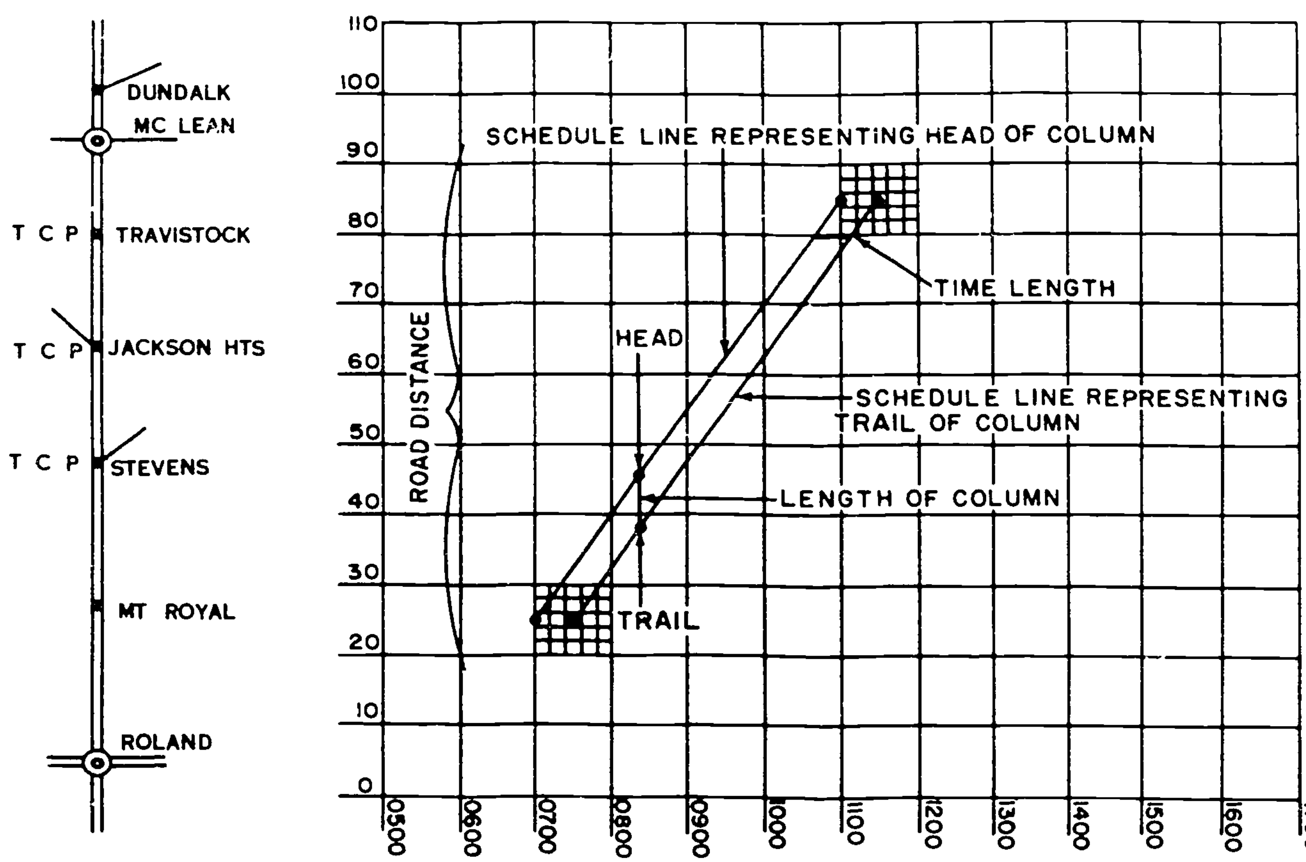

Figure 4–1. March graph.

CQ8-4

4-3. Convoy Organization and Control

Convoys don't just happen; they are organized. The element of control plays a major part in maintaining the integrity of any convoy.

C43. Specify the internal composition of convoys and the responsibilities of various elements.

Internal Composition of Convoys. Every convoy is made up of three internal elements or parts: head, main body, and trail. In the case of small columns, the functions of the three parts may be combined. For example, a convoy may be as small as two vehicles moving together under one commander. In such a small movement, both vehicles are usually task vehicles carrying loads and constitute the main body. The first vehicle also contains the persons who perform the functions of the head, and the second vehicle contains trail personnel.

In addition to the above elements, large convoys often make use of detached parties. These detached parties, advance and followup, are not a part of the main column and operate apart from it. They are detailed to perform special duties when the situation requires their use. The functions of the various elements are discussed in the following paragraphs.

Head. The head is the first element of the column in the order of march. The lead vehicle should contain the convoy commander or an officer or noncommissioned officer who represents the commander. He or she is there to handle any problems that occur at the head of the column. This would consist of such things as correctly following the prescribed route, checking in at scheduled points, receiving any orders or change in orders, and issuing such instructions as may be required. He or she may also contact and coordinate with civil authorities along the route of the movement.

A lead vehicle should also contain a pace setter. The pace setter sets the pace to comply with the rate of march. The maximum pace is usually controlled by the speed that can be maintained by the slowest vehicle in the column.

Main body. The main body of the column follows the head and consists primarily of vehicles carrying troops, equipment, and supplies. This part of the convoy may be subdivided into serials and march units for easier regulation and control. For example, the commander can divide the vehicles into serials of vehicles and then subdivide the serials into march units. The convoy commander commands the entire motor march; he or she names serial commanders and march unit commanders. Each serial (and march unit when desirable) may be organized with a head, main body, and trail. Each separate element should have its own pace setter.

Once the vehicles have been organized into a suitable march column, each vehicle must be labeled to indicate its position in the column. Normally, vehicles are identified numerically. For example, the first vehicle in the column is numbered "1," the second "2," etc. If there are two or more serials, the serials are identified alphabetically, such as "A," "B," "C," etc. The designation "A-1" on a vehicle would indicate the 1st vehicle in the first serial; "B-27" would indicate the 27th vehicle in the 2d serial. Placards or some easily removed substance (chalk or tape) should be used to label the vehicles.

