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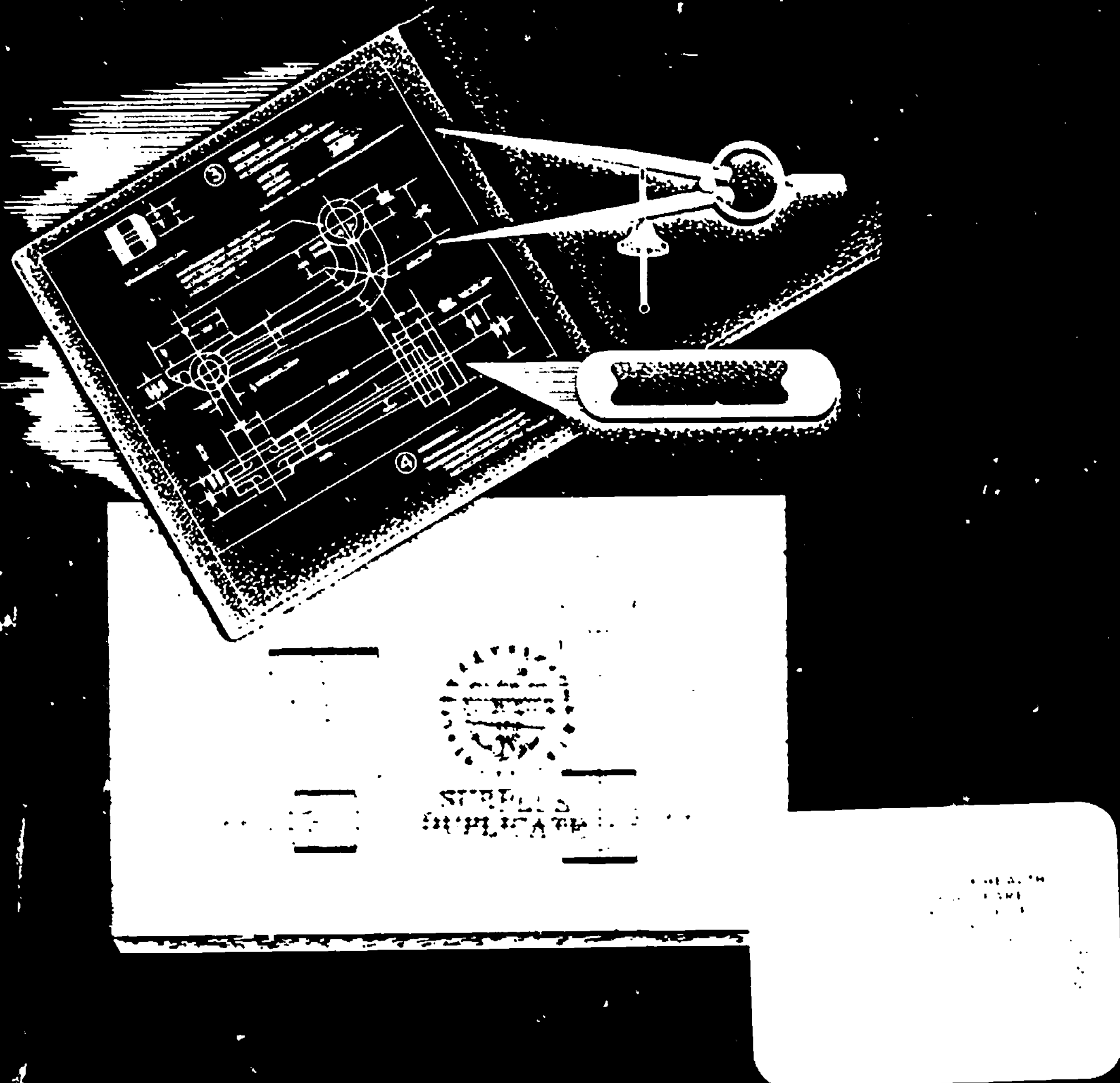
ABSTRACT

The rate training manual provides information related to the duties required to operate and maintain pattern shop equipment and the manufacture and maintenance of shipboard patterns. The manual covers the range of information expected of the patternmaker rating and is designed for independent study by the student, supplemented by other sources cited in the document. Chapters in the manual cover career preparations as a patternmaker, patternmaking and founding, handtools and woodworking machines, patternmaking structural materials, construction tecuniques, and shop mathematics. Also included are blueprints and layouts, pattern equipment, cores and core boxes, making and molding a simple parted pattern, constructing a cylindrical pattern and core box, and flanged fittings. Segmental and staved patterns and core boxes, patterns for composite castings, and an index conclude the manual. It is liberally illustrated with diagrams, photographs, and figures to aid the learner. (NH)



PATTERNMAKER 3 & 2

NAVAL TRAINING COMMAND

RATE TRAINING MANUAL **NAVTRA 10578-C**

PREFACE

The primary purpose of training is to produce a combat Navy which can guarantee victory at sea. This victory is dependent upon the readiness of the personnel aboard. Each individual is assigned tasks to perform dependent upon the needs of the ship. The information in this manual relates to tasks required to meet shipboard needs—tasks that are assigned to personnel aboard ship, serving as a Patternmaker Third Class and Patternmaker Second Class. This rate training manual provides information related to the duties required to operate and maintain pattern shop equipment and the manufacture and maintenance of shipboard patterns. It is only when we have personnel aboard who can and do perform these tasks efficiently that we will have each ship operating at a high state of readiness and add her contribution essential to victory at sea. When you are assigned duties aboard ship as an PM3 or PM2, you will be expected to have a thorough knowledge of the information contained in this manual. The degree of success of the Navy will depend in part on the ability you possess and the manner in which you perform your assigned duties.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

PREPARING FOR YOUR CAREER AS A PATTERNMAKER

If you want to be the key figure in the triple play of the Patternmaker to Molder to Machinery Repairman and want to build and create items from wood and metal, want to use your hands and head—and if you can visualize, imagine, and draw, as well as work with tools, Patternmaking is the job for you. Patternmaking is one of the most interesting and challenging jobs anyone can have in civilian and military life. The work is never monotonous because every pattern presents new and different problems.

Among skilled men, ashore and afloat, the old-fashioned wood plane rating insignia is recognized as the emblem of a craftsman possessing the creative conception, practical ability, precise skill, and sound judgment combined with practical knowledge necessary to transform an idea into an object having the length, breadth, and thickness required to produce any conceivable form to be cast in metal.

In this chapter, and the others that follow, you will find general and technical information which will aid you in attaining the knowledge and skills necessary to win the Patternmaker's emblem. Start working for it now. It's worth having. Keep in mind, however, that you cannot depend on the printed word alone to become a Patternmaker; you must supplement the information you obtain from books with actual practice, and with the knowledge acquired from observing experienced men at work.

This training manual will aid you in furthering your career as a Patternmaker. However, it is not a prerequisite to advancement. It is, instead, a manual designed to aid in your training so that you may reach higher and higher levels of proficiency as a Patternmaker.

The occupational, professional, or technical quals for the PM rating that were used as a guide in the preparation of this manual were current through change 2 (1972) to the Manual of Qualifications for Advancement, NAVPERS 18068-C. Therefore, changes in the qualifications occurring after change 2 to NAVPERS 18068-C are not necessarily reflected in the information given here.

The information contained in this training manual has been organized in such a way as to permit you to progress at a reasonable rate from the general and technical subject matter related to the PM rating to simple patterns, and finally to more complex patterns and core boxes.

Chapter 2 provides information on the various foundry processes, the basic parts of the mold, and the basic design rules necessary for the construction of a pattern that will be used in the production of a sound, usable casting.

Chapters 3, 4, and 5 discuss woodworking handtools, portable power handtools, and woodworking machinery.

Chapters 5 and 6 discuss the various structural materials used in Navy patternmaking and the construction techniques used in assembling and constructing patterns.

Chapters 8 and 9 discuss the mathematics of patternmaking, blueprint reading, and layout construction.

Chapters 10 and 11 discuss the various types of pattern equipment, cores, and core boxes that you should be familiar with in order to become an effective PM.

Chapters 12 through 16 are actual pattern projects, starting with a simple pattern and progressing into more complex patterns and core boxes. These projects are designed to give you a broad knowledge of the various construction techniques employed in the PM trade.

On the last page of each chapter, when appropriate, you will find definitions of technical terms that appear in the following chapter for the first time in the manual. You must learn these terms and their definitions as they are part of the PM's "language." It is not possible to understand patternmaking nor what another

PM is talking about without a good vocabulary of these terms.

The remainder of this chapter gives information on the Patternmaker rating, the requirements for advancement and references that will help you in reaching higher standards in the performance of your duties. This chapter also includes information on how to make the best use of rate training materials. Therefore, it is recommended that you study this chapter carefully before beginning intensive study of the remainder of this manual.

THE PATTERNMAKER RATING

The Patternmaker rating, which is a general rating, does not have any service or emergency ratings. The scope of the Patternmaker rating entails the responsibility of making wood, plaster, and metal patterns, core boxes, and flasks used by the Molder in a Navy foundry; mounting patterns on match plates and follow boards for production molding; making master patterns; making full-scale layouts of wooden patterns, core boxes, and templates; and indexing and storing patterns.

In general, the Patternmaker is assigned to a repair ship or tender where he operates the power-driven woodworking machinery and the handtools necessary to construct a pattern which is used as a tool in the hands of the Molder to produce a sound usable casting. Aboard a repair ship or tender, you will find the carpenter and the pattern shops together. These two activities are placed next to each other and share the use of the same woodworking machines and equipment. Space is precious as repair ships and tenders are combinations of a floating navy yard, a supply depot, and a training station.

In the pattern shop of a repair ship or tender, the Fireman, who is striking for Patternmaker 3, is basically on the getting acquainted-orientation detail. Usually he has had some experience in woodworking or mechanical drafting before coming into the Navy. There are usually one or two strikers in each pattern shop; they help the third, second, and first class Patternmakers in the performance of their duties. The striker cleans, sandpapers, shellacs, and stores patterns. As he progresses, he helps make the simple patterns and learns the fundamentals of the trade. One of his principle duties is learning how to maintain all of the woodworking machines in the shop and learning all the pertinent safety precautions.

There is also a Patternmaker Third Class who has started to go places in the Patternmaker rating. He reads blueprints and makes simple patterns from them. Usually he makes his patterns from worn or broken castings. Occasionally he will help make a required core box of a more complicated nature. In actual practice, many third and second class learn to do this in the lower ratings.

The Patternmaker Second Class gets into the more complicated pattern and core box work. He makes patterns from blueprints that require more detailed work, such as the hand-carving of pattern members. He also makes core boxes as necessary.

In the normal complement of a shipboard pattern shop there is a Patternmaker First Class and a Chief Patternmaker. The PM1 handles the more detailed patterns and core boxes. In the absence of the chief, he takes over the responsibility of the operation of the pattern shop. The PMC is usually primarily interested in supervisory duties. He trains the lower rated men, assigns work, checks the quality of the workmanship, handles personnel matters, works out new procedures, makes reports, orders supplies and materials, and performs other additional duties required of the Chief Petty Officer.

As a Patternmaker, you will be concerned mostly with repair activities. The Navy operates a number of different types of repair ships, but those to which you are most likely to be assigned are destroyer tenders (AD), repair ships (AR), internal combustion engine repair ships (ARG), heavy-hull repair ships (ARH), and submarine tenders (AS). Repair ships and tenders are specially designed naval ships whose primary mission is to provide repair facilities and services to the forces afloat. These ships are floating bases, capable of accomplishing a large variety of general and specialized work. In theory and in fact, these ships are small scale navy yards.

When your assignment sends you to shore duty, you will work within the framework of an organization having a similar repair mission. Occasionally the Patternmaker performs duties other than those of his rating, such as shore patrol, master at arms, and special details. Naturally, there are some exceptions, but generally, a Patternmaker, whether ashore or afloat, is assigned to the repair department.

The Patternmaker should have a good background in and an aptitude for mathematics. For those lacking in this area, the training manuals listed later in this chapter are strongly recommended. In addition to mathematics, the Navy Patternmaker should have a working knowledge of foundry and machine shop practices. The Patternmaker must have an ability to work with his hands as well as his mind. However, if you have not had much experience working with your hands, you will gain confidence in yourself and in your work through performance of your daily duties.

Your ability as a Patternmaker is not measured in terms of the amount of shop equipment that you can operate, but your ability is measured in terms of how well you can get the most out of the existing equipment to get the job done. Regardless of the type of shop equipment that you may have at your duty assignment, the experience gained will be beneficial in helping you progress to the higher levels of patternmaking.

As stated in General Order 21, naval leadership is "the art of accomplishing the Navy's mission through people." As you prepare for advancement to Patternmaker Third Class and then to Patternmaker Second Class, you will hear a great deal about your responsibility in connection with General Order 21 and the naval leadership program. The object of the general order is to revitalize and reemphasize naval leadership in all its aspects. You must be a respected and accomplished example of military and professional competence in order to accomplish the four basic principles of your naval mission which are:

1. Assure the highest level of combat effectiveness now and in the future.

2. Maintain good order and discipline.

3. Achieve the objectives of the Department of Defense Human Goals Program as set forth by the Secretary of Defense in 1969.

4. Implement the various people-oriented directives as set forth by the Chief of Naval Operations (CNO).

Although the general principles and techniques of leadership are fully covered in Military Requirements for Petty Officer 3 & 2, NAVPERS 10056-C, consider how you can live up to General Order 21 on a day-to-day basis.

Assume that you are aboard ship assigned to the pattern shop. Assume you also are the senior Patternmaker aboard and that you have several PM strikers in the shop. A big part of your job is to learn everything you can about patternmaking and foundry practice so you will be able to pass this information and knowledge to your men. You must also inspire your strikers to do their work as efficiently as possible.

A characteristic of the American fighting man is that he wants to know the reason behind his being called upon to perform certain tasks. You must explain to your strikers the importance of their work and how it affects the overall fighting efficiency of your ship. Show them that even routine tasks greatly contribute to the overall effort. During exercises and drills, make them feel that they are contributing to the overall efficiency of the ship. When led with courage, spirit, and intelligence, your men will respond by backing you up. Remember that enthusiasm is contagious, therefore you must serve as the inspiration for your men.

To lead your men effectively and gain the confidence of your superiors, you must also have a strong moral character. Some of the character traits that can be developed by conscientious study and practice are loyalty, integrity, and self-confidence.

Loyalty is one of the most essential qualities of a good leader. Loyalty to your country, to your Navy, to your division, to your chief, to your senior petty officers, and to the men who work with and for you is essential if you are to succeed.

Deal with your men squarely and honestly. If you do, you will win and hold their respect. Be dependable. Keep your promises. A reputation of being a "square shooter" is worth every effort you put into obtaining it.

Remember that good leaders display self-confidence based on the rough knowledge of their job and the ability to perform their job. If you have confidence in yourself, you will not find it difficult to inspire confidence in your men.

TRAINING FOR THE JOB

Highly trained personnel are essential to the successful functioning of the Navy. As you continue your training and become more and more proficient in job performance, you as well as the Navy benefit. In addition to enjoying the satisfaction of getting ahead in your chosen Navy career, you will be regarded with greater respect by officers and enlisted personnel, your job assignments will become more interesting and more challenging, and your pay will increase. As you advance from one rate level to the next, you increase your value to the Navy in two ways. First, you become more valuable as a specialist in your own rating, and second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

QUALIFYING FOR THE JOB

What must you do to meet the job requirements? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.
2. Complete the required military and rating manuals.
3. Demonstrate your ability to perform all those practical requirements applicable to the rate for which you are striving and have them checked off on the Record of Practical Factors, NAVTRA 1414/1.
4. Be recommended by your commanding officer after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.
5. Demonstrate your knowledge by passing written examinations on the occupational and military qualification standards for advancement.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the qualifications for advancement can change. Check with your division officer or training officer to be sure that you know the m st recent qualifications.

Advancement is not automatic. Even though you have met all the requirements, including passing the written examinations, you may not be able to "sew on the crow" or "add a stripe." The number of men in each rate and rating is controlled by a Navywide basis. Therefore, the number of men who may be advanced is limited by the number of vacancies that exist. When the number of men passing the examination exceeds the number of vacancies, some system must be used to determine which men may be advanced and which may not. The system used is the "final multiple" and is a combination of three types of advancement systems.

Merit rating system

Personnel testing system

Longevity, or seniority, system

The Navy's system provides a credit for performance, knowledge, and seniority, and, while it cannot guarantee that any one person will be advanced, it does guarantee that all men within a particular rating will have equal advancement opportunity.

A change in promotion policy has been implemented — the Passed-But-Not-Advanced (PNA) Factor. Under this policy, effective with the August 1972 examination, a man that passed the examination, but was not advanced can gain points toward promotion in his next attempt. Up to three multiple points can be gained in a single promotion period. The points can then be accumulated over six promotion periods up to a maximum of 15. The addition of the PNA factor, with its 15 points maximum, raised the number of points possible on an examination multiple from 185 to 200. This gives the examinee added incentive to keep trying for promotion in spite of repeated failure to gain a stripe because of quota limitations.

The following factors are considered in computing the final multiple.

Factor	Maximum Points	Weight
Examination Score	80	40%
Performance (Average of marks received)	50	25%
Total Active Service (1 per yr)	20	10%
Time in Present Grade (2 per yr)	20	10%
Medals and Awards	15	7.5%
PNA (Maximum 3 per exam cycle)	15	7.5%
	200	100%

REQUIREMENTS *	E1 to E2	E2 to E3	# E3 to E4	#† E4 to E5	† E5 to E6	† E6 to E7	† E7 to E8	† E8 to E9
SERVICE	4 mos. service—or completion of Recruit Training.	8 mos. as E-2.	6 mos. as E-3.	12 mos. as E-4.	24 mos. as E-5.	36 mos. as E6. 8 years total enlisted service.	36 mos. as E-7. 8 of 11 years total service must be enlisted.	24 mos. as E-8. 10 of 13 years total service must be enlisted.
SCHOOL	Recruit Training. (C.O. may advance up to 10% of graduating class.)		Class A for PR3, DT3, PT3, AME 3, HM 3, PN 3, FTB 3, MT 3,			Class B for AGC, MUC, MNC.††		
PRACTICAL FACTORS	Locally prepared check-offs.	Record of Practical Factors, NavEdTra 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS **	Locally prepared tests.	See below.	Navy-wide examinations required for all PO advancements.				Navy-wide, selection board.	
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavEdTra 10052 (current edition).					Nonresident career courses and recommended reading. See NavEdTra 10052 (current edition).	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

* All advancements require commanding officer's recommendation.
† 1 year obligated service required for E-5, and E-6; 2 years for E-7, E-8, and E-9.
# Military leadership exam required for E-4 and E-5.
** For E-2 to E-3, NAVEDTRAPRODEVCEN exams or locally prepared tests may be used.
†† Waived for qualified EOD personnel.

Figure 1-1.—Active duty advancement requirements.

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	8 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 8 yrs service	36 mos. with total 11 yrs service	24 mos. with total 13 yrs service
TOTAL TRAINING DUTY IN GRADE †	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS			Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavEdTra 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam, Selection Board.	
AUTHORIZATION	Commanding Officer		NAVEDTRAPRODEVCEN					

*Recommendation by commanding officer required for all advancements.
†Active duty periods may be substituted for training duty.

Figure 1-2.—Inactive duty advancement requirements.

All of the above information (except the examination score and the PNA factor) is submitted to the Naval Examining Center with your examination answer sheet. After grading, the examination scores, for those passing, and the PNA points (additional points awarded to those who previously passed the examination but were not advanced) are added to the other factors to arrive at the final multiple. A precedence list, which is based on final multiples, is then prepared for each pay grade within each rating. Advancement authorizations are then issued, beginning at the top of the list, for the number of men needed to fill the existing vacancies.

PREPARING FOR THE TASK

What must you do to prepare for the next level of proficiency? You must study the qualifications for advancement, work on the practical factors, study the required rate training manuals, and study other material that is required to meet job requirements. This will require that you be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, NAVTRA 1414/1, (3) a NAVTRA publication called Bibliography for Advancement Study, NAVTRA 10052, and (4) applicable rate training manuals. The following sections describe these materials and give you some practical suggestions on how to use them in preparing for the next level of proficiency.

The Quals Manual

The Manual of Qualifications for Advancement, NAVPERS 18068 (with changes), gives the minimum requirements for levels of proficiency within each rating. This manual is usually called the "Quals Manual," and the qualifications themselves are often called "quals." The qualifications are of two general types: (1) military requirements, and (2) professional or technical qualifications.

MILITARY REQUIREMENTS apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all ratings.

PROFESSIONAL QUALIFICATIONS are technical or professional requirements that are directly related to the work of each rating.

Both the military requirements and the professional qualifications are divided into subject matter groups; then, within each subject matter group, they are divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS. Practical factors are things you must be able to DO. Knowledge factors are things you must KNOW in order to perform the duties of your rating.

Study these qualifications and the military requirements carefully. The written examination for advancement will contain questions relating to the practical factors and the knowledge factors of both the military requirements and the professional qualifications. If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

The Quals Manual is kept current by means of changes. The professional qualifications for your rating were current at the time this manual was printed. By the time you are studying this manual, however, the quals for your rating may have been changed. Never trust any set of quals until you have checked the change number against an UP-TO-DATE copy of the Quals Manual.

Record of Practical Factors

Before you can take the servicewide examination for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military requirements and the professional qualifications. A special form known as the RECORD OF PRACTICAL FACTORS, NAVTRA 1414/1, is used to keep a record of your practical factor qualifications. This form is available for each rating. The form lists all practical factors, both military and professional. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the Manual of Qualifications for Advancement, and revised forms of NAVTRA 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement.

If you are transferred before you qualify in all practical factors, the NAVTRA 1414/1 form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form is actually inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start all over again and requalify in the practical factors which have already been checked off.

NAVTRA 10052

Bibliography for Advancement Study, NAVTRA 10052 (revised), is a very important publication for anyone preparing for advancement. This bibliography lists required and recommended rate training manuals and other reference material to be used by personnel working for a higher rate level. NAVTRA 10052 is revised and issued once each year by the Naval Training Command. Each revised edition is identified by a letter following the NAVTRA number. When using this publication, be SURE that you have the most recent edition.

If extensive changes in qualifications occur in any rating between the annual revisions of NAVTRA 10052, a supplementary list of study material may be issued in the form of a NAVTRA Notice. When you are preparing for a higher level, check to see whether changes have been made in the qualifications for your rating. If changes have been made, see if a NAVTRA Notice has been issued to supplement NAVTRA 10052 for your rating.

The required and recommended references are listed by rate level in NAVTRA 10052. If you are working for the level of third class, study the material that is listed for third class. If you are working for the level of second class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level.

In using NAVTRA 10052, you will notice that some rate training manuals are marked with an asterisk (*). Any manual marked in this way is MANDATORY—that is, it must be completed at the indicated rate level before you can be eligible to take the servicewide examination for advancement. Each mandatory manual may be completed by (1) passing the appropriate enlisted correspondence course that is based on the mandatory training manual; (2) passing locally prepared tests based on the information given in the training manual; or (3) in some cases, successfully completing the appropriate Class A school.

(NOTE: The Navy's only Patternmaker school is a Class A school situated in San Diego, California. This school condenses the equivalent of a 10,600-hour civilian patternmaker apprentice program into a 20-week course. You should contact your information and education office or your career counselor for information about attending this school if it is your desire to do so.)

Do not overlook the section of NAVTRA 10052 which lists the required and recommended references relating to the military requirements for advancement. Personnel of ALL ratings must complete the mandatory military requirements training manual for the appropriate rate level before they can be eligible to advance.

The references in NAVTRA 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NAVTRA 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Rate Training Manuals

There are two general types of Rate Training Manuals. TRAINING MANUALS (such as this one) are prepared for most enlisted ratings. A rate training manual gives information that is directly related to the professional qualifications of ONE rating. SUBJECT MATTER MANUALS or BASIC MANUALS give information that applies to more than one rating.

Rate Training Manuals are revised from time to time to keep them up-to-date technically. The revision of a Rate Training Manual is identified by a letter following the NAVTRA number. You can tell whether any particular copy of a Rate Training Manual is the latest edition by checking the NAVTRA number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NAVTRA 10061. (NAVTRA 10061 is actually a catalog that lists all current training manuals and correspondence courses and is revised annually. You will find this catalog useful in planning your study program.)

The following suggestions may help you to make the best use of this manual and other

Navy training publications when you are preparing for a higher rate level.

1. Study the military requirements and the professional qualifications for your rating before you study the training manual, and refer to the quals frequently as you study.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the training manual intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book. As you look through the book in this way, ask yourself some questions: What do I need to learn about this? What do I already know about this? How is this information related to information given in other chapters? How is this information related to the qualifications for advancement?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training manual, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use Enlisted Correspondence Courses whenever you can. The correspondence courses are based on Rate Training Manuals or on other appropriate texts. As mentioned before, completion of a mandatory Rate Training Manual can be accomplished by passing an Enlisted Correspondence Course based on the Rate Training Manual. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory training manuals. Taking a correspondence course helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study Rate Training Manuals. You are working for advancement to third class or second class right now, but someday you will be working toward higher rates. Anything extra that you can learn now will help you both now and later.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some of the publications described here are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance; it is likely to be a waste of time, and may even be seriously misleading.

NAVAL TRAINING (NAVTRA) PUBLICATIONS

Effective 15 January 1972, the Naval Training Support Command and its field activities came directly under the command of the Chief of Naval Training. Training materials published by the Naval Training Command after the above date are designated as NAVTRA in lieu of NAVPERS; the number remains as originally assigned for most publications. The designators of publications printed prior to the above date will be changed as each publication is revised.

Some of the publications that you will need to study or refer to as you prepare for a higher rate level have already been discussed earlier in this chapter. Some additional publications that you may find useful are listed here.

Tools and Their Uses, NAVPERS 10085-B
Blueprint Reading and Sketching, NAVPERS 10077-C
Fireman, NAVPERS 10520-D
Mathematics, Vol. 1, NAVPERS 10069-C
Molder, NAVPERS 10584-C

In addition, you may find it useful to consult the Rate Training Manuals prepared for other Group VII (Engineering and Hull) ratings. References to these training manuals will add to your knowledge of the duties of other men in the engineering and repair departments aboard ship.

NAVSHIPS PUBLICATIONS

A number of publications issued by NAVSHIPS will be of interest to you. While you do not need to know everything that is given in the publications mentioned here, you should have a general idea of where to find information in NAVSHIPS publications.

The Naval Ships Technical Manual is the basic doctrine publication of NAVSHIPS. Chapters of particular importance to you include the following:

Chapter 9005. . . Tables of Technical Data
Chapter 9910. . . Workshop Equipment on Ships

The Foundry Manual, NAVSHIPS 250-0334 is the basic manual for foundry practice in the Navy. It is intended primarily for use by foundry personnel aboard repair ships and tenders.

The Naval Ship Systems Command Technical News is a monthly publication which contains interesting and useful articles. This magazine is particularly useful because it presents information which supplements and clarifies information given in the NAVSHIPS Technical Manual and because it presents information on new developments.

MANUFACTURERS' TECHNICAL MANUALS

The manufacturers' technical manuals that are furnished with most machinery units and many items of equipment are valuable sources of information on operation, maintenance, and repair. The manufacturers' technical manuals that deal with NAVSHIPS machinery and equipment are given NAVSHIPS numbers. You should also become familiar with patternmaker's handbooks, machinery handbooks, and machinist's handbooks, so that you will know how to locate information in these publications.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Training films are listed in the United States Navy Film Catalog, NAVAIR 10-1-777. Copies may be ordered in accordance with the Navy Stock List of Forms and Publications, NAVSUP 2002. Supplements to the Film Catalog are issued as appropriate.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed.

GLOSSARY OF TERMS

The following definitions are of terms used in Chapter 2.

AIR HOLE—Hole in a casting caused by air or gas trapped in the metal during solidification.

ALLOY—Any composite metal produced by the mixing of two or more metals.

ALUMINUM—A light, white metal obtained from clays.

ATMOSPHERIC PRESSURE — The pressure of air at sea level, approximately 14.7 pounds per square inch.

BASIN — A cavity on top of the cope into which metal is poured before it enters the sprue.

BENCH MOLDING — The process of making small molds on a bench.

BINDERS — Materials used to hold molding sand together.

BLIND RISER — An internal riser which does not reach to the exterior of the mold.

BLOW HOLE — A hole in a casting caused by trapped air or gases.

BOSS — A projection on a casting of circular cross section

BOTTOM BOARD — A rough board similar to a molding board upon which the finished mold rests.

BOTTOM POUR MOLD — Mold with the gate so positioned as to allow the molten metal to enter the mold cavity at the lowest possible point.

BRASS — An alloy composed chiefly of copper and zinc.

BRONZE — An alloy composed chiefly of copper and tin.

CAST IRON — The most common of metals, mined as iron ore.

CAST STEEL — Cast iron that has been hardened and toughened by one of the various steelmaking processes.

CENTERLINE — Well defined knife or gage line placed upon the work to serve as a basis from which dimensions are to be measured.

CENTRIFUGAL CASTING — Process of filling molds by pouring the metal into a sand or metal mold revolving about either its horizontal axis or vertical axis, or pouring the metal into a mold that is revolved before solidification of the metal is complete. The molten metal is moved from the center of the mold to the periphery by centrifugal force.

CHAPLET — Metal supports used to hold a core in place with the size of the core seat is inadequate.

CONTRACTION — The amount that the metal will have decreased in size from the time it is poured to the time the temperature has fallen to the normal temperature of the metal.

CONTRACTION, LIQUID — Shrinkage or contraction in molten metal as it cools from one temperature to another while in the liquid state.

CONTRACTION, SOLID — Shrinkage or contraction as a metal cools from the solidifying temperature to room temperature.

COPE — The top section of a flask.

CORE — That part of a mold or body of sand which forms a hole, a recess, or the interior of a casting. Particularly applied to those bodies of sand formed within a core box and subsequently baked.

CORE BOX — Specially constructed form into which sand is rammed to give the required shape to a core.

CORE CAVITY — The interior form of a core box that gives shape to the core.

CORE PLATE — Metal plate used to support cores while they are being baked.

CORE PRINT — That part of a pattern which has been so designed as to form a seat to locate and support a core within a mold.

CORE SAND — Sand free from clay; it is nearly pure silica (any sharp sea sand).

CRACKER CORE — A vent core used to break the skin in the riser and allow the atmospheric pressure to push the metal into the mold cavity. Also called a "fire-cracker."

CROSS SECTION — A view of the interior of an object that is represented as being cut in two, the cut surface presenting the cross section of the object.

DRAFT — The angle of slant tending away from the line of parting given to those surfaces of a pattern which would lie in the direction in which the pattern or its component parts are drawn from the sand.

DRAG — The bottom section of a flask.

DRAWING — Removing a pattern from the sand.

DRY SAND MOLD — A mold which has been baked in an oven to fix its shape permanently and to give it a hard surface.

FEED HEAD — A reservoir of molten metal from which the casting feeds as it solidifies. Also called a riser.

FEEDING — Supplying additional molten metal to a casting to compensate for volume shrinkage during solidification.

FERROUS — Relating to or containing iron.

FILLET — Concave corner piece used at the intersection of surfaces. A struck fillet is one that is dressed to shape in place. A planted fillet is one that is made separately and affixed in place.

FINISH ALLOWANCE — An amount of stock left upon the surface of a casting for the operation of machine finish.

FLOOR MOLDING — The process of making large molds on the foundry floor.

FOUNDING OR FOUNDRY PRACTICE — The art or craft in which molten metal is given shape by being poured into molds.

FOUNDATION MEMBERS — Permanent or temporary members over which a pattern is built.

FREEZING — The solidification of molten metal in the mold.

GATE — Channel that conducts the metal from the sprue to the mold cavity. Specifically, the point where molten metal enters the casting cavity. Sometimes employed as a general term to indicate the entire assembly of connected columns and channels carrying the metal from the top of the mold to that part forming the casting cavity proper. Term also applies to the pattern parts which form the passages, or the metal that fills them.

GREEN SAND — Sand containing sufficient refractory clay substance to bond strongly without destroying the venting quality when rammed to the required degree of hardness.

GRIND — Truing up the surface of a casting with an abrasive wheel or belt.

HORN GATE — A circular-shaped gate or sprue form having a rectangular or round cross section, used when the molten metal is to enter the mold cavity well below the parting line.

LOAM MOLD — A mold built up of brick, covered with a loam mud and then baked before being poured.

MACHINE FINISH — Operation of turning or cutting an amount of stock from the surface of metal in order to produce a finished surface. Allowances for machine finish have to be made on the pattern.

MALLEABLE CAST IRON — Cast iron made ductile through an annealing process.

METAL PATTERN — Patterns made from aluminum, brass, bronze, white metal, and cast iron used as patterns in high production work.

MODEL — A facsimile of an object, either miniature or full size.

MOLD — As applied to founding is a body of sand containing the impression of a pattern.

MOLD CAVITY — Impression left in the sand by a pattern.

MOLD WEIGHTS — Weights placed on the cope of the mold to help overcome the lifting pressure.

NATURAL BONDED SAND — Sand containing a sufficient amount of clay bond, either present in its natural state or added before shipment, to make the sand suitable for immediate use.

NONFERROUS — Pertaining to metals not having iron as the base metal.

NOWEL — The lower section of the flask, more commonly called the drag.

OPEN RISER — A riser that is not covered. It is open to the atmosphere.

PAD — Shallow projection on a casting distinguished from a boss or lug by shape and size.

PADDING—Is used to induce progressive solidification in members or sections of uniform thickness and to prevent the defect known as midwall, or centerline shrinkage.

PARTED PATTERN—Pattern made in two or more parts. See split pattern.

POURING BASIC CORE—A cavity on top of the cope into which metal is poured.

PARTING—Joint or plane of separation in a mold of two or more sections.

PARTING LINE—That line about a pattern where the pattern or its mold separates.

PATTERN—Form modeled in any material from which a mold may be made; it is the basis of foundry practice.

PATTERNMAKING—Deals with the modeling in wood, metal, or other materials, of objects that are to be cast in metal.

PERMANENT MOLD—A long-life mold into which metal is poured by gravity.

PERMEABILITY—Refers to the venting qualities or to the rate at which gases can pass through the sand.

PIT MOLDING—The process of making very large molds in pits in the foundry floor.

PLASTER PATTERN—A pattern made from plaster of paris.

POURING—Filling the mold with molten metal.

RAMMING—Packing sand around the pattern in making a mold.

REFRACTOR—Material having heat-resisting qualities.

RIB—A stiffening member.

RISER—An opening made from the mold cavity to the top of the mold in which the metal will rise during the pouring operation and which may later act as a feeder for the prevention of porosity in the casting due to shrinkage.

RUNNER—Channel through which the molten metal is conducted to the gate or gates from the sprue or down gate.

SHELL MOLDING—A sand molding process in which a mixture of sand and thermosetting plastic is applied to a heated metal pattern.

SHRINK HOLE—A hole or cavity in a casting resulting from contraction and insufficient feed metal, and formed during the time the metal changes from the liquid to the solid state.

SHRINKAGE—Arrangement of the molecules of metal as it passes from a liquid to a solid state. (See contraction.)

SKIN-DRYING—Drying or baking only the surface of the mold.

SLUSH MOLDING—A process in which the metal is allowed to cool long enough to form a shell, and then the mold is inverted and the remaining molten metal is poured out, leaving a hollow center.

SPRUE—An opening that conducts the metal from the top of the mold to the gate or gates. The term SPRUE is also applied to the metal which fills the pouring channels and is found attached to the casting.

STRESS RELIEVING—Heat treatment to remove stresses or casting strains.

SYNTHETIC SAND—Sand which is mixed in correct proportions of unbonded sand and a suitable binder such as clay, and then tempered.

TEMPERING SAND—Dampening and mixing sand to produce a uniform distribution of moisture.

VENT—An opening in a mold or core to permit escape of steam and gases.

VENTING—Perforating the sand over and around a mold cavity with a venting needle to assist in the escape of the gases.

WHIRL GATE—A gate or sprue arranged to introduce metal into a mold tangentially, thereby giving the metal a swirling motion.

CHAPTER 2

PATTERNMAKING AND FOUNDING

As a patternmaker, you will probably be assigned to a repair ship or tender and will work closely with the foundry and other shops within the repair department. Therefore, this chapter includes information on the types and functions of repair ships and tenders, and the repair department organization and the functions of its officers, personnel, and shops; greater detail is provided about your job and some of the skills you must have.

REPAIR SHIPS AND TENDERS

In effect, repair ships and tenders are floating bases, capable of performing a variety of maintenance and repair services that are beyond the capabilities of the ships they serve. They are rather like small-scale Navy yards, with the same primary mission: to provide repair facilities and services to the forces afloat.

The most common type of repair ship, designated AR, provides general and specific repairs to all types of ships. Special types of repair ships have been developed for special uses; for example, the ARG is designed for the repair of internal combustion engines.

Each type of tender provides services for one type of ship, as indicated by the designation of the tender. The two best known types of tenders are the destroyer tender (AD) and the submarine tender (AS). Both conventional submarines and fleet ballistic missile submarines are tended by AS's; however, the organization of the repair department of an AS that tends fleet ballistic missile submarines differs somewhat from that of an AS that tends conventional submarines.

Since repairs and services to other ships are the primary functions of all repair ships and tenders, it is obvious that the repair department on a repair ship or tender makes a direct and vital contribution to fleet support. The operating forces of the fleet depend upon the services provided by all personnel of the repair department.

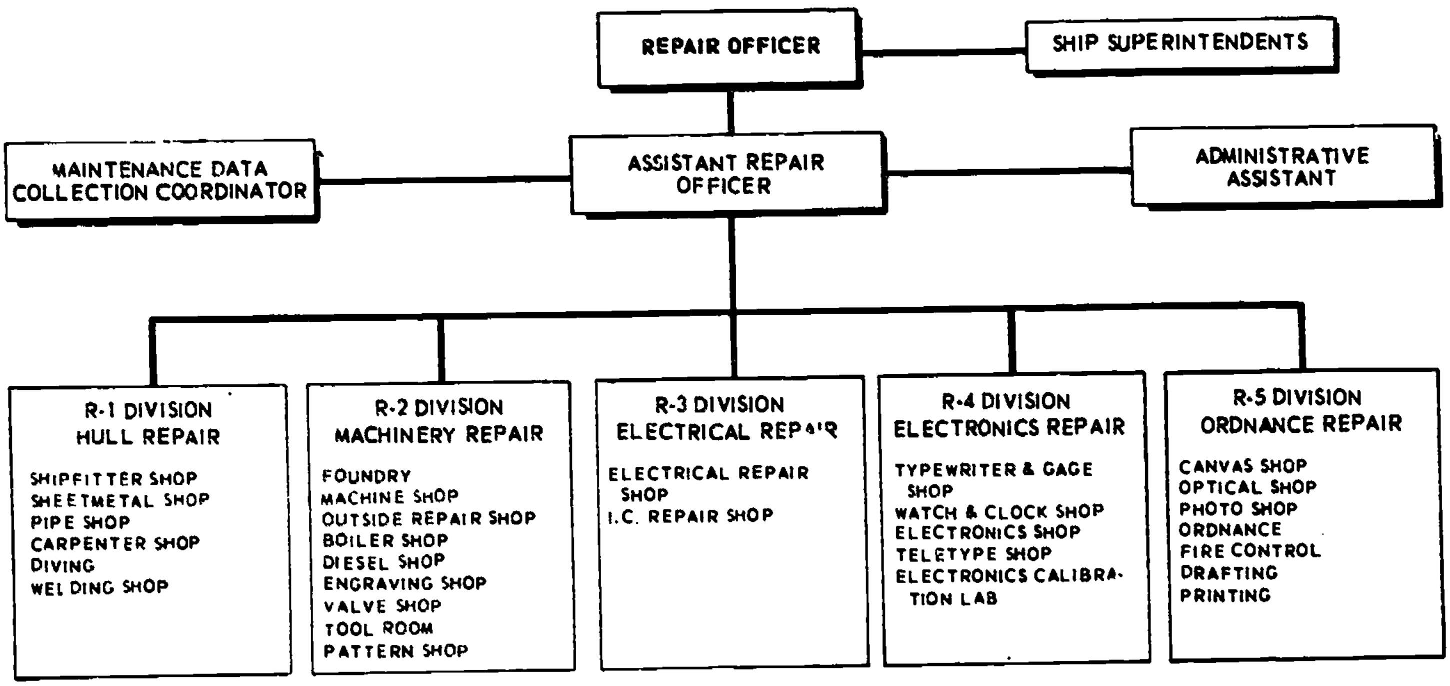
REPAIR DEPARTMENT

The type of repair ship to which you will probably be assigned will be one of the following: destroyer tender (AD), repair ship (AR), internal combustion engine repair ship (ARG), or submarine tender (AS). When you are assigned to shore duty at your trade, you will almost certainly be assigned to a billet in the Repair Department, of the shore installation. Since the shore-based installation has the same essential mission as the repair ship, the organization will be similar.

When you report aboard ship, you will need to learn the lines of authority and responsibility in the repair department. You will need to find out where your orders and assignments originate, exactly what is expected of you, and where to go for information, assistance, and advice. You can start acquiring this knowledge by studying the following material on repair department organization and personnel.

Repair department organization varies somewhat from one ship to another, as may be seen by comparison of figures 2-1 and 2-2. Figure 2-1 shows the organization of the repair department on a typical repair ship (AR); figure 2-2 shows the organization of the repair department on a fleet ballistic missile (FBM) submarine tender (AS).

In comparing these two illustrations, you will notice several differences. For one thing, the repair department on the AR includes an ordnance repair division (R-5) which is not included in the repair department of the AS. Instead, the AS has a separate weapons repair



63.10(AR)

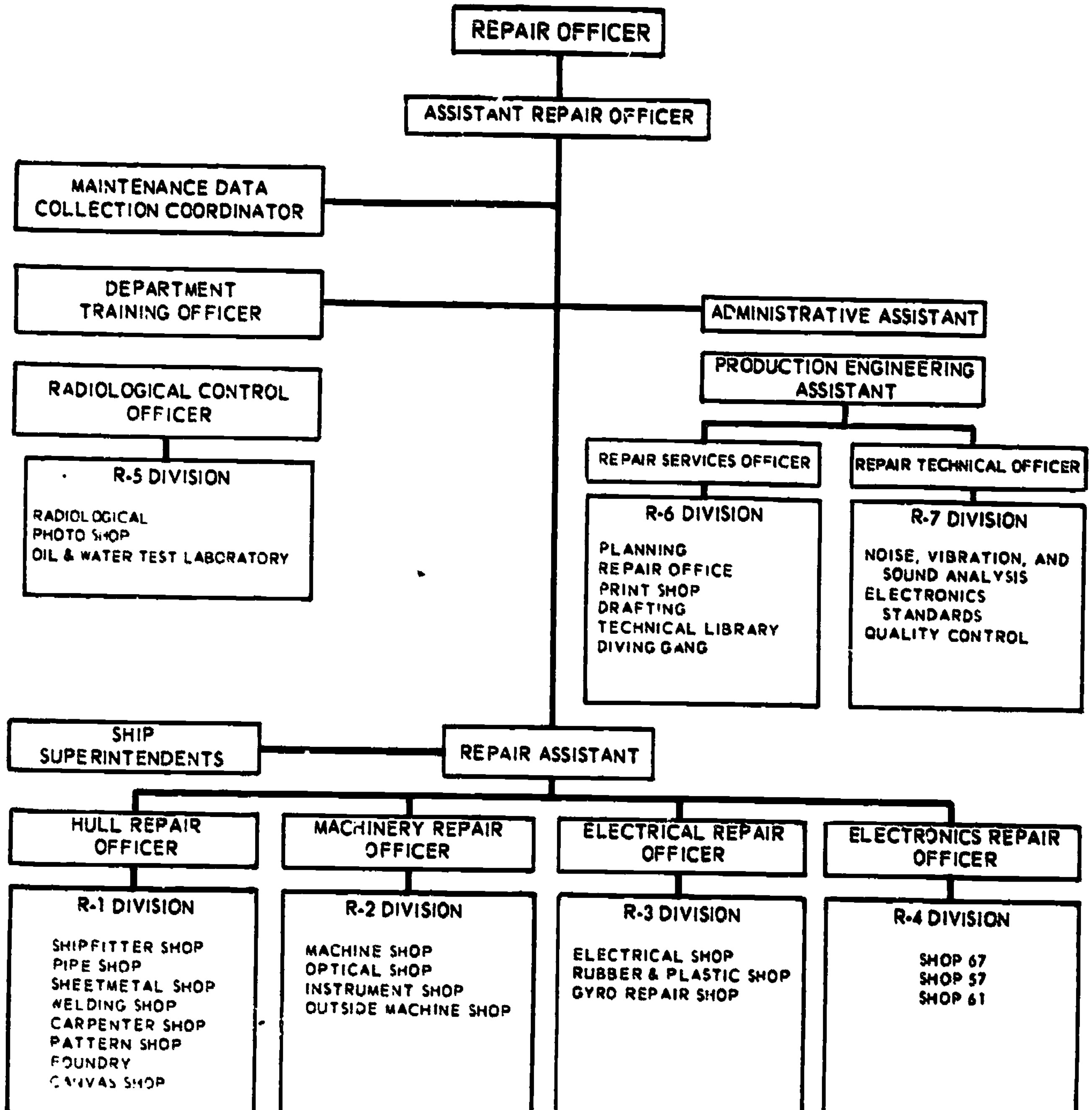
Figure 2-1.—Organization of repair department on typical repair ship (AR).

department under a weapons repair officer. Another difference is in the location of the shops you will work in. On all types of repair ships, you will probably be assigned to the R-1 or R-2 division. The pattern shop is normally within the R-1 division organization; however, depending largely on the ship's structure, the pattern shop could be within the R-2 division organization. Regardless of the division, your duties will be the same.

The duties of personnel in the repair department vary somewhat according to the type of ship. However the following description of personnel functions will give you a general idea of the way things are in most repair departments.

REPAIR OFFICER

On a repair ship or tender, the repair officer is head of the repair department. As head of the repair department, the repair officer is responsible under the commanding officer for the accomplishment of repairs and alterations assigned by competent authority to be accomplished on the ships tended or granted availabilities. The repair officer is also responsible for the accomplishment of repairs and alterations to the ship itself (tender or repair ship) that are beyond the capacity of the engineering or other departments. It is the responsibility of the repair officer to maintain a well organized and efficiently operated department, or, in other words, ensure that his subordinates are performing as required. To do this, he issues and enforces repair department orders which govern department procedures. Like other department heads, he is also responsible for enforcing orders of higher authority. He must know the current workload and capacity of his crew and facilities, and keep the staff maintenance representative informed of the current status in order that the latter officer may properly schedule and assign ships. He is responsible for the review of work requests received via the staff maintenance representative from the ships assigned for repair, and for acceptance or rejection of the individual jobs according to the capacity of his department. He is responsible for the review and acceptance of any work lists or work requests which develop after an availability period has started. He is also responsible for operating his department within the allotment granted, and for the initiation of requests for further funds, if required. He must ensure the accuracy, correctness, and promptness of all correspondence, including messages, prepared for the commanding officer's signature. The repair officer is charged with the review



63.10(AS)
Figure 2-2.—Organization of repair department on fleet ballistic missile submarine tender (AS).

of all personnel matters arising within his divisions such as training, advancement, assignment to divisions, and leave. In order to acquire a thorough knowledge of conditions and ensure adequate standards, he must make frequent inspections of his department and require his division officers to make corrections as necessary.

Specific duties of the repair officer vary somewhat, depending upon the type of repair ship or tender. In general, however, a summary of the repair officer's duties include the following:

1. Planning, preparing, and executing schedules covering alterations and repair work assigned to the repair department.

2. Establishing and operating the Planned Maintenance Subsystem of the 3-M System.
3. Coordinating repair capabilities, work assignments, and available personnel to ensure maximum utilization of manpower.
4. Supervising and inspecting repairs and services to ensure timely and satisfactory completion of work; providing controls for quality control.
5. Preparing records, reports, forms, and orders in connection with repair functions and duties.
6. Ensuring proper operation of all equipment and material assigned to the repair department.
7. Ensuring strict compliance with safety precautions and security measures.
8. Reporting progress of major repairs and alterations to the commanding officer; keeping the executive officer informed; reporting promptly any inability to meet scheduled completion dates.

ASSISTANT REPAIR OFFICER

In the absence of the repair officer, the assistant repair officer is charged with the responsibilities of the repair officer. As the assistant repair officer, he is the personnel administrator for the repair department. Under his cognizance are the assignment of personnel, the administrative control of the repair office, and the depa ment control of training.

Specific duties of the assistant repair officer may vary somewhat, depending upon the type of repair ship or tender. In general, however, the duties of the assistant repair officer include the following:

1. Assigns personnel to divisions, schools, shore patrol, and beach guard.
2. Maintains a basic knowledge of applicable courses, schools, and rating programs necessary to further the men's education and their advancement for the benefit of the men, the ship, and the Navy.
3. Maintains the office stores and accounts.
4. Assists the repair officer in all matters pertaining to general office routine, current availabilities of ships assigned to the repair ship or tender, and liaison between the repair office and the ships alongside, and shipyards.
5. Reviews all work requests on receipt.
6. Assigns work and priority rating to the divisions and shops.
7. Maintains liaison with the supply department for materials on order, or to be ordered for the work requested.
8. Procures the necessary blueprints, sketches, or samples for the shops.
9. Schedules the services of tugs, cranes, and technical services, as available, for successful completion of an availability.
10. Surveys the reports from the shops to ascertain the successful completion of all work during the allotted time.
11. Analyzes man-hour shop reports to determine an even balance of work versus personnel assigned. Regulates the coordination between the repair office and the shops towards the full productive capacity of the repair facilities.

OTHER ASSISTANTS

In addition to the assistant repair officer, there are usually several other officers who assist the repair officer in the performance of repaor department functions. These may include a production engineering assistant, a repair assistant, a radiological control officer, a department training officer, and an administrative assistant.

DIVISION OFFICERS

Each division within the repair department is under a division officer. The division officer may be a commissioned officer, a warrant officer, or a chief petty officer. The duties of the division officer vary, of course, according to the nature of the work done in the division.

ENLISTED PERSONNEL

As a Patternmaker assigned to the repair department of a repair ship or tender, you will work with men in a number of other ratings. It will be very much to your advantage to learn who these people are and what kind of work they do. Ratings that are often assigned to the repair department include (but are not limited to) the following: Opticalmen, Electronics Technicians, Radiomen, Fire Control Technicians, Gunner's Mates, Draftsmen, Lithographers, Hull Maintenance Technicians, Molders, Machinery Repairmen, Machinist's Mates, Boiler Technicians, Boiler Repairmen, Enginemen, Electrician's Mates, and I. C. Electricians. Ratings with which you will work closely, especially on castings, are the Molder, the Machinery Repairman, and the Hull Maintenance Technician.

You can get some idea of the work done by men of these ratings by looking through the Manual of Qualifications for Advancement, NAVPERS 18068 (revised). You can also learn about the work of these ratings by observing how the work is handled in the repair department. In handling repair work, it is often necessary for two or more shops (and two or more ratings) to cooperate in order to complete corrective maintenance actions.

REPAIR DEPARTMENT SHOPS

Each shop in the repair department is assigned to one of the divisions. As a Patternmaker, you will be concerned primarily with the pattern shop. However, you will find it very useful to learn as much as you can about the other shops. After you have gotten acquainted with personnel in your own shop and have learned to find your way around your own working spaces, make an effort to find out something about the other shops in the division and department. Find out where each shop is located, what kind of work is done in each shop, and what administrative procedures are necessary when one shop must call on the services of another for assistance in completing corrective maintenance actions.

On most repair ships and tenders, the pattern shop will be combined with the carpenter shop and will be responsible for all kinds of work involving the use of wood. However, the pattern shop's primary mission is the production of patterns for the foundry. Thus, it is obvious that the shop layout and work schedules in a combined pattern and carpenter shop must be flexible to allow for the various sizes of jobs which may be scheduled.

Shop layout and arrangement vary somewhat from one ship to another, depending upon the space available, the nature and amount of equipment provided, and the services that must be provided by the ship.

PATTERNMAKING

Patternmaking and foundry practice (founding) are two of the various crafts or trades comprising the metal industry; patternmaking is one of the most important of these skills but is probably the least understood. Patternmaking and founding date back to the very first time man created implements for his own use by pouring liquid metal into a simple mold.

Patternmaking is the process consisting of forming in wood, metal, plaster or plastics (to exact specifications) patterns of inventions, tools, machinery parts, and other items. The pattern is used as a tool in the foundry for making a mold of appropriate material for the sole purpose of casting liquid metal into the required size and shape. Founding includes the making of a mold from an appropriate mold material, the selection and melting of the proper metal or alloy, and the pouring and cooling of the liquid metal in the mold cavity so that sound usable castings result.

To meet the demands of patternmaking and founding, a Patternmaker must be able to use all of the conventional and certain special woodworking tools (hand as well as mechanical), read blueprints, and visualize the shape and form of the pattern to be constructed. In addition, he must know woods and other pattern materials in order to select the material best suited. He must have a working knowledge of foundry work and machine shop practice. Moreover, the Patternmaker must be able to compute metal shrinkage for the construction of a pattern that is accurate to within 1/64 of an inch of the desired dimensions given by the engineering designer. Therefore, patternmaking and founding are closely related trades, particularly as founding applies to the practice of producing objects from metal by one of the casting processes.

Because of the importance of foundry practice, castings are usually classified by using the terminology of the method of molding, the casting process, and the mold material. Whichever combination is used in the production of a casting, it is controlled by certain advantages and limitations of the variety of materials to be used in constructing the mold.

Casting processes offer the engineering designer the greatest possible variety of design features and metallurgical properties. Therefore, among the different processes available for shaping metal, the casting process is the most flexible. Without a pattern of some description the foundries of today would find it very difficult if not impossible to operate.

Before foundry practice was developed into a highly technical skill, most decisions pertaining to pattern construction and the method to be used to produce the cast part were made by the Patternmaker. Pattern construction rather than mold design was too often the primary consideration. Now though, it is fully realized that the pattern is merely a means to an end;

the mold's design, with which a metallurgically sound casting may be produced, is considered before the pattern is made. Experience has shown that sound castings are consistently produced in the most economical manner when supervisory personnel, representing the shops concerned with the several phases of a casting's production, cooperate in planning the production method. Pooling the skills of such a planning team is necessary to create a sound pattern design that will produce a serviceable casting free from sand, shrinkage, porosity, hot tears, cracks, blow holes, cold shuts, drops, rat tails, pin holes, and other imperfections.

To define a pattern accurately in all its aspects is difficult, but in simple terms a pattern is a model or guide with which a mold is made. From the Molder's viewpoint the model (pattern) is an imitation of a part that is to be made from metal. The pattern is constructed with certain modifications in order that the Molder may accurately duplicate it in molding sand. Core prints are attached to the pattern for support of the dry sand cores that will form the interior part of the casting. Additional metal thickness (finish) is added to provide for final machining of the casting. The pattern is also made slightly oversize to compensate for the natural shrinkage or contraction of the metal as it cools to room temperature.

The mold is actually a negative print of the pattern in molding sand. The pattern must be removed from the sand, leaving an undamaged cavity that can be filled with molten metal. To remove (draw) the pattern from the mold, a parting line (parting) and draft must be provided on the pattern. Prior to the construction of the pattern, these things must be determined and they are as much the responsibility of the Molder as they are of the Patternmaker. In effect, the plan for the molding procedure is set up before the pattern is even started.