If all vehicles in a convoy are to remain together from origin to destination, slower vehicles should be placed near the head of the column. This arrangement serves as a governor on the faster vehicles and prevents large gaps from developing between elements within the column. It may be desirable for the column to move in small segments because small units create less disruption of traffic over the routes used. In this case, vehicles are grouped with the faster ones at the head. As the column progresses, gaps between serials or march units become progressively greater.

Trail. The trail is the last element of a motor column. The trail officer or noncommissioned officer represents the commander in such functions as preventing straggling and maintaining discipline. Usually, maintenance and possible medical personnel included in the trail are under the supervision of the trail officer. The final clearance of designated points by the column is checked by the trail officer, and he or she takes such action as may be required. He or she also makes sure that traffic from the rear is warned of the convoy ahead, and he or she picks up guides and markers. In case of breakdowns, the trail personnel make repairs, arrange for towing, or see that the vehicle is properly attended until disposition of vehicle and cargo can be effected.

Detached parties. Advance parties may be provided by a higher headquarters or detailed from the convoy. Their mission is to locate and arrange for bivouac areas; for quarters or billets; for loading and parking facilities; and for supplies, rations, water, fuel, and medical attendance before the convoy arrives. The advance parties are responsible also for traffic reconnaissance except when the movement is made over an already reconnoitered route. The advance parties also post guides, traffic control personnel, and route markers as needed.

The followup detachment is designated to inspect bivouac areas and other halt sites after they are vacated by the convoy. They must correct and report to the commander of the convoy any undesirable conditions noted. During operation in peacetime, the followup party completes the necessary paperwork in connection with leased camp sites and with claims arising from damage. On the road, this party may pick up guides, guards, and markers which have been placed by the advance party. Providing for the disposition of dead or wounded and of disabled vehicles is also a responsibility of the followup parties.

Exercises (C43):

1. Explain how a convoy of two vehicles can have all three elements of a convoy.

2. What is a detached party?

3. List five things for which the head of the column is responsible.

4. Which unit determines the rate of march for a convoy?

5. How is internal control maintained in a large convoy?

6. What does the sign or chalk designation "D–19" on a vehicle in a convoy indicate?

C44. State convoy communications methods; given situations involving the need for communication within a convoy, determine the possible methods.

Intracolumn Communication. Intracolumn communications help provide convoy control. Sign messages from the front of the column may be written on a board and posted on the driving side of the road or displayed by a guide. Such messages are then noted by the drivers as they pass the signboard.

Written messages directed to a unit or vehicle in the column may be delivered by a messenger or given to a guide stationed along the route who will transfer it to the proper vehicle.

Two-way radios may be located in the control cars of the commander and at the head and trail. When supplemented by receivers in other vehicles in the column, they provide the best intracolumn communications and afford maximum control of a column.

Whistles and other audible signaling devices (horn, siren, etc.) can be used as a means of tranmitting a command to a column when a code has been established.

Visual hand and arm signals constitute another means of march communication. Column control signals may be given from the cab of a vehicle or by a person standing on the road. The meaning of the standard hand and arm signals used for convoy control is contained in AFM 77–2, *Manual for the Wheeled Vehicle Driver*.

Exercises (C44):

1. List four methods of communicating between personnel within a convoy.

2. A message for the driver of the vehicle B–3 could be delivered by what means?

3. Serial B is to be rerouted a short distance. There is no radio communications within the convoy. How could the drivers of this serial be notified?

C45. State the purpose of, and consideration in scheduling, halts during convoy operations.

Halts. Halts are made for purposes of rest, personal comfort and relief, messing, refueling, maintenance and inspection of equipment, and allowing other traffic to pass.

Short halts. Routine short halts will be made at the discretion of the commander. Short halts, when specifically ordered, should normally be made for 10 minutes after every 110 minutes of driving time.

Long Halts. Long halts (messing, refueling, and bivouacking) should coincide and must always be specifically ordered and plotted on road movement graphs. The locations for scheduled halts should be selected in advance. They may be prescribed by higher authority, located tentatively by map references, or selected by the reconnaissance party.

Comfort of personnel and servicing facilities for vehicles are important considerations in selecting sites for long halts. If a column starts from a populous area, its first halt should be delayed, when practical, until a rural area is reached to facilitate relief of personnel. Columns should be halted at points providing a minimum of 200 yards of clear visibility to the front and rear of the column. Guards, warning flags, caution lights, or flares should be posted in the front and to the rear of the column if it presents a hazard to passing traffic.

During halts, all personnel have certain responsibilities Officers and noncommissioned officers check the welfare of personnel, the security of loads, and the performance of operator maintenance. Control personnel make necessary inspections and give instructions to insure resumption of the movement with a minimum of confusion at the end of the halt. Mess, medical, and maintenance personnel perform such special duties as the purpose and duration of the halt permits. Drivers inspect their vehicles and security of loads and make necessary corrections.

Exercises (C45):

1. Why are halts made during a convoy movement?

2. How often should shorter halts be scheduled for a convoy?

3. What are two important things to consider when scheduling long halts?

ANSWERS FOR EXERCISES

CHAPTER 1

References

C01 – 1. First aid measures for injuries such as fractures and chest wounds, for emergencies such as drowning and electric shock, and for common emergencies such as minor wounds and unconsciousness. You should learn as much as you can about first aid measures for sickness and injury resulting from industrial toxic substances.
C01 – 2. Observations of the plans, soles, nail beds, mucous membranes of the lips and mouth, and mucous membrane which lines the eyelids and is reflected onto the eyeball.
C01 – 3. Know what to do and what not to do.

C02 – 1. The four lifesaving steps are: assure breathing, stop the bleeding, protect the wound, and prevent or treat shock.
C02 – 2. Pulling clothing over the wound increases the danger of infection, and moving the wounded part may make the wound worse, as well as cause needless pain.

C03 – 1. True.
C03 – 2. True.
C03 – 3. True.
C03 – 4. True.
C03 – 5. False. The sword-swallowing position means the victim's chin and neck are stretched away from his chest.
C03 – 6. True.
C03 – 7. True.