Where does this plan for the molding procedure come from? Actually, there are two common sources, either an old casting or a blueprint. If the source is an old casting, the planning will be simplified. The metal of the old casting must be identified, the parting line and the amount of draft must be determined, and the sections (interior or exterior) that are to contain a core are established. A close visual inspection of the old casting will provide the answer to most of these questions. The parting line can usually be determined by a thin line of metal (fin) protruding a short distance from the side of the casting. The draft extends from the parting line on a slight angle to the surface that is away from the parting line. When the source of a plan is a blueprint, it becomes necessary for the Molder to read and interpret the blueprint if he is to assist the Patternmaker in planning the construction of the pattern and the mold. (Additional information on blueprints and blueprint reading may be found in chapter 9 of this training manual and in Blueprint Reading and Sketching, NAVPERS 10077-C.)

FOUNDRY WORK

Founding or foundry practice, involves four basic procedures: molding, coremaking, melting and pouring molten metals, and cleaning and finishing. Each of these basic procedures may be considered a trade within itself, and each requires special skills and knowledge that are peculiar only to the foundry. Briefly, the four basic procedures in the production of a casting are described in the following paragraphs.

The MOLD may be considered the heart of the foundry because it represents the center of all activities and other phases of foundry practices are grouped around it. The purpose of a mold is to form a cavity with accurate dimensions that will hold and support molten metal until it becomes solid. A mold is constructed of tempered sand bonded with clay or binders that is rammed in a flask and around a pattern that has the required shape and size for the desired casting. Provisions are made for the opening of the mold and the withdrawal of the pattern. An opening is provided for introducing the molten metal into the mold cavity left when the pattern is removed.

COREMAKING is closely related to the mold because the core actually becomes a part of the mold prior to pouring of the molten metal. The purpose of a core is to form a cavity within the casting or to aid the Molder when the surface of the mold cavity is irregular or difficult to form molding sand. The core has a difficult job to perform and therefore core sand mixtures require a special treatment. The sand from which the core is made is prepared from materials that provide the core with the ability to occupy these cavities in the mold without collapsing. The prepared sand mixture is rammed into CORE BOXES that will give the core the desired shape. The core box is removed from the core and the core is placed on a flat metal plate and baked in an oven to fully develop the properties that are characteristic of the materials that are used in the core sand mixture. After finishing and assembly, the core is placed in the mold cavity where it serves to form part of the interior or exterior of the casting.

MELTING and POURING of metals is a science that requires the utmost accuracy and skill if sound usable castings are to be produced that will meet the rigid specifications set forth by NAVSHIPS. Melting is done in units called FURNACES, either oil-fired or electric. Heats are prepared from basic metals and placed in the furnace. The furnace operator melts the metal and brings the temperature up to the required pouring temperature. When the metal or alloy is ready for pouring, the metal is tapped from the furnace into ladles, transported to the mold, and poured into the mold cavity through the opening in the mold provided by the Molder. As the metal becomes solid, the casting will assume the shape of the original part or pattern from which the mold was made.

After cooling to room temperature, the mold is opened and the sand is removed from around the casting. The casting is now ready for the final phase of producing a casting, CLEANING and FINISHING. When a casting is taken from the mold there is a certain amount of sand that will adhere to the surface of the casting. High temperature metals will fuse or penetrate the sand to depths of varying degrees. Therefore the sand must be removed by sand blasting, wire brushing, or chipping prior to the machining of the casting. All cores must be knocked out of the casting, all projections not part of the finished casting are to be removed, and all as-cast surfaces must be smooth. Any defect(s) in the casting must be found, and repaired if possible; when repairing is not possible, the casting is rejected and another made.

In the Navy, these founding practices are accomplished in foundries which are classified according to the type and volume of work accomplished.

The equipment required for a specific class foundry, however, is determined by its intended services. For example, a foundry that is capable of casting steel, cast iron, brass, and bronze up to 800 pounds maximum weight, would have two electric furnaces (capacity 500 pounds each), one oil fired furnace, one sand muller (3 cubic foot), one or two core ovens, one sand blast cabinet, one metal cutting bandsaw, and one floor grinder.

Unlike the above class foundry, another intended service class foundry may be established at approximately 300 pounds for brass and bronze. In this instance, some of the equipment necessary for the 800 pound foundry would not be required in a 300 pound foundry. Therefore, various foundries will have limited equipment normally based on the intended service.

Classes A, B, C, D, and E represent foundries designed for five types of services in accordance with the type of metal used or quantity of metal poured. However, due to variations within a class, the type of equipment allowance for each specific ship will be determined by its intended service, as indicated in the ship's specifications.

Class A foundries are capable of casting steel, cast iron, brass, and bronze, up to 800 pounds maximum weight; and casting aluminum, babbitt, and zinc up to 200 pounds maximum weight.

Class B foundries are capable of casting steel on a limited basis up to 500 pounds; cast iron, brass, and bronze up to 700 pounds; and aluminum, babbitt, and zinc up to 200 pounds.

Class C foundries are capable of casting steel on a limited basis up to 300 pounds, and cast iron up to 400 pounds on a limited basis. Brass and bronze up to 600 pounds, and aluminum, babbitt, and zinc up to 200 pounds, can be cast in Class C foundries. In foundries of this class, an oil-fired furnace is used when electric power is limited.

Class D foundries are capable of producing castings principally of brass and bronze up to 600 pounds, and only a limited amount of cast iron where additional air is available for higher heat input.

Castings of brass and bronze up to 300 pounds, and low temperature allows up to 100 pounds, can be produced in Class E foundries. Although cast iron may be melted in Class E foundries, it is costly to do so. A knowledge of the capacity and heat output of the furnaces aboard your ship or station will enable you to determine the maximum weight casting of a certain alloy that can be produced with this equipment. In addition, the molding method employed, and many other factors will determine the soundness of the casting which can be produced.

FOUNDRY PROCESSES

The selection of the proper casting process best suited for a design depends on both the technical and economical aspects; that is, such features as size and shape, section thickness, dimensional tolerances, finishing requirements and the number of castings to be produced.

Because each casting process has its own limitations and possesses certain design requirements, a general acquaintance with the various casting processes commonly used in the Navy is necessary. The various casting processes and their effect upon certain pattern construction features are described in the following paragraphs.

SAND CASTING PROCESS

Of all the casting processes used in the production of castings, the most common is the sand casting method. In the sand casting method, sand is used which contains sufficient refractory clay substance to bond strongly without destroying the venting quality when it is rammed to the required degree of hardness for the size and shape of the casting.

Based upon the sand conditioning treatment prior to use and before the casting is poured, molds may be green sand, dry sand, or skin-dried.

Green Sand Molding

Green sand molds may be of natural bonded sand or synthetic (all purpose) sand and can be poured as soon as they are rammed.

Molds made from natural bonded sand contain a sufficient amount of clay bond—either present when the sand was taken from its deposit site, or added before shipment—to make the sand suitable for immediate use. Adding moisture and tempering is the only treatment necessary before use. Molds made from synthetic sand are made by mixing correct proportions of an unbonded sand and a suitable binder such as clay, and tempering the mixture before use.

Detailed information on molding sands used for ferrous and nonferrous metals and alloys may be found in the Navy Training Manuals prepared for the Molder rating.

Dry Sand Molding

A dry sand mold is slowly baked in an oven before it is used. Dry sand molds are generally used for heavy castings. Dry sand molding has certain disadvantages. The rigidity of the mold resists metal contraction during the solidification of the casting; this resistance is sometimes great enough to cause the casting to crack. On the average, however, dry sand molds provide the best type of molding process for producing heavy castings which will be dependable under normal operating service conditions.

The hard mold surface of a dry sand mold enables it to (1) withstand the eroding action and the force of the flowing metal, and (2) support the weight of large volumes of metal. The baking of the mold eliminates moisture, lessening the possibility of the formation of mold gases and rapid chilling of the metal.

Skin-Dried Molding

A skin-dried mold is one that has been surface heated with a torch; it is used when the requirements call for a mold having the surface characteristics of a dry sand mold, combined with the collapsibility of a green sand mold. Skin-dried molds may also be used when an oven is not available for baking a dry sand mold. When using a skin-dried mold, the melt (liquid metal) must be ready to pour as soon as the mold is completed. The effect of skin-drying will be lost if the mold is allowed to stand, since moisture from the backing sand will penetrate back to the mold cavity surface.

Bench, Floor, and Pit Molding

Molds may be classified according to size: bench molds, floor molds, or pit molds. Bench molds are those small and light enough to be handled by one man; most of the molds required in Navy work will be of this type. A mold that is too large for one man to handle is usually constructed on the foundry floor. Pit molds are used when the size of the casting requires a mold constructed in a large pit in the foundry floor. A Navy Molder will rarely, if ever, have to construct a pit mold.

Shell Molding

Shell molding is a sand molding process consisting of the direct application of heated metal patterns and thermosetting plastics. This process takes advantage of the thermosetting properties of the phenolic resins to bind the fine silica grains of sand in the construction of a mold. The shell molding technique is used for making castings in a mold that is merely a shell of sand varying in thickness from 1/8 to 3/16 inch, depending upon the weight and size of the casting.

Some of the advantages of shell molding are:

1. Better casting quality.
2. Closer tolerances.
3. Minimized burn-in, resulting in cleaner castings.
4. Better as-cast surface finish.
5. Sounder castings.
6. Minimized locked-in stresses.
7. More castings per ton of metal poured.
8. Greater machinability.
9. Greater pickup of detail.
10. Thinner sections may be poured.
11. Need for chaplets is reduced.
12. Lightness of molds results in lower mold cost.
13. Less sand handling, resulting in cleaner working conditions.

SPECIAL MOLDING PROCESSES

The previously mentioned molding methods are the methods and processes most commonly used in the Navy. However, several other methods of producing castings are available to the foundryman: plaster, permanent, precision investment, centrifugal, and slush molding. A brief description of these special processes is given in the following paragraphs.

Plaster Mold Casting

Plaster molding is a definite refinement of the sand casting method of producing castings. The patterns used for this process are not subjected to the abrasion action of the mold material as in sand molding. In contrast to other methods of casting metals, plaster molding uses an investment material such as gypsum (plaster of paris) to provide the controlling factors for liquid metal poured into molds that are properly treated with water and dried. To the mold investment material various other ingredients, such as talc, asbestos fiber, silica sand, or silica flour have been added to obtain the required mold properties.

When properly employed, plaster molding produces a mold that will result in a casting with a smooth casting surface, free from holes, surface marks, and other casting defects. In addition, this method makes possible the exact duplication of the fine detail of the pattern.

The plaster mold is made by placing a suitable frame (flask) over the pattern and pouring the prepared liquid investment (slurry) into the frame. When the investment sets, (hardens) the pattern is removed from the mold and processed by heating to dehydrate the finished mold. The parts of the mold (cope, drag, cores, etc.), are then assembled and poured.

Due to the insulating characteristics of the dehydrated mold, a lower pouring temperature than is required for the sand casting method, may be used without danger of premature solidification (freezing) of the casting.

Permanent Mold Casting

The term "permanent mold" is somewhat of an incorrect designation, as there is no truly permanent mold. However, the term is applied to that type of foundry mold made of metal or a refractory material capable of being used to produce a large number of castings. Castings made from permanent molds are somewhat finer in grain structure than those cast by the sand casting method due to the more rapid solidification of the metal. Therefore, machining of small castings made from permanent molds may be eliminated because of better surface conditions of the metal.

Erosion of the metal mold caused by high pouring temperature is the limiting factor in determining the life expectancy of the permanent mold. Therefore, the first consideration in the mold construction is the proper selection of the best material at the most economical cost. Cast iron, steel, brass and bronze are the materials used in metal molds. (Cast iron is the most commonly used.)

Other factors to be considered for the life expectancy of the mold depend on the characteristics of the metal being cast, the mold design, mold construction, and the basic design of the finished casting.

Precision Investment Casting

Precision investment casting is a modern version of the Lost Wax Process where the wax pattern is embedded in an investment of silica sand instead of refractory clay.

The process begins with the preparation of one or more patterns which are made oversize to compensate for the shrinkage upon solidification of the metal in the manufacture of a metal mold. The mold is finished and used to produce the required number of wax patterns. From the wax patterns (pattern, sprue, runner, and gates attached), a silica sand investment mold is made.

When the investment hardens, the mold is inverted and heated to melt out the wax pattern, thus producing a mold cavity having the exact shape and size of the pattern.

Centrifugal Casting

In centrifugal casting, liquid metal is poured into a rotating mold (either sand-lined or carbon or permanent). The speed of the rotating mold is limited and controlled by the size and weight of the casting. While the mold is rotating, a centrifugal force of 75 times the force of gravity is produced to force the molten metal against the mold wall and hold it there until freezing (solidification) of the metal.

The pressure created by the centrifugal force, produces desirable characteristics in the casting, such as: greater density, freedom from gases, and freedom from inclusions.

Castings produced by the centrifugal casting method have a better surface finish and require less machining on the outer surface than sand castings. However, they require more machining on the inner surfaces due to the lightness of the impurities in the molten metal; the impurities are forced to the inside of the mold by the greater centrifugal force of the heavier metal.

Centrifugal castings have a finer grain structure and better mechanical properties than ordinary sand castings. In addition, it is possible to produce thinner walled castings (such as cylinder liners, piston rings, engine cylinder barrels, and pipe) than by any other casting process. The thickness of the casting depends only upon the amount of molten metal that is introduced into the mold.

Slush Casting

Slush castings of a small nature are made by utilizing sand or metal molds to produce thin walled castings primarily for ornamental or statuary work. In this process, the metal is allowed to cool long enough to form a shell. As soon as the desired thickness of the shell is obtained, the mold is inverted and the remaining liquid metal is poured out, leaving a hollow center in the casting. This casting process is used only for castings of the lead and zinc alloys.

Lost Wax Process

One of the oldest and most fascinating methods of casting metals is the CIRE PERDU or LOST WAX PROCESS. The lost wax process was used by the ancients in the casting of statuary bronzes. Castings have been found that were molded and cast before 3000 B.C. Even today, to the average person, including a vast army of foundrymen (Patternmakers and Molders), the entire process is wrapped in mystery.

Basically, the process involves making a wax pattern or model over which a semiplastic or plastic refractory clay is poured or worked about the pattern. The refractory clay (mold) is allowed to dry and harden after which it is baked. During the baking, the wax melts and runs out of the mold, leaving a cavity to be filled by the metal being cast, duplicating the fine detail left by the wax pattern. The mold is provided with an aperture or gates for the removal of the melted wax and for pouring of the molten metal. Small holes or mold vents are also provided to release any trapped gases during the pouring of the metal.

Because of the melting of the wax (destruction of the pattern) in the evolution of making the mold, the lost wax process is slow and very expensive. However, the basic principles of the lost wax process are used in the manufacture of castings by the precision investment method.

An interesting fact is that the Navy Dental Technician also uses the basic principles of the lost wax process and centrifugal casting in the manufacture of dentures.

ELEMENTS OF A MOLD

A mold is a form into which molten metal is poured to produce a casting. A number of different materials (loam, cement, plaster of paris, metal) may be used to construct molds, but in the Navy foundries the basic molding material is always sand. This sand may be natural bonded, or it may be synthetic (all purpose).

Besides the factor of good sand control, there are a number of other requirements that must be met in constructing an adequate mold. The sand must be properly rammed; the pattern must first be properly set in the mold, and later properly withdrawn; the system of sprues and gates must be designed so that the molten metal will flow freely into the mold cavity; risers must be provided, in all but the simplest castings, as a reservoir of hot metal to compensate for shrinkage as the casting solidifies; and molds must be vented to permit easy escape of gases.

Some applications will require the use of cores, to provide for bolt holes, bosses, etc., on the finished casting. It may be necessary to use chaplets to hold such cores in place. In occasional cases, facing nails must be used to lock the mold cavity surface with the body of the mold. In heavy sections of a casting, chills may be needed to ensure directional solidification.

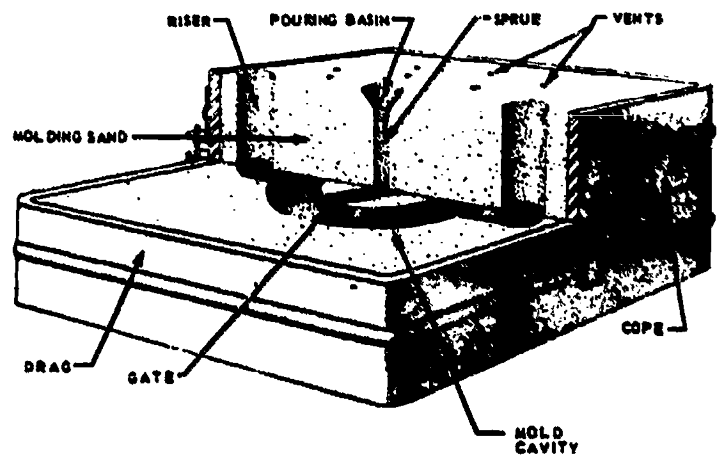
A single design that might be invariably followed in constructing a mold is not feasible, since the kind of pattern, and the material, size, and operating requirements of the castings, necessitate many variations. This chapter, therefore, is not designed to tell you how to construct the ideal mold. Its purpose is rather to give you the general principles of mold design.

The size and shape of the casting determine the kind of mold to be used as well as the details of its construction. Nevertheless every mold has several common component parts. Obviously, a mold requires a cavity having the shape of the desired casting. Of equal importance, though, is the means provided for the entrance of molten metal and the provisions made for insuring proper solidification, and thus a sound casting. Normally, the parts of a mold, in addition to the cope, drag, and mold cavity, are the pouring basin, sprue, gate, riser, and vents. Sometimes, a core may be required.

The path of the molten metal is as follows: Molten metal is poured into a basin located in or on the top of the cope; from there it passes down a vertical sprue through the cope, and into a horizontal channel or gate that is cut in the parting plane of the drag and leads into the mold cavity. These basic elements are shown in figure 2-3. The riser and vents, also illustrated in the figure, are not a part of the design for conducting the molten metal from ladle to mold cavity. However, vents always, and risers usually, are necessary to the casting process.

MOLD CAVITY

For very simple castings, the molding cavity may be confined to the drag portion of the mold, but in most cases you will ram up your pattern so that the mold cavity is in both cope



68.1

Figure 2-3.—Basic parts of a mold.

and drag, in relatively equal proportions. The procedures that you should follow in constructing the cavity are discussed in a later section of this training manual.

The fundamental requirement is that, after drawing the pattern, you have a cavity left that is essentially the size and shape of the casting to be made.

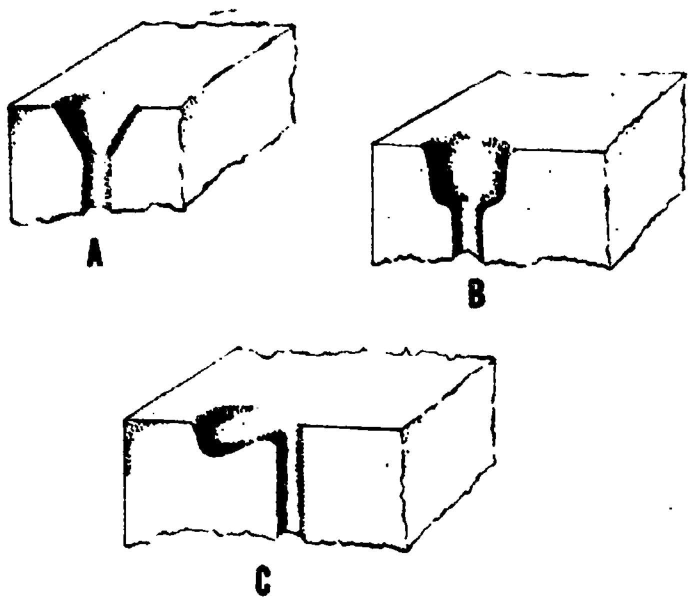
Sprues, gates, and risers are rammed up at the same time as the pattern. After the pattern is withdrawn, the Molder can add any required finishing touches to sprues and gates. Such finishing touches would be slicking down the sand, and rounding off sharp edges.

POURING BASIN AND SPRUE

Several designs of pouring basins are satisfactory. A tapered, conelike cavity can be formed directly over the sprue; this is probably the most commonly used design. However, the basin may also be shaped like the mouthpiece of a trumpet, or it may be located alongside the sprue. Typical pouring basin designs are illustrated in figure 2-4.

A pouring basin of the type shown at A in figure 2-4 has the diameter at the top of the cup about 2 1/2 or 3 times that of the sprue, and has the cup walls at a steep angle. The depth of the cup should be slightly less than the diameter at the wide part. This is the general type that you should use on molds with a sprue diameter of 2 inches or more.

The type of pouring basin illustrated at B in figure 2-4 is used for castings where the



68.2

Figure 2-4.—Pouring basins.

sprue is less than 2 inches in diameter. The diameter at the top of the basin should be about three times that of the sprue, and the depth of the basin should be slightly less than the diameter. The shape of this basin provides a larger metal capacity than does the cone-shaped type of similar dimensions; it enables you to pour the metal without splashing, and to keep the cup filled while the casting is poured.

The type of basin illustrated at C of figure 2-4 utilizes the damlike entrance to the sprue to separate the slag from the molten metal. Like types A and B, of figure 2-4, this pouring basin must be wide enough and deep enough to prevent the splashing of metal during pouring. The basin must be adequate for the sprue, and its capacity must be sufficient to permit pouring without splashing. The basin may be constructed either in the cope or as a separate structure on top of the cope, depending upon the amount of space that is available in the cope.

Unless the basin is kept filled during the pouring procedure, it will fail to serve its function of excluding slag and dirt from the mold. Since the slag and dirt rise to the top of the molten metal, the chances of keeping it out of the mold cavity are better if you can fill the pouring basin before any metal runs through the sprue.

GATES

The gate is an opening between the sprue (or runner) and the mold cavity, providing a channel for the molten metal. Actually, few molds are made with a single gate, since multiple gating ensures rapid filling of the mold cavity, and prevents the concentration of hot spots. However, in discussing the various types of gating systems, we can speak of each type as a single gate.

Gating from the top of the mold cavity leads to turbulence in the molten metal, and is likely to cause erosion of the molding sand. Gating from the bottom of the mold cavity cuts down turbulence and erosion, and is a practical aid to the production of clean castings.

Regardless of type of gate, there are certain important principles necessary in producing sound castings:

1. A gate must be small enough so that it is kept full of molten metal during pouring.
2. The gate must be large enough to admit a sufficient amount of metal to fill the cavity before the metal freezes and stops flowing.
3. Size, shape, and cross-section thickness of the casting help to determine the type of gate to be used.
4. Gates should be placed where it will be easy to grind the casting true.

Unless the type of gate that is used is capable of feeding the required amount of metal, there may be a malformation of the casting. To ensure proper feeding for the various sizes and shapes of castings, the foundry industry has developed a number of different designs for gating.

PARTING LINE GATES are easily constructed; in most cases they are simply channels, between sprue and mold cavity, cut in the drag of the mold parting joint. Figure 2-3 illustrates a mold with a parting line gating system.

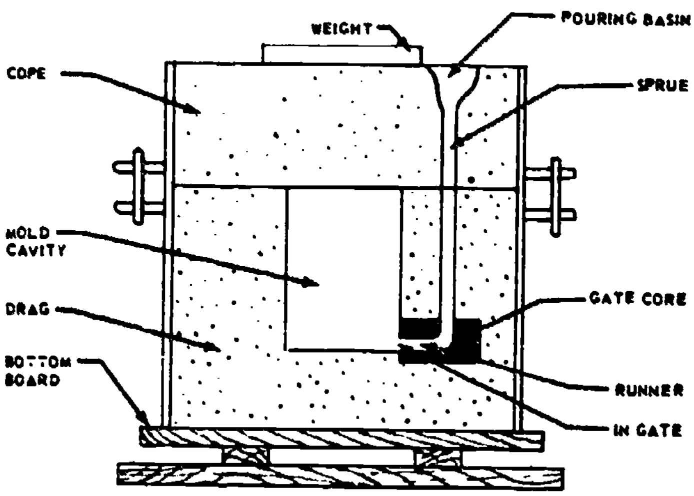
BOTTOM GATING is especially good for working with bronzes or with alloys that have a tendency to drossing. This type of gating introduces the metal into the cavity with a minimum of turbulence. Figure 2-5 illustrates a mold gated with a bottom gating system.

TOP GATING is suitable for use only if the mold is capable of withstanding erosion, and if the casting metal is nondrossing.

STEP GATES illustrate a type of combination gating system that includes the good features of both top and bottom gating. Each gate is constructed with an upward incline, as indicated in figure 2-6. The first metal in the mold enters through the bottom gate; as the cavity fills, a higher level gate becomes active.

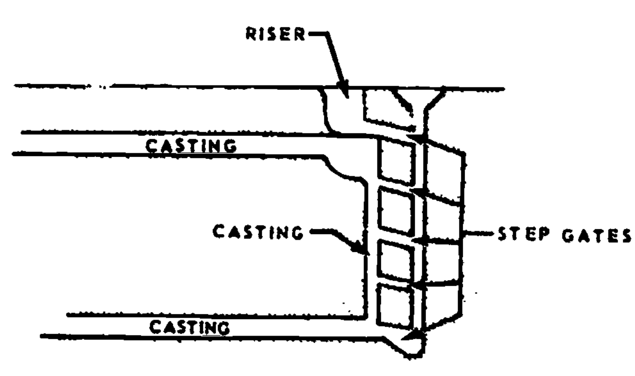
WHIRL GATES combined with parting gates are a useful device for collecting and trapping dross, dirt, and eroded sand. This combination develops a swirling action which washes dirt and sand on top of the metal stream into the riser.

A SKIMMING GATE is advisable in cases where dirt-free castings are required. The skimmer is very much like a riser, but its primary function is to receive excess liquid metal rather than to feed it.



68.3

Figure 2-5.—Mold gated from bottom, with gate core used to prevent cutting.



68.4

Figure 2-6.--Step gating.

Skimming gates are rarely used except where clean castings are definitely required, since the use of this type of gate demands more metal than would ordinarily be melted for a casting of the specific size.

PENCIL GATES can be used when a relatively large volume of metal must be rapidly introduced into a thin casting. These gates have a circular cross section and are usually employed in clusters.

HORN GATE, which is just what the name suggests, is a common design for a bottom gate. It is a circular-shaped gate or sprue form having a rectangular or round cross section, and is used when the molten metal is to enter the mold cavity well below the parting line.

RISERS

When a casting is bulky, and slow to solidify in the center, the gating system alone is not enough to feed the casting; this is because the gate, which must be kept relatively small, could freeze completely while the bulky part of the casting is still liquid. The dam produced by the solidified metal in the gate would obstruct any additional feed to the casting. When feed is obstructed, the shrinkage that occurs as the casting solidifies will leave cavities in the finished casting.

The use of risers to feed the casting is designed to prevent this type of cavity from developing. The riser, of course, must be large enough so that the metal for which it serves as a reservoir will remain liquid until the casting has solidified.

The principal function of a riser is to serve as a source of molten feed metal for those portions of a casting that are the last to solidify. Determine which sections of a casting will need to be fed, and then design risers that will supply these sections. It is important, too, that you know the alloy used in the specific casting, because solidification problems vary, depending upon the type of metal involved.

There are a few general rules concerning shape and dimensions of risers:

The SHAPE of the riser is ordinarily cylindrical, in order to provide the greatest practical ratio of volume to surface area. It is important that this ratio be greater for the riser than for the section that it feeds. If the metal in the riser and in the section were to solidify at the same rate, the riser would serve no purpose.

A spherical shape has the smallest surface area for a given volume, but it is not a practical shape for an open riser. Blind risers usually approximate the form of a sphere. Rectangular shapes are inefficient, since their corners rapidly solidify, and the effective portion for feeding is limited to the largest ellipse or circle that can be inscribed in the cross section of the riser.

To determine the DIAMETER of the riser where it contacts the casting section, draw a cross-sectional view of the section, and inscribe within it the largest possible circle. Measure the diameter of the inscribed circle, and multiply it by 1.5, to obtain the diameter of the riser where it contacts the casting. The riser should widen to a slightly greater diameter above the point of contact, or neck.

A HEIGHT of 1 1/2 times the diameter should give maximum effectiveness to the riser. Do not be misled into thinking that giving added height to the riser will ensure keeping the neck area open, because of the added pressure from the column of molten metal. Actually, you will only be decreasing the number of casting that can be poured from a given melt, since you will be wasting metal to keep the too large riser filled. Too short a riser is equally inefficient, since it will fail to provide sufficient metal to compensate for casting shrinkage.

The open riser, cut all the way through the cope, is easier to construct than the blind riser. Further, it is open to the atmosphere, and atmospheric pressure on the surface of the metal in the riser operates to feed the casting.

The blind riser is more efficient in the delivery of feed metal. The dome shape, a closer approach to the ideal spherical shape, makes it more effective as a reservoir. Because the riser is surrounded by sand, it does not lose heat through radiation to the atmosphere. To provide a specific amount of feed, therefore, the blind riser may be smaller than an open riser; this results in a conservation of metal.

The same need for atmospheric pressure to force feed metal into the casting exists in the case of the blind riser. Here the pressure passes through the permeable sand in the mold, and is given access to the riser through a vent core. The size of the vent core should be proportional to the diameter of the riser.

The small gate through which a blind riser is poured freezes soon after pouring is completed. Riser and casting then form a closed system. As shrinkage occurs in the casting, a partial vacuum is created; atmospheric pressure on the metal in the riser forces metal into the casting, to relieve this vacuum.

VENTS

Molds must be vented to expedite the escape of steam and gas generated within the mold as the sand is raised to a high temperature. These vents are made after the cope has been rammed and struck off, by forcing the vent wire down through the cope to the mold cavity.

Pressure of the molten metal against the mold sand forces the steam (from the moisture in the sand) to flow away from the casting, and deeper into the sand. As it reaches sand that is still cold, the steam condenses, and thus adds more moisture content to this portion of the mold. With the heat from the casting penetrating deeper into the mold, the moisture is driven farther away, until it is concentrated in a thin envelope of sand surrounding the casting.

Once this impermeable envelope forms, the steam is forced back into the casting which is still liquid. These kickbacks of steam may carry some sand with them; the result will be that the casting will show blowholes and sandholes, or streaks of unsound metal.

Besides causing these defects in the castings, confined gases may build up pressure sufficient to blow some of the liquid metal out of the mold. Venting, therefore, is a very important factor in obtaining good castings. Locating the vents is also important; they must be within the impermeable envelope of sand, or else they will prove utterly useless in providing for the escape of gas.

BASIC DESIGN OF CASTINGS

The Patternmaker's major goal is the production of precision patterns that will enable the Molder to make sound castings. Many of your jobs as a Patternmaker will involve working from blueprints which give you a great deal of information in concise form. Blueprints give you the name of the part, the material to be used, the number of castings required, the kind of finish, and heat treatment data, as well as the size and shape of the object. Yet, a lot of important information needed to produce the casting is not shown on the drawing. Usually, no information is given on how the pattern should be constructed or how the part should be molded. These details are left to the craftsmanship of the Patternmaker and the Molder. It is important, therefore, that the Patternmaker confer with the Molder, and sometimes with the Machinery Repairman and Hull Maintenance Technician as well, before building the pattern. In a few instances, however, when a certain special result is required, the molding method or the position of molding may be specified on the blueprint.

When the design of the part is complicated, it is often difficult to visualize the casting from the print. Under these circumstances it is helpful to construct a model, either to scale or full size, to eliminate the possibility of error in visualization. With this model you can better visualize how the metal will enter the mold and how it will solidify. It will help you to decide how the casting is to be molded, and to see more clearly the problems that will face the Molder. It also will help you to plan the procedures for constructing the pattern.

The patterns made in the pattern shop must be well planned, designed, and constructed to enable the Molder to produce sound castings. Normally, design is the responsibility of a design engineer. Occasionally, the Patternmaker, in cooperation with the Molder, may be called on to create a new part or to redesign an old part that has prematurely and repeatedly failed in service. Therefore, it is the Patternmaker's responsibility to know the sound, basic rules of design or redesign so that the casting will have the requisite strength and function properties that are required. A knowledge of the basic engineering and foundry principles that are fundamental to producing sound castings will help in making good patterns.

BACKGROUND FOR DESIGN

In designing a casting, you must consider and provide for the solidification characteristics of the metal used. Molten metal solidifies in the mold as a gradually thickening envelope or skin. The rapidity of this solidification is governed primarily by the relation between the section mass, mold surface area, and the solidification range of the metal. Obviously, other things being equal, the thinner sections will solidify before the thicker ones.

During solidification of the metal, a pronounced contraction takes place. This means that additional metal, more than that required for the initial filling of the mold cavity, must be supplied or fed to the solidifying casting to ensure internal soundness. This additional metal, stored in the risers, must remain liquid until the casting has solidified. It is important that the casting sections be proportioned and positioned so that the sections most distant from the risers solidify first. Subsequent solidification then progresses toward the risered section where the hottest metal is located.

While solidifying, the cast metal takes on an increasingly rigid form. The solidification is accompanied by contraction. The pattern's shrinkage allowance must compensate for this contraction or castings will not be the desired size. This contraction in the cast metal is opposed by the mold, and often by parts of the casting itself because of its irregular shape. This is likely to result in severe contraction stresses; and castings then must be heat-treated. The different cooling rates of thin and heavy sections result in the cooling and severe contraction of the thin sections prior to the complete solidification of the heavy sections. This results in stressing the partially solidified, and still very weak, heavy section.

Besides solidification, the crystal structure of metals requires consideration from the designer. Most metals solidify by the formation and growth of crystals. The relative size of the crystals is determined largely by the time consumed in solidifying and cooling in the mold. As this time is greater for heavy sections, the crystalline structure of a heavy section is correspondingly coarser than that of the lighter sections. In the case of steel, coarse crystallization means lower physical properties. With the nonferrous metals, a separation of the lower melting point constituents is likely to occur.

In designing a casting, follow the specific design rules as much as possible. Try to simplify the design wherever you can. Simple designs reduce the patternmaking and molding costs. If a complicated design is unavoidable, check the possibility of making the part in sections which later can be bolted, riveted, or welded together. If possible, avoid using loose pieces, deep pockets, or closer dimensional tolerances than necessary, in the pattern. Do not let the simplicity of shape fool you, though. Frequently, those parts having what appear to be simple shapes present the most difficult feeding problems. For example, a brick-shaped object is one of the most difficult shapes to cast with complete internal soundness.

Large, flat-plate castings or thin walled cylinders also look simple but pose some very difficult molding problems.

SPECIFIC DESIGN RULES

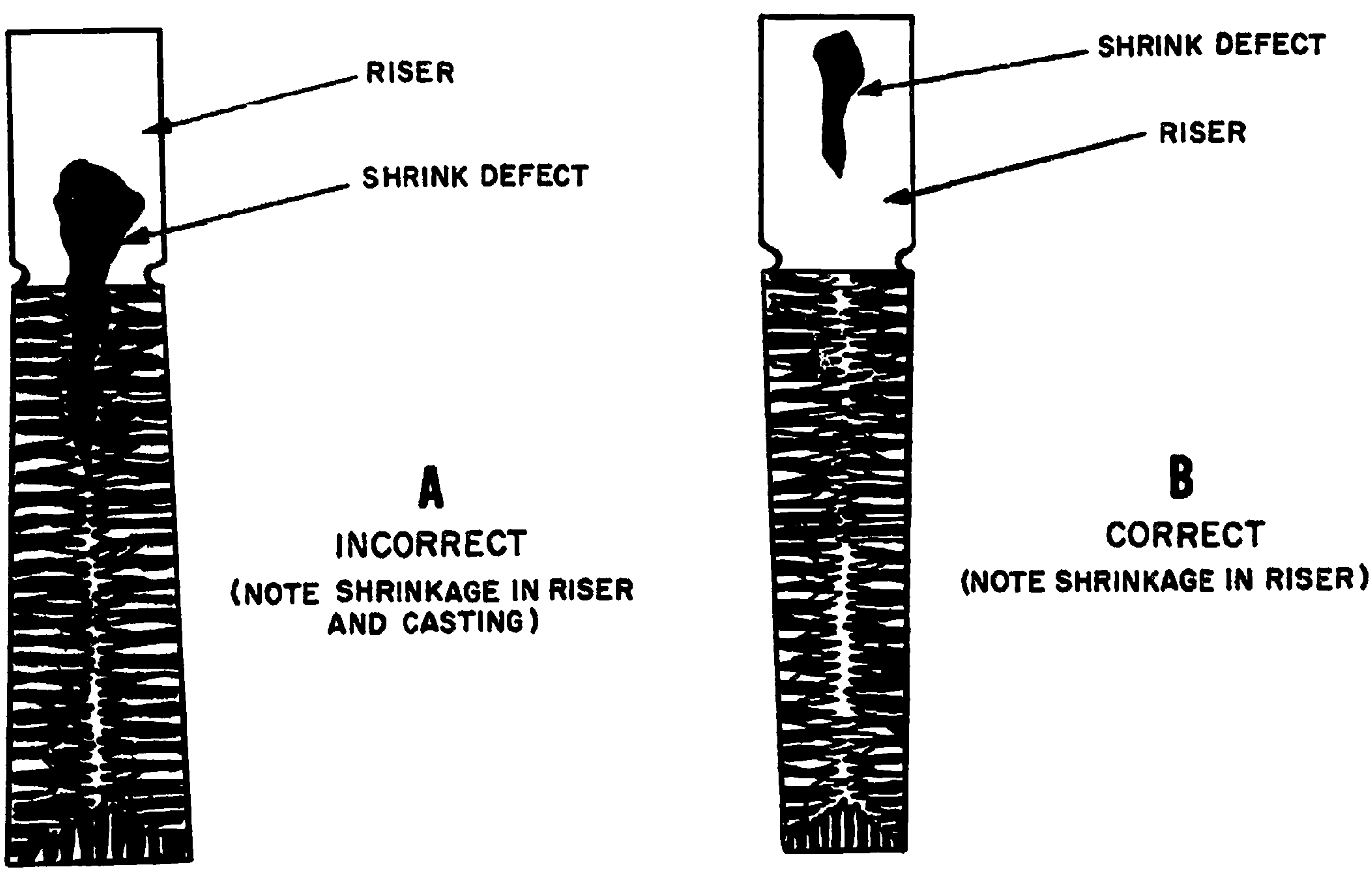
There are several specific rules to follow in designing a casting. One rule is to avoid sharp angles by using gradual contours. The shape of the casting section affects the metal structure. Rounded corners are advantageous in the formation of the crystal grains.

A design must also provide for the shrinkage which occurs in metals when they change from a liquid to a solid state. The parts must increase in thickness progressively to points where risers will provide the metal needed to offset the metal shrinkage. A riser cannot feed a section of uniform thickness for a distance greater than approximately 4 1/2 times the section thickness. Therefore, it is important that casting sections having considerable length, but not accessible for risering, be tapered rather than uniform in cross section. Further, the larger portion of the section should be near the riser. Figure 2-7 illustrates two examples of correct and incorrect methods of designing for casting soundness.

Castings should be designed so that large differences in cross sections do not exist. The various sections should be as uniform as possible. But at the same time, the length of uniform sections must not exceed the ability of the riser to feed the section. Heavier sections should be tapered into the lighter one gradually, never abruptly.

A minimum casting thickness must be maintained. The minimum cross-section thickness through which a molten metal will normally flow is indicated in the following guide:

	Inch
Aluminum	1/8
Brass and bronze	3/32
Cast iron	1/8
Steel	3/16



68.5

Figure 2-7.—Use of taper in casting design.

The sections should be no thicker than necessary, but should be sufficiently thick to permit the proper running of the metal in the mold.

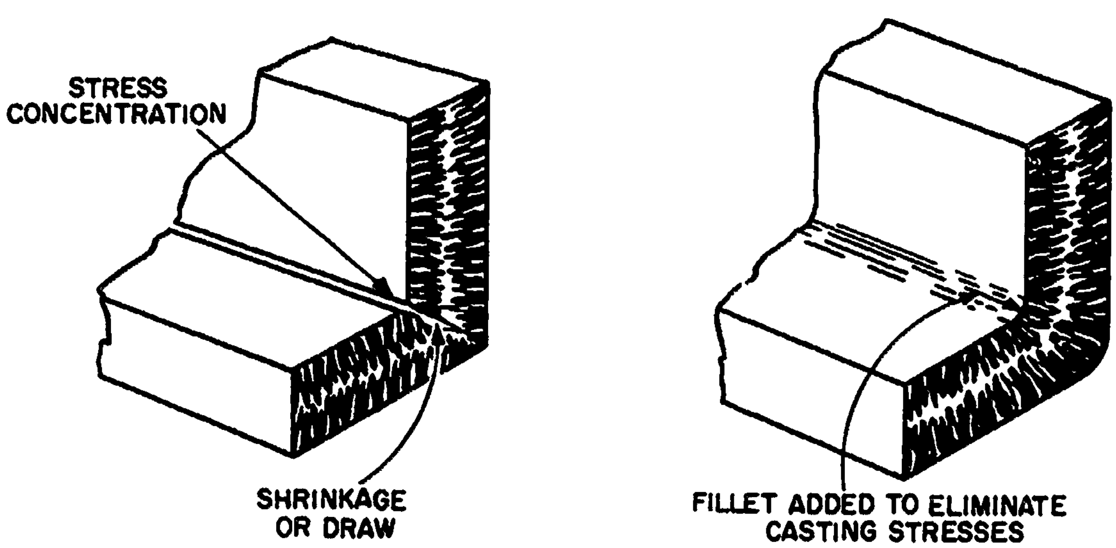
In designing adjoining sections, there are a few rules to follow. Figure 2-8 illustrates the avoidance of sharp corners by using a curve to avoid heat and stress concentration. Intersecting members of equal cross-sectional thickness do not create a molding problem if the joint location can be directly fed by a riser. All too frequently, though, it is impossible to feed these members directly. One way to avoid an area of excessive mass and at the same time obtain a more uniform section thickness is to stagger the intersecting members. Stagger the cross members or ribs, and eliminate sharp corners at adjoining sections. Do not bring more than three sections together, because shrinkage and porosity troubles occur most frequently at member junctions. If the gradual blending of the sections is not possible, use fillets at the junctions.

Use fillets at all sharp angles, especially at inside corners, to make the corners more moldable and to eliminate a plane of weakness resulting from a peculiar type of grain growth which occurs at sharp internal angles. The arrangement of the grain growth (crystals) is so that the lines of strength are perpendicular to the face of the casting. The size of the fillet depends on several factors: the kind of metal, the thickness of the wall section, and the shape and size of the casting. Large fillets produce nonuniform metal thickness and tend to cause nonuniform cooling, resulting in a weak casting. Fillets that are too large are just as bad as none at all. A good rule is to make the radius of the fillet one-half to one-third the size of the mean cross-sectional thickness of the sections joined. (See fig. 2-9.)

Bosses and pads should not be included in the casting design unless absolutely necessary. They increase the metal's thickness and create hot spots which may lead to improper solidification and to coarse grain structure. If bosses and pads are used, they should be blended into the casting by tapering or flattening the fillets. If several pads are required for one surface, they should be joined as a panel of uniform thickness. (See fig. 2-10.)

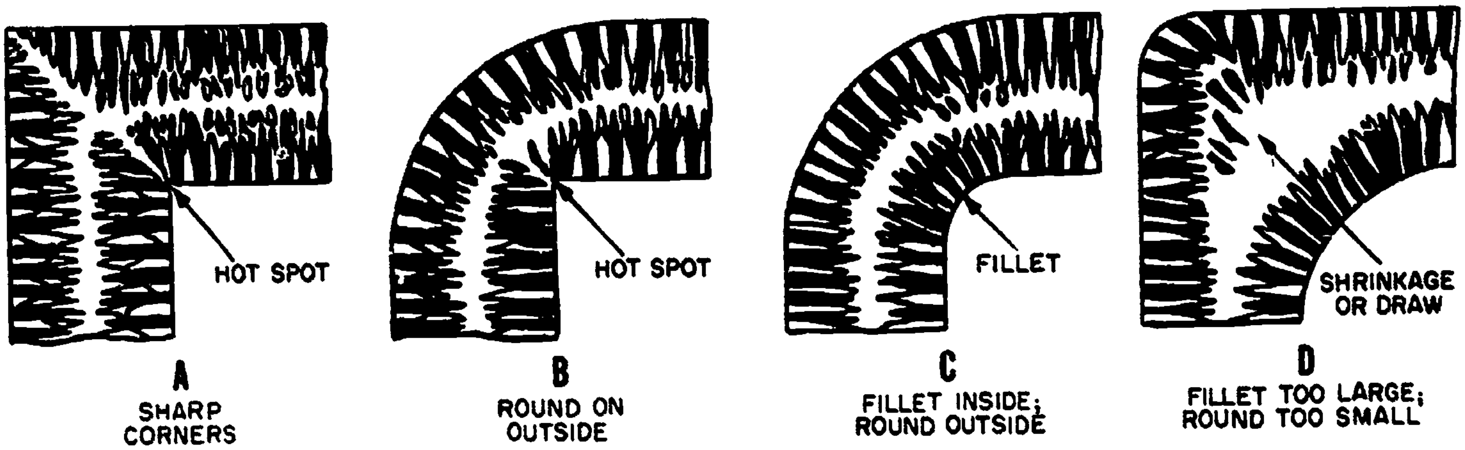
If possible, design a casting so the surfaces to be machined are cast in the drag section of the mold. If such surfaces must be cast in the cope section, you must provide an extra allowance for the finish.

In addition to bosses and pads, a Patternmaker may be confronted with the problem of designing ribs. The primary use of ribs is to reinforce the casting without increasing overall wall thickness. Properly designed ribs also reduce the tendency of large flat areas to distort.



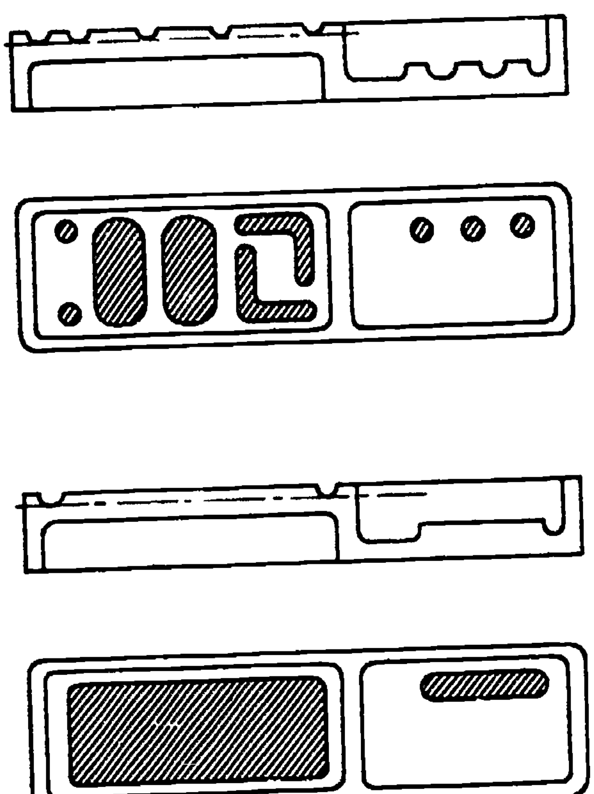
23.5(68)

Figure 2-8.—Design for adjoining sections.



68.6

Figure 2-9.—Grain structure created by fillets.



23.10(68)

Figure 2-10.—Designing a panel to simplify machining.

For maximum effectiveness, ribs must not be too shallow in depth nor too widely spaced. Ribs should also be rounded at the edges, correctly filleted, and not more than 80 percent of the casting thickness. When a reentrant angle, an angle having toes projecting inwardly, is to be made with ribbed strengtheners, casting difficulties may be eliminated by using cores to provide holes in the ribs. In this way, the sectional mass of metal may be reduced at the juncture of the rib and the angle, thus contributing to proper metal solidification. This background in casting design and foundry principles should enable you to select the type of pattern equipment most suitable for each specific job.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 3.

CHAMFER—To bevel a sharp edge.

CONTRACTION RULE—(shrinkage rule)—A rule having the graduations so enlarged as to compensate for the lessening in the size of a casting caused by the decreasing size of the cooling metal.

CORNER TOOL—A tool used for slicking the corner of a mold, inaccessible to the ordinary form of finishing tools.

COUNTERBORE—The cylindrical enlargement of the end of a hole for receiving and setting the head of a screw below the surface.

DOWELS—Pins of various types used on the joint between the sections on parted patterns or core boxes to assure their correct registering. Also used on loose pieces for temporary attachment to patterns or core boxes while sand is being rammed.

JIG—Any device so arranged that it will expedite a hand or machine operation.

LAYOUT BOARD—A board upon which a layout of a pattern is made.

PATTERN LAYOUT—Full-size layout on a board of a pattern to be constructed using shrinkage rule and showing its arrangement and structural features.

STRAIGHT EDGE—Relatively long piece of material having one or both edges a true plane.

SEGMENTAL CONSTRUCTION—Building up in a series of courses a pattern structure of segments with the alternating end joints occurring midway between those of the preceding course.

TEMPLATE—This piece of material with the edge corresponding to a specific contour and used as a guide for checking purposes.

WORKING EDGE—Edge surface of a piece of material that has been planed straight and square with the working face.

WORKING FACE—Surface of a piece of material that has been planed true and that is to be used as a basis for the dressing of all other surfaces.

CHAPTER 3

PATTERNMAKER HANDTOOLS

Although machines are used by the Patternmaker, a great deal of his work must be done by hand as no machine has yet been designed that can replace the skill of the Patternmaker with his handtools.

Patternmaking requires the use of many different woodworking tools and drawing instruments, each of which is designed to do a specific job. The skilled craftsman knows what each tool can and cannot do and selects the proper equipment for the particular job. The proper use of tools not only enables you to turn out quality work but also helps you to develop safe working habits.

Many of the tools used by the Patternmaker are the same as those used by the draftsman, carpenter, and cabinetmaker. However, the building of wooden patterns from which metal castings are to be made, presents special problems requiring special tools. For example, the Patternmaker works to such close tolerances that the thickness of a pencil line is often enough to cause an error in measurement. Thus, the Patternmaker scribes all lines on the layout with a bench knife. The Patternmaker also uses a shrink rule (which allows for the normal contraction of cooling metal) in drawing a layout for a pattern. Forming curved sections of a pattern and core box may require the use of planes, sole planes, spokeshaves, special carving tools, and templates. The rough handling to which a pattern is exposed and the tendency of wood to warp under the extremes of temperature and humidity in the foundry make it necessary for the Patternmaker to glue and to fasten securely the component parts of the pattern. For this, he uses special holding tools, clamps, pinch dogs, and jigs. The direction of wood grain must also be taken into consideration during the fabrication of a pattern.

The most important handtools are arranged and discussed in groups according to the kind of work they are designed to do, such as measuring, marking or laying out, cutting and carving, forcing and holding, and abrading.

The various tools discussed in this chapter are by no means all the tools that exist in these categories, however, they are the tools you will normally find in a Navy pattern shop.

MEASURING TOOLS

The measuring tools normally found in a Navy pattern shop are various types of rules, calipers, squares, and gages.

Their primary function is the measuring of lengths, diameters, angles, radii, and all other geometric forms.

RULES

The chances are that you have used numerous rules. The three types of RULES most used in the pattern shop are: The SHRINK RULE, 6-FOOT FOLDING RULE, and the STANDARD STEEL RULE or scale. Figure 3-1 illustrates the comparison of a standard steel rule to shrinkage or contraction rules.

Shrink Rule

The SHRINK or CONTRACTION RULE has been devised to compensate for the contraction of a casting while its metal is cooling and contracting. It is an expanded rule which has had its graduations increased to allow for this decrease in size of the casting. Since all metals do not contract the same, it is necessary to have more than one shrink rule. A variety of such rules are therefore in use, but the most common ones are the 1/10-inch-shrink-per-foot rule for cast iron, the 3/16-inch rule for brass and bronze, and the 5/32-inch rule for aluminum.

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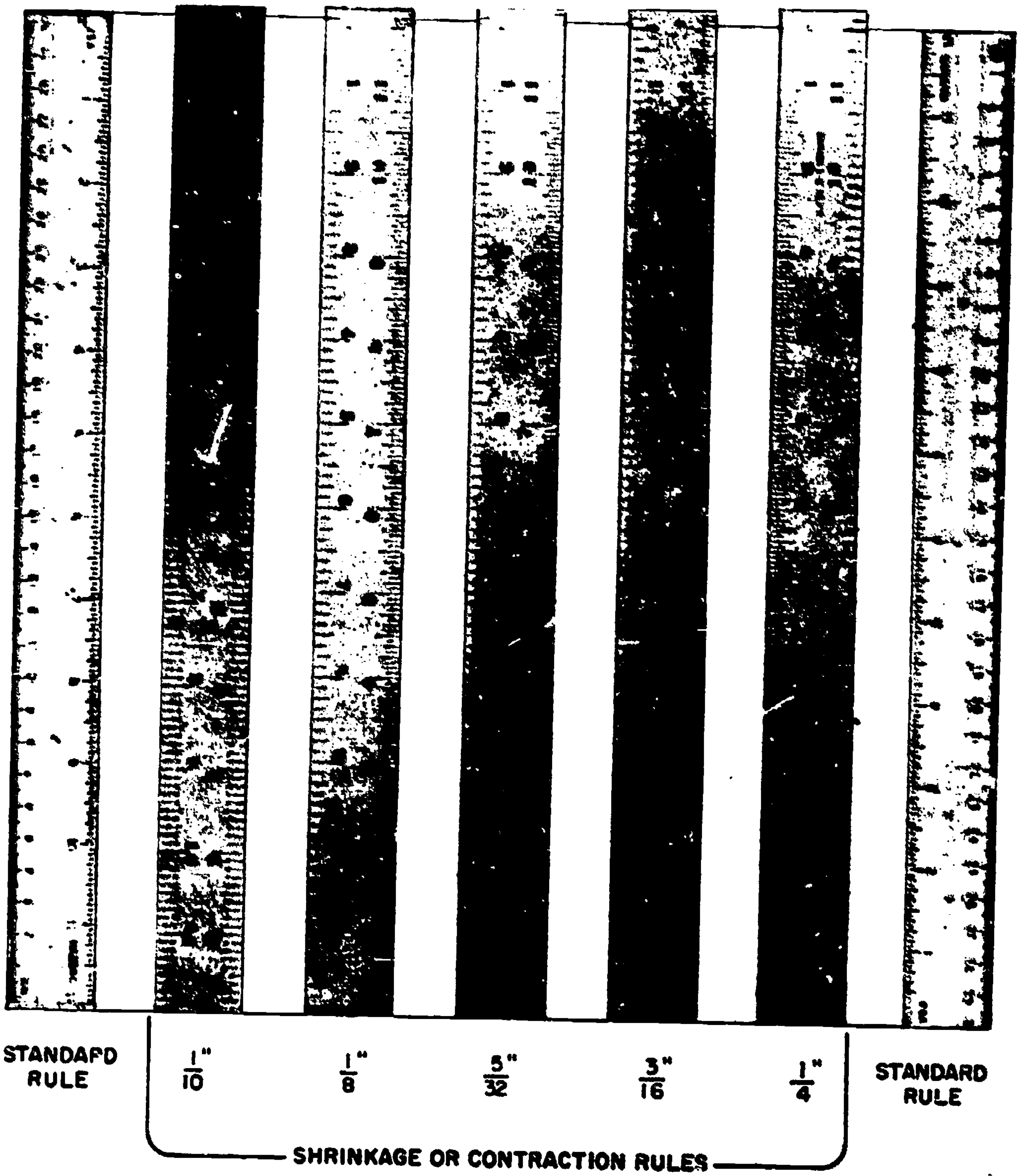


4.16(68C)

Figure 3-1.—Comparison of a standard rule to shrink rules.