C04 – 1. (1) a, C.
(2) b, A.
(3) a, C.
(4) b, B.
(5) c, A.
(6) c, A.
(7) b, A.
(8) c, A.
(9) a, B.
(10) c, A.

C05 – 1. You dress a wound to reduce bleeding and to protect it from infection and further injury.
C05 – 2. A dressing is a pack or padding placed directly on the wound.
C05 – 3. A bandage is the material you use to hold a dressing in place or create pressure to stop the blood flow.

C06 – 1. True.
C06 – 2. True.
C06 – 3. False. Cold and clammy skin is indicative of shock.
C06 – 4. True.
C06 – 5. False. Wine is alcoholic, and alcoholic beverages should not be given to any injured person.
C06 – 6. True.
C06 – 7. True.
C06 – 8. False. You treat for shock whenever the symptoms appear. If they don't appear, you start treating to prevent shock, after assuring breathing and stopping the bleeding.

C07 – 1. (1) a.
(2) b.
(3) c.
(4) d.
(5) e.

C08 – 1. True.
C08 – 2. True.
C08 – 3. True.
C08 – 4. False. Change "stroke" to "exhaustion."
C08 – 5. True.
C08 – 6. False. Change "6" to "12."
C08 – 7. True.
C08 – 8. True.
C08 – 9. False. Change "when he or she regains consciousness" to "at once."

C09 – 1. True.
C09 – 2. True.
C09 – 3. True.
C09 – 4. True.
C09 – 5. True.

CHAPTER 2

C10 – 1. True.
C10 – 2. True.
C10 – 3. True.
C10 – 4. True.

C11 – 1. Infection is the invasion of a person's body by disease-producing organisms.
C11 – 2. a. Skin and mucous membranes.
b. Cellular system (lymphatic system).
c. Blood system.

C12 – 1. True.
C12 – 2. True.
C12 – 3. True.
C12 – 4. True.
C12 – 5. False. Delete "toothpaste." Insert "a toothbrush alone."
C12 – 6. True.
C12 – 7. True.

C13 – 1. (1) c, B.
(2) a, E.
(3) b, D.
(4) d, A.

C14 – 1. a. 4.
b. 2.
c. 1.
d. 3.
C14 – 2. a. Iodine tablets; calcium hypochlorite ampules.
b. Calcium hypochlorite.
c. Twenty minutes after mixing.
d. One canteen.

C15 – 1. True.
C15 – 2. False. Change "is not" to "is."
C15 – 3. False. Change "are suitable" to "are not suitable."
C15 – 4. True.
C15 – 5. True.

C16 − 1. c.
2. d.
3. a.
4. e.

C17 − 1. Bite.
C17 − 2. Body, head.
C17 − 3. Seams, neck, waist.
C17 − 4. Sifter.

C18 − 1. C.
C18 − 2. C.
C18 − 3. X.
C18 − 4. C.
C18 − 5. X.

C19 − 1. T.
C19 − 2. F.
C19 − 3. T.
C19 − 4. T.

C20 − 1. Insects.
C20 − 2. Brush, vegetation, animals.
C20 − 3. Crush, mouthparts.
C20 − 4. World, climates.
C20 − 5. Person, personal.
C20 − 6. Rodents.

C21 − 1. Human.
C21 − 2. Rodent-borne.
C21 − 3. Infestation, food, harborage.
C21 − 4. Containers.
C21 − 5. Mechanical.
C21 − 6. Traps, bait.

C22 − 1. T.
C22 − 2. T.
C22 − 3. X.
C22 − 4. X.
C22 − 5. T.
C22 − 6. T.

CHAPTER 3

C23 − 1. Concealment from direct and indirect observation.
C23 − 2. Hiding.
C23 − 3. Deceiving.
C23 − 4. Choice of position, camouflage discipline, and camouflage construction.
C23 − 5. Noise and light discipline.

C24 − 1. Burnt cork, charcoal, lampblack, and mud.
C24 − 2. Paint, bands, and helmet covers.
C24 − 3. The position of the enemy force.
C24 − 4. Through use of camouflage nets.

C25 − 1. Cover.
C25 − 2. Concealment.
C25 − 3. Use both.

C26 − 1. Rushing is a technique where you start from the prone position or cover, pick a location to move to, and quickly get up and run to that position.
C26 − 2. The low crawl is pushing and pulling yourself along the ground with your weapon lying across your arm and your head low to the ground; the high crawl allows you to hold your head up and carry your weapon across your arms in front of your body.
C26 − 3. To walk at night, you lift your legs high and come down on your toes.

C27 − 1. Part of your force moves forward 10 to 15 meters at a time while the remainder of the force lays down cover fire.
C27 − 2. The only difference between individual and team fire and movement is that the number of people moving at one time is greater with team movement.

C28 − 1. To advance on a hostile position and gain a position close enough to be able to conduct an assault.
C28 − 2. To lay down sufficient fire on the hostile position to provide an effective cover for the maneuver echelon.

C29 − 1. a. To observe a large area for enemy activity.
b. To specifically locate enemy activity as you move through an area.
c. To observe a single point and record information concerning enemy activity.
C29 − 2. (1) b.
(2) 0.
(3) c.
(4) 0.
(5) a.

C30 − 1. a. Destroy a moving or temporarily halted target.
b. Attack and destroy an enemy position and then withdraw.
c. Move into an area, destroy or remove the enemy, and hold the territory.
d. Screen or cover the flanks of a position, area, or route.
e. Establish a road block to prevent enemy movement or reinforcement, seize key terrain to prevent enemy use, or act as a blocking force.
C30 − 2. (1) d.
(2) a.
(3) 0.
(4) b.
(5) e.
(6) c.

C31 − 1. a. Preparation—gather intelligence and plan counterattack.
b. Fire and maneuver—depart the line of departure and maneuver under cover fire to the final coordination line.
c. Assault—cover fire is shifted away from the maneuver echelon as they stand and assault the hostile position, retake, and secure the position.

C32 − 1. Men in kill zone assault the ambush position. Men not in kill zone maneuver against the ambush force. Eliminate the ambush or break contact as directed.
C32 − 2. Men in kill zone return fire and take available cover. Men not in kill zone maneuver against the ambush force. Eliminate the ambush or break contact as directed.

C33 − 1. To insure that all hostile forces have fled or been neutralized and all boobytraps found and disarmed.
C33 − 2. Areas and buildings previously held by an enemy are taken from enemy control and made available for occupation by friendly forces.
C33 − 3. Enter building from top; search and clear from top to bottom.
C33 − 4. Enter on second floor, search and clear second floor; proceed to top of building and search and clear down.
C33 − 5. Reconnaissance in force, flight size.
C33 − 6. Raid, squad size.

C34 − 1. No.
C34 − 2. Yes.
C34 − 3. Yes.

C35 − 1. d.

C35 − 2. c.
C35 − 3. b.
C35 − 4. e.
C35 − 5. a.

C36 − 1. b. To break up enemy attack formations and to hold or channel the enemy in areas covered by your most intensive fire.
C36 − 2. c. To camouflage the position of your primary wire barriers and to connect barriers surrounding your defensive positions.
C36 − 3. a. To prevent surprise assaults from points close to your defensive area.

C37 − 1. c.
C37 − 2. g.
C37 − 3. b, e.
C37 − 4. e.
C37 − 5. d.

C37 – 6. e.
C37 – 7. f.
C37 – 8. e.
C37 – 9. a.
C37 – 10. c.
C37 – 11. b.

CHAPTER 4

C38 – 1. a. Motor column in which a prescribed space between vehicles is maintained, regardless of speed.
b. Time-distance graph used in planning and controlling motor marches.
c. Major subdivision of a motor column, consisting of elements from one area to the same destination.
d. Number used to multiply the speedometer reading to determine vehicle distance in yards.
e. Time required for a motor column to move a certain distance at a given rate of speed.
f. Number of vehicles passing a given point within a given time period.
g. A convoy of general-purpose vehicles which do not exceed legal limitations and which are not carrying hazardous cargo.
h. A convoy of vehicles exceeding legal size limitations or traveling at unusually slow speed.

C39 – 1. The amount and type of cargo that is to be moved.
C39 – 2. It is used to gather information concerning the route and the adjacent areas for planning the move.
C39 – 3. Number and type vehicles needed.
C39 – 4. Maps; forecasters; fuel (or repairs, rations, water); points (or bottlenecks).

C40 – 1. Base transportation officer in coordination with the security police officer.
C40 – 2. Security officer.
C40 – 3. The American Trucking Association, Inc.
C40 – 4. State, local military, and Director of Transportation, Headquarters USAF.
C40 – 5. DD Forms 1265 and 1266.

C41 – 1. Vehicle spacing.
C41 – 2. Close column march.
C41 – 3. Open column march.
C41 – 4. Because to an enemy observer, the move looks like ordinary traffic flow.
C41 – 5. (1) Requires the greatest amount of time to complete a move.
(2) Internal control of the column is difficult.
(3) Usually requires more detailed briefing of drivers.
(4) Maintenance, refueling, and messing are sometimes difficult to arrange.
(5) Tactical employment of unit may be difficult during march.

C42 – 1. 60 miles.
C42 – 2. 1100 hours.
C42 – 3. 1130 hours.
C42 – 4. 7 miles.
C42 – 5. Jackson Heights.

C43 – 1. A convoy of two vehicles would have more than one function performed by each vehicle. Normally, both vehicles are load-carrying and would constitute the main body. The lead vehicle carries the individual in charge (head), and the second vehicle would act as the trail.
C43 – 2. A detached party operates apart from the column and performs special duties in advance of or following the convoy.
C43 – 3. The head of the convoy follows the prescribed route, checks in at scheduled points, receives orders or changes in orders, issues instructions as required, and coordinates with civil authorities along the route.
C43 – 4. The pace setter (usually slowest vehicle).
C43 – 5. By subdividing the convoy into serials and, where necessary, march units. Each of these has a commander.
C43 – 6. The 19th vehicle in the 4th serial.

C44 – 1. Signs, written messages (delivered by messenger or guide), two-way radios, sounds, and signals (such as hand and arm signals).
C44 – 2. Written message or two-way radio.
C44 – 3. Signs posted on roadway.

C45 – 1. They provide for periods of rest, personal comfort, and relief, messing, refueling, maintenance and inspection of equipment, and allowing other traffic to pass.
C45 – 2. They should be scheduled to allow 10 minutes rest after each 110 minutes of driving time.
C45 – 3. (1) The comfort of personnel and (2) servicing facilities for vehicles.

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STOP - 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

55252 07 22

GENERAL CONTINGENCY RESPONSIBILITIES

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

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MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

Note to Student: This volume review exercise contains 77 four-option items and 3 three-option items.

1. (C01) Skin color changes caused by shock as a result of injuries can be found on

   a. the palms of the hands.
   b. the soles of the feet.
   c. the nail beds or eyelids.
   d. all of these.

2. (C01) Which one of the following statements concerning first aid is *false?*

   a. A person administering first aid deals with the whole situation.
   b. In administering first aid, it is just as important to know what not to do as it is what to do.
   c. In administering first aid, you should attempt treatment that is beyond your skill.
   d. First aid refers to the treatment given the sick and injured before a trained individual has administered medical treatment.

3. (C02) The second step of the four lifesaving steps of first-aid is

   a. protect the wound.
   b. prevent or treat shock.
   c. stop the bleeding.
   d. ensure breathing.

4. (C02) The best way to remove clothing from an injured person who has a broken leg is to

   a. cut the clothing away.
   b. have the injured person remove it.
   c. have someone lift the injured person's leg to remove the clothing.

5. (C03) In addition to foreign matter, what are the main causes of airway obstruction?

   a. Vomitus and false teeth.
   b. Relaxed jaw and vomitus.
   c. Vomitus and neck position.
   d. Relaxed jaw and nech position.

6. (C03) The head position that stretches the throat of an injured person to keep the airway open is called

   a. jaw high position.
   b. the slanted necked position.
   c. the stretched cjom position.
   d. sword-swallowing position.