Linear contractions of metal and alloys have been determined by experimentation and converted into tables. (See chapters 8 and 10 of this manual.) Such tables are intended merely as guides because each specific job may require some minor deviation.

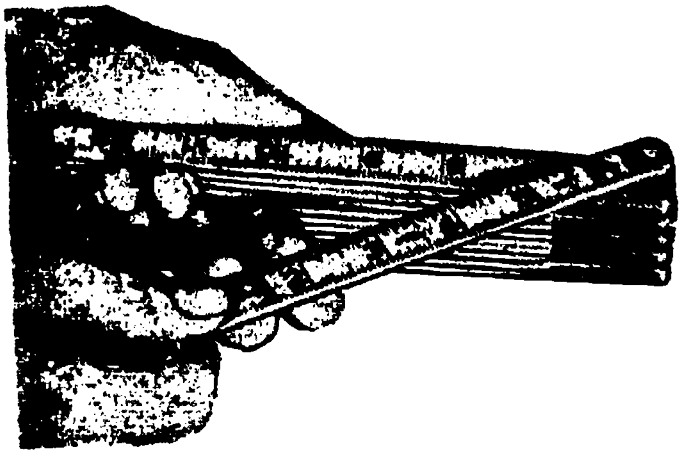
The shrink rule comes in 6-inch, 1-foot, and 2-foot lengths. Actually, the 24-inch shrink rule for bronze and brass is 24 3/8 inches in length. In using the shrink rule, the Patternmaker proceeds just as though he were using a standard rule. However, when the pattern is completed its dimensions are longer in the same proportion than the shrink rule is longer than the standard rule.

When making a layout from a blueprint, it is advisable to stow in a bench drawer all other shrink rules not being used at the moment, to prevent picking up the wrong rule.

When working from a sample casting, the Patternmaker will first take measurements from the casting with a standard rule and then use the proper shrink rule for the layout work. Some kind of suitable standard or common rule is used.

Folding Rule

The 6-FOOT FOLDING RULE (fig. 3-2) is commonly used for measuring rough stock and for estimating sizes of castings. It is not used for accurate final measurement in layout and pattern construction. Be careful when folding and unfolding this rule as it is easily broken. Oil the joints occasionally, and be sure that you keep glue and shellac out of the joints.



4.16(133F)

Figure 3-2.—Multiple folding rule.

Standard Rule

When more accurate measurements are required than can be obtained with the folding rule, the STANDARD STEEL rule is used (fig. 3-1). This rule is quite similar to the shrink rule except that it is graduated in standard or normal length. The lengths normally found in a Navy pattern shop are 6, 12, 24, and 36 inches.

The standard rule is used chiefly to measure castings. Keep it clean and oil it down at the end of the day to prevent rusting. Never use a standard rule (or any other rule) as a prying tool or screwdriver since it is quite brittle.

Even with adequate maintenance and care, the ends of a steel scale have a tendency to wear off through normal usage over a period of time. For this reason, most Patternmakers develop the habit of making all measurements from the 1-inch graduation mark rather than from the zero end of the scale.

CALIPERS

There are many types and variations within types of calipers. What we will discuss here are the types that will normally be found in a Navy pattern shop.

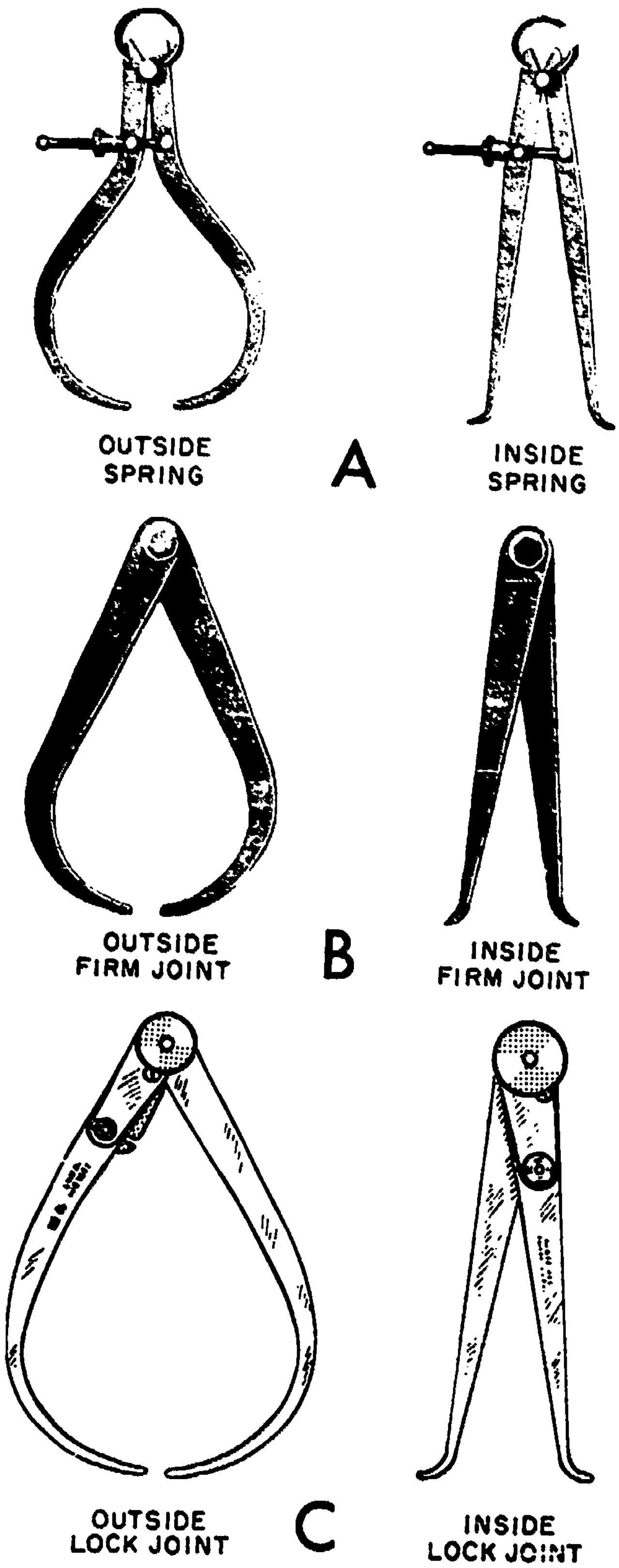
Calipers are used for measuring diameters and distances or for comparing sizes or dimensions with standards such as the standard rule.

There are INSIDE and OUTSIDE calipers, the size of which are determined by the length of one leg which is the maximum dimension they are designed to measure. For example, a 3-inch caliper will measure a distance of 3 inches with accuracy. If the designed distance is exceeded (some calipers will exceed their designed size by over 30 percent), the legs will usually be sprung resulting in an inaccurate measurement.

The basic types of calipers normally found in Navy pattern shops are the SPRING, FIRM JOINT, and LOCK JOINT CALIPERS shown in figure 3-3.

Spring Calipers

The spring caliper (fig. 3-3A) is available in sizes from 2 to 8 inches. The friction of the adjusting nut and screw works against the tension of the spring which holds the legs in any set position. They are available with either the quick spring adjusting nut or the more common solid nut. The quick adjusting nut is the most desirable as it allows you to make



4.17(68C)A
Figure 3-3.—Basic types of calipers.

quick and positive adjustments. The threads of the nut firmly engage the screw at the slightest pressure from the leg and when the pressure is removed, the nut is released and allowed to slide freely over the screw.

Firm Joint Calipers

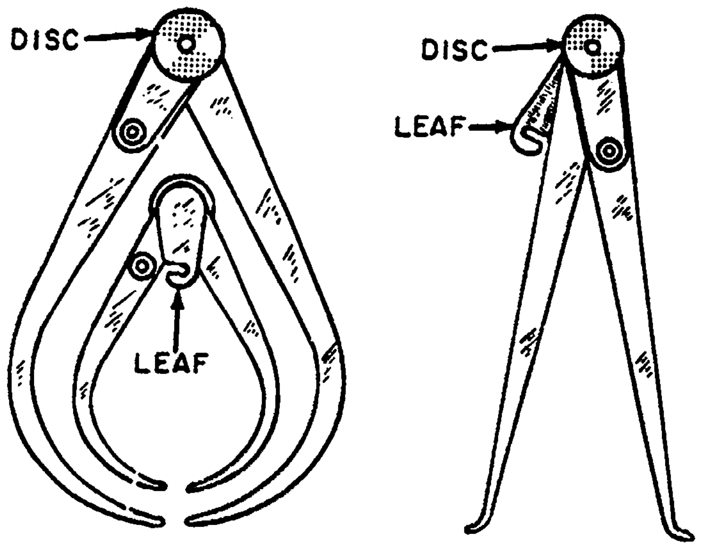
The firm joint type (fig. 3-3B) is available in a number of sizes from 3 to 24 inches. This type of caliper is equipped with a nut and stud that provides sufficient friction to hold the legs in any set position. Some calipers of this type are equipped with an adjusting screw for fine adjustments.

Lock Joint Calipers

The lock joint caliper (fig. 3-3C) is available in 4 to 24 inch sizes. It features a joint that can be quickly and firmly locked by a slight turn of the large knurled disk. A spring washer under the disk maintains proper tension of the legs when the joint is unlocked.

These calipers are also provided with an adjusting screw to permit close adjustments for fine measurements. After the legs have been set to the approximate size and the joint locked, the final adjustment is made by a few turns of the adjusting nut.

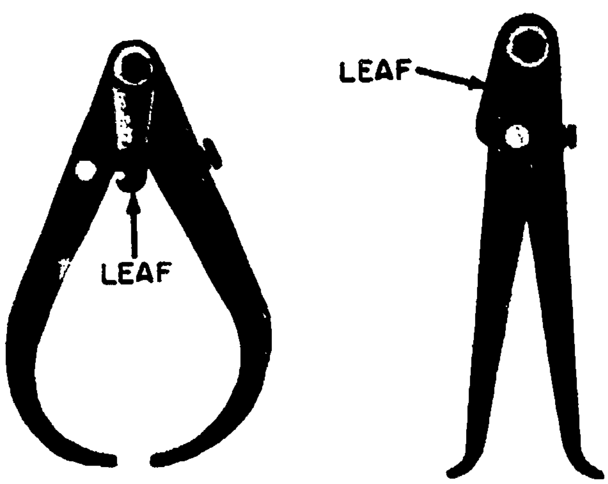
A variation of the lock joint caliper is the lock joint transfer caliper (fig. 3-4). It is also available in 4 to 24 inch sizes. It has the same



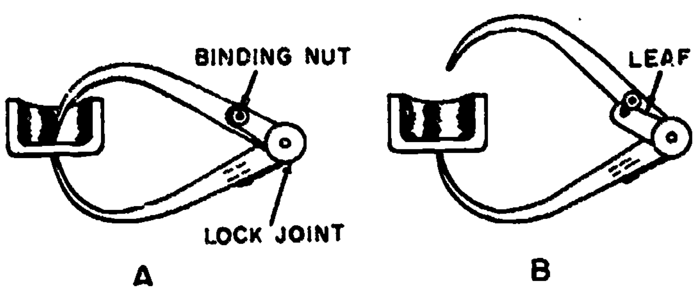
4.17(68C)B
Figure 3-4.—Lock joint transfer calipers.

features of the lock joint caliper plus a leaf or transfer arm that is locked in place by the large disk. One leg of this caliper is secured to the leaf by a binding nut which, when released, allows the leg to swing free. This feature allows you to take measurements from the inside of chambered cavities, over flanges and other places where it is necessary to move the legs after they have been set to size. The transfer caliper is also available as a firm joint type (fig. 3-5). However, the lock joint is considered to be superior.

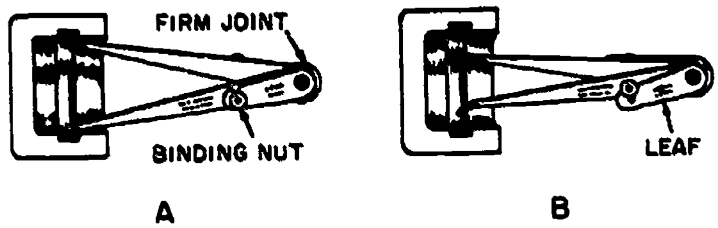
To use it, set the size, lock the joint by tightening the large disk, loosen the binding nut (the leg will swing free, but the leaf will stay in place), remove the caliper, then return the leg to its place in the leaf and tighten the binding nut. The exact size can now be transferred to a rule. Figures 3-6 and 3-7 illustrate the use of transfer calipers.



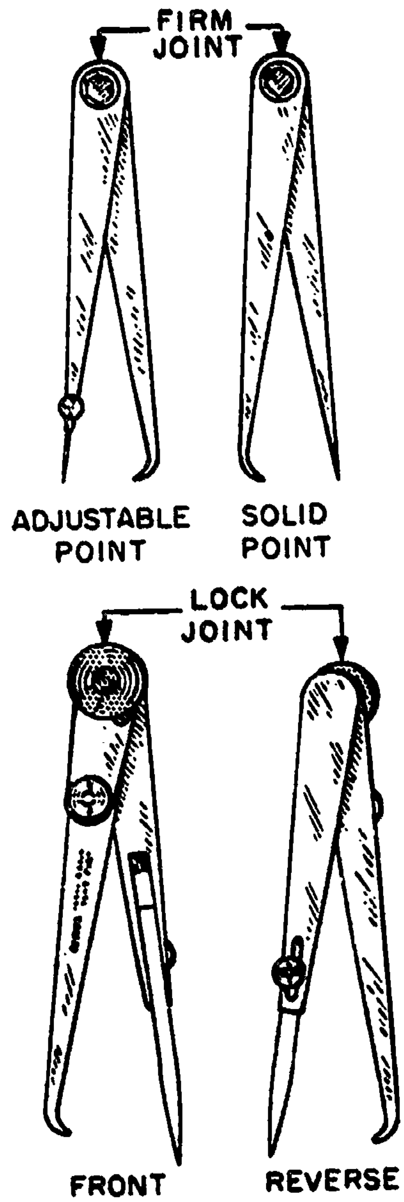
4.17A.3&.7
Figure 3-5.—Firm joint transfer calipers.



4.17C
Figure 3-6.—Measuring the thickness of the bottom of a cup with an outside transfer caliper.



4.17D
Figure 3-7.—Measuring a hard to reach inside dimension with an inside transfer caliper.



4.17(68C)C
Figure 3-8.—Hermaphrodite calipers.

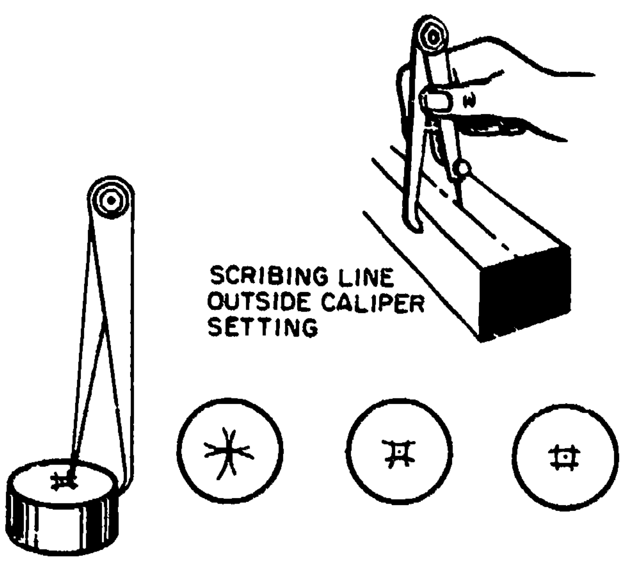
Another useful variation of both the lock and firm joint types is the hermaphrodite caliper (fig. 3-8). It is actually a cross between a divider and a caliper as it has one leg of each. It is used for scribing parallel lines from an edge or locating the center of circular objects, as shown in figure 3-9.

Use of Calipers

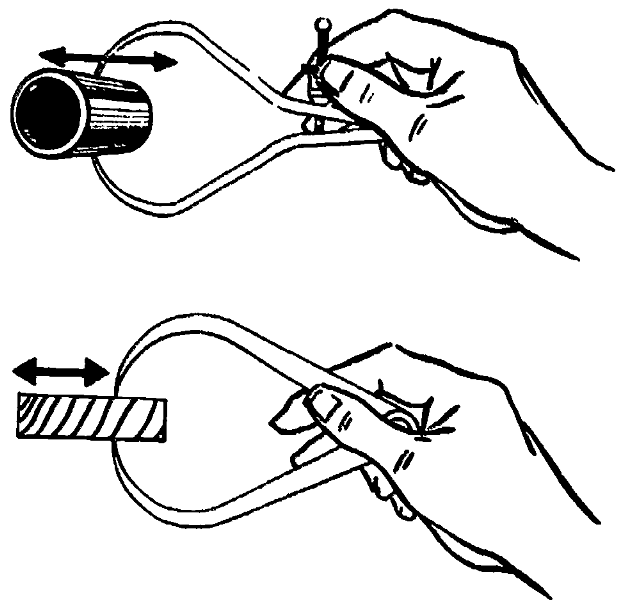
A caliper is generally used in one of two ways. Either the caliper is set to the dimension of the object and the dimension transferred to a scale, or it is set to a scale and the object worked until it checks with the dimension set up on the caliper. Figures 3-10 and 3-11 illustrate the use of outside and inside calipers.

A good sense of feel must be acquired to use calipers properly. They should be adjusted to where just enough drag or friction is felt to ensure contact of both legs to the object being measured. They should never be forced over the work. Too much drag will spring the legs and result in an inaccurate measurement.

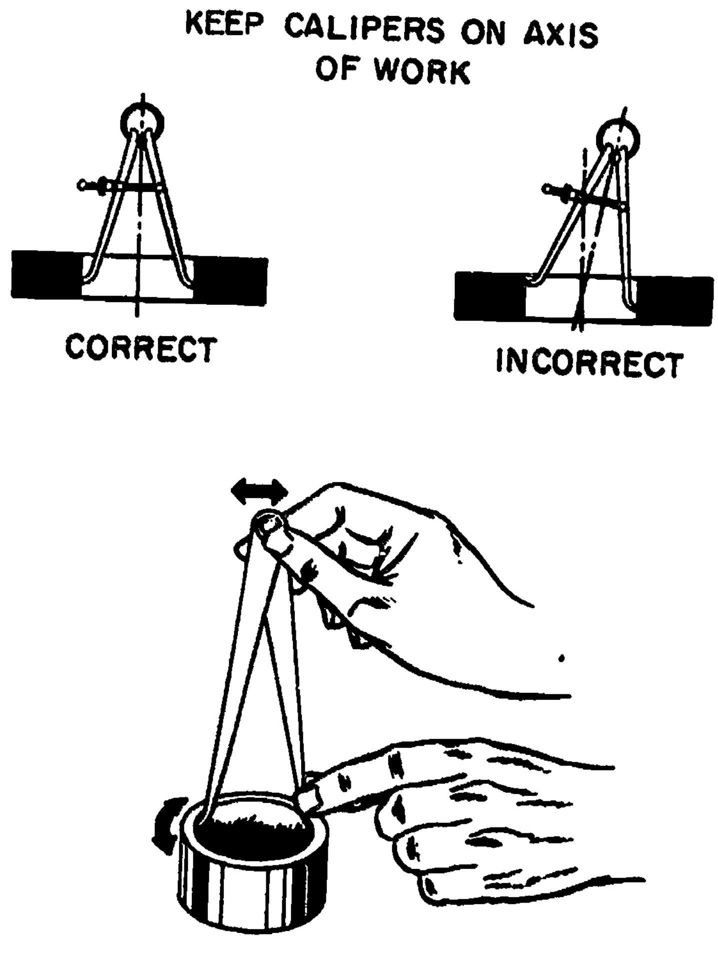
When adjusting calipers to a scale, it is good practice to measure from the 1 inch mark rather than from the end. The end of the scale may be worn or damaged which would result in an inaccurate setting.



4.17L
Figure 3-9.—Using the hermaphrodite caliper.



4.17B
Figure 3-10.—Using an outside caliper.



4.17(68C)D
Figure 3-11.—Using inside calipers.

Calipers are measuring instruments and must be properly cared for. They must be kept clean and lightly oiled. Do not over-oil the joint of firm joint calipers or you may have difficulty in keeping them tight. In storing them, always hang them up. Never throw them loose into a drawer or cabinet. Never use calipers for any use other than for what they were intended. Remember that the accuracy of your work depends upon the accuracy of your measuring instruments. NOTE: Never set a caliper on work that is revolving in a machine. The contact of one leg of a caliper on a revolving surface will tend to draw the other leg over the work because of the friction between the moving surfaces. Only a slight force is necessary to spring the legs of a caliper so that measurements made on moving surfaces are never accurate.

COMBINATION SQUARE

A complete combination square set (fig. 3-12) is the most versatile layout and measuring tool used by the Patternmaker. It combines the functions of several tools and serves a wide variety of purposes.

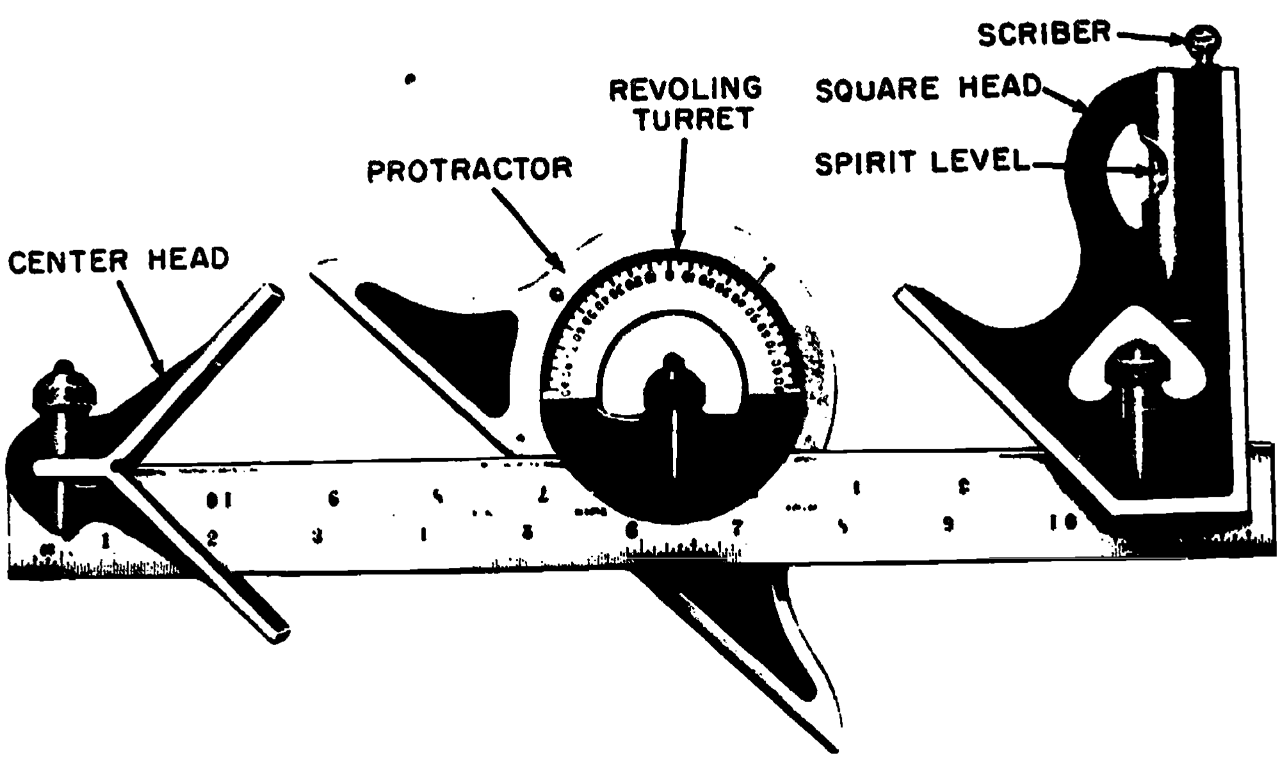
It consists of a grooved, hardened STEEL SCALE (blade), SQUARE HEAD, CENTER HEAD, and PROTRACTOR HEAD all of which are removable.

The blade is usually 12 inches long although blades are available from 4 to 24 inches in length. It is usually engraved in four graduated scales; 1/64, 1/32, 1/16, and 1/8 inch. Used alone it serves as a very accurate standard scale and straight edge.

The square head consists of three faces, a spirit level, scriber, and a thumb nut for holding the blade firmly in position. Two of the faces are ground at right angles (90° to each other and the third at 45°). The head can be adjusted and secured to any position on the blade. It can thus serve as a depth gage, height gage, scribing gage, or for checking a circular cavity for trueness as well as laying out or checking for squareness and 45° angles.

The center head is a V shaped attachment with two faces ground at 90° to each other. When the blade is inserted, it bisects the angle thus enabling you to find the exact center of circular objects such as bosses or shafts.

The protractor head is available in two types; the "single" or "non reversing" type which



29.25

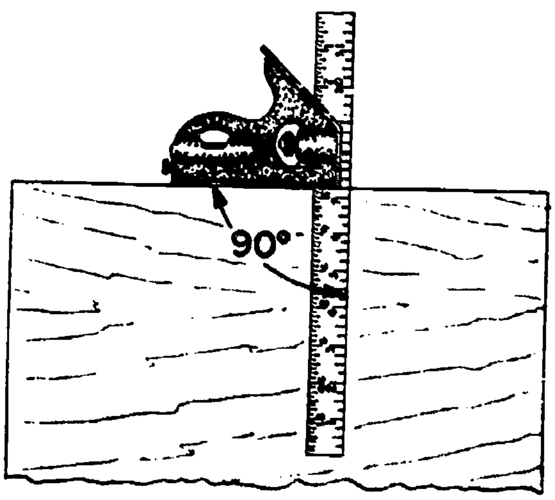
Figure 3-12.—Combination square set.

has only one shoulder or the "double" or "reversing" type which has two shoulders. They both consist of a revolving turret which has a receptacle for the blade, a thumb nut for holding the blade firmly in place, and on some models, a small spirit level. Located on the body of the protractor are two small thumb screws for locking the turret in position.

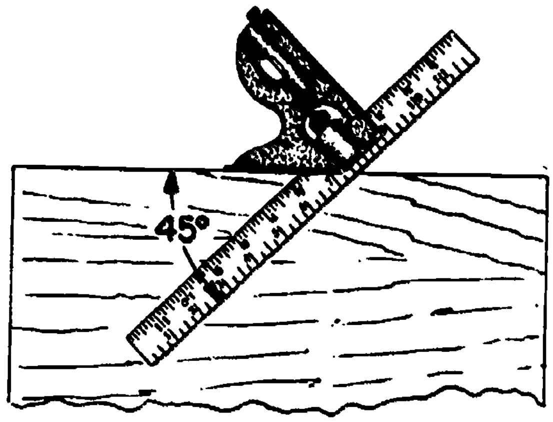
The turret is engraved with angular graduations of either 0 to 180° or 0 to 90° right or left in 1° increments thus allowing you to layout or check angles within 1°. Some models will have both 90 and 180 degree scales engraved on the face of the turret and some will have both right and left 180° scales engraved which enables you to read not only the angle required but also the supplement to that angle. For instance, if the angle required is 70°, the supplement to that angle will read 110°. Figures 3-13 through 3-16 illustrate some of the uses of the combination square.

SLIDING "T" BEVEL

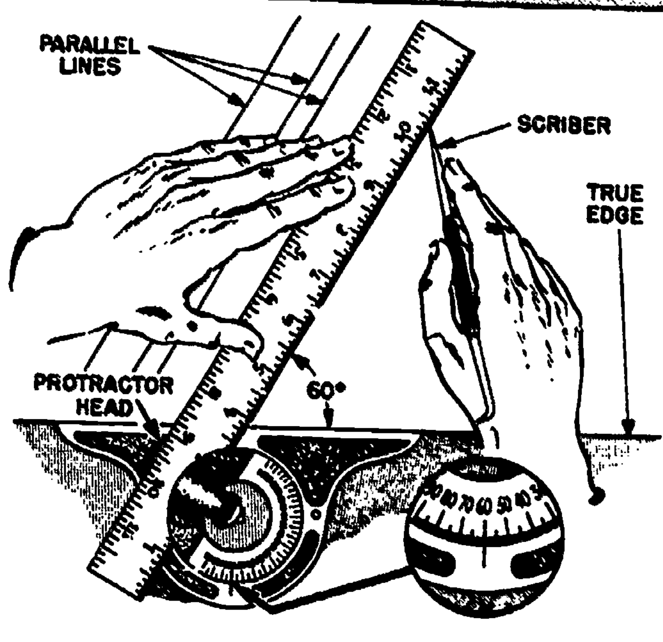
The sliding "T" bevel (fig. 3-17) is an adjustable try square consisting of a slotted steel blade, beveled on one end, and either a wooden or metal handle. The blade may be adjusted to any angle and secured in place by a nut on the hinge or a thumb screw on the butt of the handle.



28.16
Figure 3-13.—Squaring a line on stock with a combination square.



28.19
Figure 3-14.—Using a combination square to lay out a 45° angle.



28.20
Figure 3-15.—Drawing angular lines with a combination square.

The sliding "T" bevel has no graduations, therefore, if a given angle is to be set or an existing angle read, it must be used with a protractor, square, or other graduated measuring device (fig. 3-18).

The sliding "T" bevel is used for transferring angles, testing chamfers for trueness, and is also handy for laying out and testing the draft of a pattern (fig. 3-19).

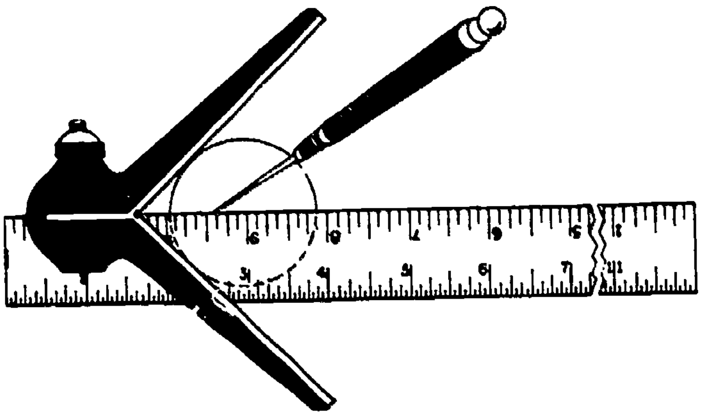


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Figure 3-16.—Locating a center with a combination square.

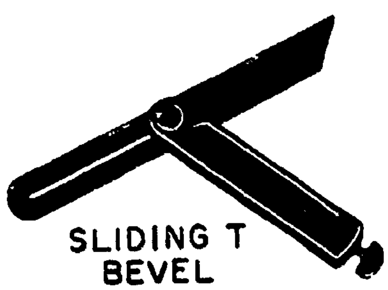

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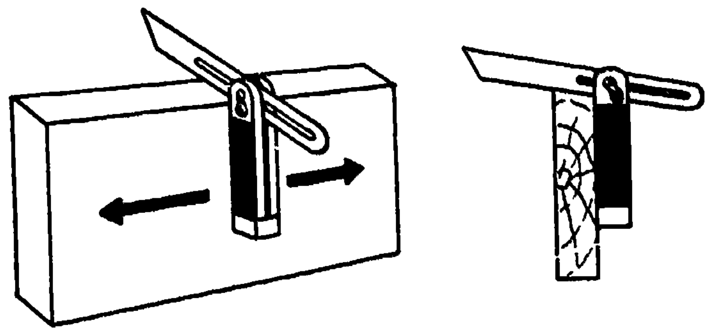
Figure 3-17.—Sliding T-bevel.

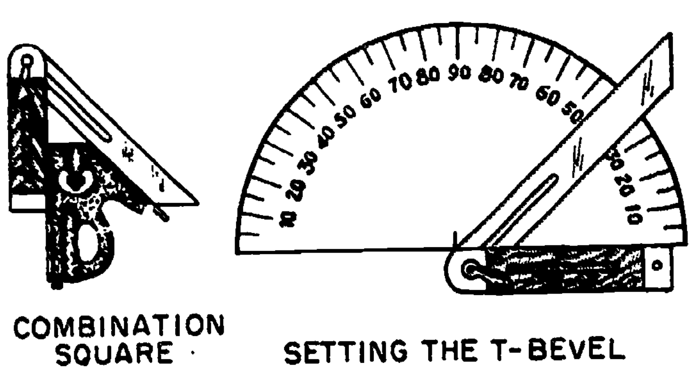


44.26B

Figure 3-19.—Testing the trueness of a bevel.

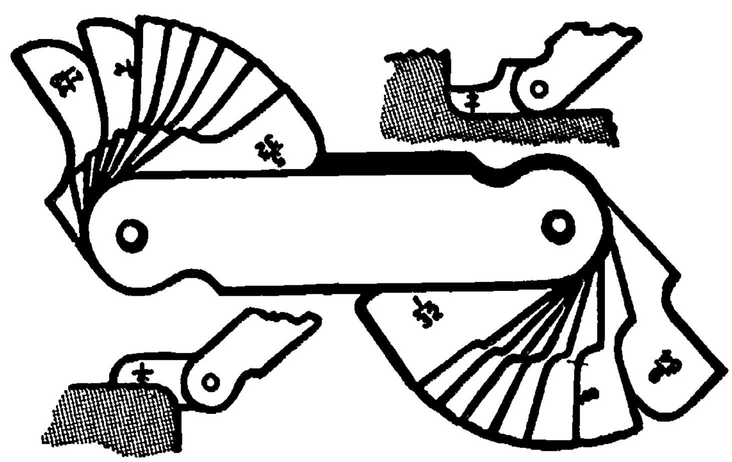
FILLET GAGE

A FILLET or RADIUS GAGE, shown in figure 3-20, is a useful tool for measuring fillets and radii. Notice that it can be used to gage inside as well as outside corners. When a blade is found that fits the curve being checked, read the fractional size on the face of the blade. When you are using this gage to measure the sample casting from which you are making a pattern, remember to take into consideration the fact that the corners of the old sample casting are probably well worn, giving you excessive readings on the gage.



44.26A

Figure 3-18.—Adjusting a sliding T-bevel to a desired setting.



5.14(68)

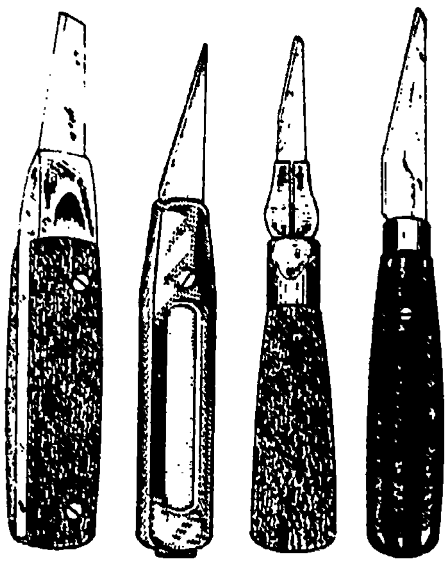
Figure 3-20.—Radius and fillet gage.

MARKING OR LAYOUT TOOLS

Marking or layout tools are normally used along with measuring tools. They are used to scribe or cut lines and outlines in the various geometric shapes necessary for pattern layout and construction.

The BENCH KNIFE (fig. 3-21) is probably the tool that is most used in the pattern shop. This knife is used to strike straight lines on layout work, to strike off accurate measurements on stock during construction, to whittle or carve patterns, and to cut and trim leather fillets. The bench knife has its blade loose in a slot so that the length of the blade can be increased as it is worn or ground down. Likewise, the sharpened portion of the blade can be withdrawn into the handle to protect the cutting edge when it is not in use.

The SCRIBE (fig. 3-22) is used to strike straight or irregular lines on metal surfaces as well as on layouts and patterns.



44.210(68C)
Figure 3-21. — Bench knives.

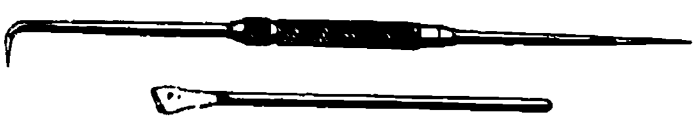


Figure 3-22. —Scribe.

The MARKING GAGE (fig. 3-23) is used to scribe lines parallel to the working edge. It is a rod about 6 inches long with a sliding head. The marking is done by a small point fitted at one end of the rod.

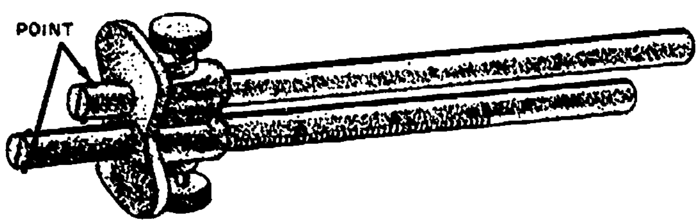
The PANEL GAGE (fig. 3-24) is another commonly used marking gage. Its head is much larger and its rod longer (usually about 18 inches long) than that of the marking gage. This gage has a much greater range of distance and is used mainly for layout work where the other type will not reach.

DIVIDERS (figs. 3-25 and 3-26) are essentially two legs hinged together at the top with some type of locking or adjusting device provided. The legs may both be sharpened or one leg may be designed to receive a pencil or other marking instrument.

The size of dividers is determined by the length of one leg and they come in a variety of sizes and types.

The types of dividers are the same as calipers; spring joint, firm joint, and lock joint, the spring joint type being the most popular. However, the lock joint type divider (also called the "wing divider") differs from the lock joint caliper in that the divider has a quadrant that is attached to one leg and passes through the other (fig. 3-26). The locking device is either on the quadrant or on the leg through which the quadrant passes.

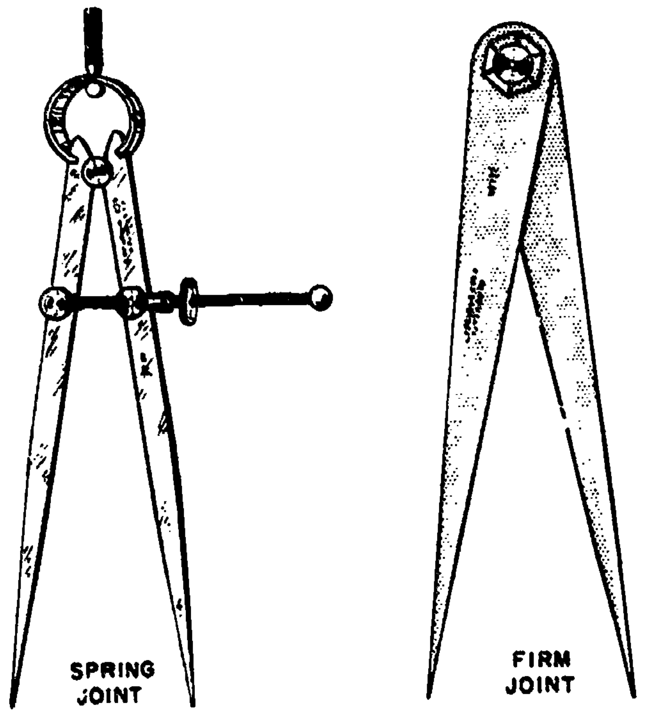
In setting dividers to a dimension on a scale, the usual procedure is to locate one point in one of the inch graduations of the rule and to adjust the nut or screw so that the other point falls easily into the correct graduation (fig. 3-27A). Make certain points of the divider are not blunt (fig. 3-27B).



68.199
Figure 3-23. — Marking gage.

45.132(68B)

Figure 3-24.—Panel gage.

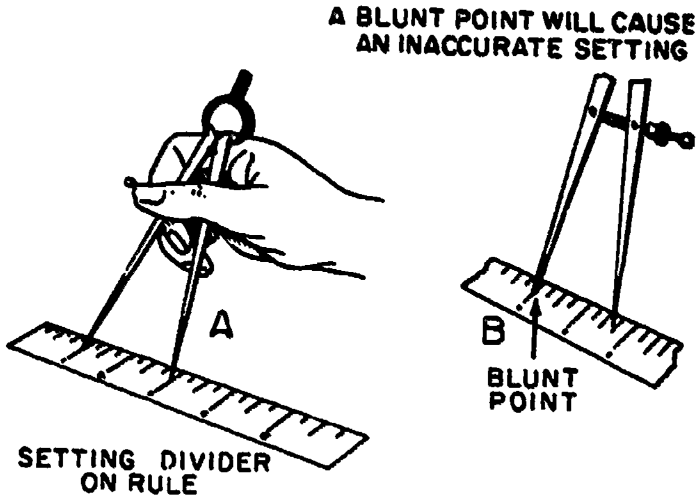


45.132(68C)A

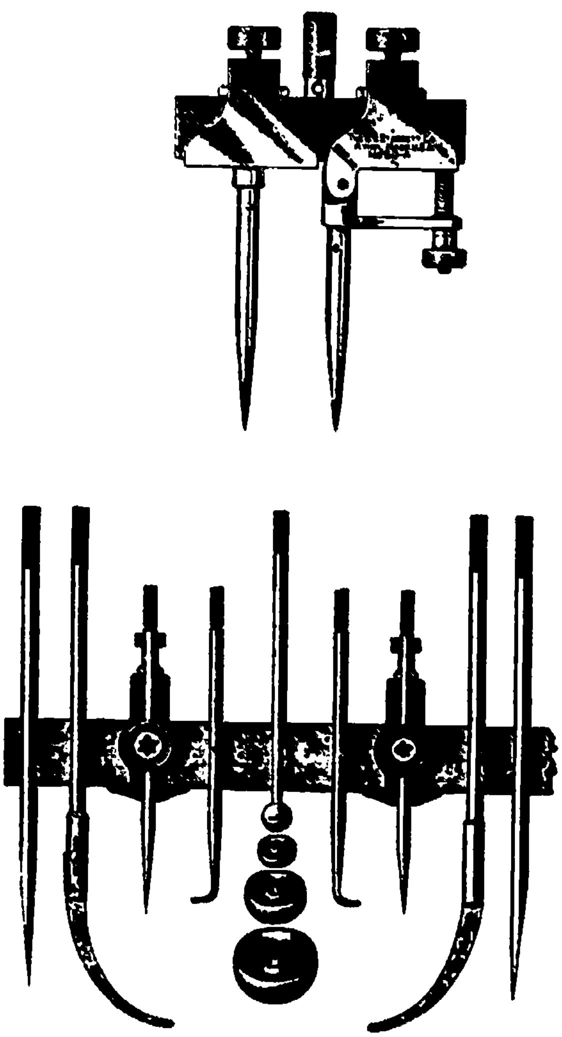
Figure 3-25.—Dividers.

45.132(68C)B

Figure 3-26.—Wing divider.



45.132(68C)C
Figure 3-27.—Setting dividers.



34
Figure 3-28.—Trammels.

When transferring a dimension from a part or tool to the scale on a rule, use the same care in adjusting the points of the dividers, making sure that there is no pressure tending to spring the points either in or out.

The primary functions of TRAMMELS (fig. 3-28) are the same as those of the divider, but for work that is beyond the capacity of dividers. They can also be used as calipers if you are in possession of the auxiliary attachments.

The basic trammel is a set consisting of two heads (trams) and either a metal or wooden beam. The wood beam must be manufactured by the Patternmaker as it is not provided by the manufacturer.

The trams have provision for attaching points which are available in various lengths. Some types may also have provision for a pencil or pencil lead on one tram. Usually one tram will have a device for fine adjustment.

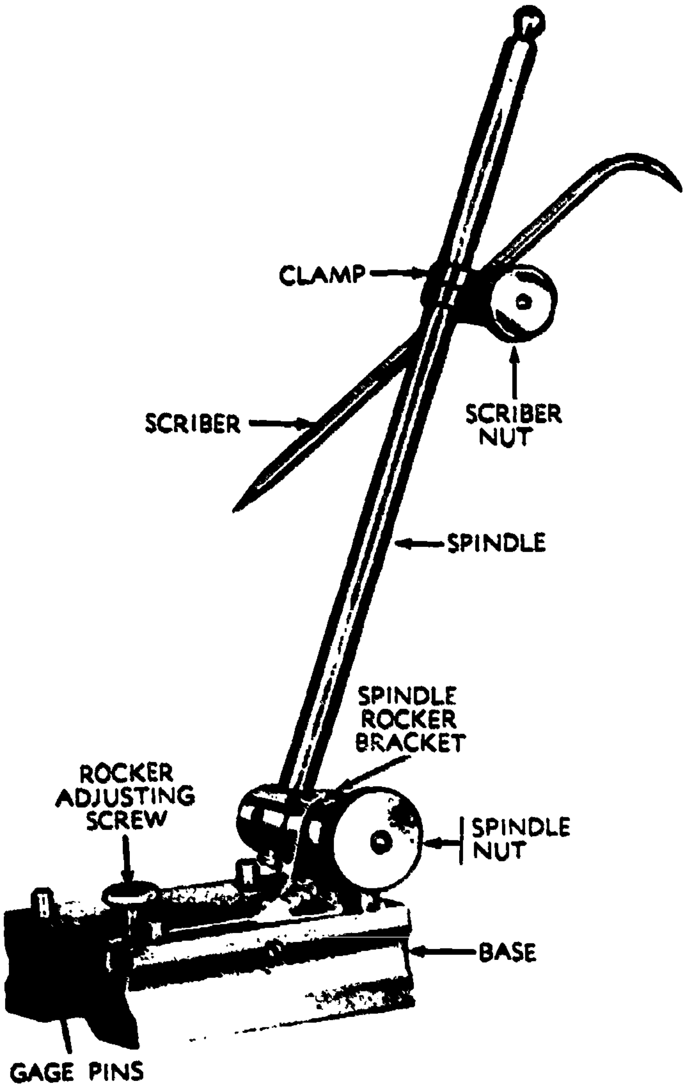
The auxiliaries usually consist of two sets of caliper legs and a set of ball points with holder. The ball points with holder are used for scribing or measuring from the center of a hole.

The SURFACE GAGE (fig. 3-29) is a tool used in pattern layout and construction to pick up or transfer a line and indicate the accuracy or parallelism of one surface to another.

The surface gage consists of a base which has a deep "V" groove cut into the bottom and allows it to be clamped to a cylindrical surface, a rocker adjusting screw for fine adjustments, gage pins which, when depressed, allow you to scribe lines parallel to an edge, a spindle rocker bracket, and a spindle nut. An adjustable spindle is attached to the base by inserting it through the spindle nut mounting. The adjustable spindle is equipped with a clamp and scriber nut for securing a scriber. A dial indicator may be used in place of the scriber or the scriber can be attached directly to the spindle nut mounting and used where the working space is limited and the height of the work is within range of the scriber.

The size of the surface gage is determined by the length of the spindle and is available in 4 to 18 inch lengths, the average or most commonly used size being 9 to 12 inches.

The surface gage (fig. 3-30) is often used together with a SURFACE PLATE which is

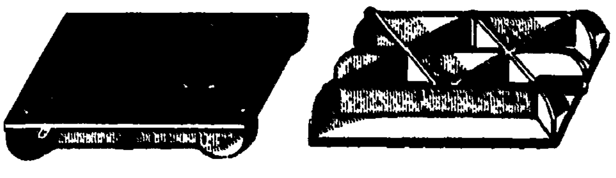


28.25.3

Figure 3-29.—Surface gage.

usually a rectangular steel or cast iron plate that is heavily ribbed and reinforced on the underside. The surface of the plate is ground to a true plane and can be used for testing a surface or edge for flatness as well as a level base on which the surface gage and the part to be measured are placed to obtain accurate measurements (fig. 3-31).

The surface plate must be kept lightly oiled to prevent rusting and pitting and should be covered when not in use to prevent scratching, nicking, and denting. It must be handled carefully to prevent twisting and warping. Never use the surface plate as an anvil or as a workbench except for precision layout work.



44.28

Figure 3-30.—Surface plate.

The MONKEY GAGE is a modification of the surface gage. It permits the Patternmaker to make a measurement and to pick up a line behind an obstruction where the conventional surface gage is unable to reach.

A MOUSE is a sharp-pointed tool (fig. 3-32) used for marking off material to fit closely to an irregular surface. The point of the tool is flush with the face and—with the aid of a square-edged block—can be used to project lines from the top to the bottom of any irregularly shaped object.

CUTTING AND CARVING TOOLS

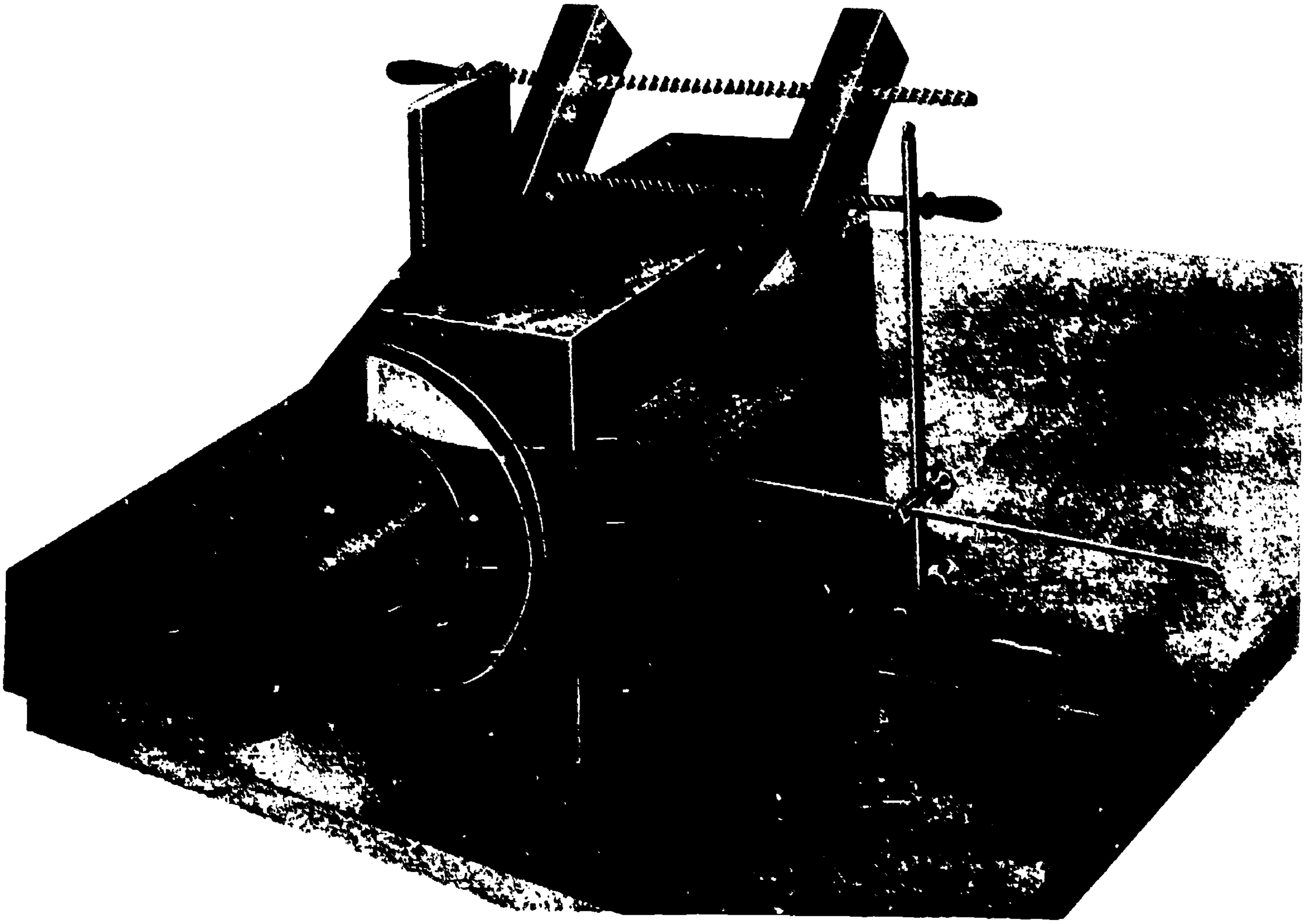
At the beginning of this chapter it is stated that "no machine has yet been designed that can replace the skill of the Patternmaker and his handtools." This is especially true in the case of cutting and carving tools for these are the tools that you will use to actually form the pattern.

HANDSAWS

The term "handsaw" is usually used in reference to the wood cutting rip saw or crosscut saw. However, there are a large variety of hand operated saws designed to serve special purposes, some of which are the BACKSAW, PATTERNMAKER'S SAW, DOVETAIL SAW, and COPING SAW.

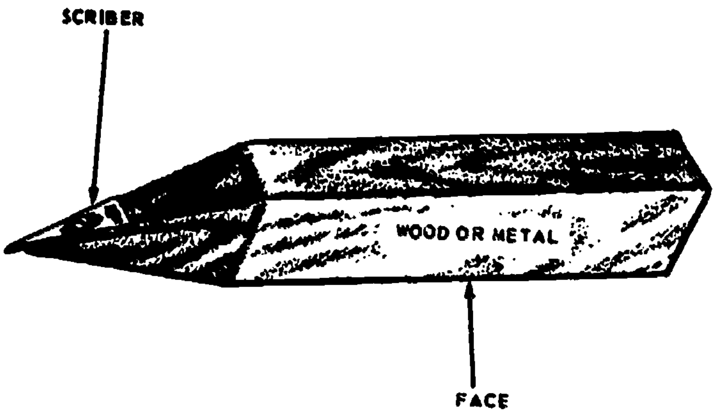
As their names imply, the ripsaw has teeth designed for cutting with the wood grain (ripping) and the teeth of the crosscut saw are designed for cutting across the wood grain (crosscutting).

Figure 3-33 illustrates the two different blade shapes of handsaws (skew back and straight back) and identifies their various parts.



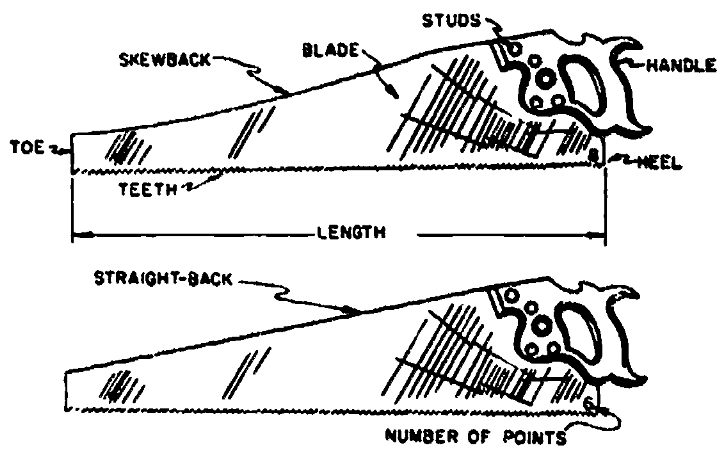
28.25(68)

Figure 3-31.—Using a surface gage and surface plate to lay out a centerline.



68.7

Figure 3-32.—A mouse.



29.15(68C)AX

Figure 3-33.—Handsaw.

The SKEW BACKSAW has a slight curve toward the top of the blade. This gives the saw greater flexibility over the STRAIGHT BACKSAW and makes it possible to cut slight curves with the toe end of the blade.

Special note should be taken of the number stamped near the heel of the blade. This tells you how many teeth per inch (points) are contained in the saw blade.

The blades of handsaws are made of spring steel that have been specially tempered so that they will retain their shape and cutting edge and still be easily sharpened and set. The cutting edge of the blade is usually thicker than the back edge. This gives additional strength to the cutting edge while giving clearance to the rest of the saw blade.

Handsaws vary in length from 20 to 28 inches. The most common length being 26 inches. The blade length and number of teeth per inch identify the size of the saw. For instance, a ripsaw may be identified as a 5 point 24. This tells you that the saw has 5 points (teeth) per inch and is 24 inches long.

Ripsaws

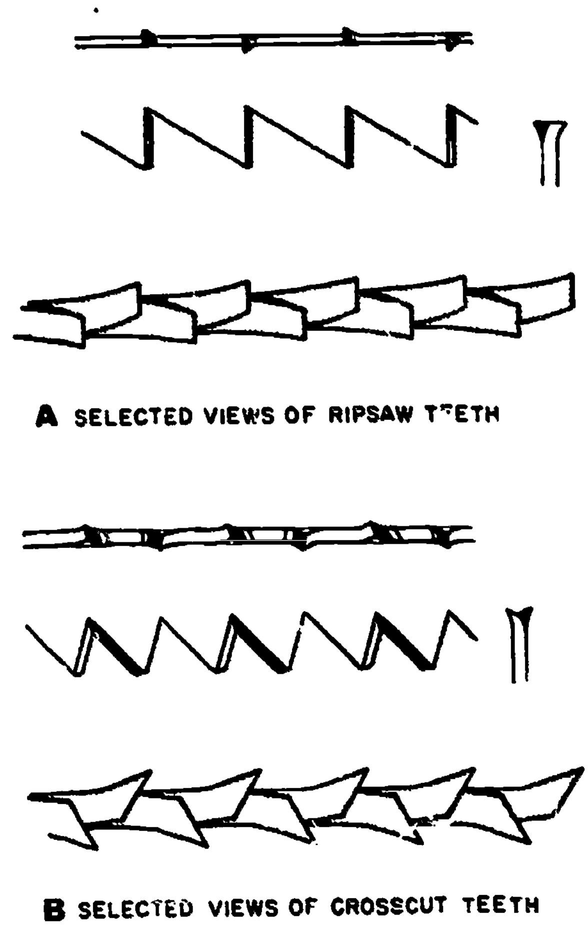
The teeth of a ripsaw are shaped like small chisels and are slanted at an angle of 8° (fig. 3-34A) so that the wood fibers can be ripped as well as cut. Figure 3-35 illustrates the cutting action of the ripsaw.

A ripsaw will normally have from 4 to 8 points. The 8 point saw is used for thin stock. As the stock thickness increases, use a coarser saw (less points). The most common ripsaws have 5 1/2 or 6 points.

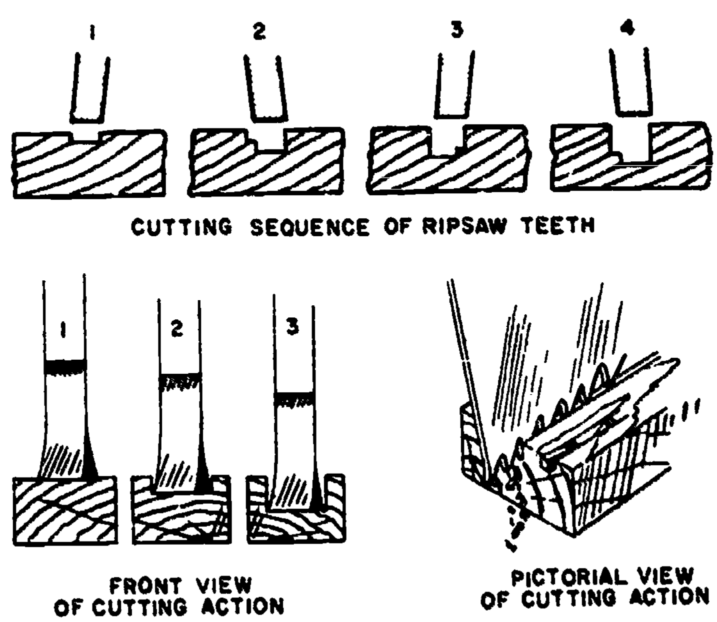
Listed below are some pointers on using the ripsaw.

1. Select the proper saw and layout the guide lines on the stock.
2. Support the stock so that it will not rock or teeter making certain that there is enough height to allow for the saw stroke.
3. Hold the saw so that it is in line with your shoulder and also the guide line (fig. 3-36).
4. Place the heel of the saw alongside the guide mark on the waste side, holding the saw at about a 60° angle (fig. 3-37).

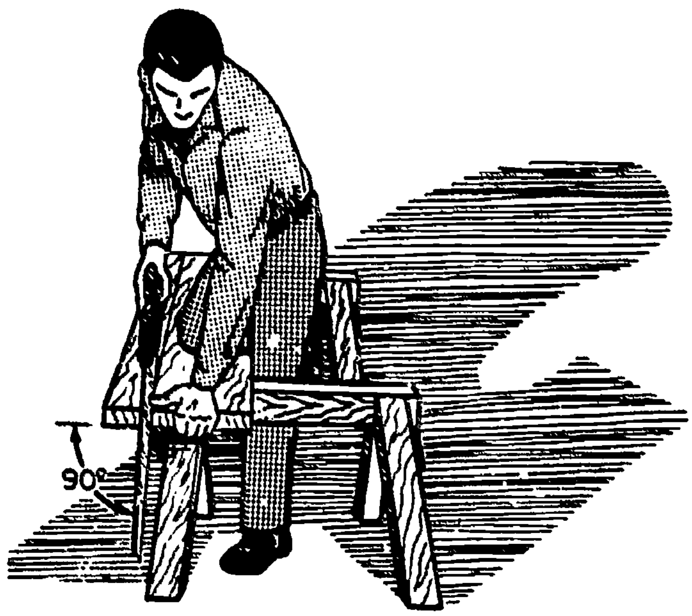
NOTE: If the saw does not cut smoothly on the downstroke, decrease the angle until the saw cuts smoothly.



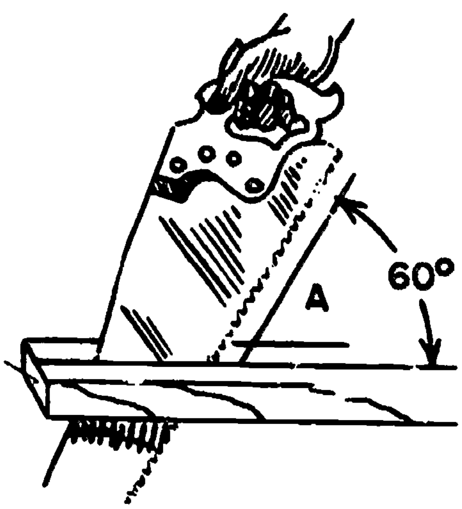
29.15(68C)BX
Figure 3-34.—Ripsaw and crosscut saw teeth.



29.15(68C)CX
Figure 3-35.—Cutting action of a ripsaw.



29.15(68C)D
Figure 3-36.—Using the crosscut handsaw.



29.15(68C)EX
Figure 3-37.—Sawing with a ripsaw.

5. Place the thumb of your free hand against the side of the blade and above the teeth as a guide (fig. 3-36).

6. Draw the saw lightly toward you until a saw kerf (cut) has been formed.

7. Gently push the saw down and deepen the kerf.

8. Use short, gentle strokes until the saw is well started. As the saw kerf deepens, lengthen the stroke keeping a light, even pressure on the saw. The toe of the saw should be about 3 inches below the stock at the end of the upward stroke. If it is pulled back further, the saw is apt to buckle on the downstroke.

CAUTION: Do not force the saw. If you force the saw, it is apt to buckle. If you force the saw when starting the cut, it may jump out of the kerf and cut your thumb.

9. As the saw cut nears completion, shorten the stroke and support the waste stock with your free hand.

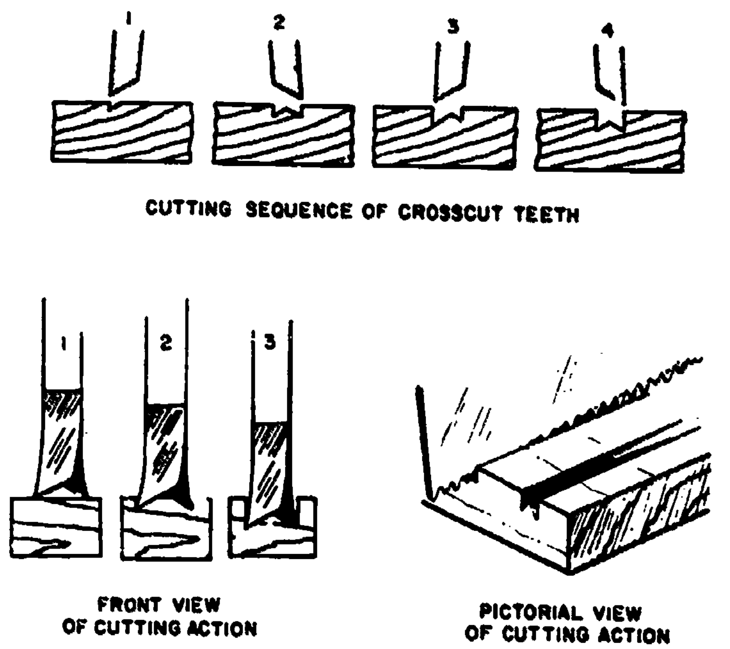
10. If the saw binds on long cuts, place a wedge in the saw kerf to hold it open.

Crosscut Saws

The teeth of a crosscut saw are knife shaped (fig. 3-34B), to produce a scoring and cutting action across the grain on either the up or down stroke with about 75 percent of the action being done on the downstroke. The cutting action of a crosscut saw is illustrated in figure 3-38.

Crosscut saws normally range from 6 to 14 points. The most common crosscut saws have 8 to 10 points.

As is the case with ripsaws, the coarser saw is designed for heavier material while the finer the saw, (more points) the smoother the cut will be.



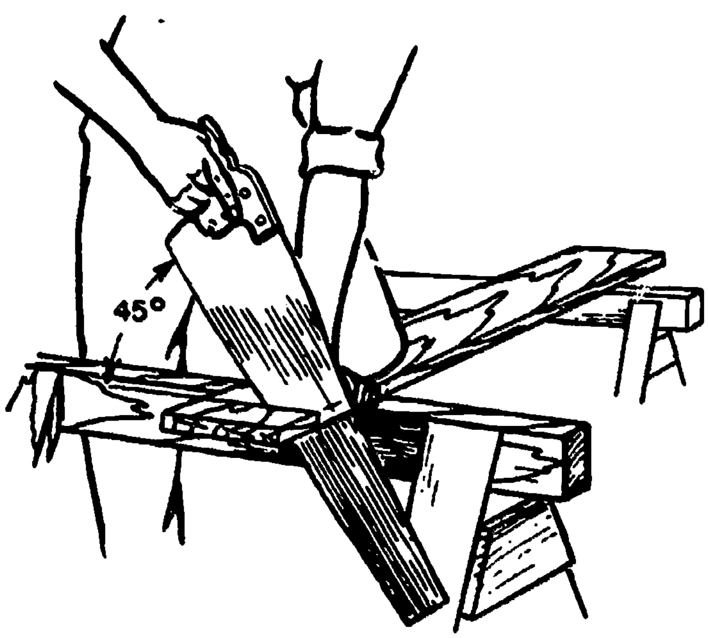
29.15(68C)FX
Figure 3-38.—Cutting action of a crosscut saw.

The cutting procedure for the crosscut saw is the same as for the ripsaw except that the saw is held at about a 45° angle (fig. 3-39).

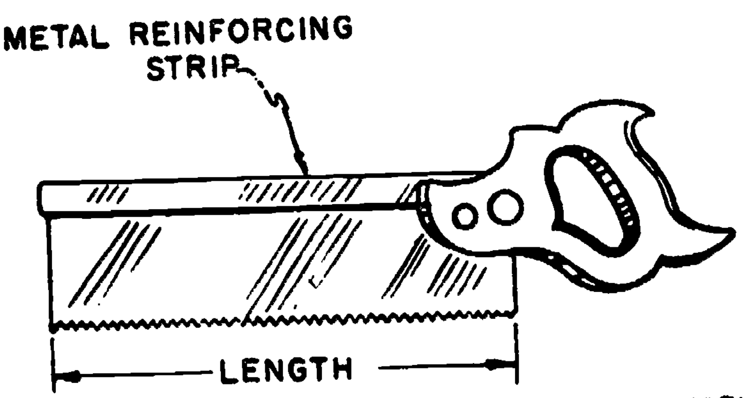
Backsaw

The backsaw (fig. 3-40) is usually a thin, crosscut type saw having from 10 to 14 points and used for precision cutting such as in pattern joinery and miter cutting. The blade has a reinforced back for rigidity and is made in 8 to 26 inch lengths. The longer backsaws are sometimes called miter saws.

The backsaw is designed to make smooth, finish cuts. Therefore, the cut must be made to the guide line.



29.20(68C)AX
Figure 3-39.—Sawing with a crosscut saw.



29.20(68C)B
Figure 3-40.—Backsaw.

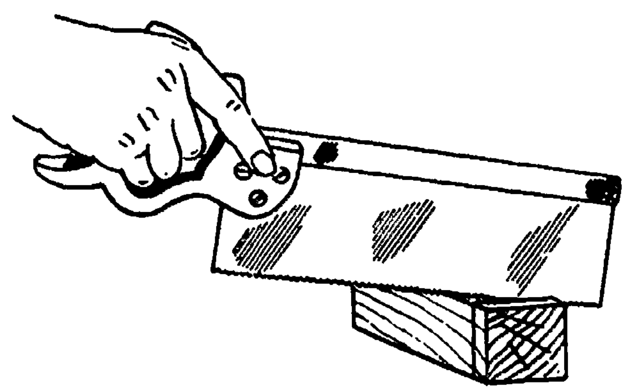
When starting the cut with a backsaw, angle the saw slightly (fig. 3-41) and as the cut progresses, gradually decrease the angle until you are cutting parallel to the face of the stock as in figure 3-42.

Dovetail Saw

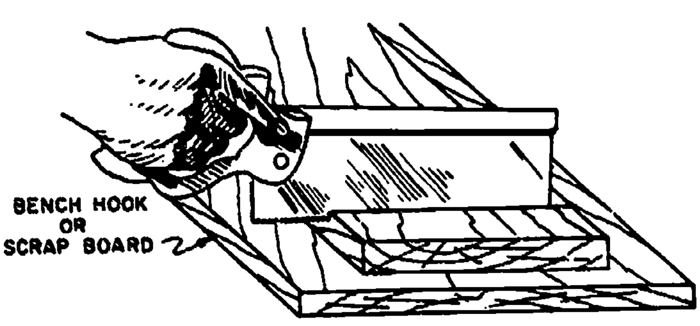
The dovetail saw (fig. 3-43A) is a type of backsaw used for very fine, smooth work where a backsaw would not be practical. The blade is very thin and ranges in length from 6 to 10 inches.

Patternmaker's Saw

The Patternmaker's saw (fig. 3-43B) is also designed for very fine, smooth cutting. It is usually 7 1/2 inches long and normally has 14 points. Because of its size and shape, the Patternmaker's saw can be used in small, hard



29.20(68C)CX
Figure 3-41.—Starting the cut.



29.20(68C)DX
Figure 3-42.—Using the backsaw.

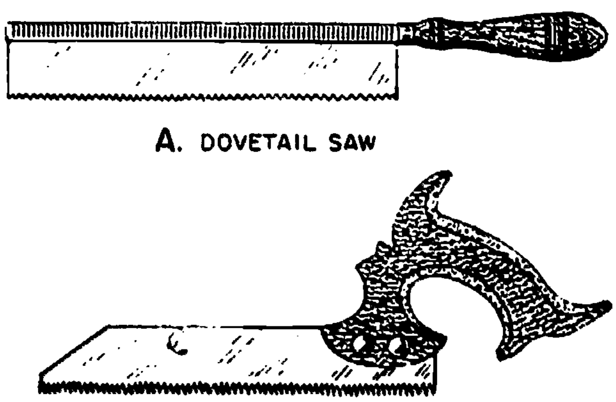
to get at areas where most saws couldn't be used.

Coping Saw

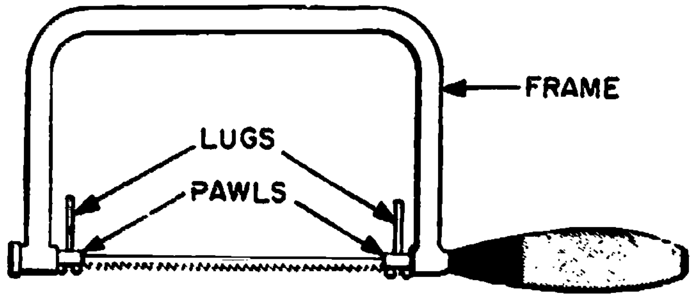
The coping saw (fig. 3-44) is used for making very fine, irregular cuts on thin material and for forming the end cuts (joints) on moldings.

The coping saw consists of a spring steel frame, two slotted pawls for holding the blade, two lugs for turning the blade, and a wooden handle into which the rear pawl is threaded for tensioning the blade.

There are both flat and spiral blades made for the coping saw. The spiral blade is similar to a round rasp which allows you to cut in any direction without turning the saw frame. The normal flat blade requires you to turn the frame or blade in order to follow an irregular line.



29.20(68C)E
Figure 3-43.—Dovetail and Patternmaker's saws.



29.21
Figure 3-44.—Coping saw.

The blade is normally inserted into the frame with the teeth pointing away from the handle. However, some cuts are best made with the teeth pointing toward the handle. When inserting the blade, sufficient tension should be applied so that the blade will not buckle under normal cutting conditions.

The best method for learning to cut accurately with the coping saw is by practicing on scrap stock. The coping saw requires a great deal of skill and, when used by a skilled craftsman, can be a very accurate cutting tool.

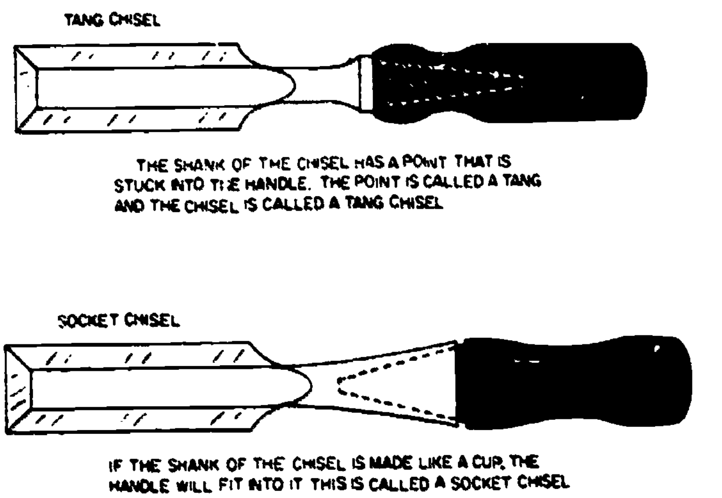
Safety Precautions
and Maintenance

1. Select the right saw for the job. Don't use a ripsaw for crosscutting or visa versa, etc.
2. Never force a saw. If a saw binds in the cut and then is forced through the wood, a kink is almost certain to result. A kinked saw is useless. Use a wedge to hold the saw kerf open.
3. Make certain that nails, staples, and other foreign objects are removed from the wood before it is sawed.
4. Be sure that the piece to be cut is well supported or secured.
5. Ensure that the material to be cut is supported high enough to allow for the full stroke of the saw without striking the floor or other object.
6. Do not leave saws laying around or stored loose in a tool box. When the saw is not in use, stow it away by either hanging it by the handle or in notches with the cutting edge up.
7. Keep all saws clean and free of rust by lightly oiling or by waxing the blade.

WOOD CHISELS

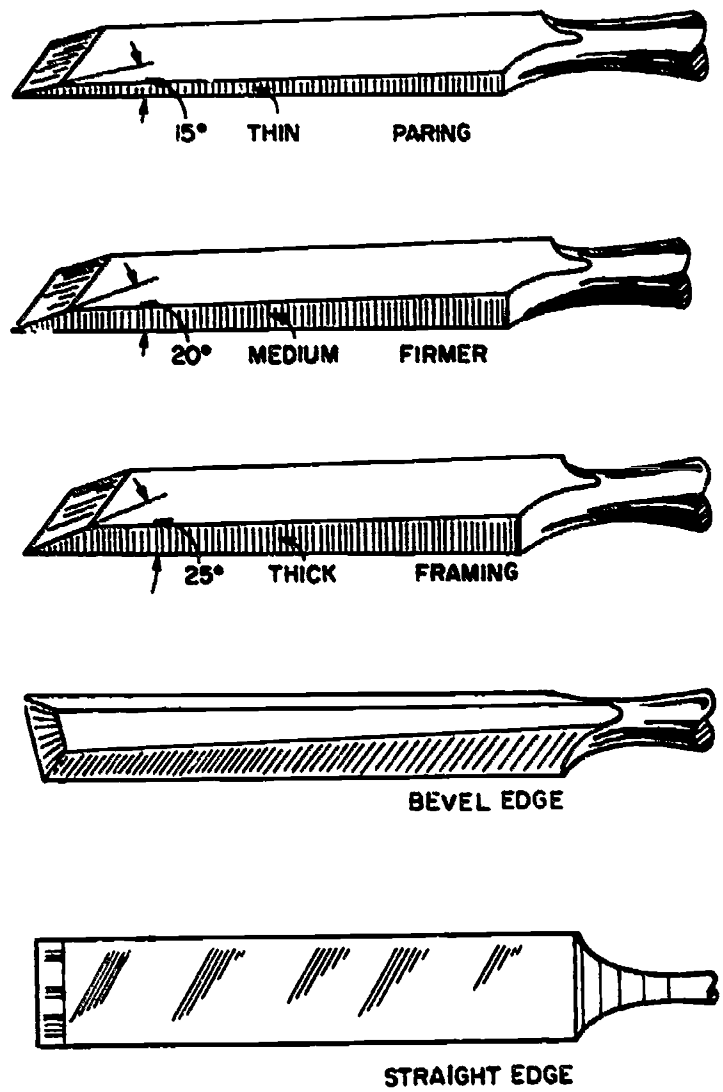
A wood chisel is a steel tool fitted with a wooden or plastic handle. It has a single beveled cutting edge on the end of the steel part, or blade. According to their construction, chisels may be divided into two general classes: TANG chisels and SOCKET chisels (fig. 3-45).

The SOCKET CLASS has the blade and handle socket forged from one piece of high carbon steel and is usually used for heavy work where a great deal of force is required. One end of a wooden or plastic handle is tapered to fit into the socket which allows you to use a



29.9B

Figure 3-45.—Tang and socket wood chisels.



29.9(68C)AX

Figure 3-46.—Wood chisel blade shapes.

wooden, plastic, or leather mallet for striking. Never use a hammer for striking as this will tend to mushroom the handle.

The TANG CLASS is also forged in one piece, but the handle is drilled and the tang inserted into the handle and reinforced with a ferrule or metal band. Tang class chisels are usually lighter and have thinner blades than the socket class and are to be used with hand pressure only.

Types of Wood Chisels

Wood chisels are also divided into types which are determined by their weight and thickness, the shape or design of the blade (fig. 3-46), and the work they are intended to do. There are numerous types designed for a wide variety of individual carving or cutting applications, but the most common types used by the Patternmaker are the FIRMER, BUTT, and PARING CHISELS (fig. 3-47).

The firmer chisel blade has a strong, rectangular or beveled cross section and is used for medium as well as light duty work. It is available in either the socket or tang class and is preferred by some Patternmakers.

The butt chisel is similar to the firmer chisel, but has a short blade designed for work in hard to get at places.

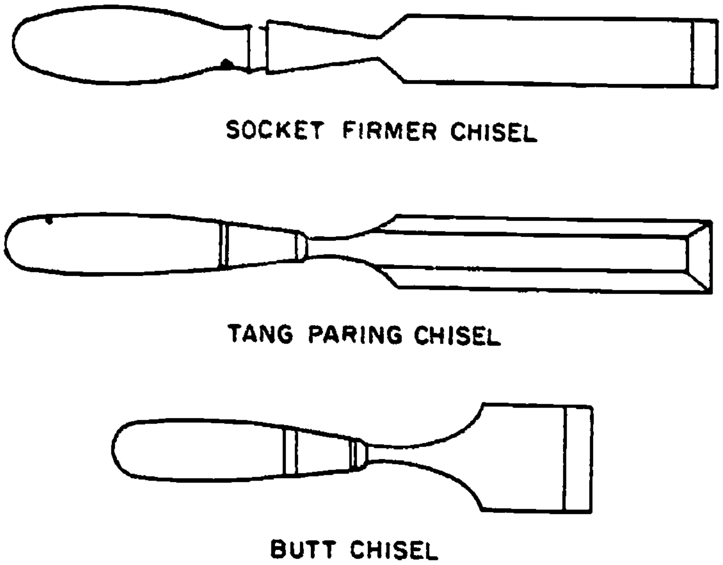
The most widely used chisel and the one preferred by most Patternmakers, is the paring chisel. Its blade is relatively thin and is available in either rectangular or beveled cross section. However, the beveled cross section is more widely preferred.

The paring chisel is designed for light duty work and is available only with a tang. The handle may be straight or bent shank. The bent shank variety is preferred as it prevents the hand or handle from coming in contact with the work.

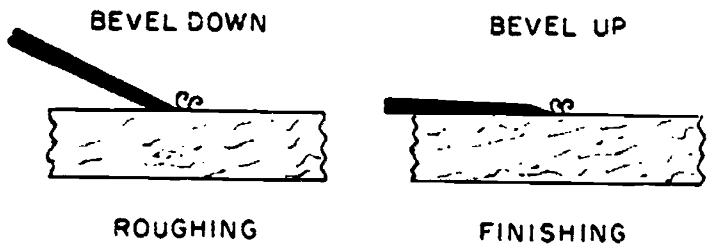
The size of a chisel is determined by the width of the cutting edge and ranges from 1/8 to 2 inches.

Use of Wood Chisels

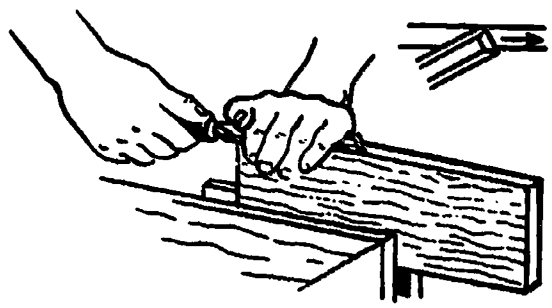
When roughing in or removing excess stock, use the chisel with the bevel side down. For finishing and smoothing, the bevel side must be up (fig. 3-48). Whenever possible, the chisel



29.9C
Figure 3-47.—Shapes of common types of wood chisels.



29.9(68C)B
Figure 3-48.—Chisel positions.



29.20(68C)FX
Figure 3-49.—Hand positions.

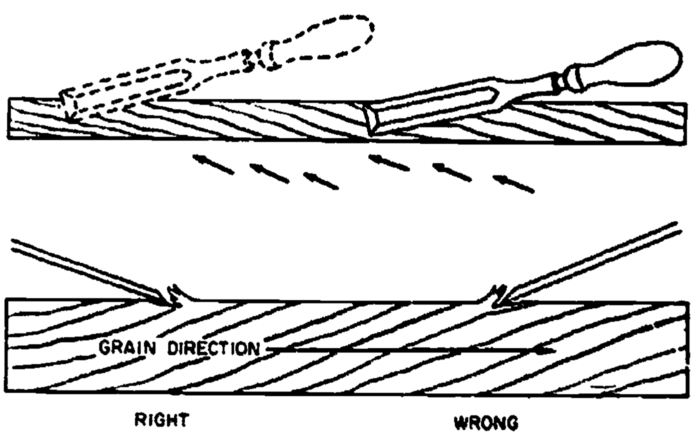
should be moved laterally as it is moved forward. This produces a shearing or slicing effect which, with care, will produce a smooth and true surface even when cutting crossgrain.

Before making a finish cut, remove the excess material to within 1/16 inch of the finish dimension with a socket class chisel, saw, or other appropriate machine or tool.

The following are basic cuts and the methods of carving them with a wood chisel.

To cut horizontally with the grain, grasp the chisel handle in one hand with the thumb extended towards the blade (fig. 3-49). The cut is controlled by holding the blade firmly with the other hand, knuckles up and the hand well back of the cutting edge. The hand on the chisel handle is used to force the chisel into the wood. The other hand pressing downward on the chisel blade regulates the length and depth of the cut. The chisel will cut more easily and leaves a smoother surface when the cutting edge is held slightly diagonal to the direction of the cut, or is given a slight lateral sliding motion (fig. 3-50). This is done by holding the tool at a slight angle and moving it to one side as it is pushed forward, or by moving it slightly from left to right at the same time you push it forward. With cross-grained wood, it is necessary to work from both directions to avoid splitting the wood at the edges. Do not hurry. Cut only fine shavings. If thick shavings are cut, the tool may dig in and split off a piece of wood which was never intended to be removed.

In cutting horizontally across the grain, the work must be held securely, as with a vise, clamp or jig. Most of the waste wood is removed by the chisel with the bevel held down. To avoid splitting at the edges, cut from each edge to the center and slightly upward so that the waste wood at the center is removed last (fig.

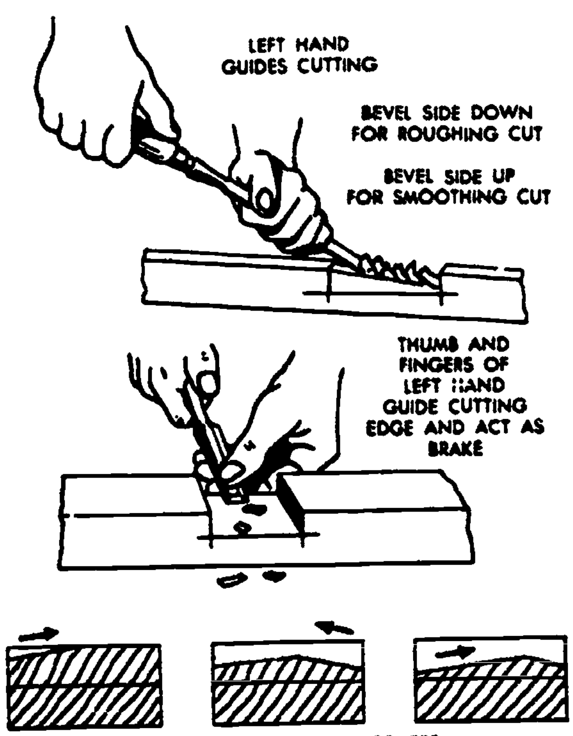


29.9
Figure 3-50.—Cutting techniques.

3-51). Finishing cuts are made with the flat side of the chisel down. Never use a mallet when making finishing cuts, even on large work. One hand pressure is all that is necessary to drive the chisel which is guided by the thumb and forefinger of the other hand. Finish cuts should also be made from each edge toward the center. Do not cut all the way across from one edge to another or the far edge may become split.

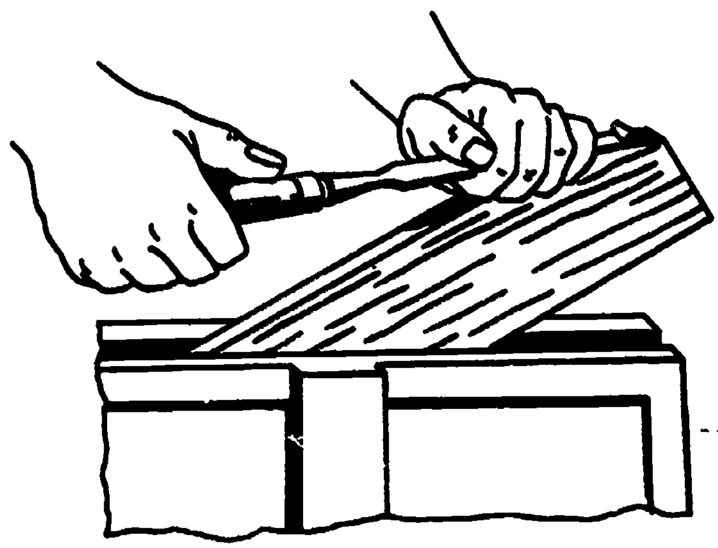
To cut diagonally across the grain, (fig. 3-52) as much waste wood as possible is first removed with a saw. Clamp the work in a vise with the guideline horizontal. Use the chisel as in cutting horizontally with the grain. It is necessary to chisel with the grain and to hold the chisel so that the cutting edge is slightly diagonal to the direction of the cut.

To cut a round corner on the end of a piece of wood, first lay out the work and remove as much waste as possible with a saw (fig. 3-53A). Use the chisel with the bevel side down to make a series of straight cuts tangent



29.9D

Figure 3-51.—Chiseling horizontally across the grain.



29.9E

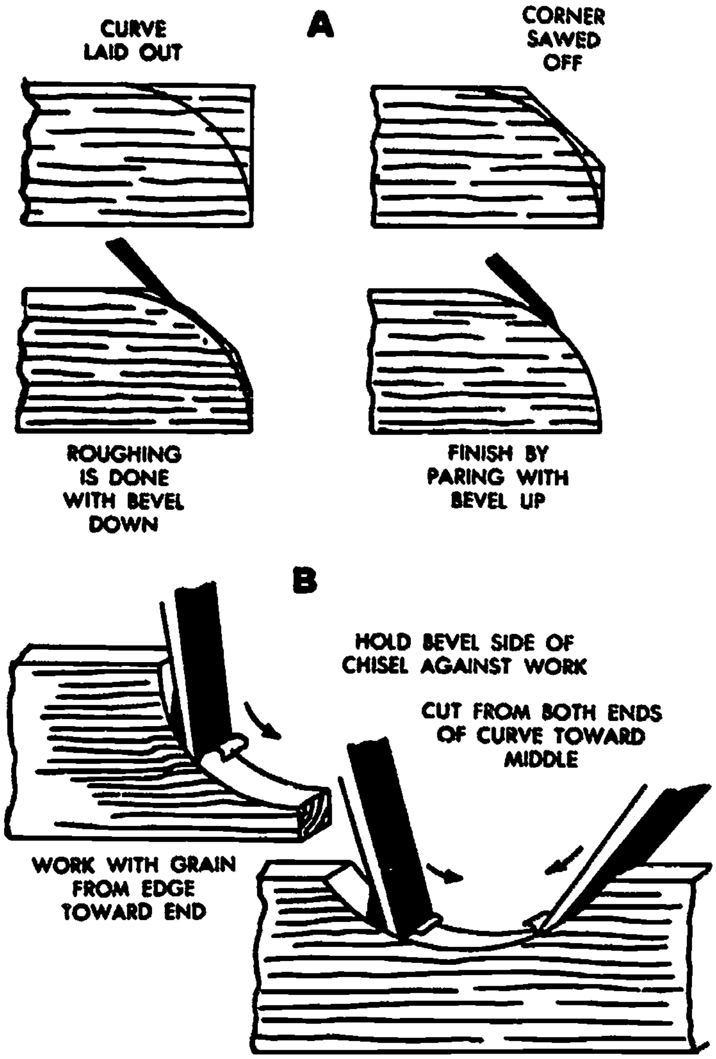
Figure 3-52.—Chiseling diagonally across grain.

to the curve. Move the chisel sideways across the work as it is moved forward. Finish the curve by paring with the bevel side up. Convex curves are cut in the same manner as a round corner.

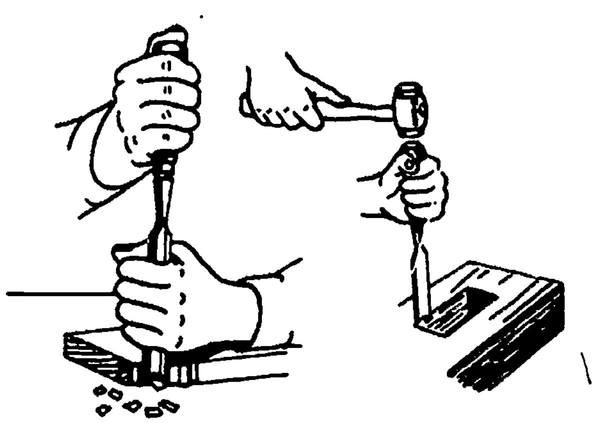
To cut a concave curve, remove most of the waste wood with a bandsaw or coping saw. Smooth and finish the curve by chiseling with the grain holding the chisel with the bevel side down (fig. 3-53B). Use one hand to hold the chisel against the work, press down on the chisel with the other hand, and, at the same time, draw back on the handle to drive the cutting edge in a sweeping curve. Care must be used to take only light cuts or the work may become damaged.

Vertical chiseling means cutting at right angles to the surface of a horizontal piece of wood. It is used on ends and edges as well as for forming recesses and depressions such as the mortise.

Before chiseling, remove as much excess material as possible with a saw, drill, or other appropriate machine or handtool, then grasp the chisel handle in one hand with the thumb pressing down on the top of the handle as shown in figure 3-54. Using the other hand as a guide, start a light cut using a shearing motion. A light cut producing thin shavings will result in a smooth and true surface.



29.9G
Figure 3-53.—Chiseling corners and curves.



29.9H
Figure 3-54.—Vertical chiseling.

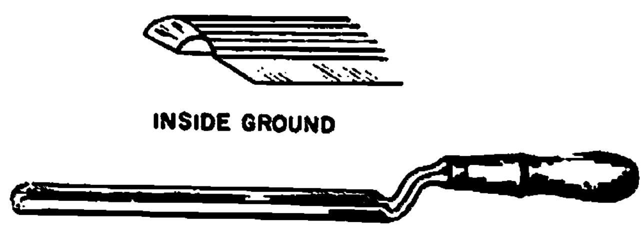
GOUGES

A gouge is a chisel with a circular cross section. It is used when hollow or concave surfaces are to be carved. They are classed the same as chisels, tang and socket, and are available in a wide variety of types. However, the types generally found in Navy pattern shops are the PARING AND FIRMER GOUGES.

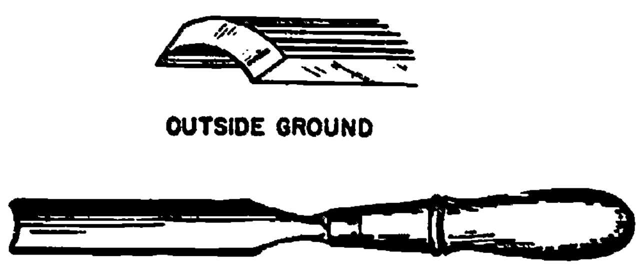
The paring gouge (fig. 3-55) is a companion to the paring chisel. It is ground or beveled on the inside face of the blade and is designed for fine, finish work. It is available only as a tang class and may have either straight or bent shank handles. The bent shank paring gouge is excellent for finishing half round core boxes.

The firmer gouge (fig. 3-56) is a companion to the firmer chisel. It is ground on the outside face of the blade and is used for the heavier work that cannot be done with a paring gouge. Like the firmer chisel, it is available with either a tang or socket.

The principles of using a gouge are the same as those of the chisel except that the shearing cut is produced by slightly revolving the gouge instead of sliding the tool diagonally.



29.9(68C)CX
Figure 3-55.—Bent shank paring gouge.

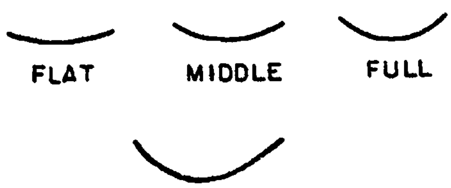


29.9(68C)DX
Figure 3-56.—Firmer gouge.

Gouges are made in sizes ranging from 1/8 to 2 inches. These sizes are specified by the manufacturer. Gouges are also available in three different SWEEPS; FULL, MIDDLE, and FLAT (fig. 3-57).

The method of determining gouge sizes and sweeps can be very confusing so read the following carefully.

Relative to size, a full sweep gouge with a specified size of 1 inch will cut a hole having a 1/2 inch radius. A middle sweep gouge having a specified size of 1 inch will cut a hole having a 1 inch radius, and a flat sweep gouge having a specified size of 1 inch will cut a hole having a 3-1/2 inch radius.



29.9(68C)EX

Figure 3-57.—Sweeps of gouges.

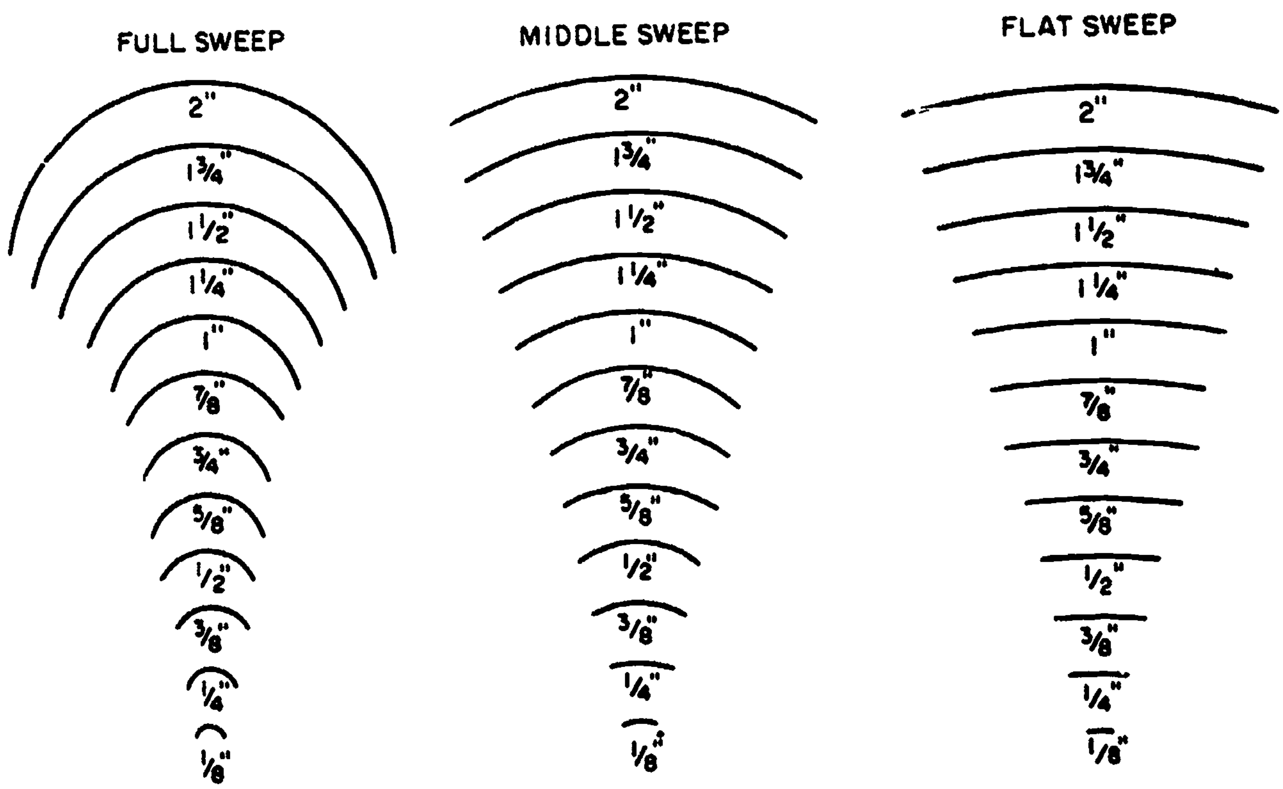
Sweep, as applied to full and middle sweep gouges, refers to the radius of the circle in which the cutting edge is formed in relation to the specified size.

Sweep, as applied to flat sweep gouges, is established by the manufacturer, apparently, with no relation between sweep or size.

The cutting edge of a full sweep gouge roughly forms a half circle, thus the diameter (2 x radius) of the gouge would be equal to the specified size of the gouge. Since, in this case, sweep and radius mean the same thing, the sweep of a full sweep gouge whose specified size is 1 inch, would be 1/2 inch.

The cutting edge of a middle sweep gouge roughly forms 1/4 of a circle. The sweep and specified size are equal. A middle sweep gouge with a specified size of 1 inch will have a sweep (radius) of 1 inch. Table 3-1 illustrates the curvatures of full, middle, and flat sweeps for the various gouge sizes.

Table 3-1.—Gouge Sizes and Sweeps



29.9(68C)F

HAND CARVING CHISELS AND GOUGES

There are numerous hand carving chisels and gouges which are available as sets or separately. They are made in a wide variety of shapes, sizes, and lengths. The principles of their use are the same as for wood chisels and gouges. A few of the more popular hand carving chisels and gouges are shown in figure 3-58.

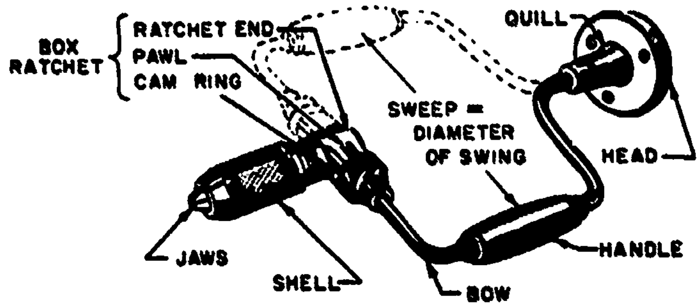
HAND BRACE

The hand brace, figure 3-59, is a tool designed to turn and guide any of the wood boring tools or special bits which have a square tang or flats ground on their shank.

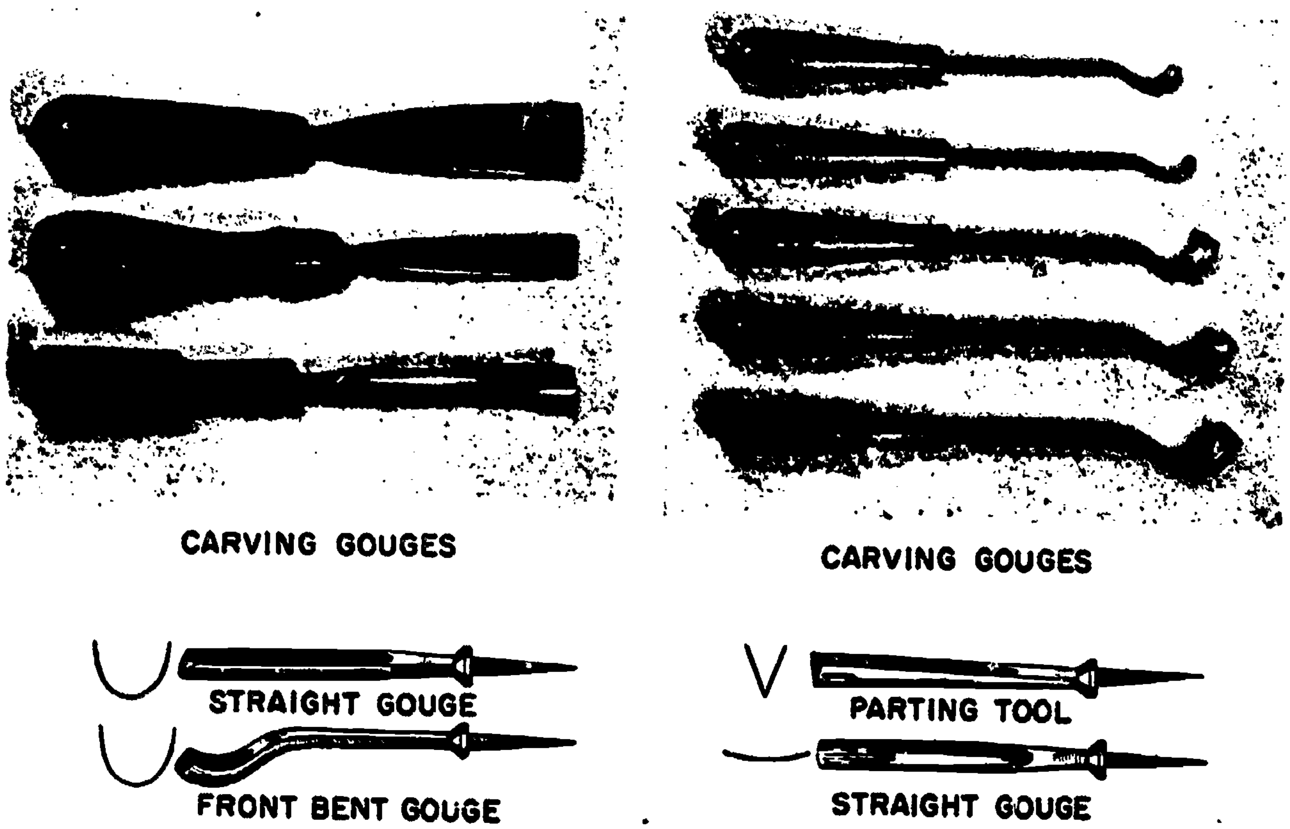
Although the hand brace has been largely replaced by the portable drill, it is still the best tool for very accurate wood boring and counterboring.

The type of brace normally found in Navy shops is the RATCHET BRACE. It includes a ratchet device (fig. 3-59) which makes possible its use in close, confined spaces where there is not enough room to make a full turn (sweep) of the handle. The ratchet may be locked or made to turn in either direction.

The size of the brace is determined by the sweep of the handle, figure 3-59. Sweep is the diameter of the circle the handle makes when it is revolved. The most common size



44.20(68C)AX
Figure 3-59.—Hand brace.

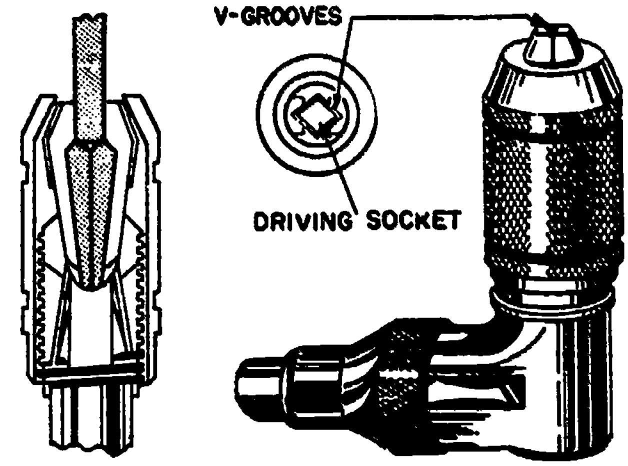


29.9(68C)GX
Figure 3-58.—Hand carving tools.

brace is 10 inches. However, the 8 inch brace is best suited for pattern shop use.

There are two types of chucks made for the brace. The preferred type has a square driving socket at the bottom of the chuck as shown in figure 3-60. The end of the bit tang must be inserted into this socket as with this type of chuck, the jaws serve to support and hold the bit in center while the turning force is transmitted by the socket.

The second type of chuck has no driving socket. Therefore, the jaws must also transmit the turning force to the bit. With this type chuck, care must be taken to seat the corners of the bit tang into the "V" grooves of the chuck jaws.



44.20G

Figure 3-60.—Hand brace chuck.

HAND DRILL

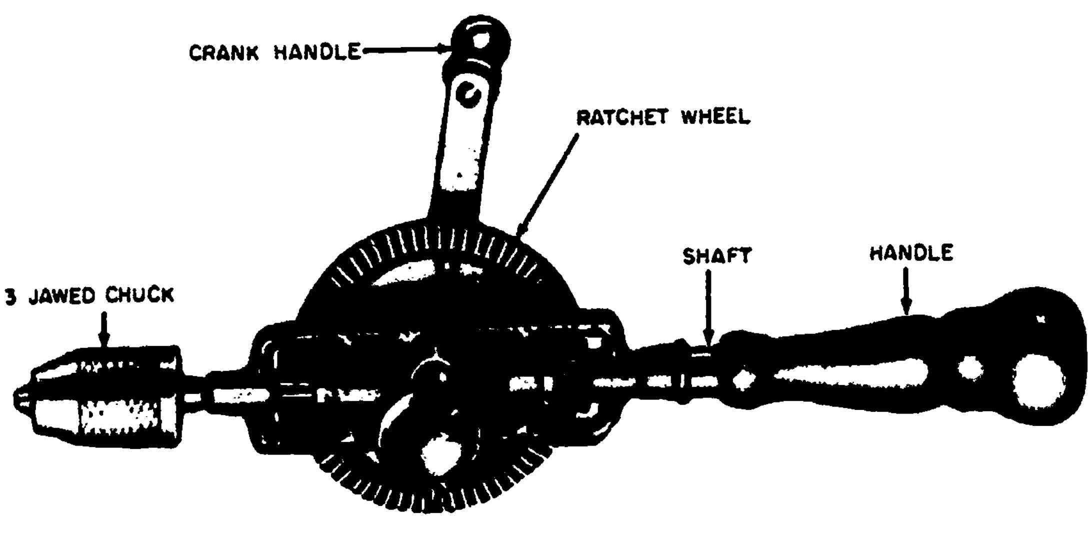
Because it is small and light, the hand drill is one of the most useful tools in the Patternmaker's tool chest. It is designed to use either twist drills or drill points for boring small holes at fairly high speed.

The hand drill has a three-jawed, hand-tightened chuck (fig. 3-61) which will accommodate straight shanked bits ranging from 1/16 to 3/8 inches in diameter. Some hand drills have a hollow handle with a removable top for storing small drill bits or a set of drill points.

The hand drill is especially useful for counterboring and countersinking in soft woods.

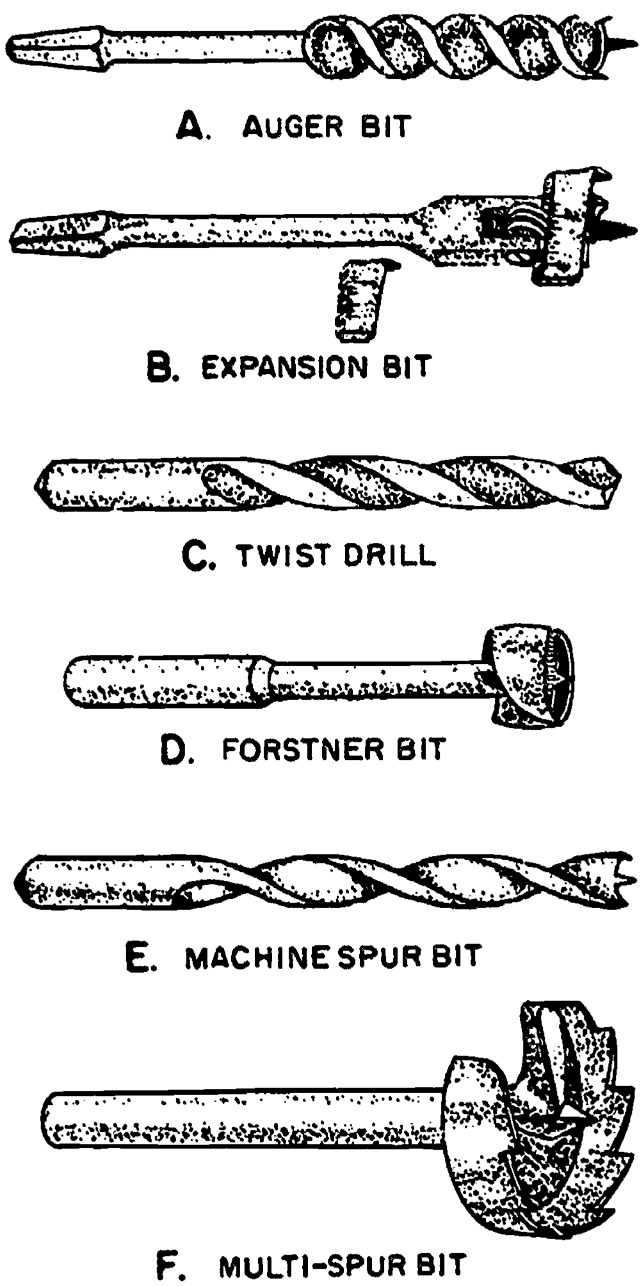
WOOD BORING BITS AND DRILLS

The wood boring bits and drills usually found in the pattern shop are shown in figure 3-62. Included are the AUGER BIT, EXPANSIVE BIT, MACHINE SPUR BIT, MULTI-SPUR BIT, FORSTNER BIT, and TWIST DRILL.