7. (C04) Which condition indicates arterial bleeding?

   a. Large amount of blood flowing from a wound.
   b. Blood oozing from a wound.
   c. Large amount of blood spurting from a wound.
   d. Large amount of blood oozing from a wound.

8. (C04) A tourniquet would be used to control what type of bleeding, if any?

   a. Capillary.
   b. Venous.
   c. Arterial.
   d. None of these.

9. (C05) What steps must you take when treating an injured person to insure you do not further contaminate a wound?

   a. Don't touch the wound, apply a sterile dressing, and use a bandage to hold the dressing in place.
   b. Probe the wound for fragments, apply a sterile dressing, and use a bandage to hold the dressing in place.
   c. Tear up your undershirt for a bandage and apply it directly to the wound.
   d. Any of these.

10. (C06) An indication that a victim has gone into deep shock is that the victim is

a. excessively thirsty.
b. retching and vomiting.
c. gasping for air.
d. listless and apathetic.

11. (C06) Which of the following things should you *not* do when treating victims for shock who have a stomach wound?

a. Reassure them and make them as comfortable as possible.
b. Keep them warm.
c. Encourage them to drink liquids.
d. Continue to observe them.

12. (C07) Identify the type of injury where a litter must be used in transporting the injured.

a. Compound fracture of a leg.
b. Compound fracture of an arm.
c. A head injury.
d. A back or neck fracture.

13. (C07) Which type of transportation would be the best when you are with a victim who must be moved a short distance and you are not exposed to gunfire?

a. Fireman's carry.
b. Two-hand carry.
c. Pistol belt drag.
d. Litter carry.

14. (C08) Of the following heat conditions, which one, if any, is the most severe?

a. Heat cramps.
b. Heat stroke.
c. Heat exhaustion.
d. All are equally severe.

15. (C08) Which one of the following first aid measures is applied in the treatment of all three heat conditions, heat stroke, heat exhaustion, and heat cramps?

a. Massage the affected area.
b. Immerse the body in the coldest water possible.
c. Transport all cases to the nearest hospital facility.
d. Give the victim water containing salt.

16. (C09) Which of the following factors would contribute to the severity of an injury caused by exposure to extreme cold weather?

a. Temperature.
b. Humidity.
c. Wind type and velocity.
d. All of these.

17. (C09) Which option correctly describes frostbitten skin?

a. Whitish, stiff, numb rather than painful.
b. Grayish in color, stiff, numb rather than painful.
c. Whitish, numb and painful.
d. Whitish, stiff and painful.

18. (C10) When you do not feel well, you should

a. report to sick call.
b. wait to see if the symptoms get worse.
c. treat yourself.
d. ask a friend for advice.

19. (C10) When should you eat foods from each of the recommended food groups?

a. Monthly.
b. Weekly.
c. Daily.
d. When they are offered.

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20. (C11) What is the third line of defense that your body provides against infection?

a. Your skin.
b. Your blood.
c. Your mucous membranes.
d. Your lymphatic system.

21. (C11) Which one of the following alternatives is *not* considered a passive defense against disease?

a. Eating properly.
b. Changing wet clothes.
c. The use of a borrowed cup.
d. Regular sleep.

22. (C12) Before airing and sunning, you should shake clothing in

a. your room.
b. the shower.
c. the open outside.
d. a closet.

23. (C12) You sun clothing that cannot be washed to

a. fade the material.
b. reduce wrinkles.
c. brighten the material.
d. reduce content of disease germs.

24. (C13) When you wear pinching shoes on your feet, the pinching will cause

a. fungus infection.
b. bunions.
c. ingrown toenails.
d. athlete's foot.

25. (C13) What is usually the cause of ingrown toenails?

a. Socks too large.
b. Socks too small.
c. Improper cutting.
d. Fungus.

26. (C14) Who certifies that water is safe to use?

a. Medical personnel.
b. Base engineer.
c. The user.
d. Sanitation personnel.

27. (C14) If you are in a field situation and need water and a lake is nearby, what action should you take?

a. Skim any film or contaminates from the surface, fill your canteen, and drink.
b. If the water is clear, dissolve one iodine tablet in the canteen of water and drink immediately.
c. If the water is clear, dissolve two iodine tablets in the canteen of water and drink.
d. If the water is clear, dissolve one iodine tablet in the canteen of water, and wait 20 minutes before drinking.

28. (C15) Improper handling of food in kitchens will result in

a. an unusual food odor.
b. an unappetizing appearance.
c. a shortage of food.
d. contamination of food.

29. (C15) A bulging can of food indicates

a. an overheated can.
b. rough treatment.
c. contaminated contents.
d. poor storage of can.

30. (C16) How deep is the straddle trench latrine dug for temporary use?

a. 1 1/2 feet.
b. 2 1/2 feet.
c. 3 1/2 feet.
d. 4 1/2 feet.

31. (C16) What is the minimum distance that must be established for the location of garbage pits to a drinking water source?

a. 25 yards.
b. 50 yards.
c. 75 yards.
d. 100 yards.

32. (C17) What type of disease is spread by lice?

a. Flu.
b. Dysentery.
c. Relapsing fever.
d. Snail fever.

33. (C17) Lice found on personnel obtain their food from

a. body powder.
b. dust particles.
c. table crumbs.
d. human blood.

34. (C18) What types of diseases have flies been known to carry and transmit to humans?

a. Dysentery.
b. Cholera.
c. Typhoid.
d. All of these.

35. (C18) Flies pick up their food with

a. mouthparts that act as sponges.
b. their feet.
c. their wings.
d. hair on their feet and legs.

36. (C19) Why should insecticide powder not be used on cats to control fleas?

a. Cats are sensitive to powder.
b. Cats lick themselves to clean their fur.
c. Liquid works better on cats.
d. Powder will not penetrate cat fur.

37. (C19) How does the flea transmit plague to man?

a. By carrying the germ on the flea legs.
b. By depositing eggs on man.
c. Through the flea bite.
d. Through breathing on man by the flea.

38. (C20) What are two types of ticks?

a. Large and small.
b. Long and short.
c. Black and brown.
d. Hard and soft.

39. (C20) Where should you grasp an imbedded tick to remove it from the skin?

a. Close to the mouthparts.
b. The legs.
c. The abdomen.

40. (C21) Rocky mountain spotted fever is transmitted to man by

a. ticks.
b. flies.
c. lice.
d. chiggers.

41. (C21) Man becomes infected with trichinosis by

a. tick bites.
b. consuming infected pork.
c. fly bites.
d. breathing the germs.

42. (C22) Encephalitis (sleeping sickness) usually affects man by

a. causing severe headache.
b. causing internal bleeding.
c. causing severe muscular pain.
d. affecting the central nervous system.

43. (C23) What is the primary disadvantage of indirect observation?

a. Far reaching, covers large areas.
b. Produces a record of area observed.
c. Costly in human lives.
d. Seldom allows detection of movement.

44. (C23) Which of the following alternatives is a camouflage method?

a. Hiding.
b. Blending.
c. Deceiving.
d. All of these.

45. (C24) Which of the following materials may best be used for skin tonedown?

a. Mud or soil.
b. Burnt cork.
c. Shoe polish.
d. Skin toner.

46. (C24) Which statement is correct pertaining to your actions after you hear a flare pop and it illuminates the area?

a. Run for the nearest cover.
b. Drop to the ground and remain motionless.
c. Freeze in place with your face pointed toward the ground.
d. Freeze in place and look toward the direction of the flare to detect and fire on enemy movement.

47. (C25) Of the following statements pertaining to concealment, which one is true?

a. Concealment is protection from enemy invasion.
b. Concealment may be natural, such as bushes, grasses, and shadows.
c. Concealment should not be artificial, such as burlap, or nets.
d. Concealment is protection from enemy fire.

48. (C26) In the rushing technique, what is the maximum distance you should try to rush at one time?

a. 5 meters.
b. 10 meters.
c. 15 meters.
d. 20 meters.

49. (C27) What elements would govern the advancing of a unit while it is under enemy fire?

a. The number of personnel moving and the manner in which they move depend on the size of the unit and terrain only.
b. The number of personnel moving and the manner in which they move depend on the terrain and volume of fire being received only.
c. The number of personnel moving and the manner in which they move depend only on the number of personnel in the unit and fire being received.
d. The number of personnel moving and the manner in which they move depend on the enemy fire being received, number of personnel in unit, and terrain.

50. (C27) When your unit is under heavy enemy fire, what is the safest way for the unit to move?

a. In groups of 2 or 3.
b. Individual movement.
c. By squads.
d. Move the entire unit at one time.

51. (C28) When dividing your force into base of fire echelons and maneuver echelon, what would be the two factors to consider?

a. Time of day and situation.
b. Element of surprise and time of day.
c. Situation and the integrity of the elements.
d. Time of day and available cover.

52. (C29) What type of patrol, if any, would be identified with the assigned task of locating specific enemy positions and reconfirming previous data?

a. Area surveillance.
b. Area reconnaissance.
c. Point reconnaissance.
d. None of these.

53. (C30) What type of combat patrol has the mission of screening or covering the flanks of your position or area?

a. Security patrol.
b. Ambush patrol.
c. Search and clear patrol.
d. Economy of force patrol.

54. (C30) What type of patrol would best be utilized to act as a blocking force to allow a major effort to be made without interference at another location?

a. Security patrol.
b. Ambush patrol.
c. Rapid patrol.
d. Economy of force patrol.

55. (C31) To mount a counterattack, what essential information must you have?

a. The size of the enemy force.
b. Type of weapon or weapons the enemy force has.
c. How well protected the enemy force is.
d. All of these.

56. (C31) In a combat assault, the purpose of the base man, team or squad is to

a. give cover fire to the advancing forces.
b. assist in the evacuation of wounded.
c. control the speed or direction of the assault.
d. act as a rear guard.

57. (C32) Of the examples given below, select the one that applies to actions to be taken in both near and far ambush.

a. Those personnel not in the kill zone maneuver against the ambush.
b. The attack or return fire is continued until the enemy position is destroyed or you are ordered to break contact.
c. The assault or attack should always be on the ambush position.
d. Retreat as rapidly as possible without awaiting orders.

58. (C33) What is the best way to enter and search a building?

a. Enter the building from the top.
b. Enter the building through the basement.
c. Enter the building at the first floor level.
d. Any door or window on basement level of the building.

59. (C33) The primary objective of a search and clear operation is to

a. clear the area of hostile troops.
b. gain control of enemy territory.
c. eliminate hostile forces and remove booby traps.

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60. (C34) Which of the following statements correctly identifies the degree of protection that field fortifications can give you?

a. Construction and strength of the fortification.
b. How well you distribute the fortifications within the tactical defense.
c. How well you adapt them to the terrain and conceal them from enemy observation.
d. All of these.

61. (C34) What determines the extent to which you would disperse while on a combat mission?

a. Mission of the unit.
b. Type of terrain.
c. The enemy situation.
d. All of these.

62. (C35) Of the following defensive positions, which one would provide the most protection?

a. Hasty emplacement.
b. Shell crater.
c. Prone emplacements.
d. Foxhole.

63. (C35) When constructing your defensive position, what items should you use to conceal your position?

a. Trees and brush.
b. Rock.
c. Soil.
d. All available natural material.

64. (C36) What are the determining factors in the classification of tactical barriers?

a. Intended use of the barrier only.
b. Depth of the barrier only.
c. Type of barrier used.
d. Use and depth of the barrier.

65. (C36) Which type of barrier would be best suited to break up enemy attack formations and channel the enemy into areas of most intensive fire?

a. Protective.
b. Tactical.
c. Supplementary.
d. Belt.

66. (C37) At what distance would standoff fencing be best utilized from the defensive position?

a. 0-10 feet.
b. 10-25 feet.
c. 25-40 feet.
d. 40-50 feet.

67. (C37) In the erection of a perimeter fence, what must you take into consideration?

a. The fence must have depth.
b. Sentries must be alert in maintaining surveillance.
c. It must be effectively covered by defensive fire.
d. All of these.