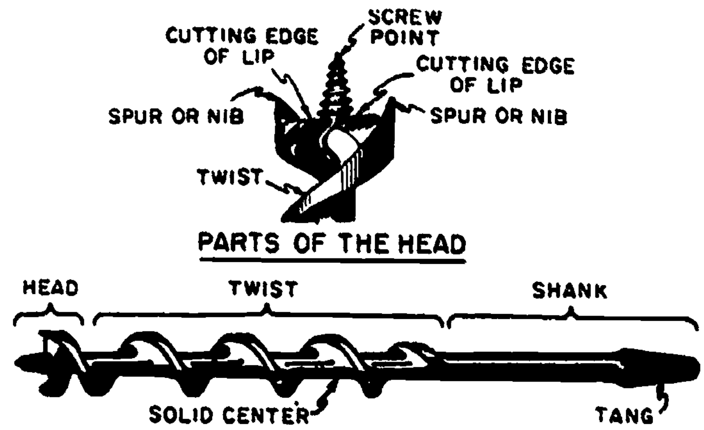


4.34

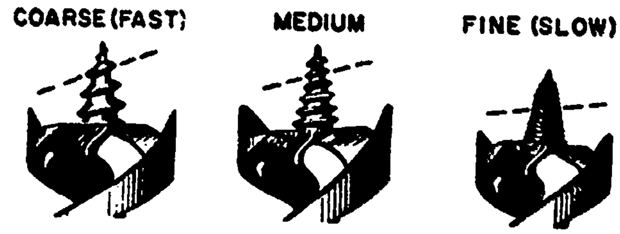
Figure 3-61.—Hand drill.



44.20(68C)B
Figure 3-62.—Wood boring bits and drills.



44.20(68C)CX
Figure 3-63.—Parts of an auger bit.



44.20(68C)DX
Figure 3-64.—Types of screw points.

Auger Bits

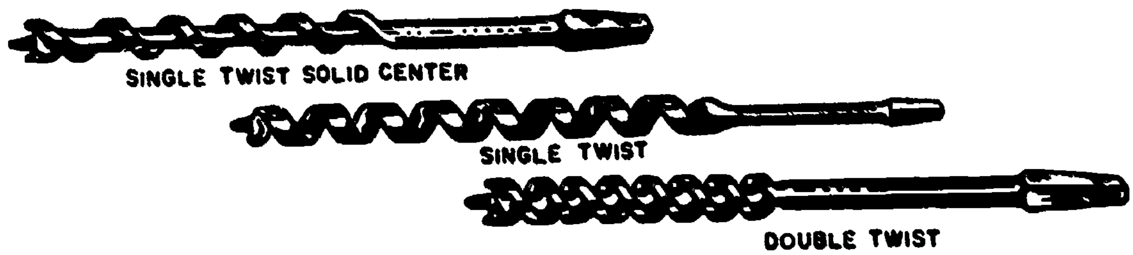
The auger bit is the most common of the wood boring bits and is designed for use with the hand brace. Basically, it consists of three parts; the head, twist, and shank as shown in figure 3-63.

The SCREW POINT functions to center the bit and also to pull the bit through the stock. There are three types of screw points made; coarse, medium, and fine as shown in figure 3-64. The bit will be drawn through the stock faster by a coarse screw point than a fine one. However, more roughness will result from the faster cut.

The SPURS function to score the outer edge of the chip as the cutting lips chisel or cut the waste material loose. It is important that the spurs and cutting lips be sharp in order to produce a smooth hole.

The TWIST of the auger bit is responsible for removing waste material after it has been cut loose by the spurs and cutting lips and is usually slightly smaller in diameter than the head. The twist is made in three styles; SINGLE TWIST, SINGLE TWIST WITH SOLID CENTER, and DOUBLE TWIST as shown in figure 3-65.

The single twist has less tendency to bind in certain materials but is more fragile than the single twist with solid center and can easily be broken.



44.20(68C)EX

Figure 3-65. — Types of twist.

The single twist with solid center clears chips more rapidly, is stronger, and more commonly used than the single or double twist.

The double twist bit bores more slowly than either of the others. However, it produces a very clean, smooth, and more accurate hole and is the most suitable of the three to bore holes for wooden dowels.

The SHANK is that part of the auger bit which fits into the chuck of the brace. It contains a square-tapered tang which has the drill size number stamped into one of the flats. This number represents the drill size in sixteenths of an inch (fig. 3-66). For instance, if the number stamped on the flat is 12,. the drill size is 12/16 inch or 3/4 inch. NOTE: All bits having a tang type shank will be numbered and sized in this manner.

Auger bits usually come in sets containing 1/4 inch (#2) to 1 inch (#16) bits. However, auger bits are made up to 2 inches (#32) in diameter.

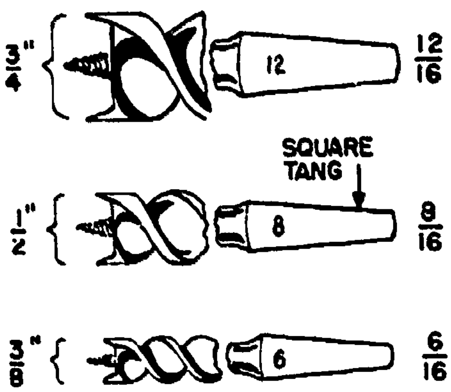
Many different lengths of auger bits are available but are generally made in three sizes which have corresponding names. The DOWEL BIT is about 5 inches long, the MEDIUM BIT about 8 inches long, and the SHIP BIT is from 18 to 24 inches long.

The "medium bit" is the length most commonly used.

Expansion Bit

Another bit designed for use with the brace is the expansion or expansive bit shown in figure 3-62B. This bit is designed for boring holes larger than 7/8 inch in diameter.

The expansion bit is composed of a screw point, body cutting edge, and usually, three adjustable cutter blades which permit the boring of holes up to 4 inches in diameter.



44.20F

Figure 3-66. — Size markings on auger bits.

The adjustable cutter blade is usually adjusted by either a mocrodial (fig. 3-67) or a simple screw arrangement.

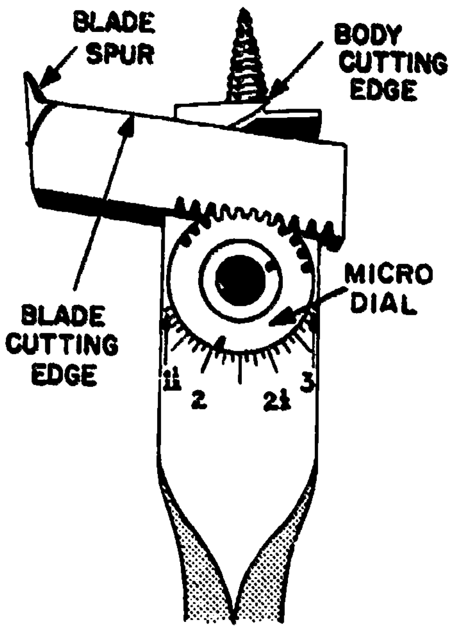
After an expansion bit has been adjusted and the cutter blade locked in place, it is good practice to make a trial cut on scrap stock to ensure that the bit is cutting the exact diameter desired.

Twist Drills

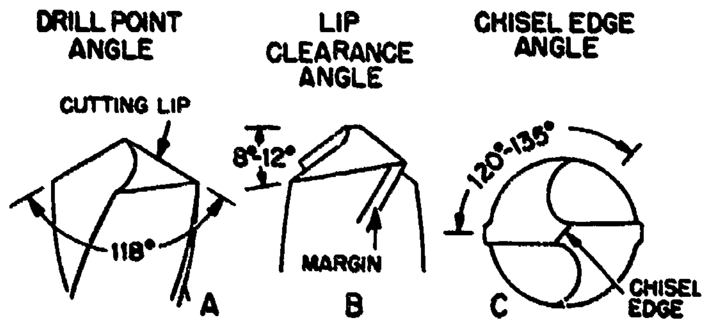
Twist drills (fig. 3-62C) are normally used by the Patternmaker for boring small holes 1/2 inch in diameter and under. They can be used with the drill press and portable drill motors as well as most of the hand drills and braces.

The twist drill is usually made of high carbon steel or high speed steel. The carbon steel drill is for low speed metal boring or high speed wood boring and the high speed steel drill is for high speed boring of metals.

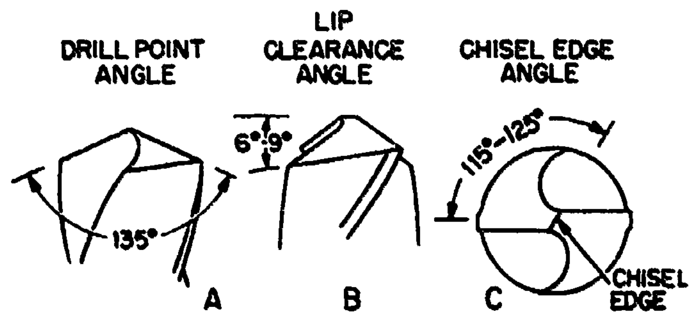
Twist drills are sharpened at various angles for boring different materials. The two most



44.21A
Figure 3-67.—Expansive bit.



44.20S
Figure 3-68.—Specifications for grinding a regular point twist drill.



44.20T
Figure 3-69.—Specifications for grinding a flat point twist drill.

common angles are the REGULAR POINT (fig. 3-68) and FLAT POINT (fig. 3-69).

The regular point has an angle of 118° and is used for general purpose boring which includes wood.

The flat point has an angle of 135° and is used for boring hard and tough materials.

Twist drills are made with various type shanks. The most common and the type used in most Navy pattern shops is the carbon steel drill with a straight shank.

With the exception of the bit stock drill, twist drills are sized in one of three different ways: by fraction, number, or letter.

Fraction designators denote the actual fractional size of the drill. Fractional sets of drills ranging in size from 1/16 to 1/2 inch are commonly used in the pattern shop.

Number and letter designators merely identify the particular drill. A drill gage or reference chart (Table 3-2) must be used to obtain the actual size of the drill. Number drills range in size from #1 (.338") through #80 (.0135") and lettered sizes range from "A" (.234") through "Z" (.413"). Note that the letter sizes are larger and start where the number sizes stop.

Forstner Bit

The forstner bit (fig. 3-62D) is designed for boring flat bottomed holes partway through the stock. It is not meant for boring completely through stock (fig. 3-70).

The forstner bit is composed of a circular steel rim, two cutting lips, and a shank.

The circular steel cutting rim is beveled from the inside to form a sharp edge. Special care must be taken not to damage this edge as it cannot be resharpened.

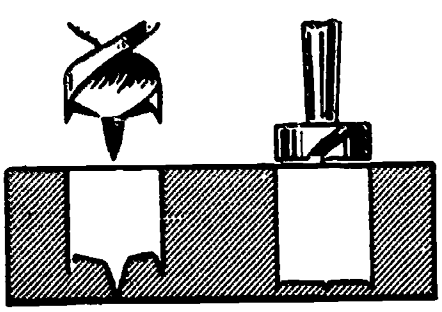
The cutting lips of the forstner bit serve the same purpose as do those of the auger bit. However, there is no twist to carry the waste stock out of the hole. Therefore, if a deep hole is to be bored, the bit must be drawn out of the hole frequently to remove the waste stock.

The forstner bit is made with or without a tang and can be used in a drill press if a slow turning speed is employed.

Table 3-2.—Twist Drill Sizes

Size	Decimal equivalents	Size	Decimal equivalents	Size	Decimal equivalents
1/2	0.5000	C	0.2420	30	0.1285
31/64	.4844	B	.2380	1/8	.1250
15/32	.4687	15/64	.2344	31	.1200
29/64	.4531	A	.2340	32	.1160
7/16	.4375	No. 1	.2280	33	.1130
27/64	.4219	2	.2210	34	.1110
Z	.4130	7/32	.2187	35	.1100
13/32	.4062	3	.2130	7/64	.1094
Y	.4040	4	.2090	36	.1065
X	.3970	5	.2055	37	.1040
25/64	.3906	6	.2040	38	.1015
W	.3860	13/64	.2031	39	.0995
V	.3770	7	.2010	40	.0980
3/8	.3750	8	.1990	41	.0960
U	.3680	9	.1960	3/32	.0937
23/64	.3594	10	.1935	42	.0935
T	.3580	11	.1910	43	.0890
S	.3480	12	.1890	44	.0860
11/32	.3437	3/16	.1875	45	.0820
R	.3390	13	.1850	46	.0810
Q	.3320	14	.1820	47	.0785
21/64	.3281	15	.1800	5/64	.0781
P	.3230	16	.1770	48	.0760
O	.3160	17	.1730	49	.0730
5/16	.3125	11/64	.1719	50	.0700
N	.3020	18	.1695	51	.0670
19/64	.2969	19	.1660	52	.0635
M	.2950	20	.1610	1/16	.0625
L	.2900	21	.1590	53	.0595
9/32	.2812	22	.1570	54	.0550
K	.2810	5/32	.1562	55	.0520
J	.2770	23	.1540	3/64	.0469
I	.2720	24	.1520	56	.0465
H	.2660	25	.1495	57	.0430
17/64	.2656	26	.1470	58	.0420
G	.2610	27	.1440	59	.0410
F	.2570	9/64	.1406	60	.0400
E 1/4	.2500	28	.1405		
D	.2460	29	.1360		

44.204



44.20(68C)GX

Figure 3-70.—Comparison of forstner to auger bit hole.

The forstner bit ranges in size from 1/4 to 2 inches in diameter and if it is a tang type it will be numbered the same way as an auger bit. If it is a straight shanked bit, it will have the fractional size stamped into the surface of the shank.

Since the forstner bit has no screw point or centering point, the exact size of the hole must be scribed with a set of dividers and the rim of the bit pressed into the scribed impression.

Machine Spur Bit

The machine spur bit (fig. 3-62E) may only be used in a drill press. It is a high speed, smooth cutting bit used for boring deep, flat bottomed holes into stock. It is a more efficient bit than the forstner bit as it has a centering point and a twist to remove waste material.

The machine spur bit is made in sizes ranging from 1/8 to 1/2 inch in diameter.

Multi-Spur Bit

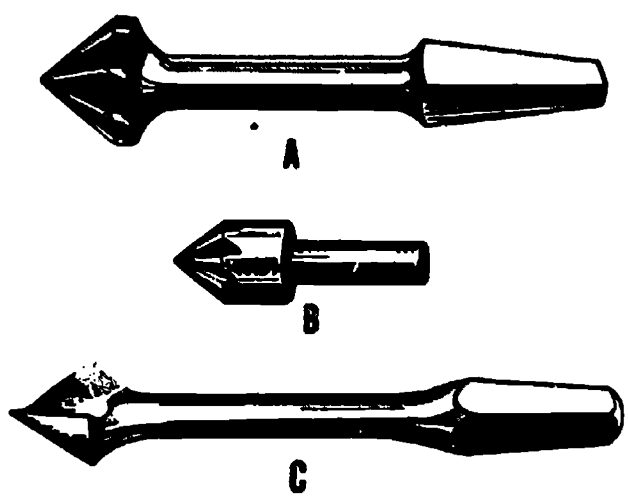
The multi-spur bit (fig. 3-62F) may also only be used in a drill press. It is designed to bore larger flat bottomed holes than the machine spur bit and ranges in size from 1/2 to 4 inches in diameter.

NOTE: As bit sizes are increased, drill press speed must be decreased.

Countersinks

The countersink is used, after a hole has been bored, to form a seat for the head of a flat headed wood screw.

Three types are shown in figure 3-71. Type "A" is made for the hand brace. Types "B" and "C" are used in either the hand drill, portable electric drill, or drill press. Although type "B" cuts more rapidly, it also produces a rough surface. Type "C" produces a very smooth seat and is the best type to use for pattern work.



28.59
Figure 3-71.— Types of countersinks.

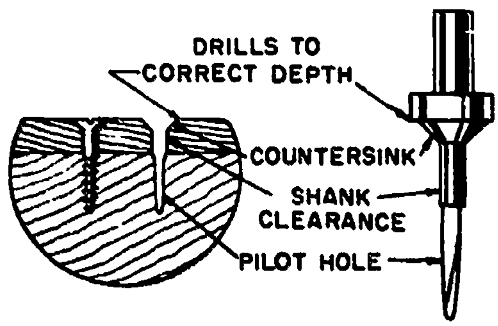
Combination Countersinks and Counterbores

There are many types of combination countersinks and counterbores. However, they all have the same function and save a lot of time.

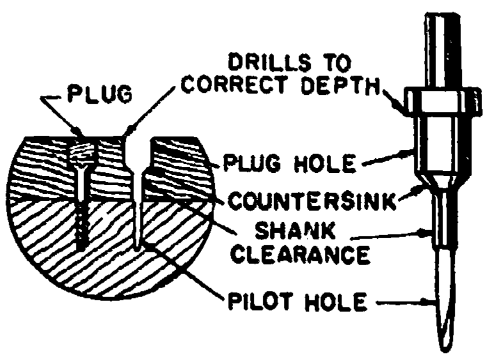
A combination countersink is illustrated in figure 3-72. It makes the pilot hole, shank clearance, and countersink in one operation for a variety of wood screw sizes ranging from 1/2 inch X #5 to 2 inch X #12.

Combination counterbores (fig. 3-73) perform the same tasks as the combination countersink plus boring a plug hole for wooden plugs. They are made for screw sizes ranging from 1 inch X #8 to 2 inch X #18.

The size of both the combination countersink and counterbore is determined by the particular size of wood screw it is designed to accommodate. They are both designed for use with the hand drill, portable electric drill, and drill press.



28.59(68C)AX
Figure 3-72.—Combination countersink.



28.59(68C)BX
Figure 3-73.—Combination counter bore.

Plug Cutters

Plug cutters (fig. 3-74) are used to cut wooden plugs for placing in counterbored holes to conceal the heads of screws and to keep the pattern surface uniform. They can only be used with low speed portable drills or a low speed drill press.

Plug cutters range in standard sizes from 3/8 to 1 inch in diameter and will usually cut end-grain plugs up to 2 inches long and cross grain plugs up to 1 inch long.

Screwdriver Bits

Screwdriver bits are made with either the REGULAR or PHILLIPS POINT for use with the hand brace (tang shank) or variable speed portable electric drill (straight shank) as shown in figure 3-75.

The regular point bits have tips which range in size from 3/16 to 1/2 inch and the phillips type is made in number 1, 2, and 3 point sizes.

Screwdriver bits can be great time savers, but special care must be taken not to twist off the head of the screw.

Drill Points

Drill points (fig. 3-76) usually come in sets ranging from 1/16 to 11/64 inches in increments of 1/64 inches. They are designed for light duty wood boring in soft textured woods and are used with the hand drill or push drill shown in figure 3-77.

Drill points for push drills have a special shank while those designed for hand drills are straight shanked.

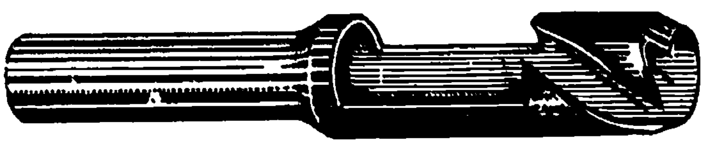
The drill point is primarily suited for boring pilot holes for wood screws.

PLANES

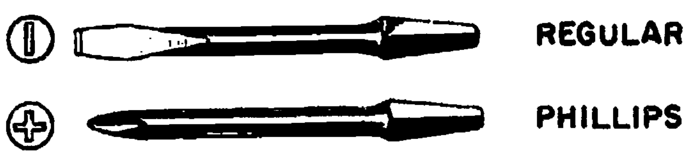
Planes comprise another important category of cutting and carving tools. They are made in different forms for a variety of different jobs but are all basically tools for smoothing or shaping the surface of wood.

Planes may be classified into the following three categories:

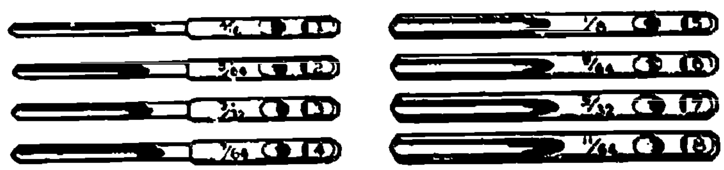
1. BENCH PLANES which contain the jointer plane, fore plane, jack plane, and smooth plane.
2. HAND PLANES which contain the block plane.
3. SPECIAL PLANES, some of which are the rabbet plane, bullnose rabbet plane, sole plane, circular plane, "V" type core box plane, and the radial core box plane.



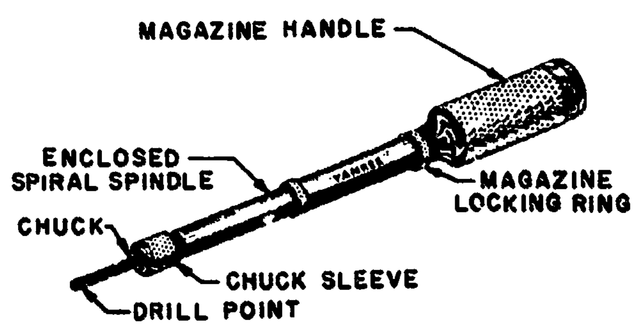
68.11
Figure 3-74. — Plug cutter.



1.14(68C)AX
Figure 3-75. — Screwdriver bits.



44.117(68C)AX
Figure 3-76. — Drill points.



44.116(68C)AX
Figure 3-77. — Push drill.

Bench planes (fig. 3-78) are used primarily for shaving and smoothing with the grain of the wood to obtain a perfectly flat surface.

The chief difference between them is in the length of the plane's sole (bottom). The longer the sole of the plane is, the more uniformly flat and true the planed surface will be. Consequently, the choosing of a suitable plane for a particular job depends on the length of the stock and the requirements for surface trueness.

The JOINTER PLANE (fig. 3-78A) has a bottom from 22 to 24 inches in length and is used when the planed surface must meet the highest requirements for trueness. The bottom of the plane may be smooth or corrugated. The plane-iron is from 2 3/8 to 2 5/8 inches in width, and is ground at right angles to the edge. The proper shape for the jointer plane-iron is illustrated in figure 3-79.

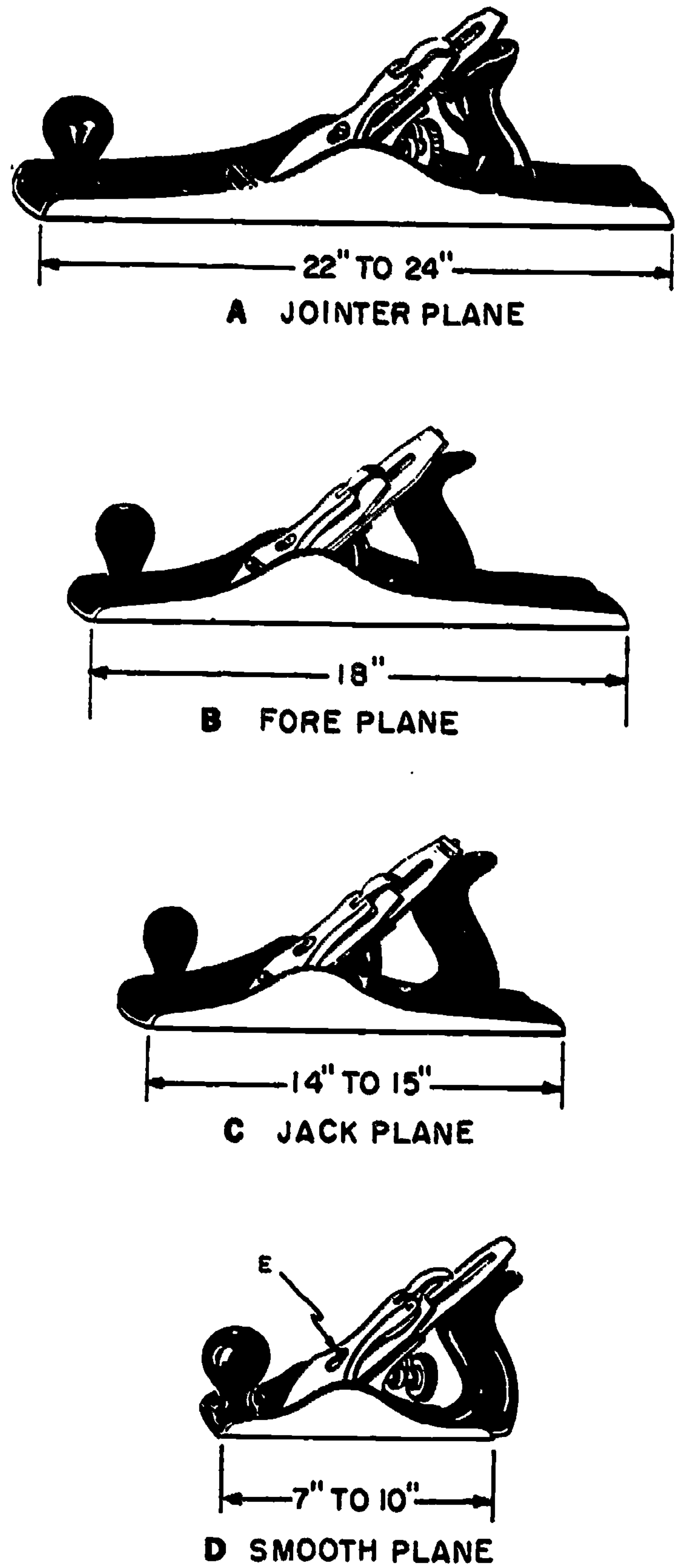
The FOREPLANE (fig. 3-78B) has a bottom 18 inches in length and is sometimes called a GAGE or SHORT jointer plane. The bottom of the plane may be smooth or corrugated. The plane iron is 2 3/8 inches in width and is ground to the shape illustrated in figure 3-79A.

The JACK PLANE (fig. 3-78C) is the general "jack-of-all-work" of the bench plane category. It has a bottom from 14 to 15 inches in length with a plane-iron from 2 to 2 1/4 inches in width, ground to the shape illustrated in figure 3-79A.

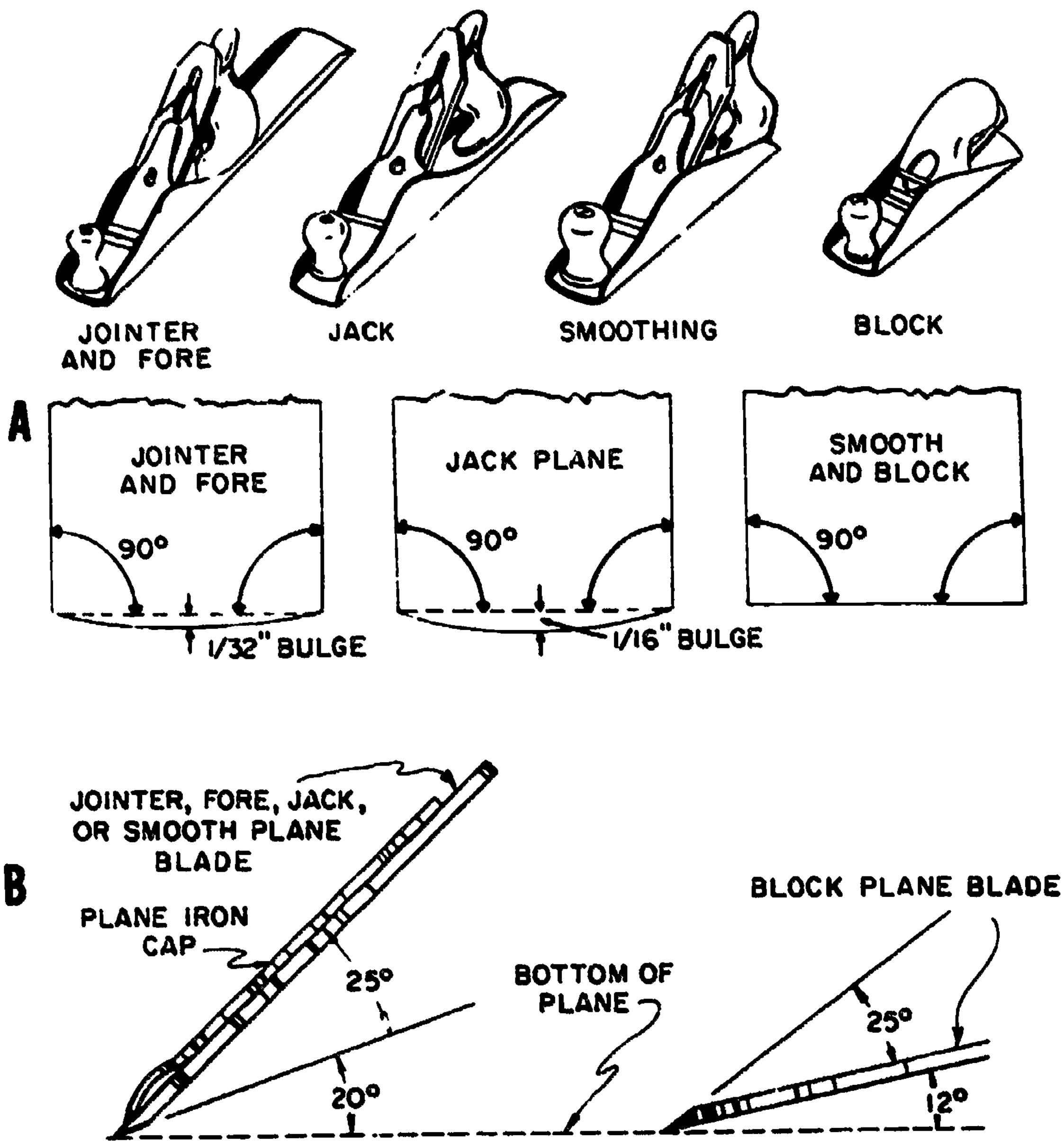
The SMOOTHING or SMOOTH PLANE (fig. 3-78D) is a short, finely set plane of 7 to 10 inches in length, used for smoothing and finishing flat work. It has a plane iron of 1 1/4 to 2 inches in width, ground to the shape illustrated in figure 3-79A.

The principal parts of a bench plane and the manner in which they are assembled, are shown in figure 3-80. The part at the rear that you grasp to push the plane ahead is called the handle; the part at the front that you grasp to guide the plane along its course is called the knob. The main body of the plane, consisting of the bottom, the sides, and the sloping part which carries the plane iron, is called the frame. The bottom of the frame is called the sole, and the opening in the sole, through which the blade emerges, is called the mouth. The front end of the sole is called the toe; the rear end, the heel.

A plane iron cap, which is screwed to the upper face of the plane iron, deflects the shaving upward through the mouth, as indicated in figure 3-81C, and thus prevents the mouth from becoming choked with jammed shavings. The edge of the

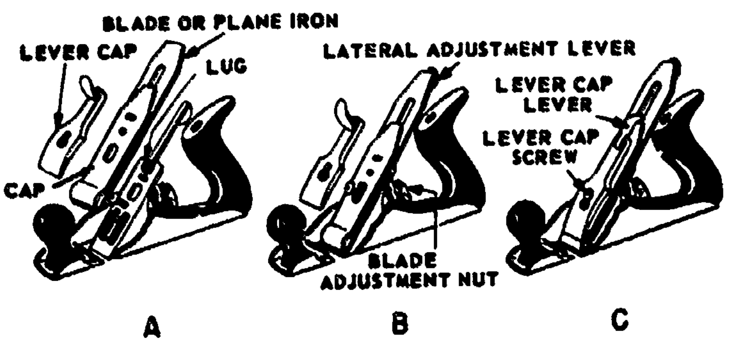


29.12(68C)AX
Figure 3-78.—Bench planes.



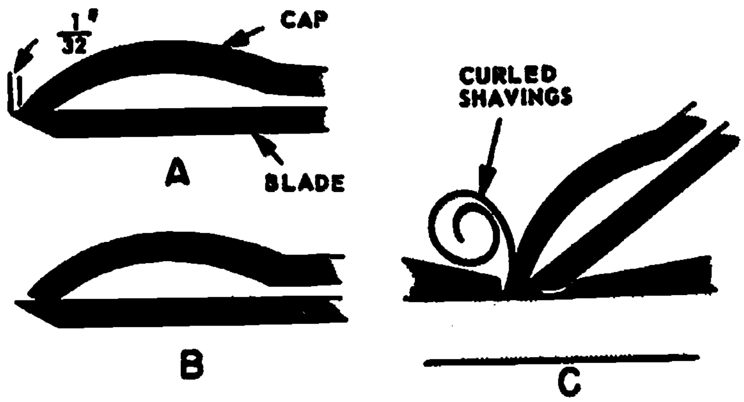
29.12(68C)BX

Figure 3-79.—Comparison of plane blades.



29.12A

Figure 3-80.—Parts of a bench plane.

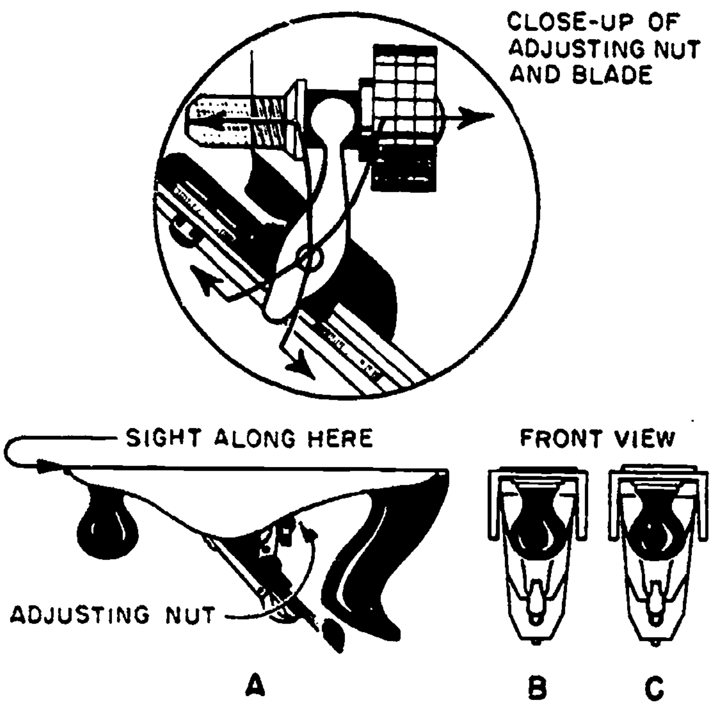


29.12B

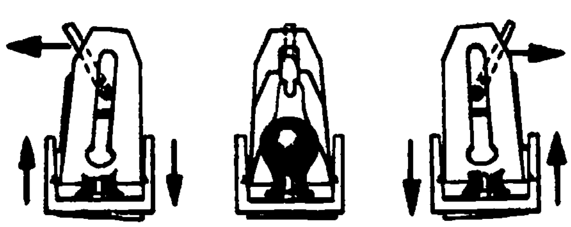
Figure 3-81.—Plane iron and plane iron cap.

cap should fit the back of the iron as shown in figure 3-81A, not as shown in figure 3-81B. The lower end of the plane iron cap should be set back 1/32 inch from the edge of the plane top, as shown in figure 3-81A. The iron in a bench plane goes in bevel-down.

The edge of the plane iron is brought into correct cutting position by the manipulation of first the ADJUSTING NUT and next the LATERAL ADJUSTMENT LEVER, as shown in figures 3-82 and 3-83. The adjusting nut moves the edge of the iron up or down; the lateral adjustment lever cants it to the right or left. To adjust the plane you hold it upside-down, sight along the sole from the toe, and work the adjusting nut until the edge of the blade appears. Then work the lateral adjustment lever until the edge of the blade is in perfect alignment with the sole, as shown in figures 3-82B and 3-83B. Then use the adjusting nut to give the blade the amount of protrusion you want. This amount will depend, of course, upon the depth of the cut you intend to make.



29.12C(68C)
Figure 3-82.—Adjusting a plane for depth.



29.12D
Figure 3-83.—Effect of manipulation of the lateral adjustment lever.

Before using any plane, it is important to inspect the blade for damage. If the blade is free of damage, check it for sharpness by following the procedures listed below.

1. Adjust the blade so that it projects slightly beyond the sole of the plane by sighting down the sole and turning the adjusting nut as in figure 3-82.

2. Adjust the lateral adjustment lever until the corners of the blade project beyond the sole at the same distance.

3. Clamp a piece of scrap stock into a vise so that its edge projects above the vise about 2 inches.

4. Make several successive strokes with the grain of the wood.

If the plane is sharp and adjusted properly, a thin, curling shaving of equal thickness should be produced without having to force the plane.

If a lot of force is required or the plane jumps, it is either dull or too deep a cut is being taken.

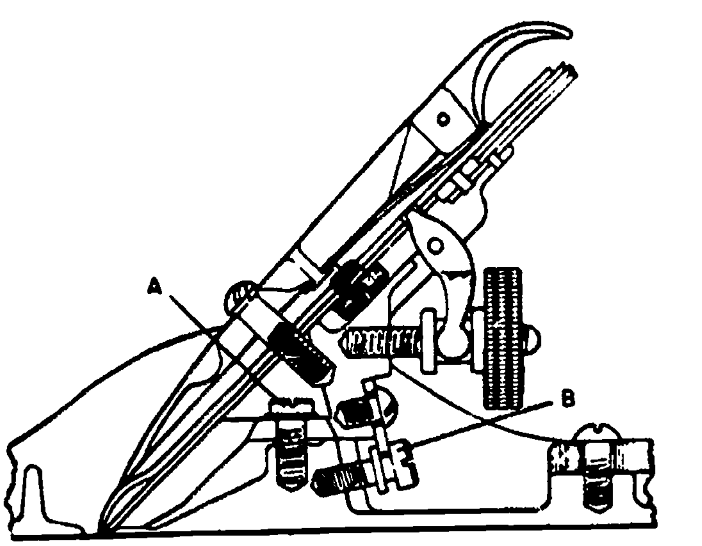
If the cut is rough and the wood surface is being torn or chipped out, it is probably because you are planing against the grain.

If the plane will not make a thin cut, it is definitely dull and must be sharpened.

CAUTION: Do not test the plane blade for sharpness by running your thumb or finger over the blade. Even a dull plane blade will cut you.

Another adjustment that should be made at this point is to the THROAT OPENING or MOUTH of the plane. This is accomplished by loosening the bed screws (fig. 3-84A) and turning the frog adjustment screw (fig. 3-84B). This adjustment controls the length that a shaving will run before breaking and has an effect on the smoothness of the cut.

A narrow throat opening will produce a shorter shaving and a smoother cut. If the



29.12(68C)CX
Figure 3-84. — Adjusting throat.

throat clogs with shavings, the throat opening should be widened.

1. Select a suitable plane for the particular job.
2. Check the material to ensure that it contains no nails, staples or other foreign material that would damage the plane blade.

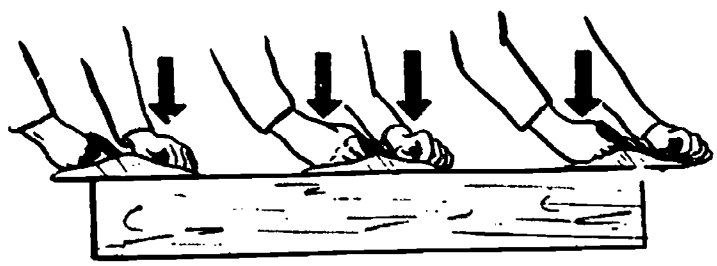
NOTE: Hardened glue will dull a plane blade rapidly. If you are planing a piece of glued-up stock, make sure that any glue residue is removed by scraping with an old plane blade or cutting under it with a wood chisel prior to planing.

3. Check the grain direction. Always plane with the grain.
4. Secure the stock to be planed so that it cannot move.
5. Take a firm position in front of the stock with one foot placed ahead of the other for balance.
6. Hold the plane with one hand on the handle and the other on the front knob.
7. When beginning the stroke, bear down firmly on the front knob and, as the cut progresses, equalize the pressure on the knob and handle. When completing the stroke, lighten the pressure on the knob and bear down on the handle (fig. 3-85). This will minimize the possibility of rounding over (dubbing) the edges.
8. Whenever possible, use a full stroke. That is, the full length of the stock.
9. Even on wooden bench tops, always lay the plane on its side when it is not in use. This prevents the blade from being dulled by grit embedded in the bench top.

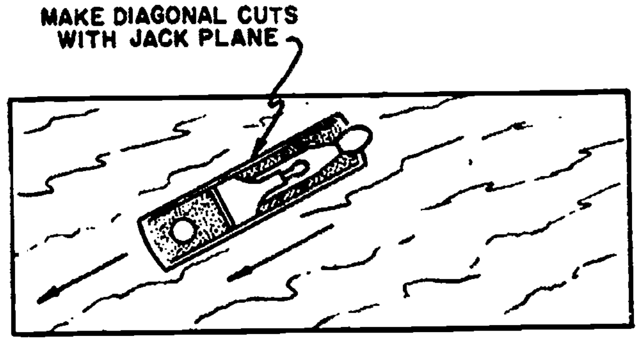
NOTE: It is not a good idea to use a plane on stock that has been sandpapered. Particles of sanding grit will be embedded in the stock surface and this material will rapidly dull the plane blade.

When planing face surfaces, it is usually better to first plane from corner to corner (diagonally) as shown in figure 3-86. Alternate by planing the complete surface from one diagonal and then planing from the opposing diagonal until the surface is flat or very close to the thickness desired.

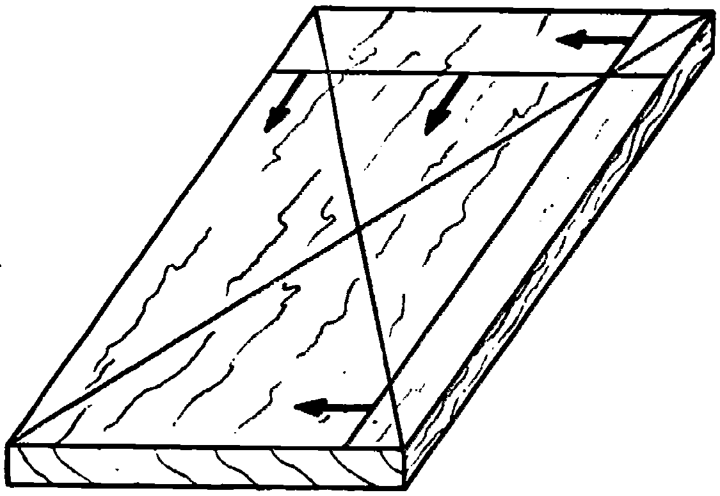
Test the surface for flatness frequently by using a straightedge in the positions shown in figure 3-87, making sure that the edge touches the stock surface at all points. If high spots are present, shade them with a pencil or chalk and plane them off. Make the final or finishing cut by planing from end to end (fig. 3-88) after



29.12(68C)D
Figure 3-85. — Pressure control on a plane.



29.12(68C)EX
Figure 3-86. — Using a diagonal stroke for smoothing a surface.



68.201

Figure 3-87.— Positions for using straightedge when checking surface flatness.

adjusting the plane blade for a shallow cut and the throat for a smooth cut.

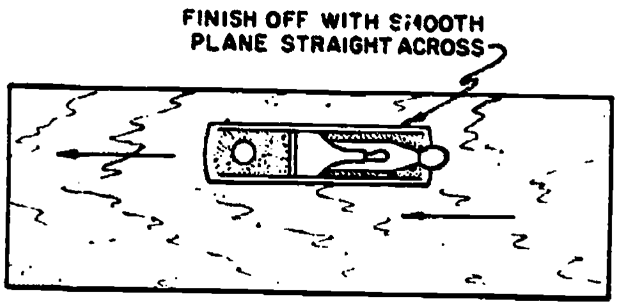
The edge of stock is usually planed to obtain a perfectly straight surface 90° to the face of the stock. Therefore, it is important for the plane blade to be parallel to the plane's sole and for the plane to be held 90° to the face surface of the stock. This can be done by employing one of the methods shown in figure 3-89.

A typical BLOCK PLANE is shown in figure 3-90. It may or may not have the throat and lateral adjustment features shown.

The block plane is primarily used for planing end grain and small pieces of stock.

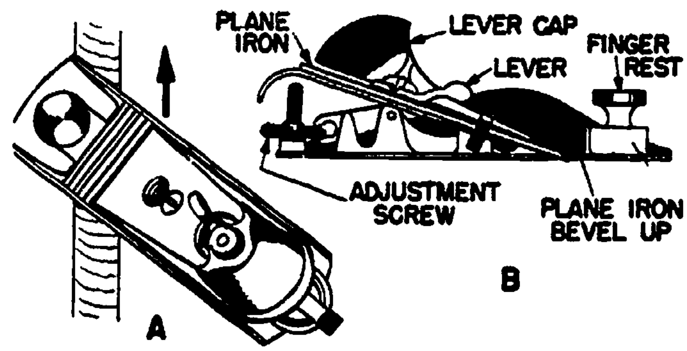
The block plane differs from bench planes in that it is designed to be held in one hand and, as shown in figure 3-91, the blade is set into the plane body at a much lower angle with the bevel up instead of down (fig. 3-79B). This makes possible the slicing cut needed to plane end grain.

When planing end grain, care must be taken not to splinter or break off the ends. Some



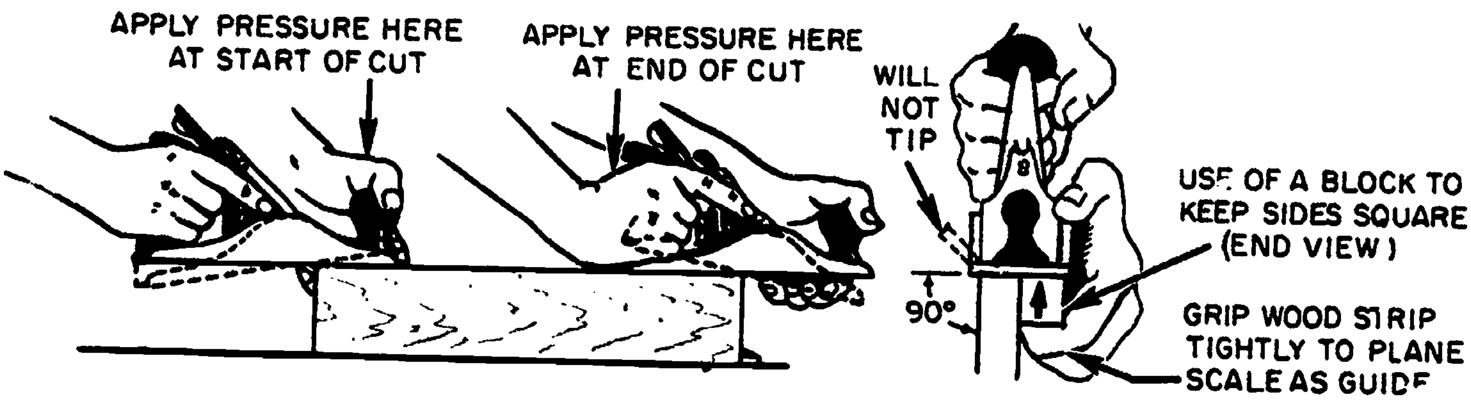
29.12(68C)FX

Figure 3-88.—Using a straight stroke for finishing a surface.



29.12E

Figure 3-90.— Block plane and nomenclature.



29.12(68C)GX

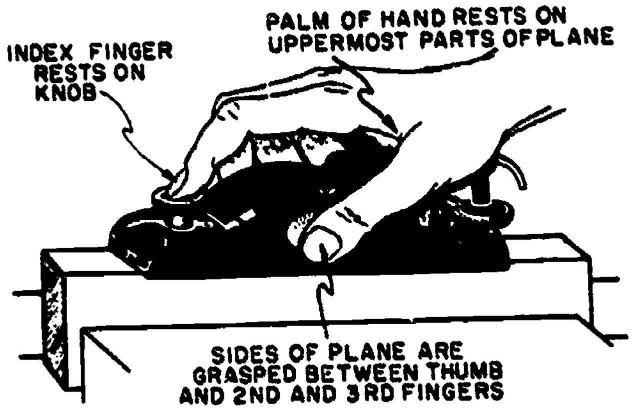
Figure 3-89.— Procedure for planing an edge.

of the methods of avoiding this are illustrated in figure 3-92.

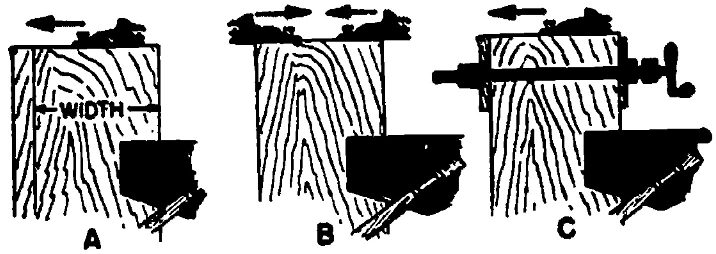
There are several different kinds of special planes used by Patternmakers. The ROUTER PLANE (fig. 3-93) has a cutting bit which can be adjusted to cut at different depths below the face of the stock. It is very useful in cutting out recesses of depressions to a uniform depth and in smoothing the bottom of grooves.

The CIRCULAR PLANE (fig. 3-94) has a flexible steel sole which may be adjusted to cut a convex or concave arc such as the outer or inner surfaces of a wheel rim.

The CURVED-SOLE PLANE (figs. 3-95 and 3-96) is designed to plane curved surfaces. The plane is equipped with a series of interchangeable soles of different degrees of curvature. Cutting irons are ground to a curved edge to match the particular sole being used. This type of plane may be easily made in the pattern shop. Construction details (a through f) are shown in figure 3-97.

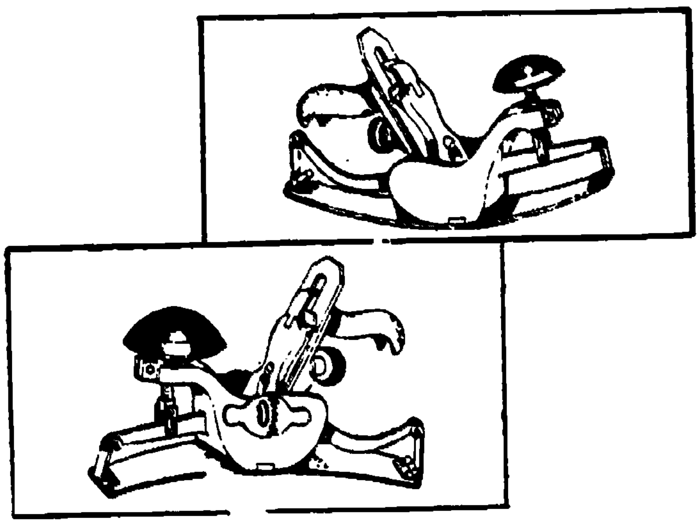


29.12(68C)HX
Figure 3-91.—How to hold a block plane.



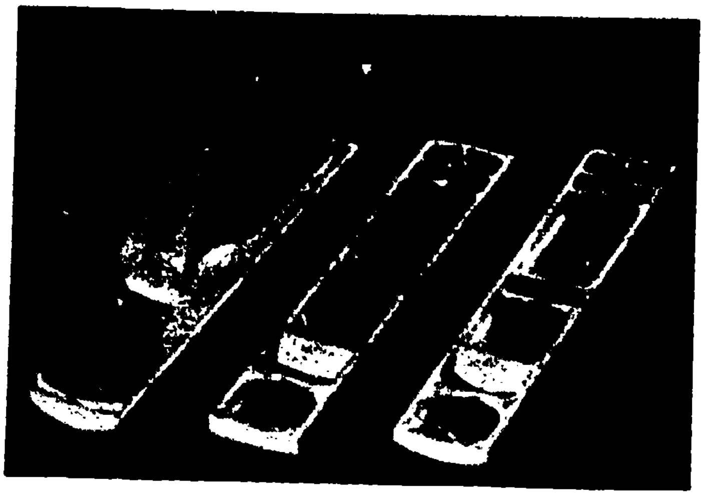
44.110
Figure 3-92.—Preventing splitting when planing the edge of stock.

29.12(68C)KX
Figure 3-93.—Router plane.

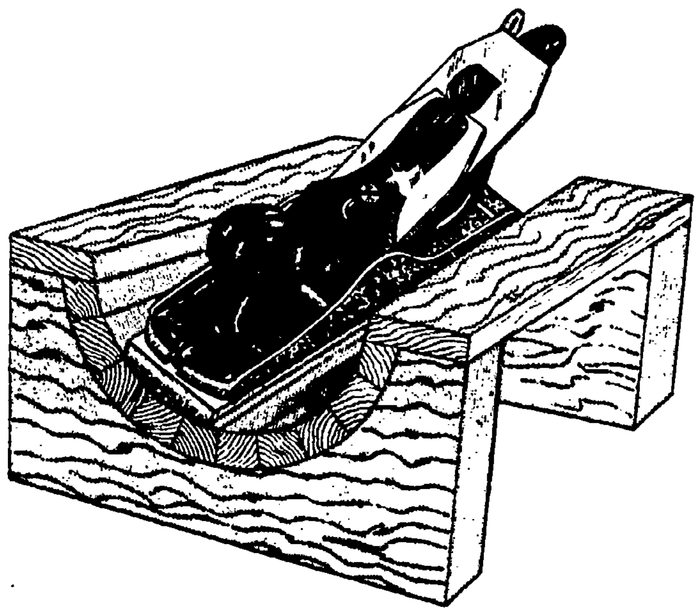


29.12(68B)
Figure 3-94.—Circular plane.

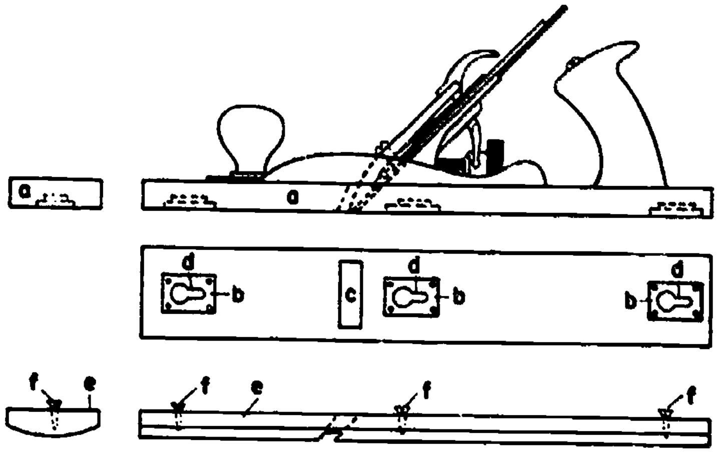
First remove the sole from an ordinary smooth plane and replace it with a hardwood base (a) about 12 to 14 inches long and 1/2 inch thick. Note that three metal plates (b) are embedded in the base and are held in place by small screws. Cut an opening (c) in the base to provide a throat for the cutting blade. Drill a circular hole with a slot (d) at one end of each of the three metal plates. Make a number of soles the size of the wood base and with different degrees of curvature. Into each sole insert three screws (f) spaced to fit the center holes of the wooden base. Allow the heads of the screws to project a little above the surface of the sole. Pass the heads of the screws (f)



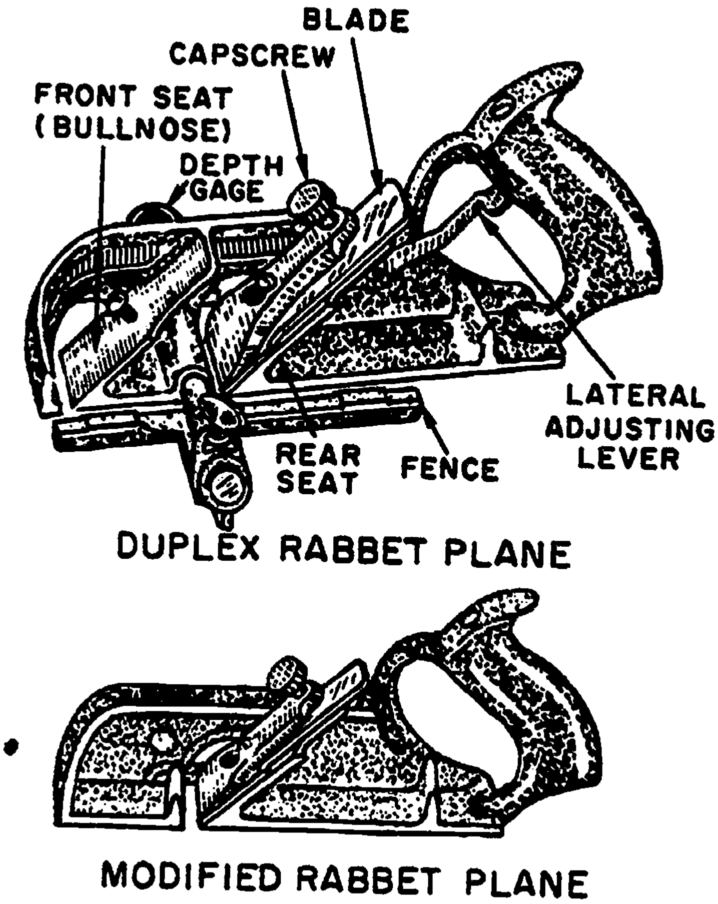
29.12(68C)L
Figure 3-95.—Curved sole plane.