68. (C38) Which of the following statements pertaining to a convoy is *false?*

a. A convoy is the movement of a group of motor vehicles under the control of a designated person.
b. All convoys are under the control of a convoy commander who must be a commissioned officer.
c. Normal convoys are those that do not exceed any legal limitations such as width, length, height, etc.
d. Convoys are normally classified as three types, normal, hazardous, and convoys transporting classified equipment.

69. (C39) Using convoy terms, what would be referred to as the average speed of a motor column over a period of time, including short, periodic halts?

a. Time distance.
b. March graph.
c. March unit.
d. Rate of march.

70. (C39) In a route reconnaissance, what sources of information are valuable to insure your convoy would not incur any problems?

a. State highway or military maps.
b. Personal knowledge of the proposed route of travel.
c. State police and weather forecasters.
d. All of these.

71. (C40) In what positions on the vehicle should warning signs be placed on vehicles carrying explosives?

a. Front and rear only.
b. Rear and sides only.
c. Both sides only.
d. Front, rear, and both sides.

72. (C40) When vehicles in a convoy are transporting explosives, what is the minimum distance that must be maintained between the vehicles?

a. 100 feet.
b. 200 feet.
c. 300 feet.
d. 400 feet.

73. (C41) Which of the following statements pertaining to close column formations is *false?*

a. Close column formation provides for rapid dispersion of vehicles.
b. In a close column formation, the full traffic capacity of the traffic lane can be used.
c. Column control is increased as the vehicles are closer together.
d. Communications are better and fewer guides, escorts and markers are needed.

74. (C41) Which of the following statements concerning open column marches is false?

a. The distance between vehicles is increased to provide better protection from enemy activity.
b. This march permits greater speeds with more safety and reduces driver fatigue.
c. This march permits greater flexibility in planning moves.
d. This march is easier to command and control as radio communications are used.

75. (C42) The primary function of a march graph is that it is used for

a. recording the progress of a convoy over a given route.
b. planning movement of a convoy over a given route.
c. control of the movement of a convoy over a given route.
d. all of these purposes.

76. (C43) Which of the statements pertaining to large convoys is *false?*

a. Large convoys are made up of three internal parts, head, main body and trail.
b. Detached parties advance and followup are not part of the main column and work separate from it.
c. In large convoys the functions of the three internal parts may be combined.
d. The part of the convoy that may be subdivided into march units and serials is the main body.

77. (C44) Which one of the following options identifies the best type of intracolumn communication?

a. Visual hand and arm signals.
b. Two way radios.
c. Whistles or other audible sounding devices.
d. Flags of different colors and shapes.

78. (C44) What Air Force publication governs the use of hand signals for convoy control?

a. AFR 127-101.
b. AFM 127-101.
c. AFM 77-2.
d. AFR 01-02.

79. (C45) When columns are halted, at what minimum distance must clear visibility be to the front and rear of the column?

a. 100 yards.
b. 200 yards.
c. 300 yards.
d. 400 yards.

80. (C45) During halts, what are the responsibilities of officers and noncommissioned officers?

a. Check vehicles and perform operators maintenance.
b. Make necessary inspections to insure resumption of movement of the column.
c. Post guards and check vehicle tires for proper inflation.
d. Check security of loads, welfare of personnel, and the performance of operator's maintenance.

END OF EXERCISE

99 01

ATC/ECI SURVEY

The remaining questions are not part of the Volume Review Exercise (VRE). *You must complete and return the answer sheet marked "Student Survey" to receive your end of course examination (CE).* This survey will not affect your score. We need your opinions of how well the CDC supports skill progression for the entire AFSC and how well you view course content and/or service. Your name and SSAN will be disassociated from your responses to the survey prior to tabulation. (See Privacy Act statement).

Using a number 2 pencil, indicate what you consider to be the appropriate response to each survey question on your answer sheet labeled "Student Survey." Do not respond to questions that do not apply to you. Your cooperation will help both ATC and ECI improve the quality of our service and courses and you'll have an active part in the management of Air Force Career Development Education and Training.

Please keep your student survey answer sheet 99 01. All VREs plus the answer sheet for 99 01 must be submitted before you will receive your course examination.

PRIVACY ACT STATEMENT

A. Authority: 5 U.S.C. 301, *Departmental Regulations*

B. Principal Purpose: To obtain student input concerning ECI course materials, examinations, administration, and student study methods and support educational research.

C. Routine Uses: Group data will be used for routine course evaluation and improvement.

1. Which of the following best describes your current Department of Defense status:

a. USAF active duty.
b. Civilian.
c. USAF Reserve/ANG.
d. Other.

2. Mark the item that best describes the counseling you received prior to enrolling into this course:

   a. I was counseled by Base Education Services Personnel
   b. My OJT Trainer/Manager counseled me.
   c. My supervisor and/or friend told me all I needed to know before I enrolled.
   d. I received no counseling.

3. If you contacted ECI for any reason during your enrollment, how would you describe the service provided?

   a. Excellent.
   b. Satisfactory.
   c. Unsatisfactory.
   d. Did not contact ECI.

4. I enrolled in this course:

   a. As a mandatory enrollment for upgrade purposes.
   b. To obtain WAPS study material.
   c. To increase my chances of cross-training.
   d. For my own personal benefit.

5. (USAFE only) How long did it take to receive your course materials *after* you received notification of enrollment?

   a. 1-9 days.
   b. 10-19 days.
   c. 20-29 days.
   d. 30 or more days.

6. (PACAF only) How long did it take to receive your course materials *after* you received notification of enrollment?

   a. 1-9 days.
   b. 10-19 days.
   c. 20-29 days.
   d. 30 or more days.

7. (ALL EXCEPT USAFE AND PACAF) How long did it take to receive your course materials *after* you received notification of enrollment?

   a. 1-9 days.
   b. 10-19 days
   c. 20-29 days.
   d. 30 or more days.

8. What was the condition of the course materials you received from ECI?

   a. A complete set of well-packaged materials.
   b. An incomplete set of well-packaged materials.
   c. A complete set of poorly-packaged materials.
   d. An incomplete set of poorly-packaged materials.

9. The amount of time I spent posting changes to this CDC was:

   a. Less than 30 minutes.
   b. Between 30 minutes and 1 hour.
   c. More than 1 hour.
   d. None, as there were no changes to post.

10. The overall reading level of the material in this course is:

   a. Much too high.
   b. Slightly high.
   c. About right.
   d. Too low.

11. If you had difficulty understanding any of the course materials, did you experience difficulty with:

   a. The technical information relevant to your AFSC.
   b. The non-technical information related to your AFSC (e.g. security).
   c. All of the materials.
   d. None of the material.

12. The illustrations in the course materials:

   a. Were of high quality and aided learning.
   b. Were of poor quality and were still useful to some degree.
   c. Were of no value.
   d. There were no illustrations.

13. The format of the text (objective followed by narrative and exercises) helped me study.

   a. Strongly agree. c. Disagree.
   b. Agree. d. Strongly disagree.

14. The volume review exercises were helpful in reviewing course information.

   a. Strongly agree. c. Disagree.
   b. Agree. d. Strongly disagree.

15. The learning objective exercises in my CDC helped me learn the material presented by the texts.

   a. Strongly agree. c. Disagree.
   b. Agree. d. Strongly disagree.

16. How much of the information in this course is covered adequately by other sources (e.g. PME)?

   a. Less than 10%. c. 20-30%.
   b. 10-19%. d. I do not know.

17. The CDC does *not* refer to people in terms denoting gender, race, or ethnic background.

   a. Strongly agree. c. Disagree.
   b. Agree. d. Strongly disagree.

18. (MANDATORY ENROLLMENTS ONLY) Which rating best describes the usefulness of the information in this course in your upgrade program?

   a. Excellent. c. Marginal.
   b. Satisfactory. d. Unsatisfactory.

19. The technical information in this course is:

   a. 90-100% current. c. 70-79% current.
   b. 80-89% current. d. Less than 70% current.

20. The CDC was too long and complex.

   a. Strongly agree. c. Disagree.
   b. Agree. d. Strongly disagree.

21. The CDC material reviewed but did not excessively repeat what I learned in technical school or through a previous CDC.

   a. Strongly agree. c. Disagree.
   b. Agree. d. Strongly disagree.

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22. The material presented by the CDC helped to prepare me for work in any job within my Air Force Specialty.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

23. The CDC material increased my career knowledge.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

24. The CDC material gave me a satisfactory knowledge of the technical areas of my AFSC.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

25. The technical material in the course was written such that I could understand it.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

26. Procedures described in the CDC were general and did not require actual work experience to understand.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

NOTE: If you know this CDC contains outdated information or does not provide the knowledge that the current specialty training standard (STS) requires you to have for upgrade training, contact your unit OJT advisor and fill out an AF Form 1284, Training Quality Report.

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 10 USC 8012 and EO 9397. PRINCIPAL PURPOSES: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package. It is utilized by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's need. Failure to provide all information would result in slower action or inability to provide assistance to the student.

SECTION I: CORRECTED OR LATEST ENROLLMENT DATA: *(Mail to: ECI, Gunter AFS AL 36118)*

1. THIS REQUEST CONCERNS COURSE (1-6)	2. TODAY'S DATE	3. ENROLLMENT DATE	4. AUTOVON NUMBER

5. SOCIAL SECURITY NUMBER (7-15)	6. GRADE/RANK	7. NAME *(First initial, second initial, last name)* (17) (18) (19-32)
– –		

8. ADDRESS *(OJT Enrollees: Address of OJT training office with zip code. All others: current mailing address with zip code.)*	(33-53) (54-75)

9. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE	10. TEST CONTROL OFFICE ZIP CODE/SHRED (31-39)

SECTION II: REQUEST FOR MATERIALS, RECORDS, OR SERVICE — FOR ECI USE ONLY

(Place an "X" through number in box to left of service requested)

1	Request address change as indicated in Section I.		16
2	Request Test Control Office change as indicated in Section I.	G	31
3	Request name change/correction (Provide Old or Incorrect data)		Vol 33-35 GR 36-38
4	Request Grade/Rank change/correction	K	33-34 35-40
5	Correct SSAN (List incorrect SSAN here) (Correct SSAN should be shown in Section I)	M	
6	Extend course completion date (Justify in REMARKS)		33-38
7	Request enrollment cancellation.	N	
8	Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 Originals were: [ ] Not received [ ] Lost [ ] Misused	P	Vol 33-35 TC 36-37
9	Send course materials. (Specify in REMARKS) [ ] Not received [ ] Lost [ ] Damaged	Q	33-34 QQ Volume 35-37
10	Course exam not yet received. Final VRE submitted for grading on ________ (date).		38 39-42
11	Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 not yet received. Answer sheet(s) submitted ________ (date).	1	39-42
12	Results for CE not yet received. Answer sheet submitted to ECI on ________ (date).	2	39-42
13	Previous inquiry ([ ] ECI Fm 17, [ ] Ltr, [ ] Msg) sent to ECI on ________ (date).	3	
14	Give instructional assistance as requested on reverse.		16
15	Other (Explain fully in REMARKS)		

REMARKS *(Continue on reverse)*

OJT STUDENTS must have their OJT Administrator certify this request. ALL OTHER STUDENTS may certify their own requests.	I certify that the information on this form is accurate and that this request cannot be answered at this station. *(Signature)*

ECI FORM 17 OCT 82 (PREVIOUS EDITIONS MAY BE USED)

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SECTION III REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE Questions or comments relating to the accuracy or currency of subject matter [illegible]ld be forwarded directly to preparing agency. For an immediate response to these questions, call or write the course author directly, using the AUTOVON number or address in the preface of each volume. All other inquiries concerning the course should be forwarded to ECI.

VRE Item Questioned:	MY QUESTION IS:
Course No	
Volume No	
VRE Form No	
VRE Item	
Answer You Chose (Letter)	
Has VRE Answer Sheet been submitted for grading?	
[ ] Yes [ ] No	
REFERENCE (Textual reference for the answer I chose can be found as shown below)	
In Volume No ______	
On Page No ______	
In [ ] left [ ] right column	
Lines ____ Through ______	

REMARKS:

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. Course workbooks have a Form 17 printed on the last page.