29.12(68C)M
Figure 3-96.—Use of the curved-sole plane.



29.12(68)EX
Figure 3-97.—Curved-sole plane.



29.12(68C)NX
Figure 3-98.—Rabbet planes.

through the holes in the wooden base (a) and pull the sole back toward the rear of the plane. This locks the heads of the screws firmly in the slots (d) and clamps the sole to the body of the plane.

The RABBET PLANE (fig. 3-98) is sometimes referred to as the FILLISTER PLANE and is used for planing dadoes, rabbets, and laps. It differs from other planes in that the cutting iron or blade extends completely across the face of the plane.

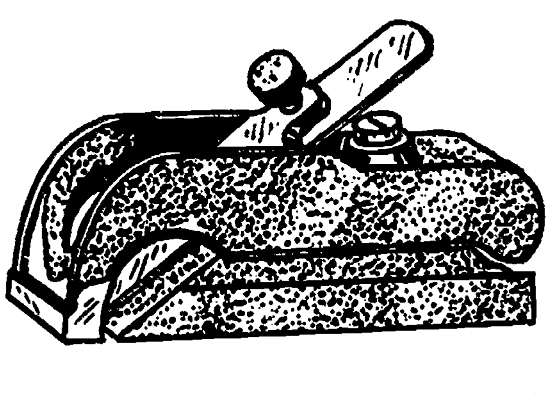
A depth gage and a spur cutter are useful attachments. Some rabbet planes, equipped with convex soles, are useful for making wooden fillets and for planing small concave grooves.

The SKEW-IRON RABBET PLANE has the cutting edge of the plane-iron set on a diagonal across the face of the plane and works more smoothly than one in which the iron is set at right angles to the side of the plane.

Another of the many variations of the rabbet plane is the BULLNOSE RABBET PLANE (fig. 3-99). It is about 4 inches long and usually uses a 1 inch cutting blade set well forward in the plane. Because of its small size, it is ideal for working in close quarters and in corners.

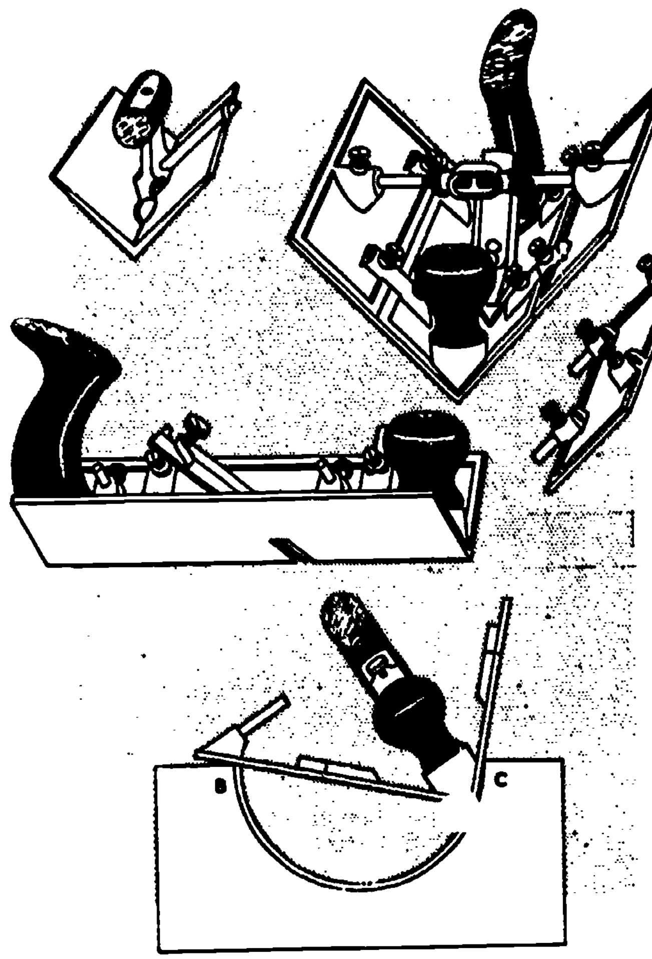
The V-TYPE CORE BOX PLANE is designed to smooth the curved surfaces of semicircular core boxes. The sides of the plane are constructed at right angles to each other. The point of the cutting blade is ground to an angle of 90°. The construction features of the V-type core box plane are based on the geometrical proposition that any angle scribed within a semicircle will be a right angle. Thus when the sides of the plane rest on the top edges (b) and (c) as shown in figure 3-100, the cutting blade will always cut on the circumference of the curved surface.

The V-type core box plane is different from other planes in that it can be used either on the right-hand or left-hand side. This feature is useful when making long core boxes which cannot be reversed and in the making of long tapered core boxes where you have to plane with



29.12(68C)P

Figure 3-99.—Bullnose rabbet plane.



29.12(68)CX

Figure 3-100.—V-type core box plane.

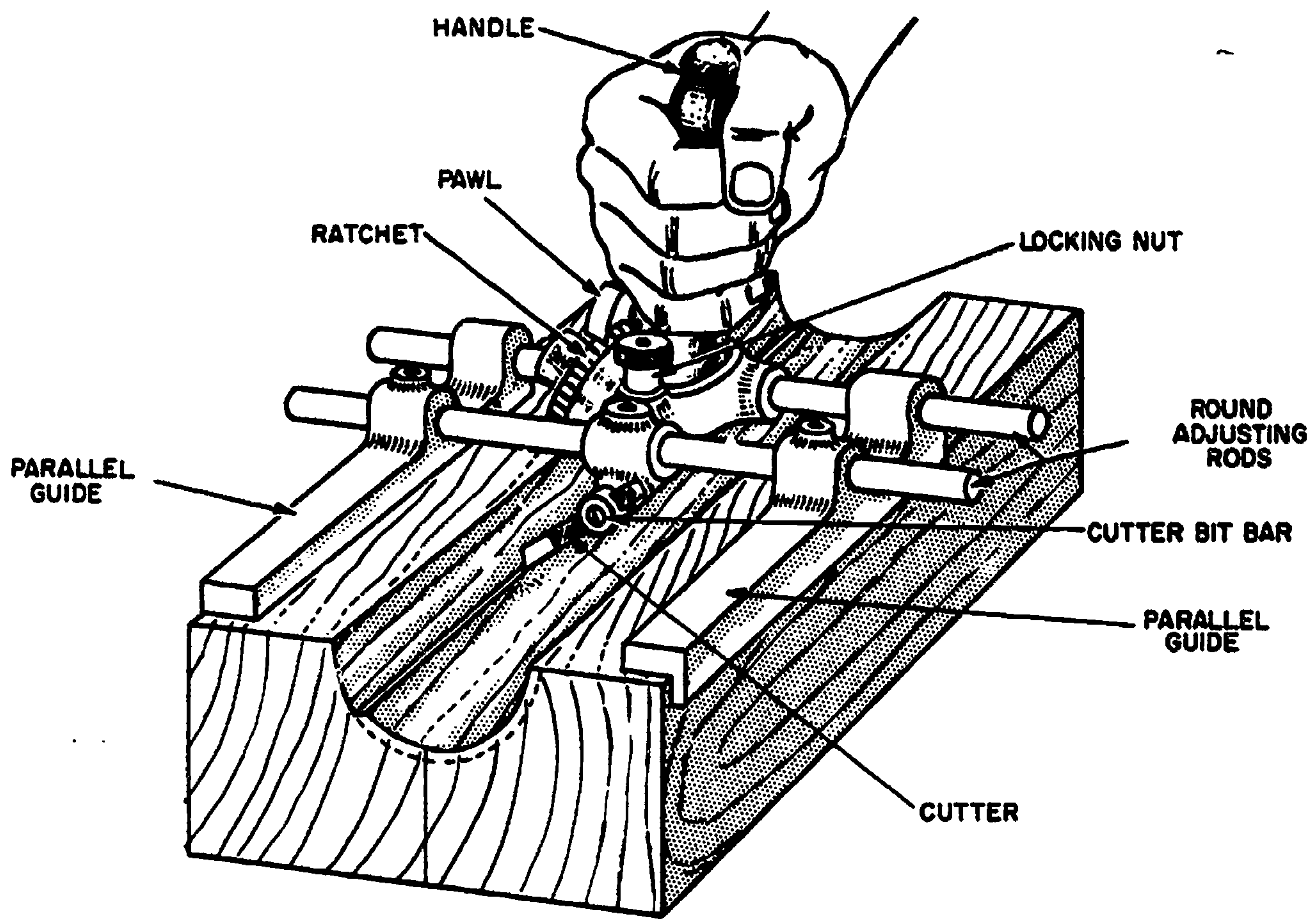
the grain of the wood. Although the V-type core box plane is designed for either right-hand or left-hand use, the cutting edge of the blade can be rounded over, thereby allowing slightly more ease in the setting of the blade. In cases where core boxes cannot be reversed, it is convenient to have two cutter blades, one with the left edge rounded over for left-hand planing and one with the right edge rounded over for right-hand planing.

The plane is also designed for additional sides to be added for the planing of core boxes of larger diameters. These sides are called additional sections. Without these additional sections, the V-type core box plane is limited in the size of the box that can be cut. With the additional sections added to the side of the plane, the range of the plane is increased to the cutting of boxes up to five inches in diameter. The additional sections are held in position with adjusting rods to hold the sides square and firmly in position. Each additional pair of sections added to the plane increases the range of the plane by adding 2 1/2 inches to the diameter that can be cut.

The only objection to this type of core box plane is that while it is being used for cutting the semicircular cavity in the pattern material, the corners of the semicircular cavity are worn off. However, this can be overcome by using hardwood strips tacked on the top surface of the pattern material along the core outline, just outside the material to be cut. The hardwood strips form rests for the sides of the plane only while the heavier part of the work is being done and must be removed prior to making the finish cut.

The RADIAL CORE BOX PLANE (fig. 3-101) is designed to make straight circular core boxes ranging from 3/4 inch to 6 inches in diameter. It is simple in design and once the proper adjustments are made, very little skill is necessary to produce an accurate semicircular core box. Due to the ease with which the radial core box plane can be used, it is frequently found in shipboard pattern shops. The radial core box plane is limited in that it cannot cut tapered core boxes, and therefore it should not be considered as a substitute for the V-type core box plane.

The radial core box plane, shown in figure 3-101, is simply a rotating cutter attached to a ratchet mechanism swung between two parallel guides. The parallel guides fit the outside surface of the material to be cut. In the operation of the plane, the rotating cutter is brought into operation by pressing the handle in the direction of the cut to be made. The pressure on the handle causes the pawl to engage the ratchet which in turn revolves the cutter bit bar several degrees in a downward arc. The pressure on the handle is kept constant while the plane is pushed forward until one continuous cut is made the full length of the core box. The parallel



29.12(68)D

Figure 3-101.—Radial core box plane.

guides are of sufficient length to retain their position on the outside of the core box after each cut is made. At the completion of the forward cut, the pressure on the handle is released and the plane is drawn back to its original position. As the plane is drawn back, the ratchet pawl is released, so that any forward motion (pressure) on the handle will engage the ratchet, causing the cutter blade to rotate into position for another cut. Each cut is made the full length of the box until a true semicircular cavity is cut to the desired radius.

The SPOKESHAVE shown in figure 3-102 may be considered a small transverse plane with end handles. Spokeshaves are generally used for cutting and shaving surfaces that are irregular and uneven when a hand plane cannot be used. The spokeshave is made in a variety of sizes and shapes with concave and convex bottoms.

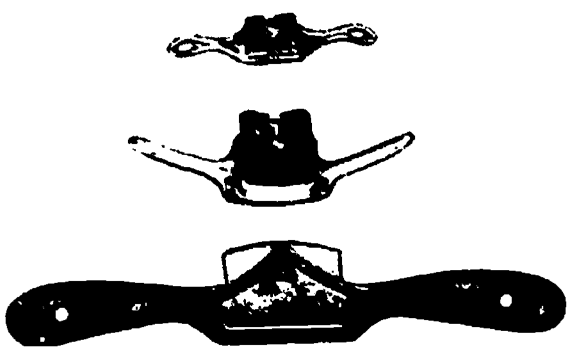
The CORNERING TOOL, shown in figure 3-103, is used for rounding the corners of patterns. It is a flat, steel bar that is shaped and ground at each end to form an elliptical cutting edge. The elliptical shape enables you to cut a limited depth in either direction, that is, when pushing the tool away from you or pulling it toward you.

The MITER BOX (fig. 3-104) is a tool designed to hold and to guide a saw at a preset angle during sawing operations. It is adjustable so that cuts may be made at other angles as well as mitering on the 45° angle. The device is especially useful in making various polygonal forms required in segmental pattern construction.

FORCING AND HOLDING TOOLS

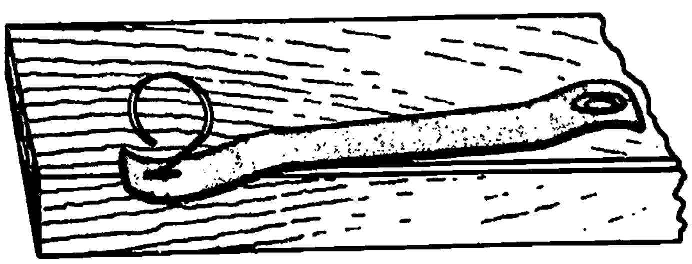
The forcing and holding group of handtools, illustrated in figure 3-105, is almost likely already familiar to you.

The CARPENTER'S HAMMER is made in various weights. The two best suited for pattern work are the 13-ounce and 14-ounce hammers.



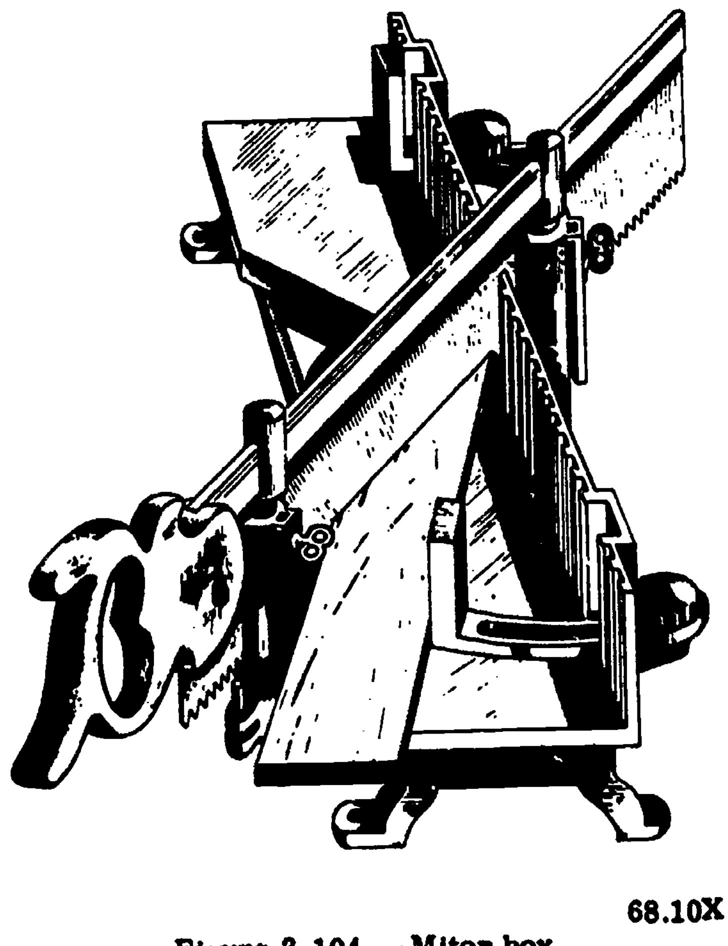
68.8(68B)

Figure 3-102.—Spokeshaves.



68.9X

Figure 3-103.—Corner rounding tool.



68.10X

Figure 3-104.—Miter box.

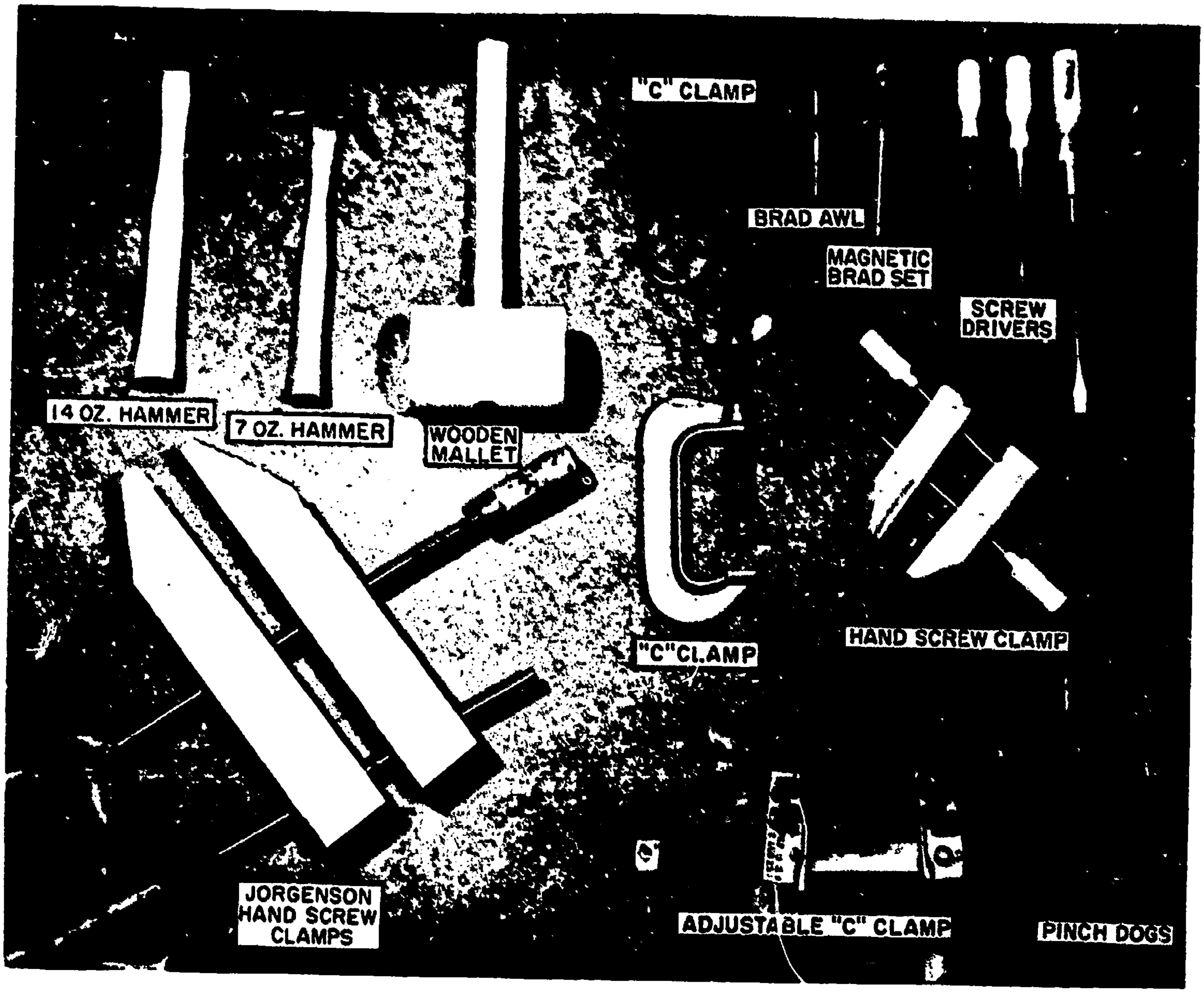


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Figure 3-105.— Forcing and holding tools.

The head of the hammer is of forged steel, designed with claws for pulling nails and with a hardened face for driving.

The PATTERNMAKER'S HAMMER is a smaller version of the carpenter's hammer, weighing 7 ounces.

The LONG-HEAD HAMMER is used chiefly on small and medium-sized work. The long end of the hammer is used for driving in a narrow or awkward space.

A MALLET is used primarily with chisels and gouges. To protect the handles of these tools, mallet heads of beech, maple, rawhide, or solid rubber are best.

The BRAD AWL is used to piece holes in wood when it is necessary to bore a small hole before driving a brad or nail in place. The brad awl has a tapered blade, and it is available in three sizes: 1/16, 3/32, and 1/8 inch.

The MAGNETIC BRAD SET is used to insert small brads in otherwise inaccessible to reach locations on the pattern.

The UNIVERSAL VISE is the most convenient holding device for pattern finishing. This vise is adjustable for holding the pattern at any desired angle.

CLAMPS are used primarily for holding parts being glued together. The JORGENSEN type is commonly called the hand clamp or parallel clamp. It has wooden jaws and adjustable steel screws with which the angle of the jaws may be adjusted to fit the work or to overlap one jaw beyond the other.

The CABINET CLAMP concentrates pressure on a small area. It is used to hold stock of quite large width that is being glued together. This clamp is manufactured with either a screw type of adjustment or an eccentric which tightens the clamp instantly.

The C-CLAMP is available in several styles. It ranges from a 2-inch to an 18-inch opening and from a 1 1/4- to 16-inch depth.

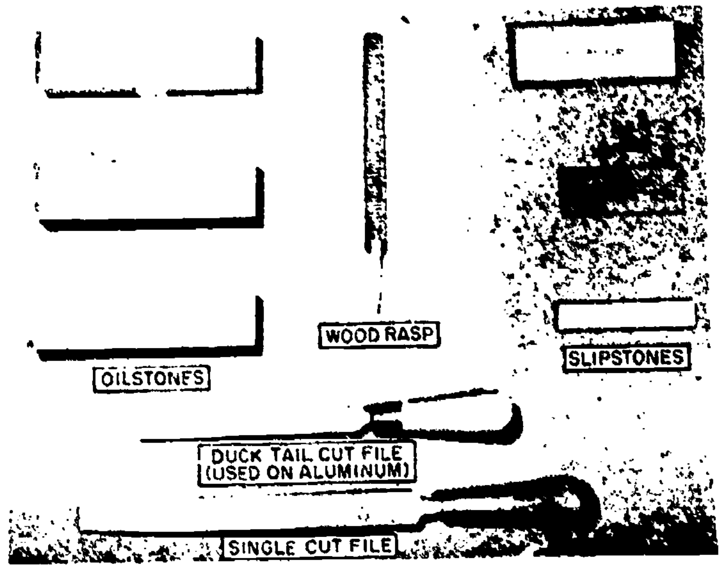
The PINCH DOG is used to clamp pieces of wood together during gluing operations when clamps cannot be used. It is also used to clamp pieces of wood together temporarily. The outsides of the two points are parallel to each other, but the inside is tapered. (See fig. 3-105.) As the pinch dog is driven into the wood, the taper draws the surfaces of the pieces tightly together. Hammering should not be done in the middle of the pinch dog. It should be done, alternately, first over one point and then over the other. Continuous hammering in the middle of the pinch dog will spring it, and in time, make is useless.

ABRADING TOOLS

After planes, chisels, and other edged tools have become dull from use, they must be resharpened. In order to do good work, they must have a keen cutting edge at all times. The cutting edge obtained by grinding a tool is too rough for paring or carving operations. It is therefore necessary to dress the edge further by whetting it on an OILSTONE. (See fig. 3-106 for the abrading tools group used by the Patternmaker.)

The cutting edge is placed on the oilstone so that the entire ground edge is bearing on it. Next, the ground edge is rubbed steadily back and forth with long strokes in an elliptical path. Check the edge from time to time and observe the results. To complete the whetting, lay the tool on its flat face and rub it back and forth parallel to the cutting edge.

During the whetting operation, oil should be applied freely to the surface of the stone. This washes away the grindings and prevents the surface of the stone from becoming clogged or



1.20:29.9N
Figure 3-106.—Abrading tools.

glazed. Wipe the surface frequently with waste or a rag cloth. Before a new stone is put into use, it should be soaked in oil for several days. Machine oil of a very light viscosity, or ordinary machine oil cut with kerosene, should be used.

There are several types of oilstones. The rectangular-faced stone is the most commonly used type. There is a tendency when using it to whet back and forth in the center of the stone, eventually producing a dip or hollow on its face. The disk-shaped type is considered superior to the rectangular-faced type because it allows a rotary motion while whetting, so that the wear on the stone is more evenly distributed.

SLIPSTONES, of the oilstone type, are used to whet the cutting edges of gouges and carving tools. During the whetting operations, however, the slipstone is moved back and forth instead of the tool being moved.

The Navy Stock List of General Stores lists more than a page of files and rasps suitable for pattern work. Only the HALF-ROUND CABINET FILE and the HALF-ROUND CABINET RASP are needed for ordinary work. The most useful sizes are 6, 8, and 10 inches.

CARE AND REPAIR OF TOOLS

By this time, you are thoroughly familiar with the Navy practice of keeping everything shipshape. In the pattern shop, this practice is most important to the successful performance of your duties. Use each tool or instrument in the manner and for the purpose for which it was designed. If tools and instruments are not properly handled, they will not be in condition to be used to do your job. Learn to handle each one in the correct manner so that it will be ready for use at all times.

Here are several reminders that you will find of assistance in caring for tools: (1) each tool or instrument should be kept clean; (2) tools should be wiped with an oily rag occasionally to prevent rusting; (3) whenever tools are not in use, they should be put away; (4) if a tool or instrument is damaged or nicked, it should not be used until repaired; (5) when laying down chisels and other cutting tools, after using them, keep them away from the edge of the workbench and also turn their cutting edges away from you.

Possibly your biggest maintenance job will be that of keeping your tools sharp. The care and maintenance of handtools is fully covered in Tools and Their Uses, NAVPERS 10085-B.

CHAPTER 4

POWER-DRIVEN PORTABLE HANDTOOLS

There are a limited number of portable power tools manufactured specifically for pattern work. Also, some of the more common portable power tools can be adapted to pattern work. However, the use of portable power tools in patternmaking is limited because of the high degree of accuracy required of pattern work.

Although your primary function as a Patternmaker is to manufacture patterns for the foundry, there are many other jobs that you will be called upon to make because as a PM, you are considered to be the finest wood craftsman available. Many of these jobs will involve carpentry skills such as shoring, paneling, and building scaffolds. Others will involve the skills of the cabinetmaker and the furniture maker in making such items as bookcases, desks, cabinets, and plaque backs. Therefore, it is necessary for you to be familiar with some of the tools of these trades.

While it is understood that we cannot possibly cover all of the portable power tools that are available, this chapter will discuss those that are most common and usually found in the pattern or carpenter shops aboard ship.

Most portable power tools are either electric or air driven. The most common variety used for woodworking is electrical.

There are several safety and operating precautions that are relevant to all electrical tools, the most important of which are those related to electrical shock.

Electrical tools are manufactured in such a way that all current-carrying parts are insulated from the housings and handles and are laboratory tested to ensure that they are safe to use when new. However, if the power unit is overloaded to the point of burnout, the tool dropped, the switch damaged, the supply cord jerked or otherwise abused, or the tool subjected to any other form of abuse, a "hot" conductor may come in contact with the tool housing and you may receive a serious electrical shock.

The electrical shock hazard is minimized by providing a low resistance grounding wire between the tool housing and a positive ground.

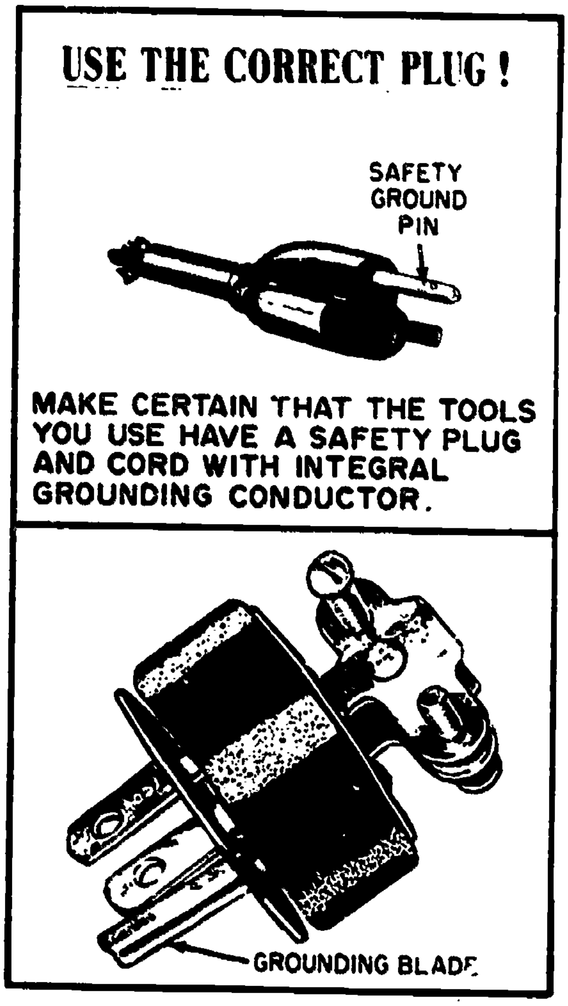
All portable electric power tools aboard ship must have a three-wire cord of sufficient length to allow freedom to use the tool and a plug such as the one shown in figure 4-1. The round prong on the plug is the ground. This type of plug is designed to fit the grounding type convenience outlet shown in figure 4-2. If this type of outlet is not available, a special adapter may be used such as the one shown in figure 4-3. It consists of the standard two prongs and a wire lead. The lead is the ground wire and must be connected to a positive ground before you use the tool. Never use a portable electric tool without first grounding it. A 120-volt shock can very easily kill you.

Many portable electric tool housings are now being made of a special high impact plastic which is more resistant to damage than aluminum. The plastic also helps to minimize the electrical shock hazard. However, the use of this plastic does not eliminate the chance of shock, nor does it eliminate the need of a positive ground.

Because portable electric power tools made by specific manufacturers will differ, the best information concerning maintenance of these tools will be found in the manufacturer's instruction booklet provided with each tool.

In order to keep your tools in good operating order, you must rigidly adhere to these instructions.

If, for some reason, a manufacturer's instruction booklet is not available, a letter written to the specific manufacturer's sales and service office listing the model number, size, type, and duty rating of the particular tool will usually get you one by return mail.



40.67(67C)A
Figure 4-1. — Three-wire grounding plug.

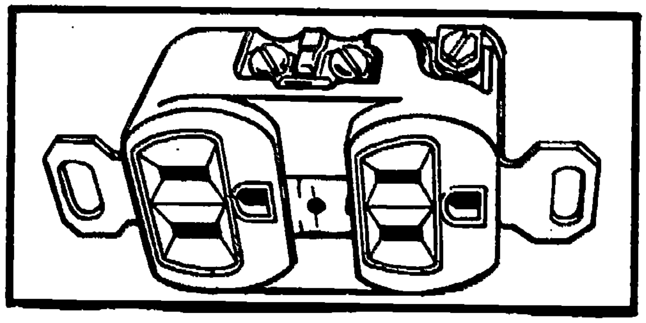


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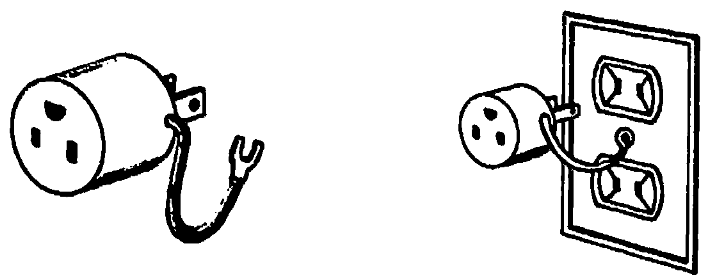
Figure 4-2. — Grounding type convenience outlet.



5.13(68C)X
Figure 4-3. — Grounding adapter.

GENERAL SAFETY PRECAUTIONS
FOR PORTABLE POWER TOOLS

1. Before using the tool, inspect the electric cord for breaks or signs of abuse.

2. Inspect the tool and ensure that it is in good condition, properly lubricated, that all adjustments are tight, blades and cutters are sharp, and that all safety guards are present and in good operating order. Ensure that the switch is in the OFF position.

3. Ensure that you are connecting to the proper electrical supply.

4. Make certain that the tool is properly connected to the electric circuit and safely grounded.

5. Never use electric tools in an area containing explosive or combustible liquids or gases.

6. Never use an electric tool while standing on a wet or damp deck.

7. Do not wear loose clothing, ties, dog tags, or the like, which might become caught in the tool you are using.

8. Make certain that the electric cord does not become fouled during the operation of the tool.

9. Do not work on any material, unless it is securely fastened so that it will not slip or twist.

10. Keep tools dry and protected from dampness and dirt.

11. Always use all of the safety guards provided.

12. Always disconnect the tool from its power source before changing blades, drill bits, cutters, sandpaper, etc.

13. Thoroughly clean the tool before restowing.

14. THINK! For the most part, safety is just simple logic. Most accidents are caused by thoughtlessness.

PORTABLE ELECTRIC CIRCULAR SAW

The portable electric circular saw is a light weight, high speed cutting tool that can be used for cutting a wide variety of materials and making special cuts when used with the appropriate cutting blade.

The saw is available as a standard duty or heavy duty tool and in horsepower ratings ranging from 1/6 to 1 1/2 hp, with speeds ranging from 1800 to 5500 rpm.

The size of the portable electric circular saw is determined by the diameter of the blade which the saw is designed to use. For instance, a saw designated as a 7 1/4 inch size will have a 7 1/4 inch diameter cutting blade. This saw is available in sizes ranging from 4 to 12 inches. The most popular size for shop use is the 7 1/4 inch heavy duty saw. However, a 10 inch heavy duty saw is the size usually found in the repair lockers aboard ship.

The voltage requirement for most portable electric saws is 120 volts a-c, but they are also made for 220 to 550 volts for either a-c or d-c current.

A typical portable electric circular saw is shown in figure 4-4. The motor housing, base, and handle are aluminum, while the adjusting knobs and end bell of the motor are plastic.

The saw is provided with a depth adjustment device which allows you to adjust the cutting depth of the blade and a bevel adjustment which allows angular adjustment from 90 to 45 degrees. See figure 4-5.

Another adjustment is provided through the use of the rip guide shown in figure 4-6. Two small knurled screws on the front of the saw base allow quick installation and setting of the rip guide and hold it firmly in position.

NOTE: It is not recommended to use the graduations on the rip guide when a high degree of accuracy is important.

Blade safety guards differ among manufacturers, but usually cover the front and bottom of the blade. The blade guard shown in figure 4-4 is a spring loaded, telescoping type which automatically returns to the closed position when the cut is finished.

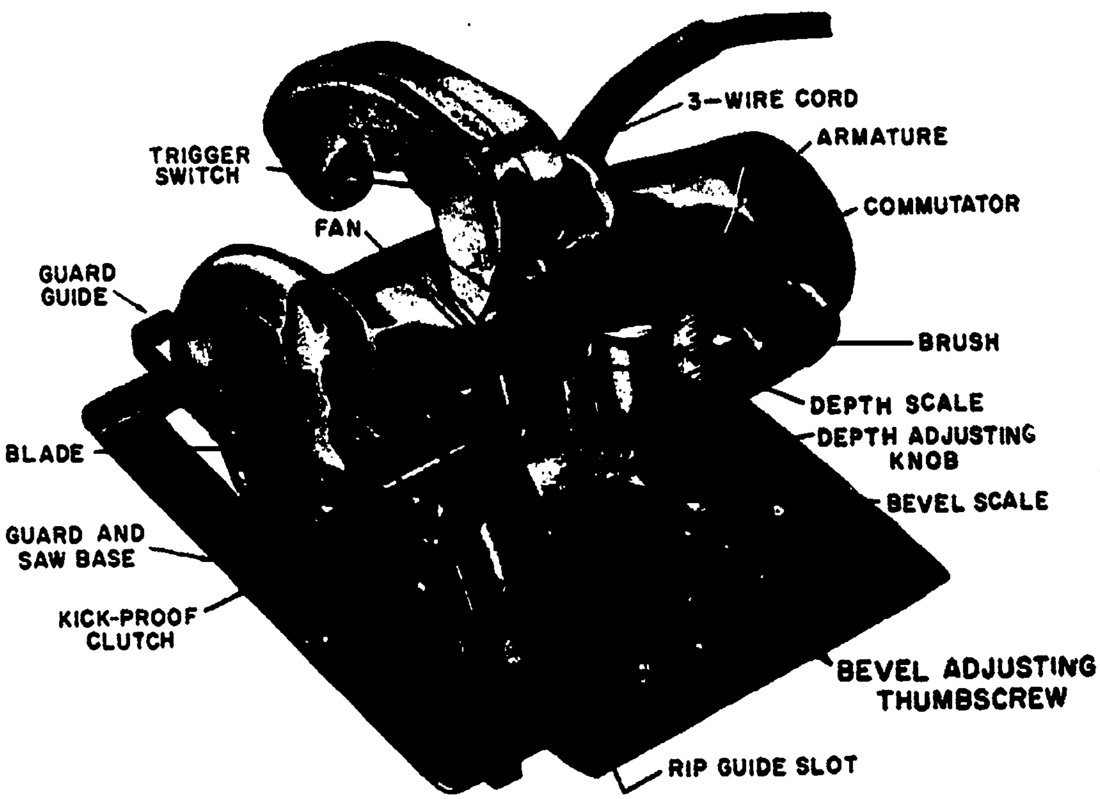
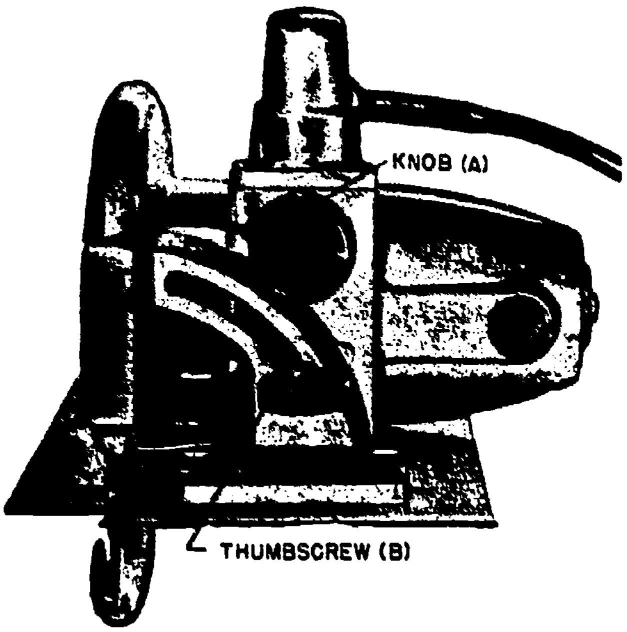


Figure 4-4.—Portable electric power saw, 7" heavy duty.



29.133(68C)BX
Figure 4-5.—Knob A controls the depth of cut. Thumbscrew B controls the bevel adjustment.

29.133(68C)CX
Figure 4-6.—Rip guide set for 1 1/4" width of rip. Broken arrow indicates blade rotation.

An additional feature of the saw shown in figure 4-4 is the kick-proof clutch. This feature is in the form of a special washer designed to relieve motor strain and possible motor burnout, but most importantly, to minimize the possibility of the saw kicking back at the operator.

The control switch of the saw, located in the handle, is a trigger type which requires constant pressure to keep it in the ON position.

USING THE CIRCULAR SAW

The first consideration that must be taken before starting any cut is the selection of the proper cutting blade for the particular type of material or type of cut to be made.

There are numerous cutting blades available for the portable circular saw which enable you to make various cuts on materials such as wood, plywood, fiberboard, plastics, and soft-metals.

You will be primarily concerned with the three most common wood cutting blades which are the rip, crosscut, and combination blades shown in figure 4-7.

The combination blade, designed to both crosscut and rip, is the blade generally used most frequently in the saw.

Saws made by specific manufacturers will differ. Therefore, the best information concerning methods of changing blades will be found in the manufacturer's instruction booklet provided with each saw.

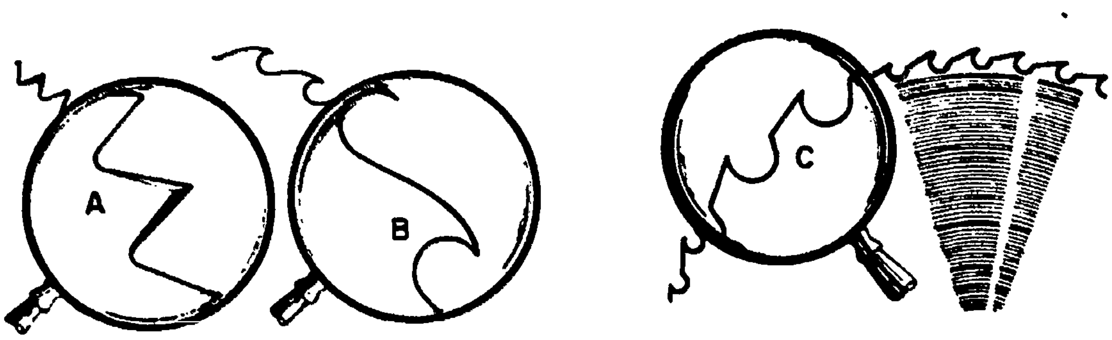
Although we will not attempt to discuss the procedure for making all the various cuts possible with the portable circular saw, we will cover the step by step procedure for making the two most common cuts which are ripping and crosscutting.

Crosscutting

Crosscutting (cutting across the grain) may be done with either the combination or crosscut blade. However, a much smoother cut will be made with the crosscut blade. The steps of the procedure for crosscutting are as follows:

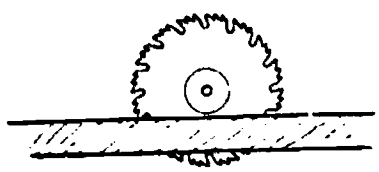
1. Be sure that the work to be cut is solidly supported.

2. Adjust the depth of cut so that the blade will extend through the material to the extent that the gullets of the teeth clear the thickness of the material as in figure 4-8.



68.202X

Figure 4-7. — Common blade types for portable circular saw. A. Crosscut B. Rip C. Combination



68.203X

Figure 4-8. — Depth setting for average cutting.

3. Be sure that the angle adjustment device is set and locked at zero or the desired angle for bevel cuts.

4. Ensure that the blade guard is operating freely and in the proper position.

5. Plug the saw into the proper power outlet, making certain that the electric cord is properly grounded and positioned so that it will not become fouled during the sawing operation.

6. Grasp the handle of the saw firmly with the forefinger ready to operate the trigger switch. Keep the other hand well out of danger.

7. Place the front of the saw base on the work so that the guide mark on the front plate and the line of cut are in line.

8. With the blade well clear of the work, start the saw and allow the blade to attain full cutting speed.

9. Advance the saw into the wood, following the line of cut with the guide mark. Save the full cutting line. As you become proficient with the saw, only half of the cutting line should be saved.

10. Guide the saw steadily through the cut. If the saw stalls, do not release the trigger switch. Instead, carefully back the saw enough to allow it to resume speed and then continue the cut. A wedge placed in the saw kerf will help prevent the saw's binding when cutting wide boards.

NOTE: If the saw stalls excessively, disconnect the power cord and check the blade for dullness or lack of set.

11. When the end of the cut is reached, release the trigger switch and allow the blade to follow through as you lift the saw out and away from the work. Take care not to twist the saw as it is removed, as this will score the work.

12. Ensure that the blade guard has returned to the closed position before laying the saw down.

NOTE: NEVER bring the saw to rest against your leg or any other part of your body. The blade guard can become jammed, leaving the blade exposed. This would result in serious injury.

Ripping

Ripping (cutting with the grain) is generally more difficult than crosscutting because of the length of the cut. This cut can be made with either the combination or the rip blade. If a smooth cut is required, use the rip blade.

Some important items to bear in mind when ripping with the portable saw are:

1. The material being cut must be well supported and not allowed to sag.

2. The material must be securely held in position.

3. The cutting blade must not cut into the supporting material.

The steps of the procedure for ripping are as follows:

1. Insert the rip guide into the saw frame. The guide may be inserted into either side of the frame for both wide or narrow widths.
2. Adjust the rip guide to the desired width and tighten the two thumbscrews to lock the guide in position.
3. Proceed as in crosscutting, steps 2 through 12. If the saw kerf seems to close and bind the blade, insert a wedge to open it and give clearance to the blade.

If the ripping is so long that it will be necessary to walk beside the material while cutting, make the following additional preparations before making the cut:

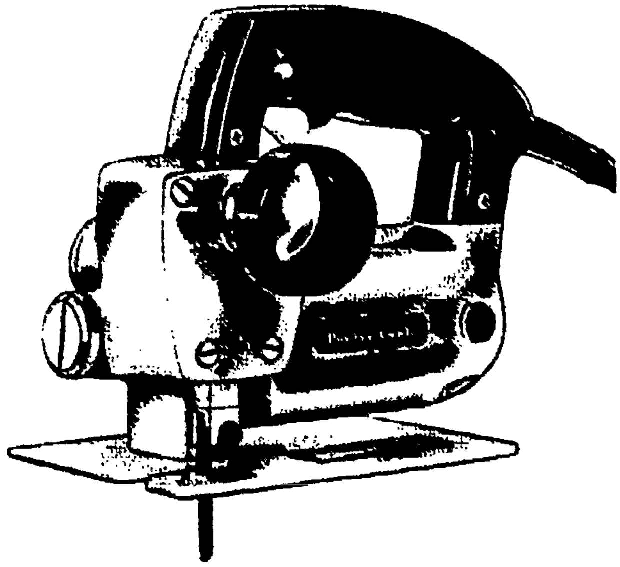
1. Support a 2" x 12" plank at least as long as the proposed cut, on two saw horses or other solid foundation at a comfortable height for cutting.
2. Place the material to be cut on the plank. Allow its edge to project beyond the edge of the plank about 1 inch more than the width of the proposed cut. Tack the material to the plank in this position, using nails that will hold it securely at each end.
3. Be sure that you have a clear, unobstructed place to walk while pushing the saw along the required length, and see that the saw cord will not become fouled while making the cut.

PORTABLE ELECTRIC SABER SAW

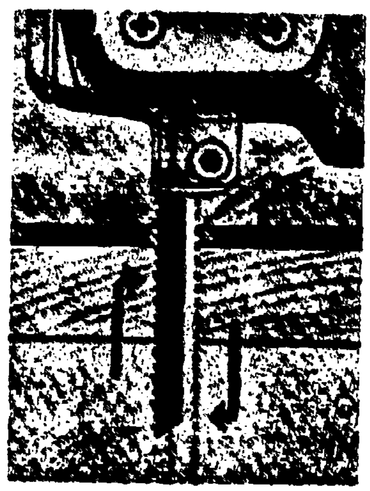
The portable electric saber saw, figure 4-9, is a relative newcomer to the woodworking trades. It is a versatile machine often referred to as the portable jigsaw as it is capable of performing most of the operations common to the jigsaw and bandsaw.

Saber saws are simple machines and all are essentially the same, consisting of a power unit, base, chuck, and switch. The saw blade may travel in a straight up and down motion or in an orbital path as shown in figure 4-10.

The power unit is usually 120 volts a-c or d-c and is available in either standard or heavy duty ratings. It must be remembered though, that although the saw is available in the heavy duty rating, it is not suitable for heavy duty work. It is a slow cutting machine, the accuracy of which is solely dependent on the skill of the operator.



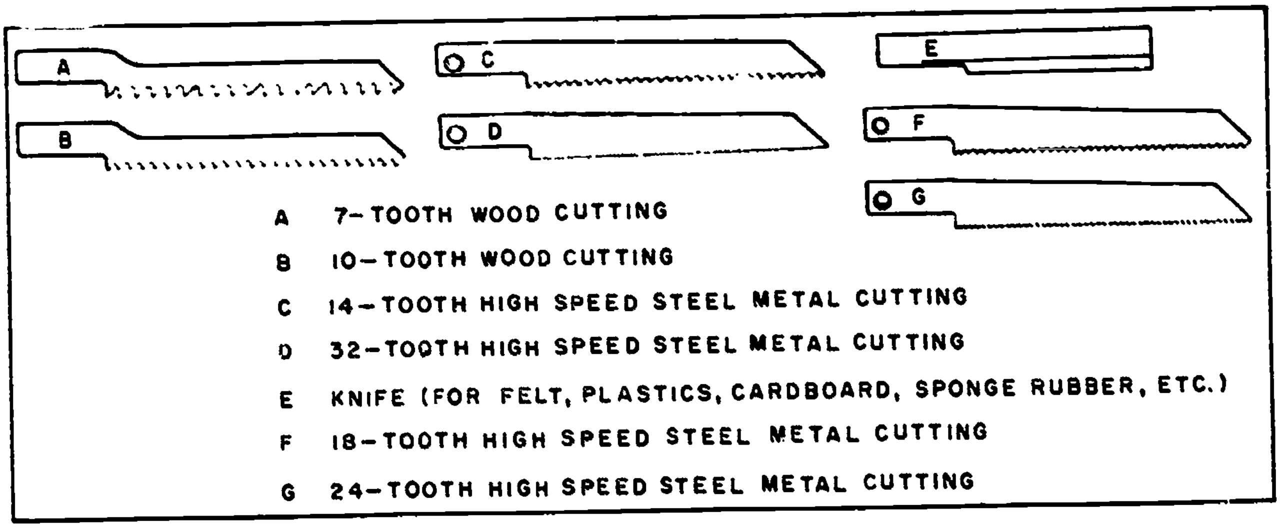
44.213(68C)X
Figure 4-9.—Saber saw.



68.204X
Figure 4-10.—Orbital action.

Because of the wide variety of blades made for this saw, figure 4-11, it is capable of cutting practically every type of construction material as well as plastics, leather, rubber, and metals, which includes steel if the saw is used for short periods of time.

Although the saber saw can be used for making straight cuts, the main advantage is its ability to cut curved or irregular work. The most distinctive feature of the saber saw is its ability to make pocket cuts without you having to drill



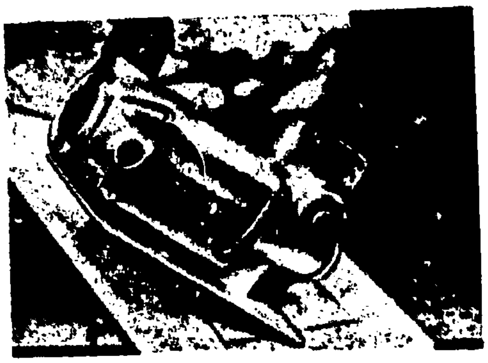
29.15(68C)X

Figure 4-11.—Types of saber saw blades.

a preliminary hole or make a lead-in cut. This feature is referred to as "plunge cutting."

In order to make a plunge cut, first measure the area to be cut out and mark it clearly with a scribe, pattern knife, or pencil. Choose a convenient starting point and hold the saw over that point and inside the line of the waste. Next, tip the machine forward until the front edge of the base rests firmly on the surface of the material and the top of the blade is well clear of the work surface as in figure 4-12. Start the motor and, after the blade has reached its full speed, lower the back of the machine and the blade will bite smoothly into the surface and down to its full depth. Do not move the machine forward until the base is fully seated on the surface of the work. As soon as the saw is fully seated on the stock, guide it along the inside of the marked area. If sharp corners are desired, cut right up to the corner of the marked edge. Stop and back up just a little, start the turn, and cut along the side. Do the same at each corner until you end up where you started. Now, go back and cut into each corner from the opposite direction. The base of the machine is wide enough so that you will have a solid guiding surface on either side of the cut.

When cutting with the saber saw, never force the machine. This will result in a rough cut, may damage the motor, and will surely break the blade.



68.205X

Figure 4-12.—Starting the plunge cut.

PORTABLE ELECTRIC SANDERS

While the portable electric sanders are seldom used in the manufacture of patterns, they are used extensively in the Navy's woodworking shops for finishing cabinet work and carpentry projects as they are great time savers.

There are three basic types of portable electric sanders, belt, disk, and finishing.

BELT SANDERS

In woodworking, the belt sander is the most widely used of the portable sanders as it is fast, versatile, and can rough sand as well as finish sand.

Typical belt sanders are shown in figures 4-13 and 4-14 with the component parts identified.

The belt sander is usually equipped with a 110 volts a-c or d-c motor delivering from 3/4 to 1 1/4 hp. This power is transmitted from the motor to the rubber-covered traction wheel, figure 4-4, through a set of reduction gears on the heavy duty models or a belt drive on the lighter duty models. The traction wheel drives an endless abrasive belt over the idler wheel in the front of the machine. This wheel not only serves as a support for the abrasive belt, but also functions to center (track) the belt on the sander.

A dust collector, figure 4-13, is available as an added feature for most belt sanders. It consists of a small air impeller which pulls the dust through itself and deposits it into a dust bag in much the same manner as a vacuum cleaner.

Portable belt sanders are made in 2, 3, 4, and 4 1/2 inch sizes. The size is determined by the width of abrasive belt that the particular sander is designed to use.

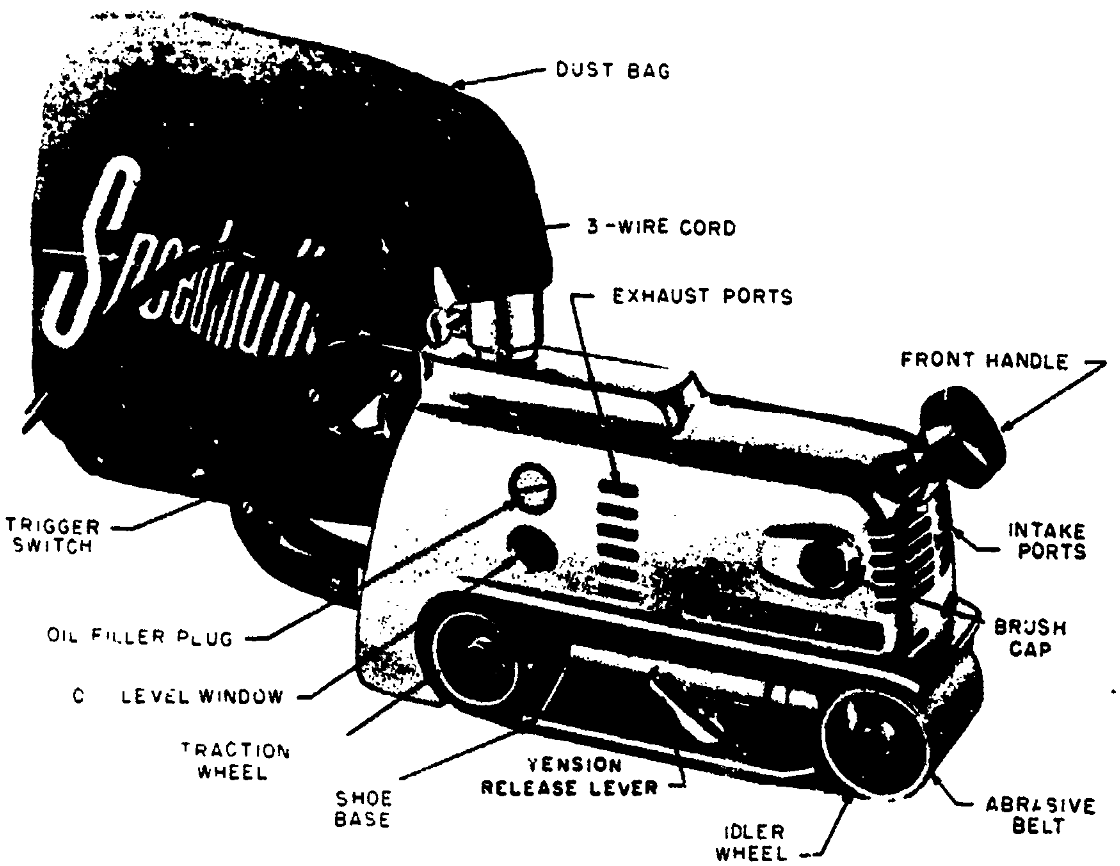
Portable belt sanders also vary from 21 to 26 inches in the length of the abrasive belt that the particular sander is designed to use. Sometimes this measurement is included in the size description of the sander. For instance, you may have a 4 1/2 x 26 inch portable belt sander in your shop. This tells you that this particular sander will use only an abrasive belt measuring 4 1/2 inches wide and 26 inches long.

Abrasive Belts

Abrasive belts designed for the portable belt sander are either cloth or paper and are coated with one of three types of abrasive material (grit); garnet, aluminum oxide, or silicon carbide.

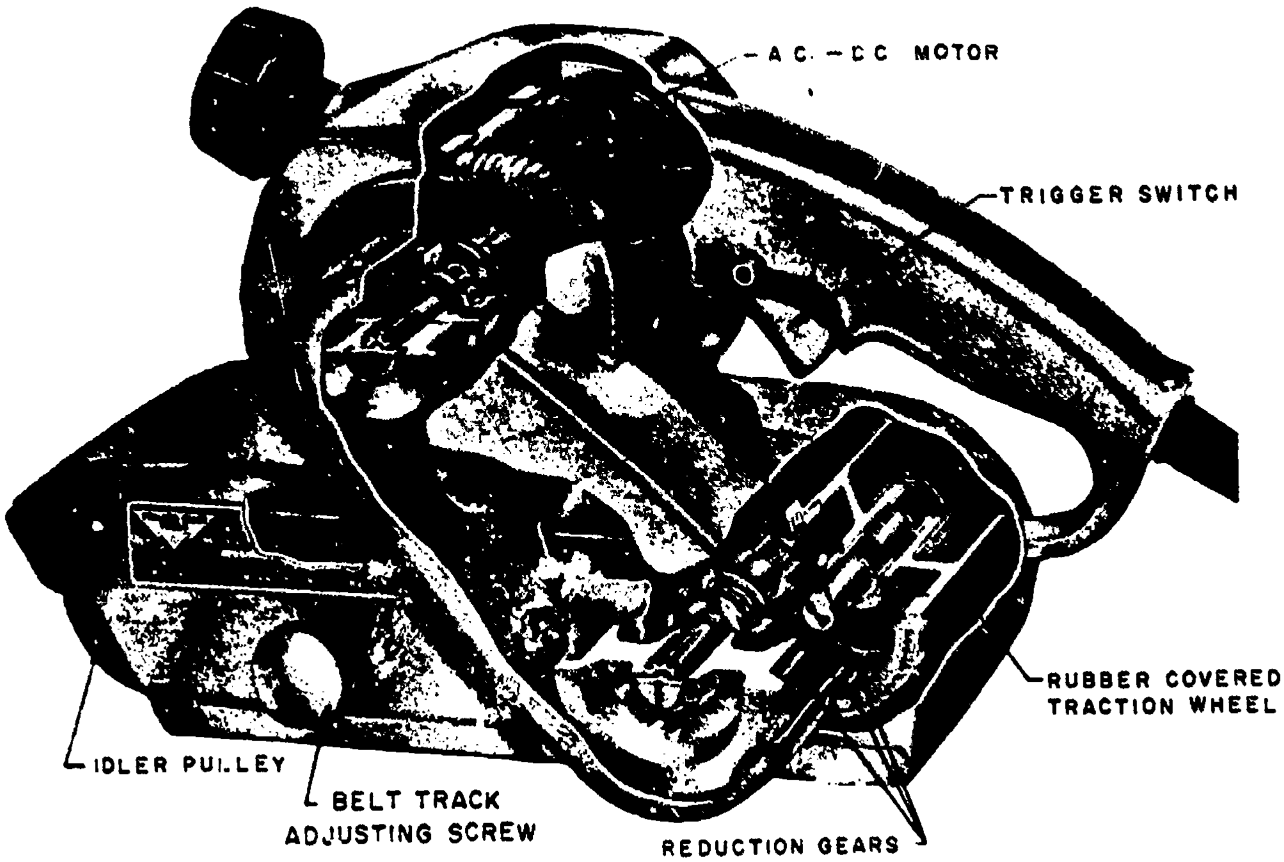
Garnet is the softest of these three materials. It is used as an abrasive coating over paper belts and is only suitable for soft textured woods.

Aluminum oxide is a harder and more durable abrasive. It is applied to cloth belts and may be



29.139(68C)AX

Figure 4-13. — Heavy duty portable belt sander.



29.139(68C)BX

Figure 4-14.—Cutaway of a light duty portable belt sander.

used for sanding all woods as well as nonferrous metals. Although aluminum oxide belts are more expensive than garnet belts, most craftsmen prefer to use them.

Silicon carbide is an extremely hard abrasive that is seldom used in the carpenter shop. It is used primarily for sanding stone, marble, glass, and ferrous metals.

All sanding abrasives are classed as either open coat or closed coat. This simply means that the abrasive material is spaced apart or close together. Open coat abrasive belts are used for fast, rough sanding and are more suited for soft woods. Close coat abrasive belts are more suited for final finishing and for hardwoods.

On the inside of every sanding belt is information identifying the type of abrasive, belt material, whether it is open or close coat, the coarseness of the abrasive, and an arrow which is used as a reference in mounting the belt. This arrow must always point in the direction of rotation.

More information on sanding abrasives is contained in chapter 6 of this manual.

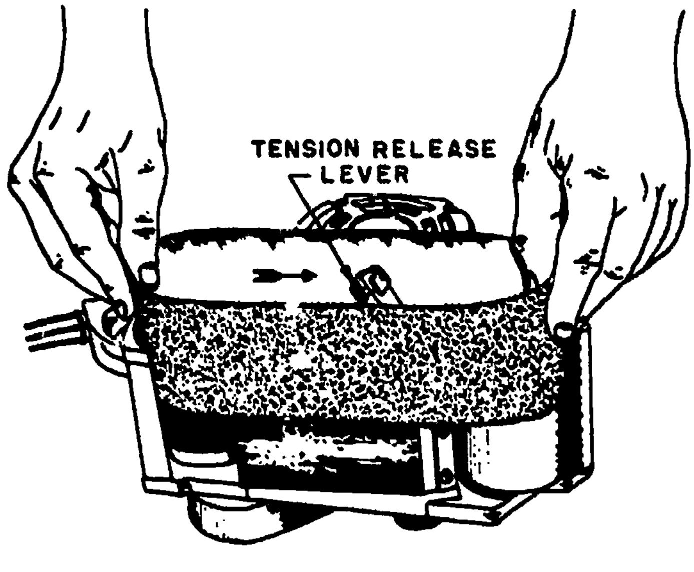
Belt Installation

The steps of the procedure for installing sanding belts are as follows:

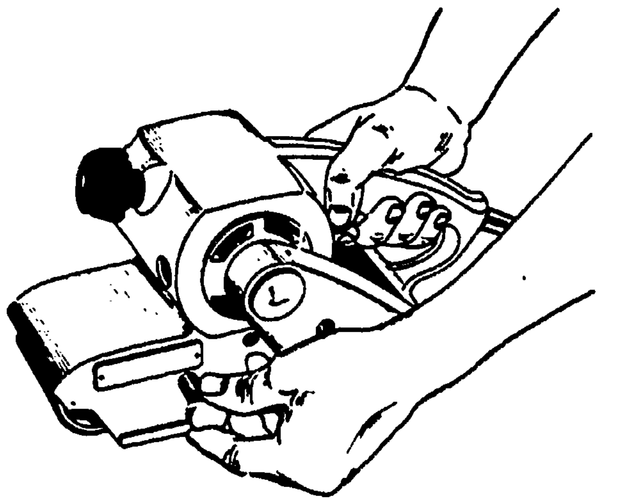
1. After selecting the right size belt having the proper abrasive grit for the job, lay the sander on its left side and retract the idler wheel by releasing the tension release lever (fig. 4-15). This decreases the span between the traction wheel and the idler wheel which permits the belt to be easily slipped into place.

2. Position the belt on the traction and idler wheels so the outer edge of the belt is flush with the ends of both wheels and the arrow inside the belt is pointing in the direction of rotation (fig. 4-15).

3. Reset the tension release lever to restore tension on the belt.



29.139(68C)CX
Figure 4-15.—Changing sanding belt.



29.139(68C)DX
Figure 4-16.—Aligning belt.

The next step is to track the belt. Correct tracking is very important as either the sander or the work will be damaged if the belt is allowed to run off center.

To track the belt, hold the sander by its rear handle with the right hand and tilt the sander back so the belt is running free. Start the motor and adjust the belt track adjusting screw either right or left (fig. 4-16) until the belt runs in the center of the traction and idler wheels.

The track will usually have to be readjusted from time to time as the sanding belts have a tendency to stretch.

NOTE: NEVER operate the belt sander with the belt running off center.

Operation of the Belt Sander

It is important to know how to use a belt sander properly. Since it is a fast cutting machine, it can ruin a job very easily if used improperly, and has done so on many occasions.

The best way to learn how to use the belt sander is to practice on scrap material until you are thoroughly familiar with the "feel" of it. The following are general procedures to be followed in using the belt sander:

1. Always be sure that the work to be sanded is secured so that it cannot move. The belt sander exerts a tremendous pulling force which can move very large work.

2. After complying with the general safety precautions discussed in the front of this chapter, lift the sander from the work by grasping both the front and rear handles and start the motor.

3. Carefully place the moving belt on the surface of the work, letting the rear of the belt gently touch first.

4. Move the sander forward as you level it. Do not press down on the sander. The weight of the machine is sufficient to produce the necessary sanding action.

5. Keep the sander moving with long overlapping strokes. Never pause during the sanding operation as the sander will quickly sand a depression in the work.

6. Be especially careful not to let the front or back of the sander drop when running out to the end of the work as this will round the edges.

7. Upon completion of sanding, lift the sander from the work and then stop the motor. Do not stop the sander while it is resting on the work, as this will tend to tear the grain of the wood and result in a rough surface.

When it is necessary to remove a large amount of material, use a coarse belt and position the sander diagonally to the grain of the wood, first left and then right, while moving the sander with the grain of the wood in overlapping strokes. This produces a faster sanding action and minimizes the possibility of creating an uneven surface.

When finish sanding, always use a fine grit abrasive belt and always position the sander parallel to the grain of the wood.

The belt sander can also be used for sanding concave surfaces with the addition of the special shoe base shown in figure 4-17. It is used in place of the regular shoe base and has a soft rubber base which permits the belt to conform to curved and irregular surfaces.

FINISHING SANDER

The finishing sander (fig. 4-18) is designed for fine sanding where only a small amount of material must be removed to obtain a desired degree of surface smoothness.

29.139(68C)EX

Figure 4-17. —Special concave sanding shoe mounted on a belt sander.

Prior to the development of the finishing sander, this phase of finishing had to be done by hand and was tedious and time consuming. While the finishing sander is not suited for all finish sanding operations and should not be used for finish sanding patterns, it is a very effective timesaver when used on cabinet and carpentry projects.

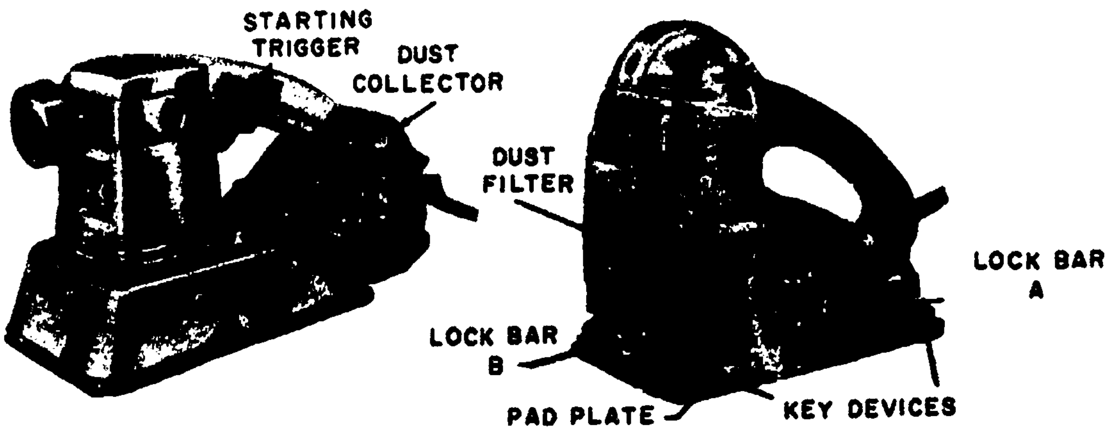
There are three types of finishing sanders made--orbital, reciprocating, and combination orbital-reciprocating, and they are available in either heavy duty or standard duty ratings.

The orbital sander moves the sanding pad in a circular motion and is preferred for general finish work, as it cuts faster than the reciprocating type. However, it does leave small (3/16" to 1/4") swirls on the surface which can be objectionable if a high quality finish is desired.

The reciprocating sander is usually a vibrator type machine and sands with a slight back and forth motion. While this machine is much slower than the orbital sander, it produces a fine quality, with the grain finish that is suitable for the finest of finishes.

The most versatile finishing sander made is the orbital-reciprocating type. By moving a lever located above the sanding pad, the machine can be made to sand with an orbital or reciprocating action.

The pad length of most finish sanders is slightly shorter than the width of a standard sheet of sandpaper and the pad width is usually equal to 1/3 of the length of a standard sheet of sandpaper. This enables you to cut three sanding pads from a sheet and attach them to the machine as needed by slipping them under



68.206(68C)AX

Figure 4-18. —Typical finishing sanders.

a spring or friction device located on each end of the sander and pulling them tight (fig. 4-19). Special care must be taken in order to keep the sandpaper tight on the sander otherwise, the motion of the machine will not be transmitted to the sandpaper.

The selection of the right type and grit of coated abrasive for a particular job is important in finish sanding.

The artificial abrasives (silicon carbide and aluminum oxide) are best as they last longer and cut faster. However, the natural abrasives (garnet and flint) are very often used for sanding soft woods and for removing old finishes as they cost a great deal less.

Table 4-1 is a table of abrasives which will be helpful in choosing the right abrasive for most jobs.

DISK SANDER

The portable electric disk sander is a good machine for removing old finishes and for rough sanding, but is not suitable for finish sanding wood.

Figure 4-20 shows the two types of disk sanders that are usually found aboard Navy ships.

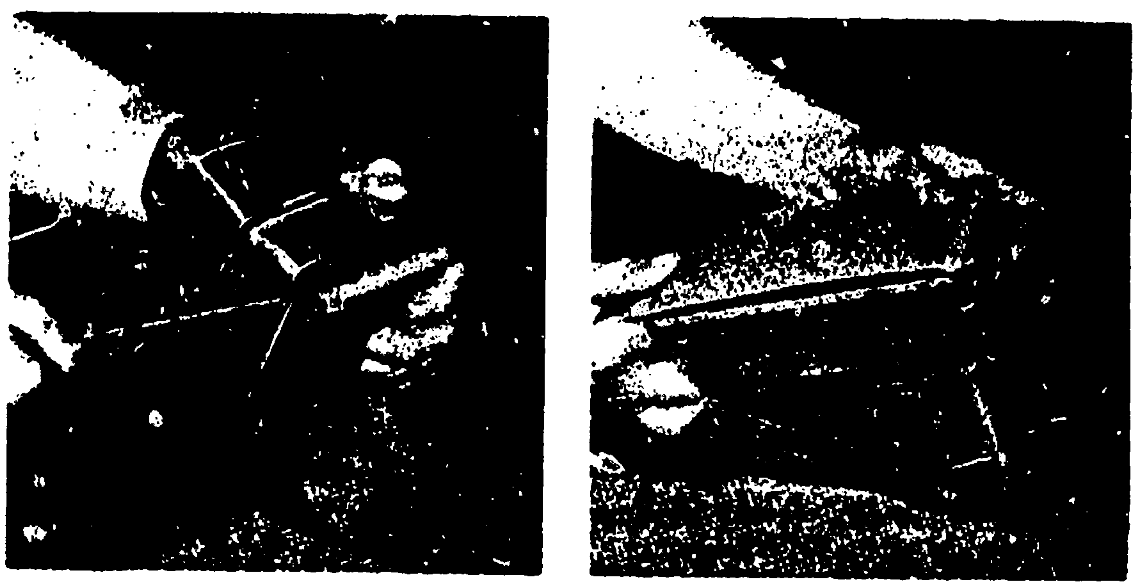
The disk sander is made in heavy and standard duty ratings and is available in a wide variety of speed ranges.

When using the disk sander, tip the machine slightly with just enough pressure to bend the disk as shown in figure 4-21. Be sure to keep the sander moving, preferably in long-sweeping arcs, to minimize the possibility of gouging the surface.

PORTABLE ELECTRIC HAND DRILL

The portable electric hand drill is probably the most used of all portable tools. It is made in more types, capacities, and by more manufacturers than any other portable power tool. A lightweight 1/4" capacity pistol drill is shown in view A of figure 4-22. A heavy duty 1/2" short type drill shown in view B of figure 4-22, is designed to get into tight spots, and ideal for heavy boat work.

The size of electric drills is determined by the maximum drill diameter that the chuck will hold. Common sizes are 1/4", 5/16", 3/8", 1/2", 5/8", 3/4", and 1". The chuck speed, which is fixed for each size drill, decreases as the size of the drill increases. The drill speed of a 1/4" drill, for instance, might be 2000 rpm at no load. The same type drill in 5/16" size



68.206(68C)BX

Figure 4-19.—Mounting sandpaper on finishing sander.

Table 4-1.—Abrasive Recommendations for Finishing Sanders

KIND OF MATERIAL	MATERIAL REMOVAL		MATERIAL REMOVAL WITH FAIR FINISH		FINE FINISH	
	GRIT	SIZE OF GRIT	GRIT	OF GRIT SIZE	GRIT	OF GRIT SIZE
Soft Wood Soft Wallboard	Cabinet Paper (Garnet)	2-1	Cabinet Paper (Garnet)	½-2/0	Finishing Paper (Garnet)	3/0-5/0
Plastics	Cabinet Paper (Aluminum Oxide)	60-100	Wet Paper "C" Weight (Silicon Carbide)	120-220	Wet Paper "A" Weight (Silicon Carbide)	240-600
Hard Wood Hard Compositions Wallboards, Etc.	Cabinet Paper (Aluminum Oxide)	36-50	Cabinet Paper (Aluminum Oxide)	60-100	Finishing Paper (Aluminum Oxide)	120-180
Soft Metals	Metal Working Cloth (Aluminum Oxide)	36-60	Cabinet Paper (Aluminum Oxide)	80-120	Wet Paper (Silicon Carbide)	150-320
Hard Metals	Metal Working Cloth (Aluminum Oxide)	40-60	Metal Working Cloth (Aluminum Oxide)	80-120	Metal Working Cloth in Oil (Aluminum Oxide)	150-320 or crocus
Hard Brittle Minerals and Compositions	Cabinet Paper (Aluminum Oxide)	50-80	Finishing Paper (Aluminum Oxide)	100-180	Wet Paper "A" Weight (Silicon Carbide)	220-320
Hard Tough Minerals and Compositions	Metal Working Cloth (Aluminum Oxide)		Metal Working Cloth (Aluminum Oxide)	80-120	Finishing Paper (Aluminum Oxide)	150-320
Paints and Varnishes	Cabinet Paper (Opencoat Garnet)	2½-1½			Wet Paper "A" Weight (Silicon Carbide)	240-400

68.207X

is 1000 rpm at no load, and the 3/8" size of the same drill is 850 rpm at no load.

The drill consists of a motor housing which contains the power unit and a series of gears for transferring the power to the chuck. The chuck may be of the keyless type or the more preferred key type. Both types contain hardened steel jaws which are tightened and released with a threaded sleeve.

There are accessories made for the portable electric drill that enable you to use it for sanding, buffing, sawing (both as a saber saw and as a circular saw), routing, as an electric screwdriver, wire brushing, paint mixing, and grinding, just to mention a few.

When using the portable electric drill, the same safety precautions are to be observed as when using any other portable power tool.

PORTABLE ELECTRIC ROUTER

The router (fig. 4-23) is the most versatile of all the portable power tools, for it both cuts and shapes. It can do most of the jobs any other power tool can do as well as the work of the lathe, shaper, and other highly sophisticated woodworking equipment.

The primary parts of the router (fig. 4-24) are much the same as those of other portable power tools. It contains a base, a chuck to hold the cutting tool, and a power unit which is usually more powerful than those of any other portable power tool.

Basically, the router is designed to cut into the surface of the stock, routing out areas, making all types of joints, shaping edges, cutting grooves, mortising, or doing any cutting job thay may need to be done. Actually, the router can do about 90 percent of all woodworking jobs.

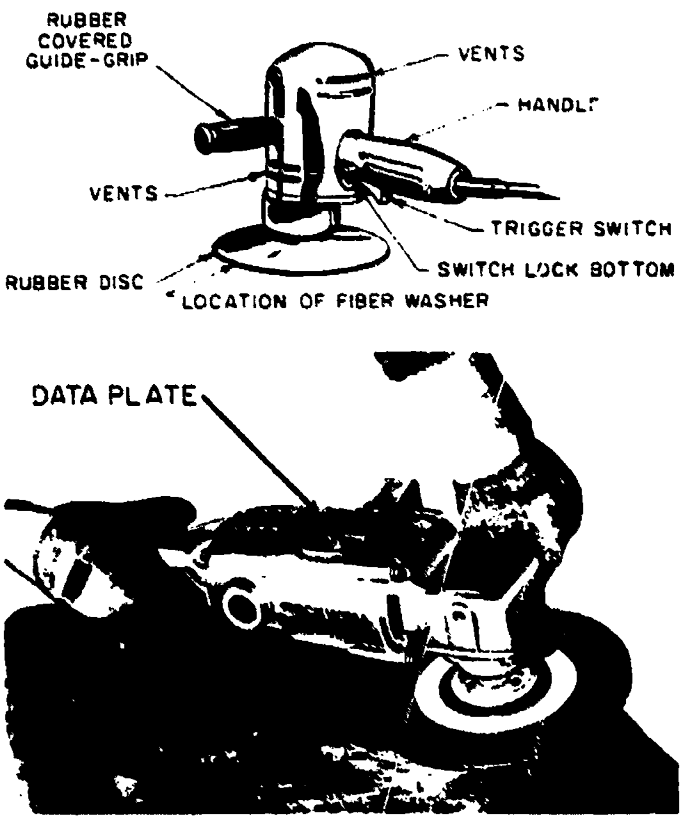


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Figure 4-20.—Portable electric disk sanders.

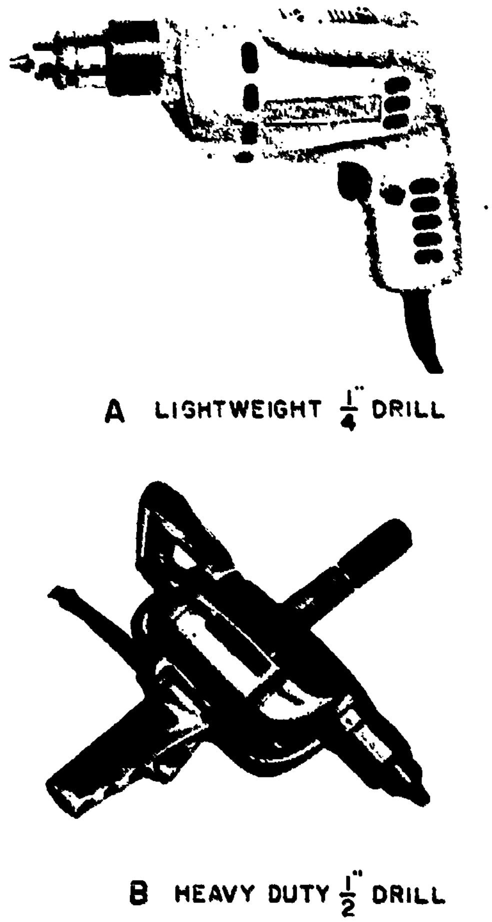

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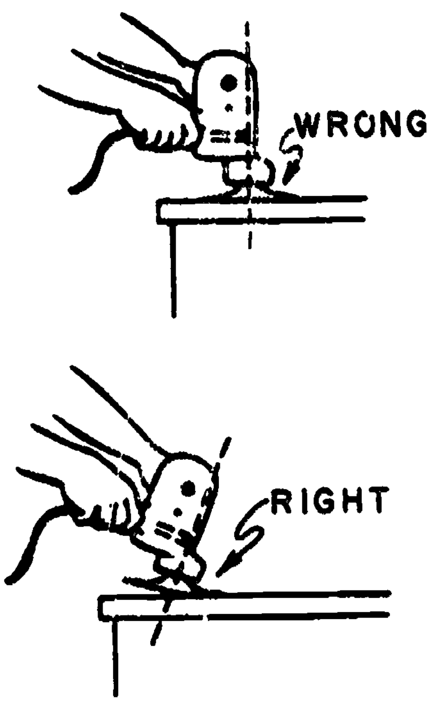
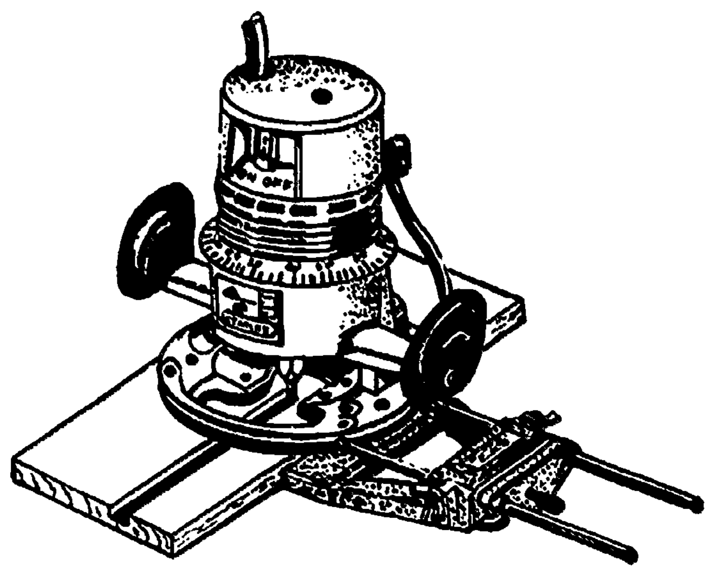
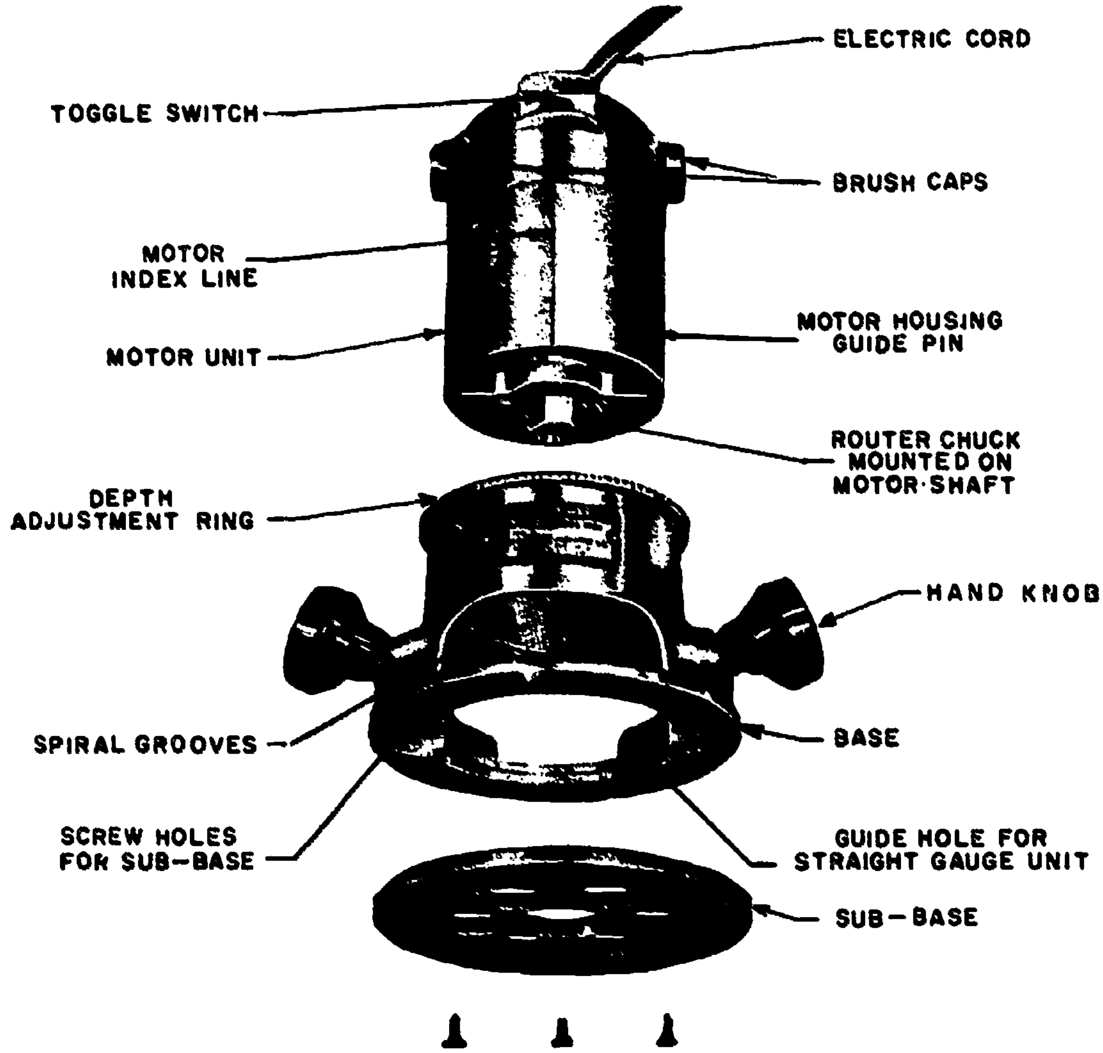
Figure 4-22.—Typical drill motors.



68.208X
Figure 4-21.—Using disk sander.



68.209(68C)A
Figure 4-23.—Portable router.



68.209(68C)BX

Figure 4-24. — The router assembly.

The router depends on sharp, precision shaped cutting bits and very high rpm (18,000 to 27,000 rpm) compared to 5,000 rpm for a high speed drill motor. Because of this high speed, the router is able to provide a cut that is smooth and accurate, requiring little or no sanding.

The router is ideal for cutting decorative edges, no matter how simple or intricate they may be; it is probably used for this purpose more than for any other. It can be used for many other things such as trimming veneers and plastic laminates, cutting out recesses to a required depth, cutting out recesses for inlays, making decorative cutouts, and as a high speed grinder, just to mention a few.

The size of the router is determined by its rated horsepower which ranges from 1/4 to 3 1/4 hp. The heavy duty routers (usually from 1 to 3 1/4 hp) are referred to as production machines and may weigh up to 25 lbs. These machines are not suitable for some of the smaller, more intricate jobs, but are still quite easy to handle for their size.

The router chuck is a wrench tightened collet type and is most commonly designed for 1/4" shank bits. However, 1/8" to 1/2" collets are available.

A knowledge of the bits made for the router is necessary in order to use the machine effectively.

Basically, there are two types of router bits — edge cutters and groove cutters. Rounding over, cove, chamfering, beading, and rabbeting bits are but a few of the edge cutting bits made for the router. Some of the groove cutting bits are the veining, V-groove, corebox, and dovetail.

Some of the edge cutting bits have a "pilot" below the cutting portion of the bit which acts as a guide.

The standard material of which bits are made is high-speed steel. Most bits are also available in tungsten carbide which will hold an edge about twenty-five times longer than a standard bit and are necessary when cutting fiberglass, hard plastic, and hard plastic laminates.

Figure 4-25 illustrates some of the bits available for the router.

Figure 4-26 illustrates the grinding wheels available for the router. These are important to the upkeep of the router bits for these bits must be kept sharp at all times. A dull bit is not only dangerous, but it can ruin a job. The grinding wheels are specially shaped for sharpening the intricate shapes of the router bits.

Many books could and have been written on the subject of using the router. Since this manual cannot possibly begin to cover the subject fully, we will only point out the few safety factors involved when using the machine and go on to discuss one of the many attachments for the router — the corebox machine.

The electrical safety precautions for the router are the same as for all portable power tools.

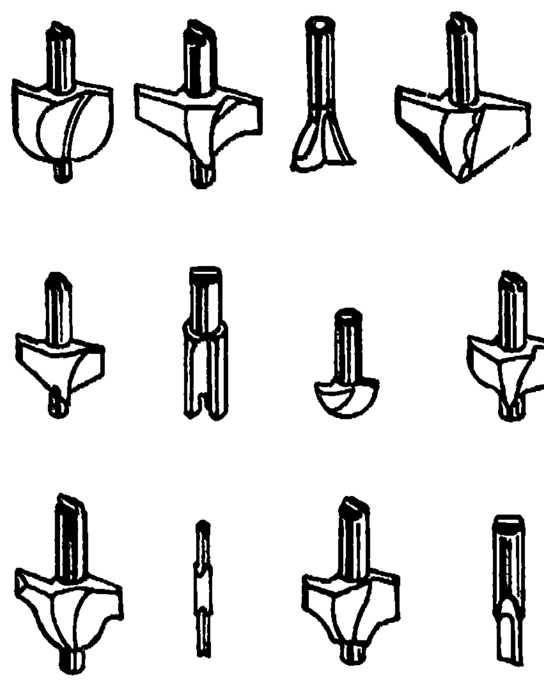


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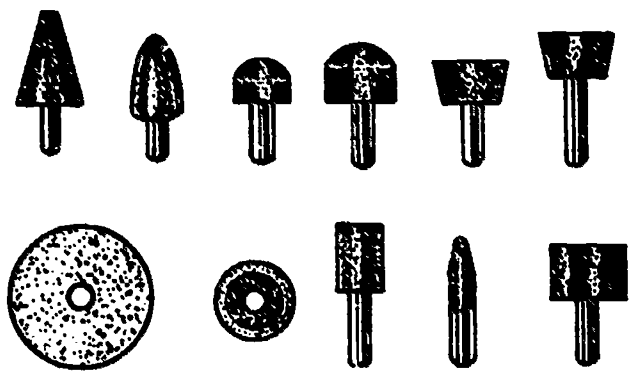
Figure 4-25. — Router bits.



28.254(68C)

Figure 4-26. — Grinding wheels for sharpening router bits.

The mechanical safety precautions consist of ensuring that the bit is wrench-tightened when mounted into the machine and all other adjusting devices are tight before starting the machine. Always make a test cut on a piece of scrap material before using the machine on the actual job, always cut against the rotation of the machine, and do not overload the machine by taking too heavy or too fast a cut. If burning of the stock occurs or the router is bogging down, you are either taking too fast a cut, too heavy a cut, or your bit is dull. Take the appropriate corrective action before proceeding.

PORTABLE ELECTRIC COREBOX MACHINE

One of the few portable power tools made for pattern work is the corebox machine. It is fast, accurate, and simple to operate which makes it a definite asset in any pattern shop.

The corebox machine is a light weight (23 to 27 lbs.) machine which is designed to produce cylindrical, spherical, or elbow-shaped cuts complete with fillets and draft in less than half the time (in most cases) required to accomplish the same jobs on the lathe. It will work elbow diameters up to 7 1/2" and leaves a smooth and completely accurate finish, needing only light finish sanding.

The corebox machine, figure 4-27, is essentially a router motor mounted on a yoke so as to swing in a circular arc from crank arms which, in turn, are controlled in unison by hand wheels at the will of the operator. The radius of the cuts is controlled by adjustments of the ends of the yoke along each crank arm.

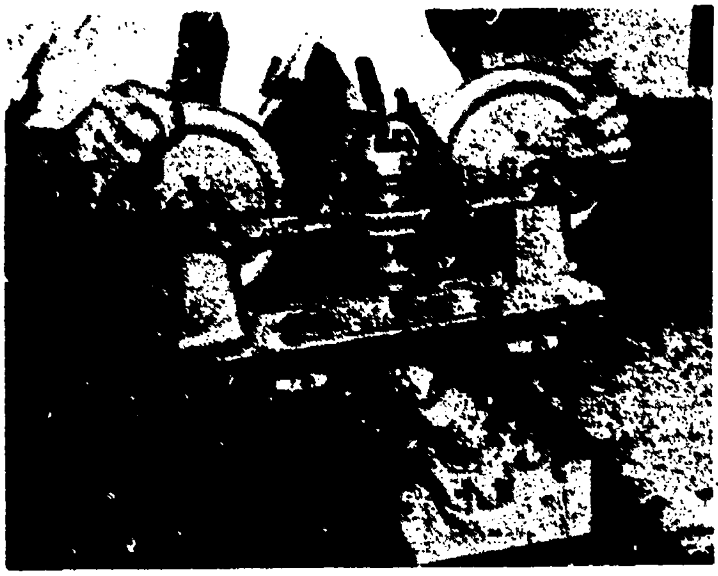


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Figure 4-27. — Corebox machine.

The entire machine is also designed to be moved along the corebox or other work and is provided with self-aligning guides for this purpose. In this way, every cut is made perfectly square with the center line.

Provision is made to limit the circular movements of the cranks and, thus, the cutter at any predetermined position in the arc. This is accomplished by drill rods passing through the yoke and adjusted vertically by set screws. The end of these rods strike the base and limit the cut to whatever degree of arc is desired from 0 to 45 degrees, using the top surface of the box as zero. Beyond 45 degrees and up to 90 degrees (that is where the movement is more nearly sideways than up and down), adjustable triangles are provided which engage a pin on the yoke itself.

On the left end of the machine under the hand wheel is a click lever which may be ON or OFF while operating. When ON, the click lever rides on the hand wheel until the crank arm reaches a level or zero position; then it automatically locks the movement of the crank arms in a starting or resetting position. Adjustment for a larger diameter may be made while the motor is running, after which both knurled hand wheels on the crank arm must be tightened securely by hand (no wrench is required). The click arm is then released and allows the arm to ride the wheel until a half circle cut is completed. Then the crank arms will lock again at the zero point for another adjustment.

The click arm will stay in the OFF position when not needed.

A brake tension is provided on the right end of the machine under the hand wheel to be used to lock the machine in any position either when the cutter is in the box or when the cutter is out. It is also used to provide certain tensions for different operations.

A centerline and a dot center are provided on each side of the machine to center same with the center line on the job. The dot center is used in connection with a pair of dividers to check the center. If the first setting should be off slightly when the trial cut is made, a micrometer adjustment is provided on the right hand side of the machine. The close adjustment is made by turning the screw right or left after the two screws in the sub-base have been loosened. These screws hold the two base plates together. After the close adjustment is made, these two screws must again be tightened before starting the machine.

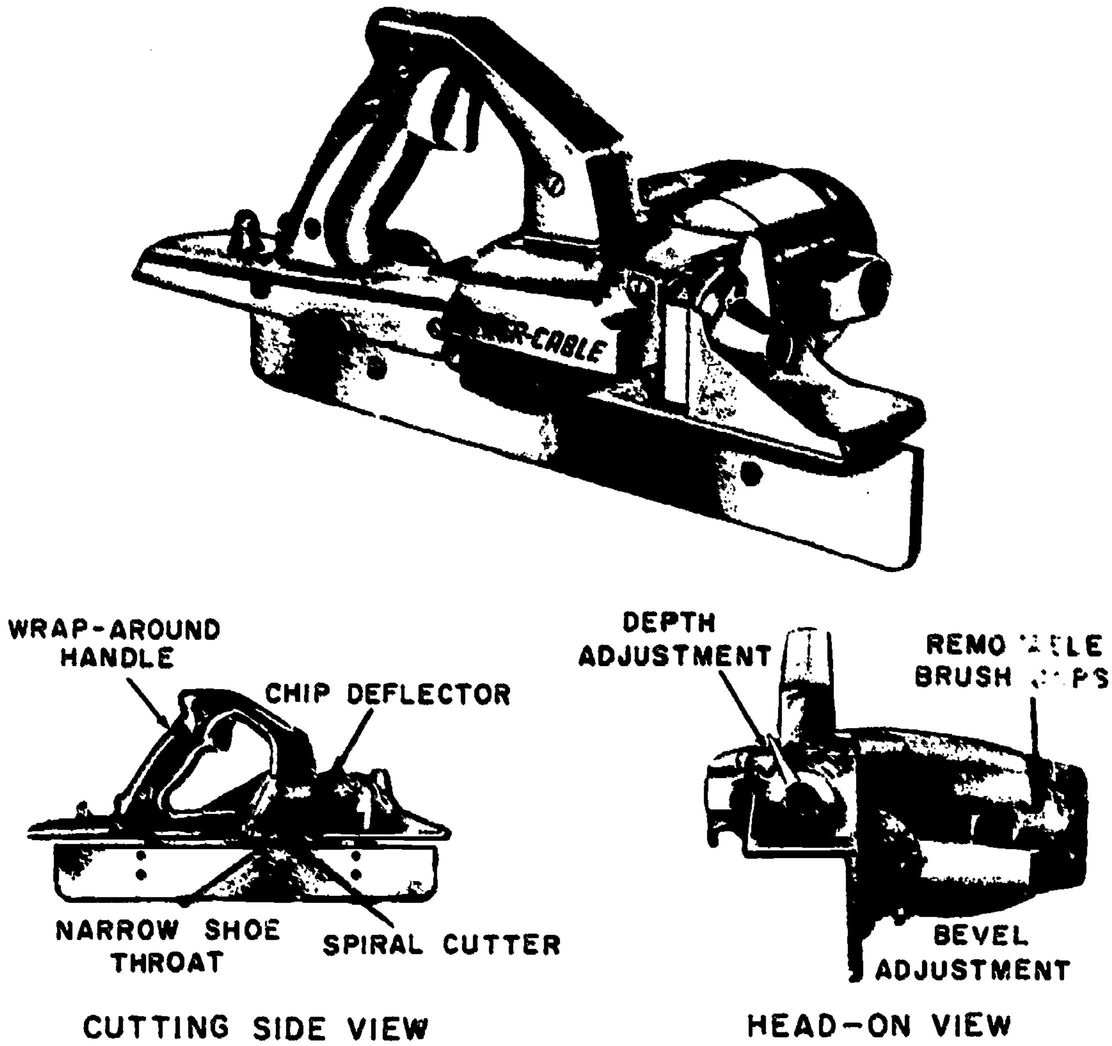
PORTABLE ELECTRIC POWER PLANE

The portable electric power plane (fig. 4-28) is widely used for trimming panels, doors, frames, etc. It is a precision tool capable of exact depth of cut up to 3/16" on some of the heavier models. However, the maximum safe depth of cut on any model is 3/32" in any one pass.

The power plane is available as a complete unit or as an accessory for some routers and can be used to good advantage on anything a hand plane can be used on, except for surface planing.

The power plane is essentially a high speed motor which drives a cutter bar, containing either straight or spiral blades, at high speed.

Operating the power plane is simply a matter of setting the depth of cut and passing the plane over the work. The stock being planed should be held in a vise, clamped to the edge of a bench, or otherwise firmly held after first making careful measurements of the piece, where it is to fit, and determining how much material has to be removed. Check the smoothness and straightness of all the edges. If a smoothing



68.212X

Figure 4-28.—Portable electric power plane.

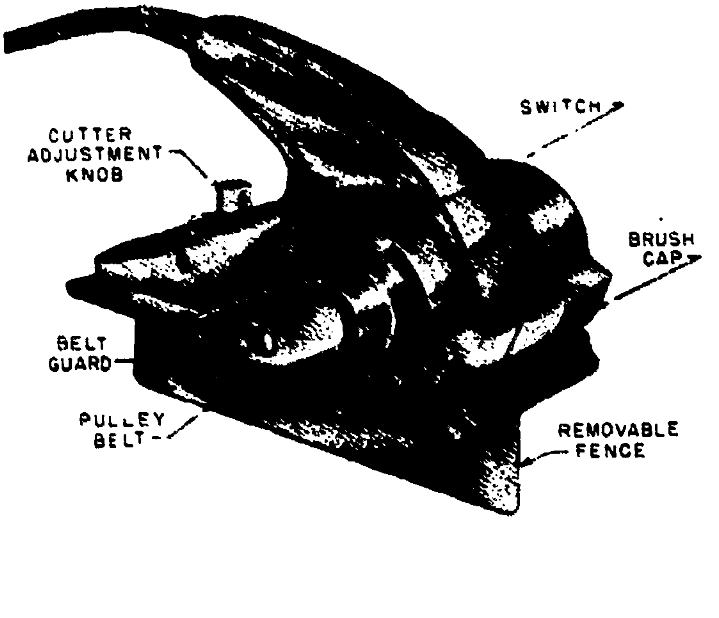
cut is desired, make that first, then check the dimensions again. Make as many passes as necessary with the plane to reach the desired dimension, checking frequently so as not to remove too much. The greater the depth of the cut, the slower you must feed the tool into the work. Feed pressure should be enough to keep the tool cutting, but not so much as to slow it down excessively. Keep chips off the work, as they can mar the surface as the tool passes over them.

The L-shaped base or fence of the plane should be pressed snugly against the work when planing, assuring that the edge will be cut square. For bevel cuts, loosen the setscrew on the base, set the base at the desired bevel, and tighten the setscrew.

PORTABLE ELECTRIC POWER BLOCK PLANE

The power block plane (fig. 4-29) is simply a small version of the power plane. However, it can be used for surface cutting as well as edge cutting, but only where small amounts of material must be removed.

In order to use the plane, grasp the plane as shown in figure 4-30. The index finger is used to actuate the switch. Next determine the grain direction of the stock and position yourself to cut with the grain. Start the plane. After the plane has attained full speed, rest the forward part of the base firmly on the surface to be planed and slowly move the plane forward so the blade contacts the surface. Continue moving



68.213X
Figure 4-29. — Power block plane.

68.214X
Figure 4-30. — Using power block plane.

the plane slowly across the surface without forcing it. Towards the end of the cut, apply greater pressure at the rear of the base so that the plane does not tilt and roll over the edge. Upon completion of planing, lift the plane clear of the work, before turning the switch off.

SPRAY GUNS

A spray gun is a precision tool that mixes air under pressure with paint, breaks it up into spray, and ejects it out in a controlled pattern.

There are several types, either with a container attached to the gun or with the gun connected to a separate container by means of hoses. There are bleeder or non-bleeder, external- or internal-mix, and pressure-, gravity-, or suction-feed guns.

The BLEEDER type of gun is one in which air is allowed to leak — or bleed — from some part of the gun in order to prevent air pressure from building up in the air hose. In this type of gun the trigger controls the fluid only. It is generally used with small air compressing outfits that have no pressure control on the air line.

The NONBLEEDER gun is equipped with an air valve which shuts off the air when the trigger is released. It is used with compressing outfits having a pressure-controlling device.

An EXTERNAL-MIX gun is one which mixes air and paint outside and in front of the gun's air cap. This type of gun can do a wide variety of work and has the power to throw a very fine spray, even of heavy material. It also permits exact control over the spray pattern. An external-mix air cap is shown in figure 4-31.

An INTERNAL-MIX spray gun mixes the air and fluid inside the air cap as pictured in figure 4-32. It is not as widely used as the external-mix gun.

In a SUCTION-FEED spray gun, the air cap, shown in figure 4-33 is designed to draw the fluid from the container by suction — in somewhat the same way that an insect spray gun operates. The suction-feed spray gun is usually used with 1-quart (or smaller) containers.

A PRESSURE-FEED gun operates by air pressure, which forces the fluid from the container into the gun. This is the type (fig. 4-34) used for large-scale painting.

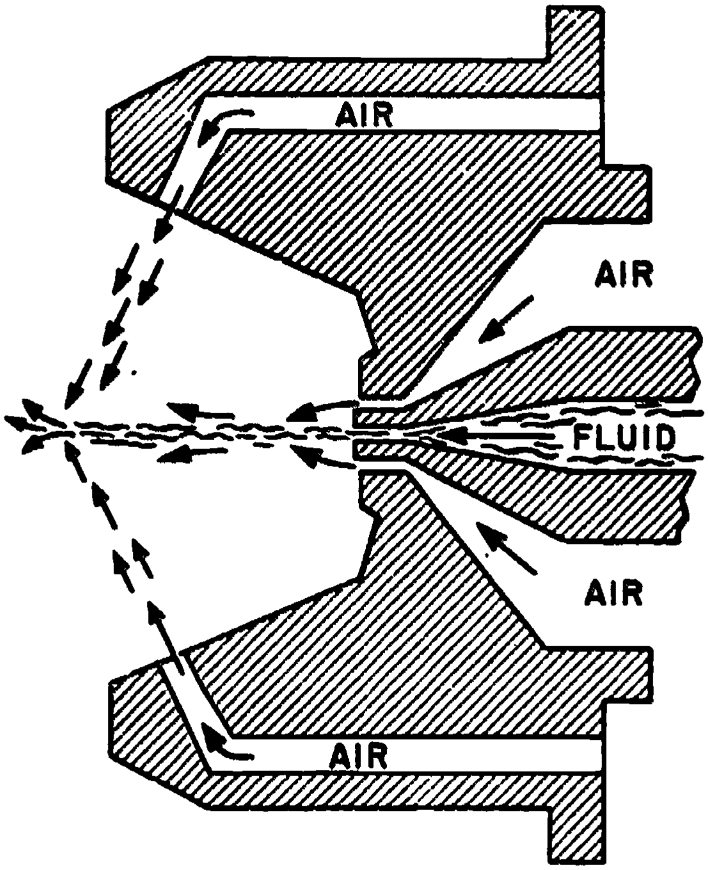


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Figure 4-31. — An external-mix cap.

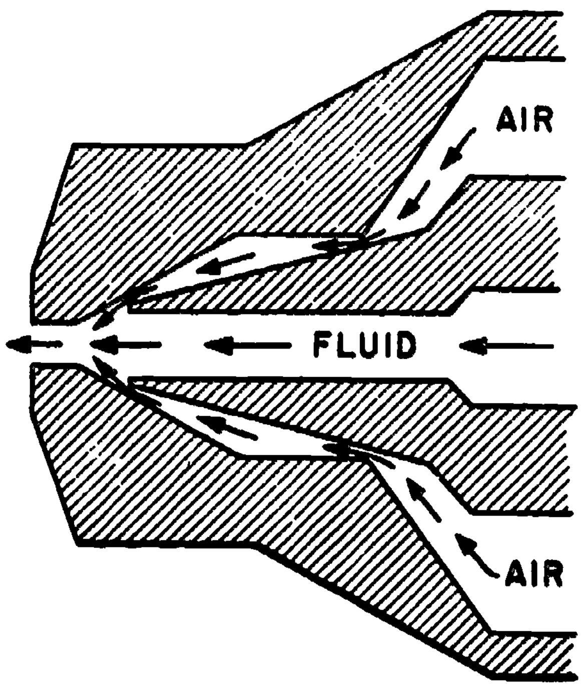

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Figure 4-32. — An internal-mix air cap.

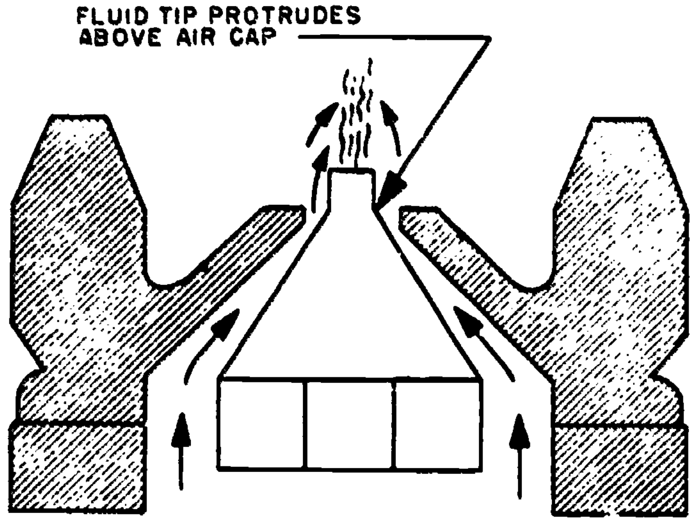

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Figure 4-33. — A suction-feed air cap.

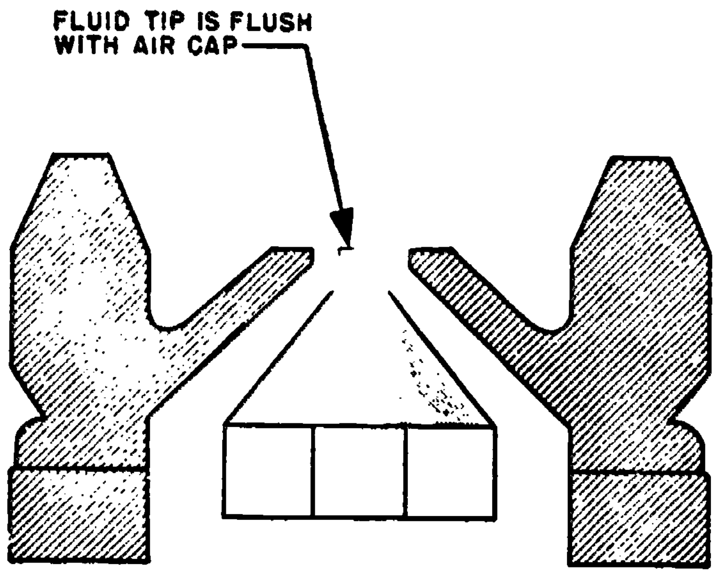

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Figure 4-34. — A pressure-feed air cap.

PARTS OF THE SPRAY GUN

The two main assemblies of the spray gun are the gun body assembly and the spray head assembly. Each of these assemblies is a collection of small parts, all of which are designed to do specific jobs.

The principal parts of the gun body assembly are shown in figure 4-35. The air valve controls the supply of air and is operated by the trigger. The spreader adjustment valve regulates the

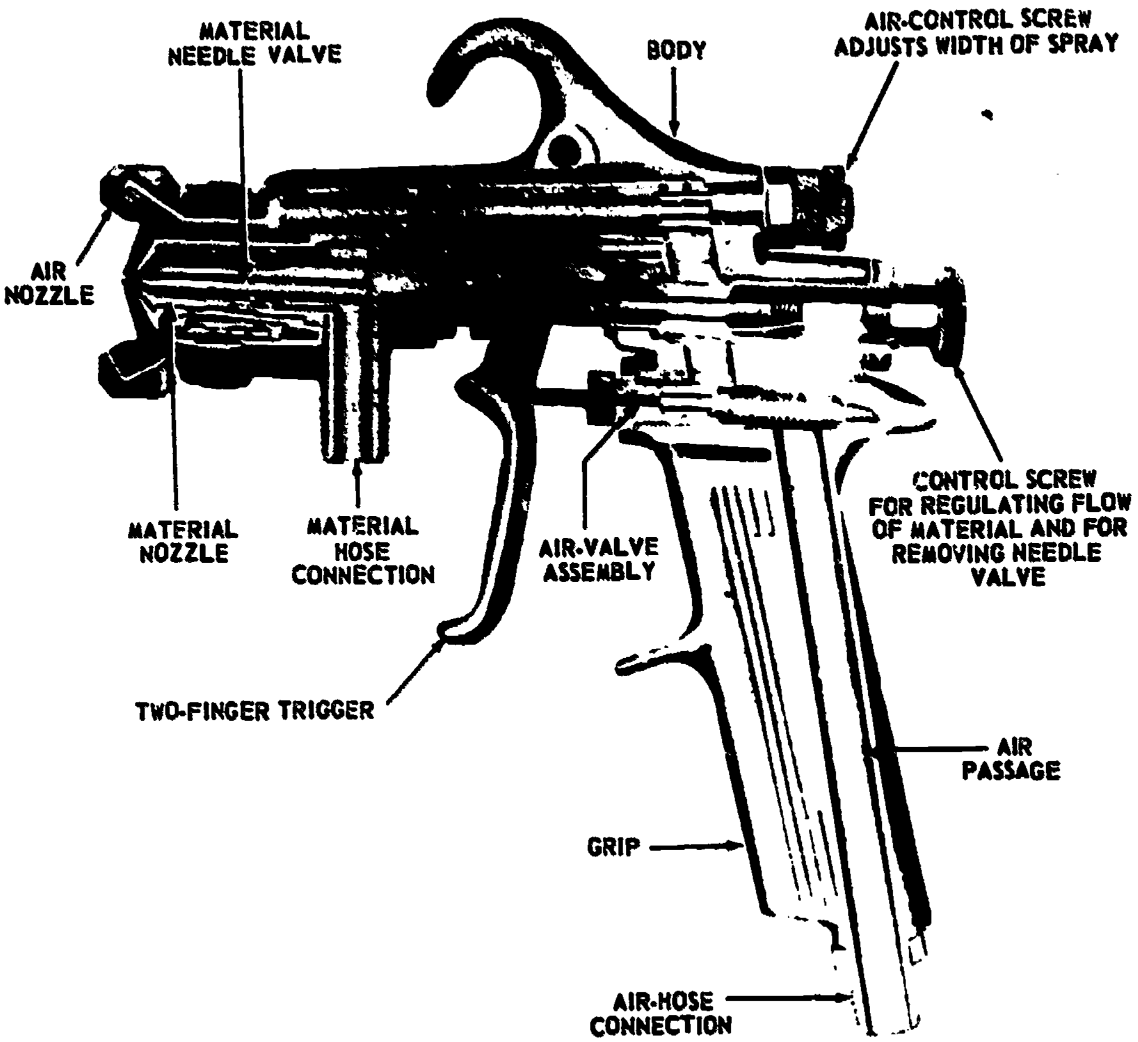

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Figure 4-35. — Cross section of a spray gun.

amount of air that is supplied to the spreader horn holes of the air cap, thus varying the paint pattern. It is fitted with a dial which can be set to give the pattern desired. The fluid needle adjustment controls the amount of spray material that passes through the gun. The spray head locking bolt locks the gun body and the removable spray head together.

Most guns are now fitted with a removable spray head assembly. This type has many advantages. It can be cleaned more easily, it permits quick change of the head when you want to use a new color or material, and, if it is damaged, a new head can be put on the old gun body.

The principal parts of the spray head assembly are the air cap, the fluid tip, fluid needles, and spray head barrel, pictured in figure 4-36.

The fluid tip regulates the flow of the spray material into the air stream. The tip encloses the end of the fluid needle. The spray head barrel is the housing which encloses the head mechanism.

LUBRICATION OF THE SPRAY GUN

Your spray gun also needs lubrication. The fluid needle packing should be removed occasionally and softened with oil. The fluid needle spring should be coated with grease or petrolatum. Figure 4-37 shows where these parts are and also the oil holes in which you occasionally should put a few drops of light oil.

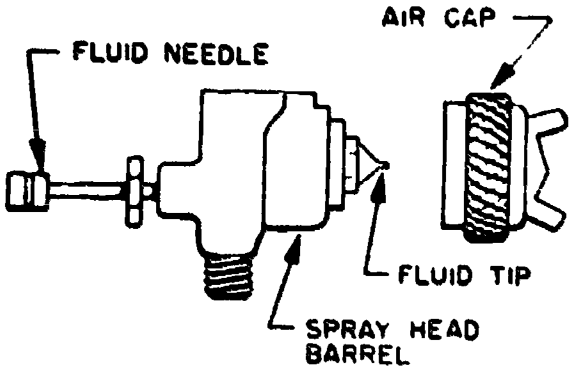

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Figure 4-36.—Principal parts of the spray head.

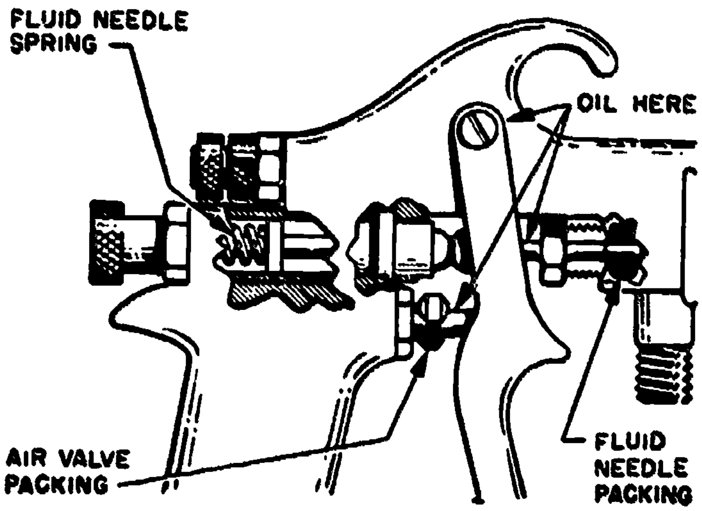

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Figure 4-37.—Lubrication points of a spray gun.

SURFACE PREPARATION

Proper surface preparation is an essential part of any paint job; paint will not adhere well, provide the required surface protection, or present a good appearance unless the surface has been properly treated. Surface preparation consists of (1) thorough cleaning of the surface, and (2) such mechanical or chemical pretreatment as may be necessary.

Wood

Prior to painting, a wood surface should be closely inspected for loose boards, defective lumber, protruding nailheads, or any other defects or irregularities. Loose boards should be nailed tight, defective lumber should be replaced, and all nailheads should be countersunk.

A dirty wood surface is cleaned for painting by sweeping, dusting, and washing with solvent or soap and water. When washing wood, take care to avoid excessive wetting, which tends to raise the grain. Wash a small area at a time, and rinse and dry immediately.

Wood which is to be given a NATURAL finish (meaning wood which will not be concealed by an opaque surface coating) may require BLEACHING to a uniform and/or light color. Bleaching is done by applying a solution of 1 lb of OXALIC ACID to 1 gal of hot water. More than one application may be required. After the solution has dried, smooth the surface with fine sandpaper.

Rough wood surfaces must be sanded smooth for painting. Mechanical SANDERS of various types are used for large areas. Hand-sanding of small areas is done by wrapping the sandpaper around a rubber, wood, or metal SANDING BLOCK. For a very rough surface, start with a coarse paper, about No. 2 or 2 1/2; follow up with a No. 1/2, No. 1, or No. 1 1/2; and finish with about a No. 2/0 grit. For fine work, such as furniture work, finish with a still finer grit.

Sap or resin in wood will stain through a coat, or even several coats, of paint. Remove sap or resin by scraping and/or sanding. Knots in resinous wood should be treated with a suitable KNOT SEALER.

Weather and Temperature

Oil-painting and water-painting should not be done in temperatures above 95° or below 45°. Varnishing, shellacking, lacquering, and enameling should not be done in temperatures below 65° or above 95°. No painting except water-painting should be done on a damp surface, or on one which is exposed to hot sunlight.

SPRAY METHOD

Complete instructions for the care, maintenance, and operation of a spray gun are contained in the manufacturer's manual, and these instructions should be carefully followed. Only a few of the major spray-painting techniques can be given here, as follows:

Spray Gun Adjustment

The first essential is the correct adjustment of the AIR CONTROL and MATERIAL CONTROL screws, to produce the type of spray best suited to the nature of the work. The air control screw adjusts the width and the density of the spray. Turning the screw clockwise concentrates the material into a round, more dense spray; turning it counterclockwise widens the spray into a fan-shaped, more diffused spray. As the spray is widened, the flow of material must be increased; if it is not, the spray will break into a fog. Turning the material control screw clockwise increases the flow of material; turning it counterclockwise decreases the flow. The most desirable character of spray (from round and solid to fan-shaped and diffused) depends upon the character of the surface and the type of material being sprayed. Experience and experiment are about the only guides here. Practice spraying should be done on waste material, using different practice adjustments, until a spray is obtained which covers uniformly and adequately.

Operational Defects
of the Spray Gun

Uneven distribution of the spray pattern is caused by clogging of one or more of the air outlets or by incorrect adjustment of the air and/or material controls.

SPITTING is the alternate discharge of paint and air. Common causes of spitting are drying of the packing around the material control needle valve, looseness of the material nozzle, and dirt in the material nozzle seat. To remedy dry packing, back off the material control needle valve and place two drops of machine oil on the packing. To remedy looseness of the material nozzle and dirt on the nozzle seat, remove the nozzle, clean the nozzle and seat with thinner, and screw the nozzle tightly back into place.

AIR LEAKAGE from the front of the gun is usually caused by improper seating of the air valve in the AIR VALVE ASSEMBLY shown in figure 4-35. Improper seating may be caused by foreign matter on the valve or seat, by wear on or damage to the valve or seat, by a broken valve spring, or by sticking of the valve stem caused by lack of lubrication.

PAINT LEAKAGE from the front of the gun is usually caused by improper seating of the material needle valve. Improper seating may be caused by damage to the valve stem or tip, by foreign matter on the tip or seat, or by a broken valve spring.

Spray-Gun Stroke

Figure 4-38 shows the correct method of stroking with a spray gun. Hold the gun 6 to 8 in. from the surface to be painted, keep the axis of the spray perpendicular to the surface, and take strokes back and forth in horizontal lines. Pull the trigger just after you start a stroke, and release it just before you finish the stroke, to avoid applying too much paint at the starting and stopping points.

Figure 4-39 shows right and wrong methods of spraying an outside corner. If you use the wrong method shown, a good deal of paint will be wasted into the air.

FIRE HAZARDS

Certain general rules regarding fire and explosion hazards apply to all situations. All paint materials should have complete label instructions which stipulate the potential fire hazards and precautions to be taken. Painters must be continuously advised and reminded of the fire hazards that exist under the particular conditions of each job, so that they will be aware of the dangers involved and assure that the necessary precautions are taken and maintained. Fire fighting equipment, of the proper type, must always be readily available in the paint shop, spray room and work areas where a potential fire hazard exists. Electric wiring and equipment installed or used in the paint

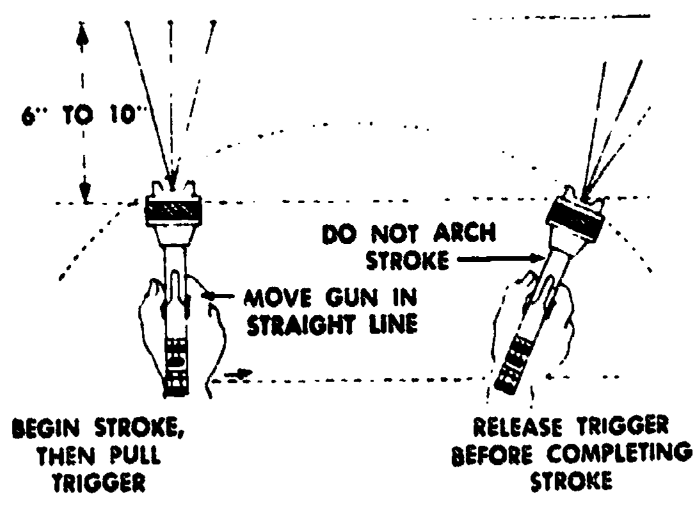

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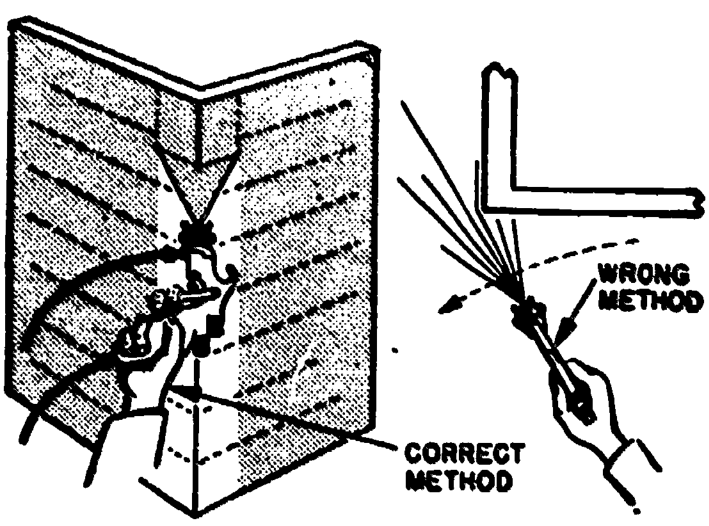
Figure 4-38. — Correct method of stroking with a spray gun.



80.244
Figure 4-39.—Right and wrong methods of spraying an outside corner.

shop, including storage room and spray room, must conform to the applicable requirements of the National Electrical Code for Hazardous Areas. The following precautions against fire must be carefully observed by all paint-handling personnel:

1. Prohibit smoking anywhere that paint is either stored, prepared for use or applied.
2. Provide for adequate ventilation in all of these areas.
3. Perform recurrent spray operations on portable items, e. g., signs, in an approved spray booth equipped with adequate ventilation, a water wash system for fume removal and explosion proof electrical equipment.
4. Wet down spray booth surfaces before cleaning them.
5. Use rubber feet on metal ladders, and be certain that personnel working in hazardous areas use rubber soled shoes.
6. Use non-sparking scrapers and brushes to clean metal surfaces where fire hazards are present.
7. Wet down paint sweepings, rags and waste with water, and store in closed metal containers until disposed of in an approved manner. Do not burn in heaters or furnaces.
8. Extinguish all pilot lights on water heaters, furnaces and other open flame equipment on all floors of the structure being painted. Be sure to turn the gas valve off.
9. When painting in confined areas near machinery or electrical equipment, open all switches and tag them to prevent their being turned on inadvertently.
10. Be sure that all mixers, pumps, motors, and lights used in the paint shop, spray room or on the job are explosion proof and electrically grounded.
11. Use pails of sand (never sawdust) near dispensing pumps and spigots to absorb any spillage or overflow.
12. During painting operations keep fire extinguishers nearby. Be sure that they are of the proper type.
13. Check ventilation and temperature regularly when working in confined areas.
14. Consult with the electricians before painting in areas where high voltage lines and equipment are located.
15. Keep all work areas clear of obstructions.
16. Clean up before, during and after painting operations. Dispose of sweepings and waste daily.

HEALTH HAZARDS

A variety of ingredients used in the manufacture of paint materials are injurious to the human body in varying degrees. While the body can withstand nominal quantities of most of these poisons for relatively short periods of time, continuous or over exposure to them may have harmful effects. Furthermore, continued exposure to some may cause the body to become sensitized so that subsequent contact, even in small amounts, may cause an aggravated reaction. To this extent, these materials are a very definite threat to the normally healthy individual and a serious danger to persons with chronic illnesses or disorders. These materials are divided into two major groups, i.e., toxic materials and skin irritating materials.

Nevertheless, health hazards can easily be avoided by a common sense approach of avoiding unnecessary contact with hazardous materials and by strict adherence to established safety measures.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 5.

CHUCK—Any of the various devices for holding work in the lathe.

FALSE CHUCK—Sometimes applied to the facing material used in rechucking a piece of work in the lathe.

FEATHER EDGE—An edge of zero thickness.

MULTIPLE SAWING—Duplicating a number of forms in one sawing operation by stacking the material.

RE-CHUCKING—Reversing of a piece of work upon a faceplate so that the surface that was against the faceplate may be turned to shape.

STAVED CONSTRUCTION—Attaching staves to polygon-shaped heads in the building of cylindrical bodies and also used for semicircular cavities.

WARPING—Distortion of a board through the absorption or expulsion of moisture. Also applied to a casting drawn out of shape by uneven cooling of the metal.

CHAPTER 5

WOODWORKING MACHINES

Your Navy provides excellent training for those Patternmakers who are interested in becoming skilled craftsmen. Among other things, the Navy furnishes modern equipment to assist in performing duties efficiently and quickly. This chapter will help familiarize you with the more important types of machines. It also discusses safety precautions, general operating practices, and the necessary care of machines.

In the operation of any motor-driven machine, safety cannot be over-emphasized. Just as you must be safety conscious at all times while driving an automobile, you must KNOW and FOLLOW all safety rules for operating power machines in the pattern shop.

Under the heading "Basic Precepts" in the United States Navy Safety Precautions, OPNAV 34P1, the following statement is made:

"Most accidents which occur in non-combatant operations can be prevented if the full cooperation of personnel is gained and vigilance is exercised to eliminate unsafe acts." The supervisor of the shop (senior petty officer) has the direct responsibility for the proper maintenance of each and every piece of shop machinery for the safety of personnel at the possible danger points so that they can be carefully safeguarded against. It is important that all shop machinery and equipment be properly maintained, and be used with intelligence and caution. It is therefore noted that wise personnel must understand the limits of the particular piece of machinery with which they are working to limit the danger to themselves and to others.

The provisions set forth by American Safety Codes are used as guides when setting up safety precautions and safety regulations governing woodworking machines and equipment. The basic safety precepts that apply to all personnel in all types of activities are listed as follows:

1. Report all unsafe conditions, shop machinery and shop equipment.
2. Observe all safety precautions and safety regulations.
3. Wear protective clothing or equipment as applicable.
4. Report all injuries and impaired health immediately.
5. In the event of an unforeseen hazardous occurrence, each individual is expected to exercise such reasonable caution as is appropriate to the situation.

General regulations, operation instructions, and safety suggestions for the more common woodworking machines are given in the following sections.

1. Always keep safety guards in proper working position when operating machines. Explain and enforce their use.
2. Make all adjustments and tighten them before power is turned on.
3. Remove all wrenches and loose tools from the machine before operating.
4. Avoid distracting the attention of anyone using a power machine.
5. Keep the floor around machines clear of waste and scrap materials.
6. Turn off all machines before leaving them.
7. Before machining, inspect all lumber for nails, checks, metal chips, or loose knots.
8. Report immediately any mechanical or physical hazard that comes to your attention. Necessary repairs are to be made by authorized personnel.
9. Always leave a machine with its table square and free of scrap.
10. Whenever possible, keep out of the line of rotating cutters.
11. When oiling machinery, properly secure and tag necessary switches.
12. Back up thin or short stock with a push-block.

13. Avoid crowding the knives or blades as crowding overloads the machine.

14. Keep your hands and fingers from extending over the edge of the stock.

15. Wherever possible, keep your small finger on top of the fence while pushing stock.

16. Store all power tool equipment in racks so that the cutting edges and points are protected.

17. Do not allow inexperienced personnel to operate any power equipment until they have been instructed concerning the hazards, the proper operation of such equipment, and the use of all protective devices.

18. Maintain sufficient space between machines to permit uncrowded and safe passage of personnel and material. Where practical, lines must be painted on deck to mark hazardous or operating areas.

19. Provide adequate lighting at all times and avoid harmful glare.

20. Provide non-skid strips on the deck at the operating station of each machine.

21. All portable power tools must be grounded and should be inspected periodically.

22. Cleaning of one's clothing or machinery with compressed air is prohibited, except on machinery as required for special cleaning operations.

23. Gloves should not be worn when one is operating machinery.

24. Goggles or face shield must be worn while doing work where dust or flying chips are a hazard to the eyes.

25. Loose, flowing, or torn clothing, neckties, long sleeves, and rings or bracelets should not be worn around machinery. Snug fitting clothing should be worn.

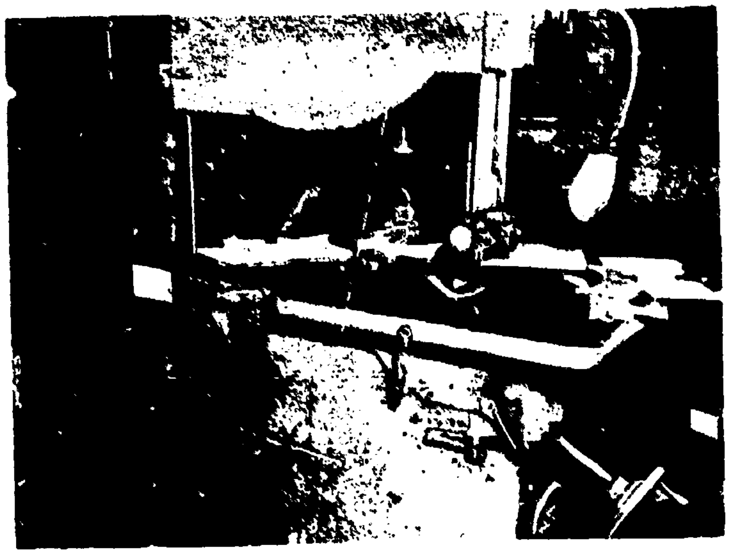
26. Guards must be kept in position at all times unless their removal is authorized.

27. Switches of power equipment should be located so that the operator can control power without reaching across the work.

Figure 5-1 shows a real life situation where the Patternmaker violated these safety rules; this carelessness led to the injury of a Seaman who was walking past the machine and slipped on the scraps of wood.

THE VERTICAL BANDSAW

The saws in the pattern shop are of great importance to the Patternmaker. In fact, one of them, the bandsaw (fig. 5-2), is perhaps the most important machine in the shop. If no other machine were in operating condition, the Patternmaker could continue to produce patterns with the aid of the bandsaw and his bench tools. But without the bandsaw he would be severely handicapped.



29.137(68)A
Figure 5-1.—Safety hazards.

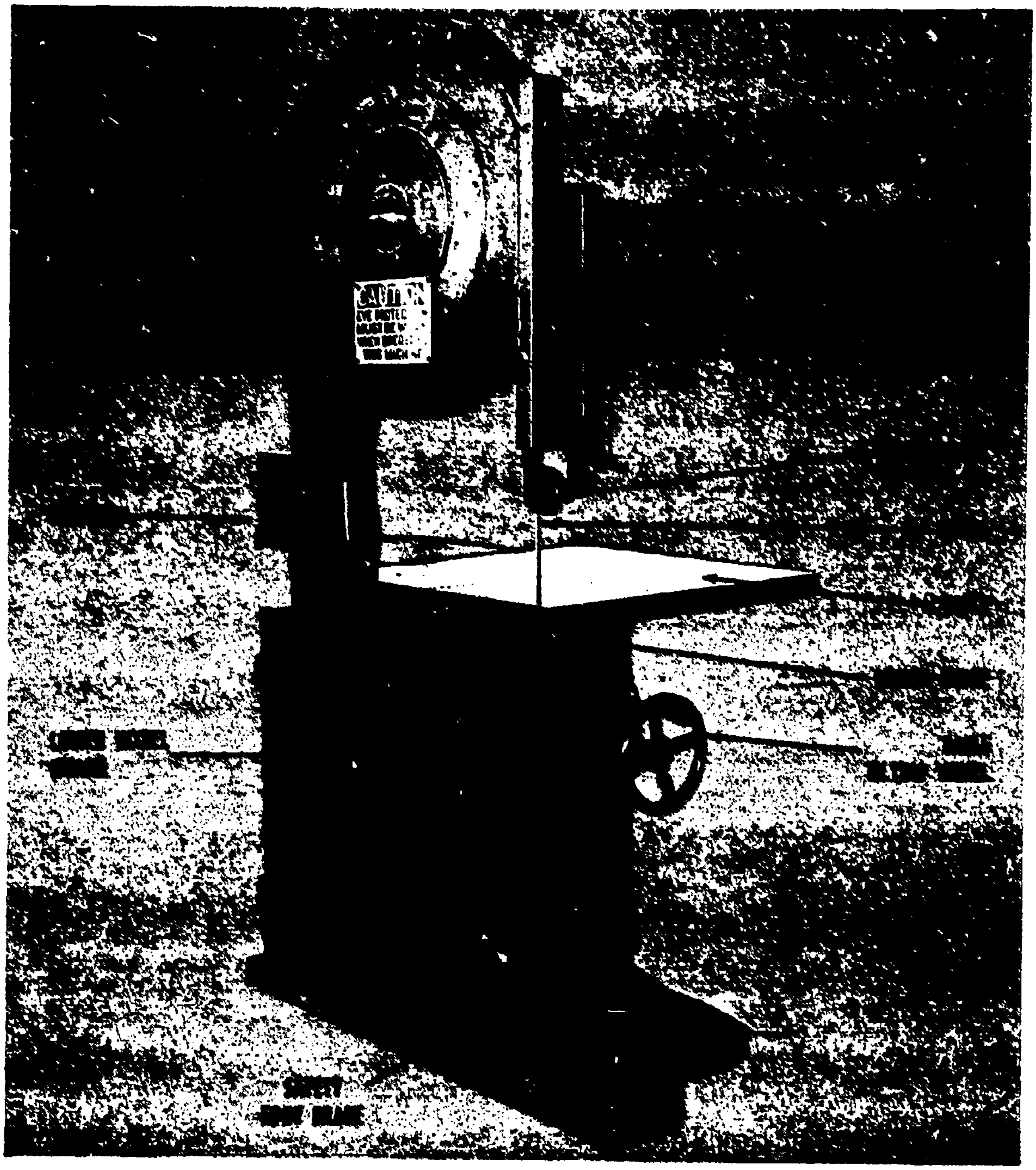
The bandsaw is used principally in the shop for sawing curves and irregular shapes. Its size is specified in terms of the diameter of its wheels. Thus the 30-inch model shown in figure 5-2 has 30-inch wheels. Other common bandsaw models are the 14-, 16-, 18-, 20-, 24-, 32-, and 36-inch sizes.

OPERATION OF BANDSAW

Bandsaws are comparatively simple machines to operate. Each manufacturer publishes technical manuals for each machine. Study these manuals and learn all the details of structure, operation, maintenance, and repair of the machine.

One of the key parts of the bandsaw is its blade, which must be sharp and accurately set to cut in a straight line. The radius of the curve or circle to be cut determines the size of the saw blade to be used; use a narrow blade to cut curves of small radii. A 1/8-inch blade will cut a 1-inch curve; a 3/16-inch blade, a 1 1/2-inch curve; a 1/4-inch blade, a 2-inch curve; and a 3/8-inch blade, a 2 1/2-inch curve, provided, in each instance, that the teeth have the correct amount of set.

The bandsaw table of the model illustrated is of ribbed cast-iron construction. The handwheel tilts the table up to 45 degrees to the right and



29.137(68)B

Figure 5-2.—A bandsaw.

down 10 degrees to the left. The table can be locked in the desired tilted position.

The blade of the saw pictured in figure 5-2 runs in a fully enclosed metal guard. The blade is also protected at the front by a guard attached to the guidepost and by an adjustable shutter guard which can be set close to the work. All moving parts are covered except that part doing the sawing between the guide and the table. The guidepost is adjustable vertically and can be locked in various positions by means of a knurled hand knob. The guides are of the frictionless ball-bearing type with one above and one below the table. The blade runs against the outer edge of a hardened steel wheel which revolves against ball bearings. The hardened steel guides are adjustable and prevent the blade from turning sidewise.

Before starting the saw, see that all adjustments are made properly and that the guards are in place. Clamp the top saw guide 1/4 to 1/2 inch above the stock. This is to prevent the stock from springing the blade while cutting and also to permit the blade to follow the line better. Always make this adjustment before you do any sawing. If necessary, adjust the angle of the top saw wheel to make sure that the saw blade rides without pressure against the guide wheels. Check to see if the bottom surface of the stock is flat. If it wobbles, the work will be inaccurate and the saw blade may kink. Before turning on the power, make sure that everything is in correct working condition. The blade should be tensioned by adjusting the distance between the wheels.

After turning on the power, be sure that the blade is operating at full speed before you start a cut. It is advisable to true up one face or edge of the stock before taking a cut with the saw. Also start the cut in the waste stock and do not crowd or cramp the blade.

Keep the top guide down close to the work at all times. When sawing curves or outlines, guide the stock along the lines marked on the face of the board. If more than one piece is to be sawed, several can be sawed at one time by nailing them together. Drive the nails from the side on which the outline is marked so that they will be visible to the saw operator. Be careful not to exceed the rated capacity of the machine.

Do not force the material too hard against the blade. A light contact with the blade will permit easier following of the line and prevent undue friction and overheating of the blade.

By keeping the saw blade well sharpened, very little forward pressure will be required for average cutting. Move stock steadily against the blade but no faster than required to give an easy cutting movement.

Avoid twisting the blade by trying to turn sharp corners. Remember that you must saw around corners. If you want to saw a very small radius, use a narrow blade.

If you find that a saw cut cannot be completed, it is better to saw out through the waste material to the edge of the stock than to back the blade out of the curved cut. This will prevent accidentally drawing the blade off the wheels.

Saw just outside the marked lines, being careful not to leave too much stock for removal later by a sanding machine or by hand. Always hold the wood being sawed with both hands. Keep your hands away from the blade and always push your work through with your hands out of line with the blade. Saw slowly at first until you have gained experience. Unless round stock can be fastened securely in a suitable V-block or other arrangement to prevent its turning, it should not be cut on a bandsaw or other power saw. Use a miter box and back saw.

When cutting curves, turn the stock carefully so that the blade will follow without twisting. If a curve is so abrupt that it seems necessary to back up and cut a new kerf, resist this temptation and cut out through the waste stock. Then replace the blade with a narrower one or one with more set. It is sometimes necessary, when cutting very small radii, to do so with a series of tangents to the curve, and to finish by paring or sanding.

If the curvature of the outline to be cut is quite sharp, saw kerfs in the waste stock before beginning the cut. See figure 5-3 which illustrates a method of cutting an inside curve.

Kerfing is done before starting to cut along the outline of the curve. Make as many kerfs as needed to break up the waste stock into small pieces. When the blade reaches the outline, draw the stock straight back easily and slowly. After the kerfs have been completed, cut the curve carefully, starting at one end of the curve and following the outline without forcing the blade.

You can also make beveled cuts (up to 45 degrees) with the bandsaw by tilting the saw

29.137(68)C

Figure 5-3. — Cutting straight kerfs with a bandsaw.

table to the desired angle. When making beveled cuts, you must be sure to place the stock on the tilted table so that the bevel will be cut in the proper direction. If you are not careful, it is very easy to make the mistake of cutting the correct angle but in the wrong direction. Pay particular attention to the safe position of your hands. The saw path through the stock is at an angle and is very deceptive. The real danger is that the saw may pass out of the stock and into the hand at a lower level. After using a tilted bandsaw table, swing the table back to the 90-degree marker and lock it in position before leaving the machine.

CAUSES OF BLADE BREAKAGE

Any one of a number of conditions may cause a bandsaw blade to break. Breakage is unavoidable when it is the result of the peculiar stresses to which such saws are subjected. The most common causes of blade breakage which may be avoided by good judgment on the part of the operator are: (1) faulty alignment and adjustment of the guides; (2) forcing or twisting a wide blade around a curve of short radius; (3) feeding too fast; (4) dullness of the teeth or the absence of sufficient set; (5) excessive tension on the blade; (6) top guide set too high above the work being cut; and (7) using a blade with a lumpy or improperly finished braze or weld. When a saw blade breaks, shut off the power immediately and then wait until the wheels stop turning before replacing the blade.

MAINTENANCE OF BANDSAW

It is very important that regular lubrication be given a bandsaw to ensure better service and longer life. The motor bearings have oil reservoirs supplied with oil cups, one cup for each bearing. The upper wheel bearings are lubricated from an oil cup which feeds a large oil reservoir extending from bearing to bearing. These oil cups should be checked daily and a small amount of oil added when necessary. The saw guide spindles are lubricated by an oil cup in the back end of each saw guide shaft. The table rocker seats and the tilting mechanism for this table should have a small amount of oil applied to them at intervals of about one month.

SAFETY RULES

1. Before starting the machine, inspect the thrust guide wheels for proper relation to the back edge of the saw blade.

2. Do not allow anyone to stand close to and in line with the saw wheels while the saw is in motion.

3. Adjust the saw guide to 1/4" to 1/2" above the stock to be cut. Do not attempt to raise or lower the guide while the saw is in motion.

4. On hearing a clicking or knocking sound at the saw guide, stop the machine immediately and inspect the entire saw blade for cracks.

5. Avoid excessive twisting of the blade when making a circular cut.

6. All work to be sawed should have a good stable contact with the saw table. Fasten patterns securely to the supporting stock.

7. When a saw blade breaks, shut off the power immediately and WAIT until the wheels stop turning before removing stock.

8. Cutting cylindrical stock is dangerous. However, it may be done safely if you secure all cylindrical work with a clamp or jig before cutting.

9. Never push work with your hand in line with the saw blade.

10. If the saw blade binds, give the blade more set or use a wedge in the saw kerf.

11. Plan cuts so that small pieces will not pass through the opening in the saw table and be carried around the wheel between the blade and the rubber tire.

12. To tilt the saw table, unlock the tilting cradle and turn the handwheel until the desired angle is indicated on the gage.

13. In a sawing operation that requires tilting the saw table, pay particular attention to the safe position of the hands. The saw path through the stock is at an angle and deceptive. The real danger is that the saw may pass out of the stock and into the hand at a lower level.

14. After using a tilted saw table, swing the table back to the 90° marker and lock it in position before leaving the machine.

15. When a heavier than normal pressure is required to advance the stock into the saw, it indicates a dull blade. Stop the machine and have a new blade fitted immediately.

REPAIRING BANDSAW BLADES

BANDSAW teeth are shaped like the teeth in a hand ripsaw, which means that their fronts are filed at 90° to the line of the saw. Reconditioning procedures are the same as they are for a hand ripsaw, except that very narrow bandsaws with very small teeth must usually be set and sharpened by special machines. Although, it is recommended that all bandsaw blades be butt welded as this method is more effective. A broken bandsaw blade may be BRAZED when no accessory welder is available. The procedure for brazing follows:

1. SCARF the two ends to be joined with a file, so that they may be joined in a SCARF JOINT as shown in figure 5-4.
2. Place the ends in a brazing clamp, or some similar device which will permit them to be brought together in perfect alignment.
3. Coat the filed surfaces with soldering flux.
4. Cut a strip of silver solder the length of the scarf and the width of the blade. Coat it with flux and insert it between the filed surfaces.
5. Heat a pair of brazing tongs (like those shown in fig. 5-4) bright red and clamp the joint together. The red-hot tongs will heat the blade and melt the solder. Keep the tongs clamped on the joint until they turn blac'.
6. Smooth the joint on both sides with a flat file, and finish it with fine emery cloth.

Figure 5-5 shows band ends being joined by using a butt welder. Equipment of this type is found on tenders and repair ships. The entire procedure for joining follows:

1. Trim both ends of the band square; clean them thoroughly. Butt the ends together in the jaws of the welder; make sure that the ends are aligned and that the seam is centered between the welder jaws. First, set the resistance knob to agree with the dial for the width of band you are going to weld. Then, press and hold the WELD button until the blade ends fuse together. Let the weld cool for a few seconds and then press the ANNEAL button until the welded area heats to a dull cherry red. Hold the welded area at that temperature momentarily by jogging the button, and then allow the temperature to fall off slowly and gradually by

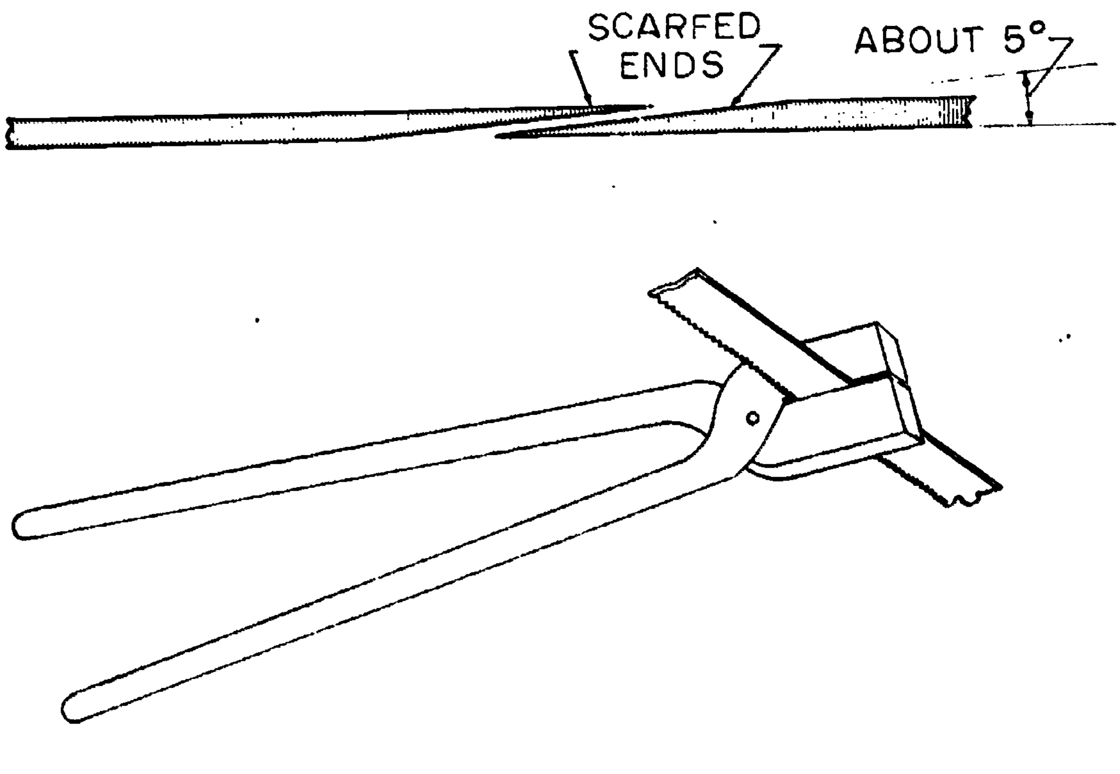


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Figure 5-4. — Rejoining a broken bandsaw blade.

28.48X
Figure 5-5.— Butt welder-grinder unit.

increasing the time between jogs. (Allow about ten seconds for this last phase.)

2. After the band has been annealed, take it out of the welder jaws and grind the weld bead with the small grinder. Grind the weld area to the same thickness as the rest of the band. Check the back edge of the band for burrs and misalignment; grind off irregularities. After the grinding is completed, place the band in the butt welder and re-anneal the welded area to destroy any hardness which may have developed during the grinding. For additional information on a butt welder, see the technical manual furnished with each machine.

CIRCULAR SAWS

The circular saw is one of our oldest forms of power machinery. It is also one of the most useful machines in the shop since it makes possible a great variety of machine operations. These operations include ripping, crosscutting, and cutting bevels, chamfers, and grooves.

There are two general types of circular saws: radial arm and table saws.

TABLE SAWS

Several types of table or bench saws are available, such as (1) single arbor, (2) double arbor, (3) tilting table, or (4) tilting arbor types. The SINGLE ARBOR saw is adaptable to a wide variety of work, such as ripping, crosscutting, mitering, beveling, and grooving. It is necessary to change blades for ripping or crosscutting. The DOUBLE ARBOR saw permits the mounting of a ripsaw blade on one arbor and a crosscut blade on the other. This feature enables you to change quickly from ripping to cutoff work.

Figure 5-6 shows a single arbor variety saw. A 16-inch model will cut stock up to 4 1/8 inches thick and an 18-inch model will cut up to 5 1/8 inches. The blade can be easily raised or lowered by a handwheel at the right-hand corner of the machine. The machine is of the fully enclosed type with a cabinet frame that encloses the blade and the other operating mechanism under the table. The larger models are provided with a splitter or spreader guard and an automatic saw guard for guarding the blade above the table. The table can be tilted to any angle up to 45°. This feature is especially useful in cutting bevels. A handwheel with worm and gear mechanisms is used for tilting the saw table. A scale and clamp held in setting the table and holding it firmly at a desired position. This saw is especially dangerous to use when the table is tilted, because sawing may require the removal of the saw guard and because the operator is forced to work in an awkward position. There is also the danger of the fence working loose and sliding down the tilted table into the revolving saw blade. To avoid such accidents, work with the fence in a position downhill from the blade. The TILTING ARBOR saw is an improvement over the tilting table saw. In these newer type saws the table remains stationary and the blade and arbor can be tilted up to 45°. The same rules of operation and maintenance apply to both tilting table and tilting arbor saws. The same gages, blades, and miscellaneous equipment are used.

Many types and sizes of saws are available but all are designed principally for crosscutting or ripping wood. In addition, such jobs as dadoing, rabbeting, splining, tenoning, and grooving are easily done on the circular saw.

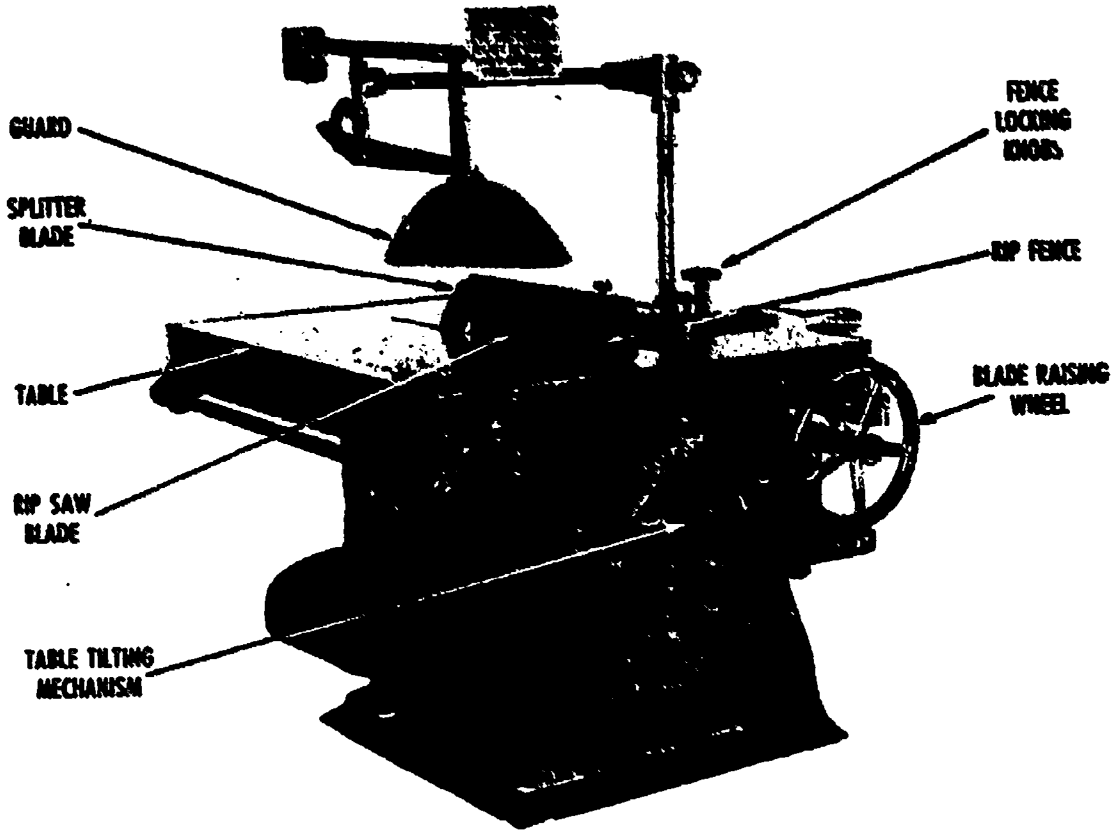

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Figure 5-6.—A single arbor variety saw.

A light-duty, tilting-arbor circular saw is shown in figure 5-7. This machine carries a 10-inch blade mounted on a tilting shaft. The CRANKWHEEL shown at the left is turned to change the angle of the saw blade with the table top. The angle is indicated on the SCALE at the front. The FRONT CRANK is turned to change the "depth of cut" adjustment of the blade. LOCKING KNOBS on each crankwheel are provided to secure the adjustment once it is established.

The RIPPING FENCE, shown on the SAW TABLE at the right, can be used on either side of the blade for ripping, rabbeting, grooving, tenoning, and other operations. Avoid dropping or springing this fence; it must be kept parallel to the saw blade. The SLIPPING CUTOFF GAGE is shown on the table at the left. It is used for crosscutting, mitering, tenoning, and dadoing. The RODS attached to this gage at the left serve as a guide for length in cutting duplicate pieces.

The blade SAFETY GUARD, secured at the back center of the table, covers the blade and

29.136

Figure 5-7.—Light duty, tilt arbor circular saw.

provides a KERF (cut) SPLITTER for ripping. The guard prevents the kerf from closing and jamming the blade. Also incorporated in this assembly is a mechanism which prevents pieces going through from being kicked back toward the operator by the fast-moving blade.

DO NOT REMOVE THE SAW GUARD. The guard won't protect your fingers if it is hanging on the bulkhead or is stowed in a locker. Use it and the chances will be better for you to keep five fingers on each hand.

A heavier bench saw is shown in figure 5-8. This machine carries a 14- or 16-inch blade and is usually powered with a 3- to 5-horsepower electric motor. The saw has a tilting arbor, a rolling or sliding left table for cutoff work, and a fine micrometer-adjustment ripping fence to the right.

Operation of Table Saws

Operating a single arbor saw appears to be a very simple job, but do not fool yourself. Observe all the directions for safe operation.

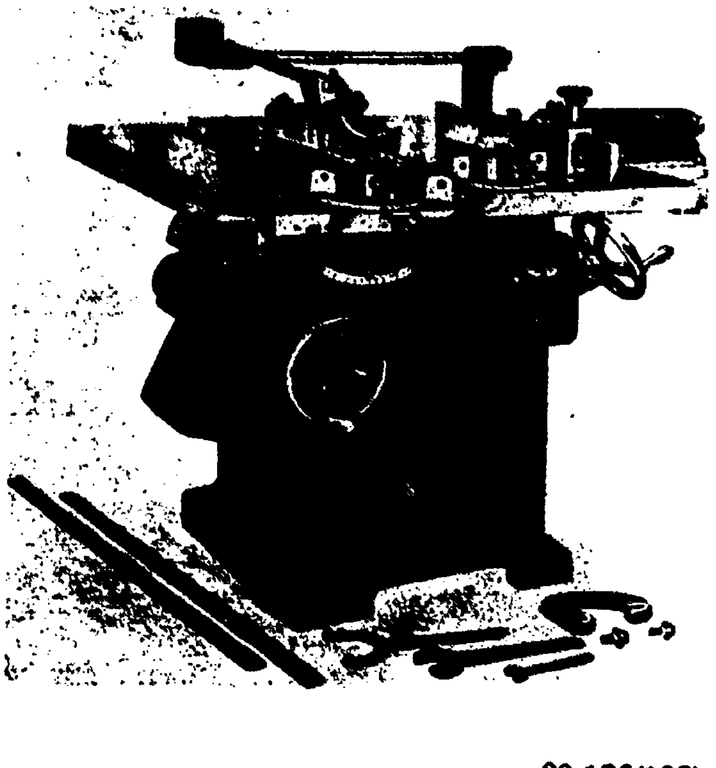

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Figure 5-8. — A 16-inch circular bench saw.

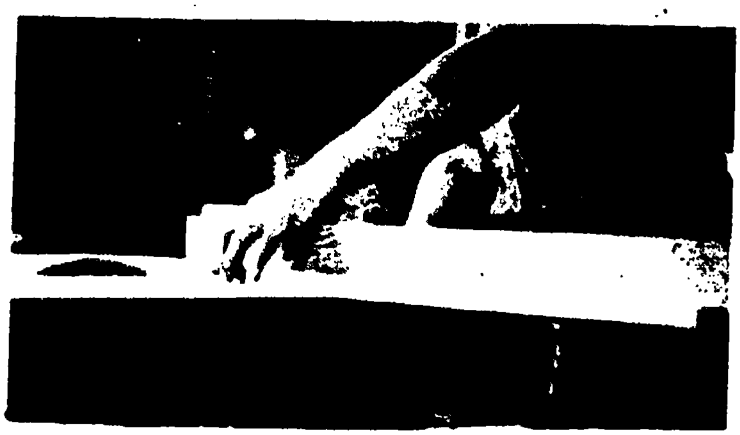
Squaring the ends of stock is one of the main uses of the crosscut saw. Before starting the machine, see that all movable parts are clamped securely, and that the table surface is at right angles to the blade. The ripping fence should be moved to the right of the table or removed entirely. For all simple cutoff sawing, have the guard in place over the blade.

Hold the stock securely against the miter gage. Several pieces may be cut at one time, up to the capacity of the machine.

Before squaring the second end, lay off the desired finished length of stock along the table. Measure from the left cutting edge of the blade, and clamp a stop rod in the slot of the universal or miter gage at the desired finished length. When handling long stock, remove the ripping fence from the table. Push the stock against the blade and cut to the finished length. (See fig. 5-9.)

The easiest operation with the circular saw is simple ripping to width. While setting the circular saw for ripping, raise the saw guard and, if practicable, swing it out of the way. Attach a ripsaw on the arbor, or, if you are using a double arbor saw bring the ripsaw into position. Raise or lower the saw table or saw as necessary so that the blade does not project more than 1/8 to 1/4 inch above the top of the stock. Set the clamp so that the table or arbor cannot move.

Set the ripping fence according to the scale on the table. After the fence is locked in position, make a final check of this adjustment with a steel rule. The fence should be away from the saw for a distance slightly greater than the desired width of the finished stock. The slight



68.14
Figure 5-9. — Crosscutting with a circular saw.

extra width, 1/16 to 1/8 inch, is to allow for finishing the ripped edge on the jointer. When very accurate settings are desired, use the micrometer adjustment on the fence. Be sure that the fence carriage is resting in the locating holes, and that it is securely fastened to the table. See that the thumbscrews which hold the fence in position are set and that the fence is at right angles to the table surface. Also see that the table is square and at right angles to the blade and that the guard is in position over the blade.

Standing at the left of the lumber, place its straightedge against the fence and feed it against the blade. Use a push stick, as shown in figures 5-10 and 5-11, when ripping stock into narrow strips. The push stick should be long enough to extend well above the fence, and deep enough to hold the stock securely on the table. When narrow strips are ripped, set the blade to project 1/8 to 1/4 inch above the stock.

Another special use of the circular saw is concaving the face of flat stock in staved pattern construction. See figure 5-12.

First adjust the height of the blade for the required depth of cut. Then swing the fence or straightedge to the proper angle for the required width of cut. Because the stock is fed into the blade at an angle, you must be especially careful not to crowd the blade.

Maintenance of Table Saws

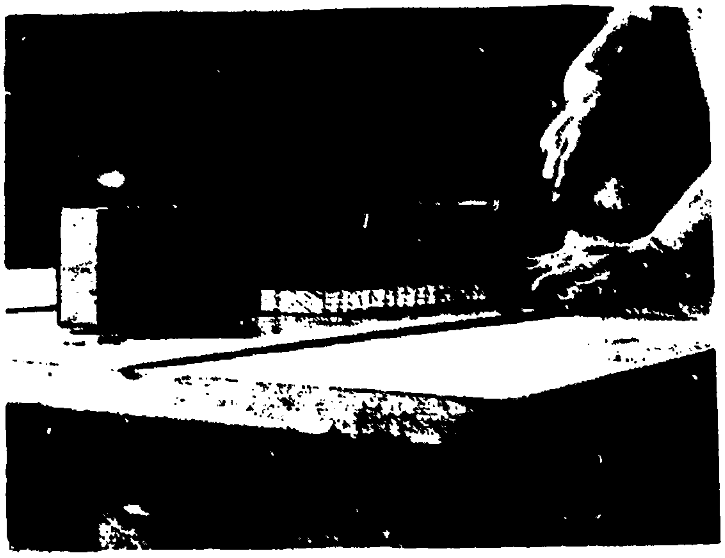
Little lubrication care is required for circular bench saws. Most of these machines are equipped with high-grade ball bearings lubricated with grease or oil. Too much oil or grease is as bad for the motor as too little. Oil or grease should never come in contact with the motor windings. The lubrication instructions of the manufacturer must be carefully followed.

The motors should be blown out at least once a week to prevent an accumulation of sawdust from closing up the ventilating openings.

Typical uses of circular saws are shown in figures 5-9 and 5-10. Note that the guards have been intentionally removed in these illustrations to show you the details of the particular operation.

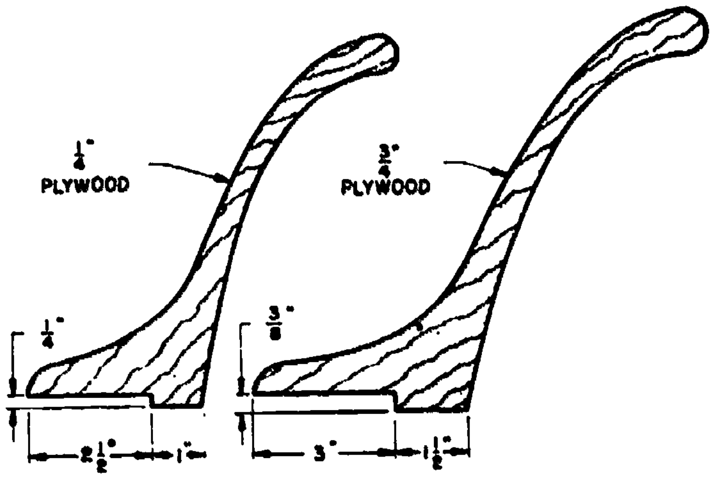
RADIAL SAWS

Figure 5-13 illustrates one of the circular saws, the RADIAL ARM saw, that you may find in your shop. It is used to cut rough stock to



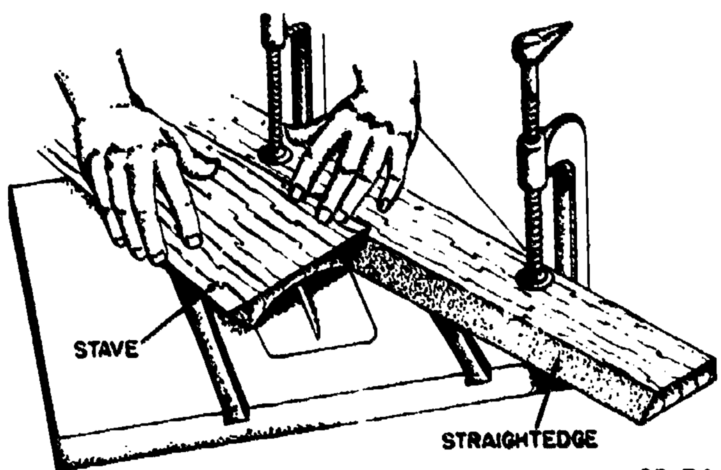
44.106(68)

Figure 5-10. — Ripping narrow stock with a push stick.



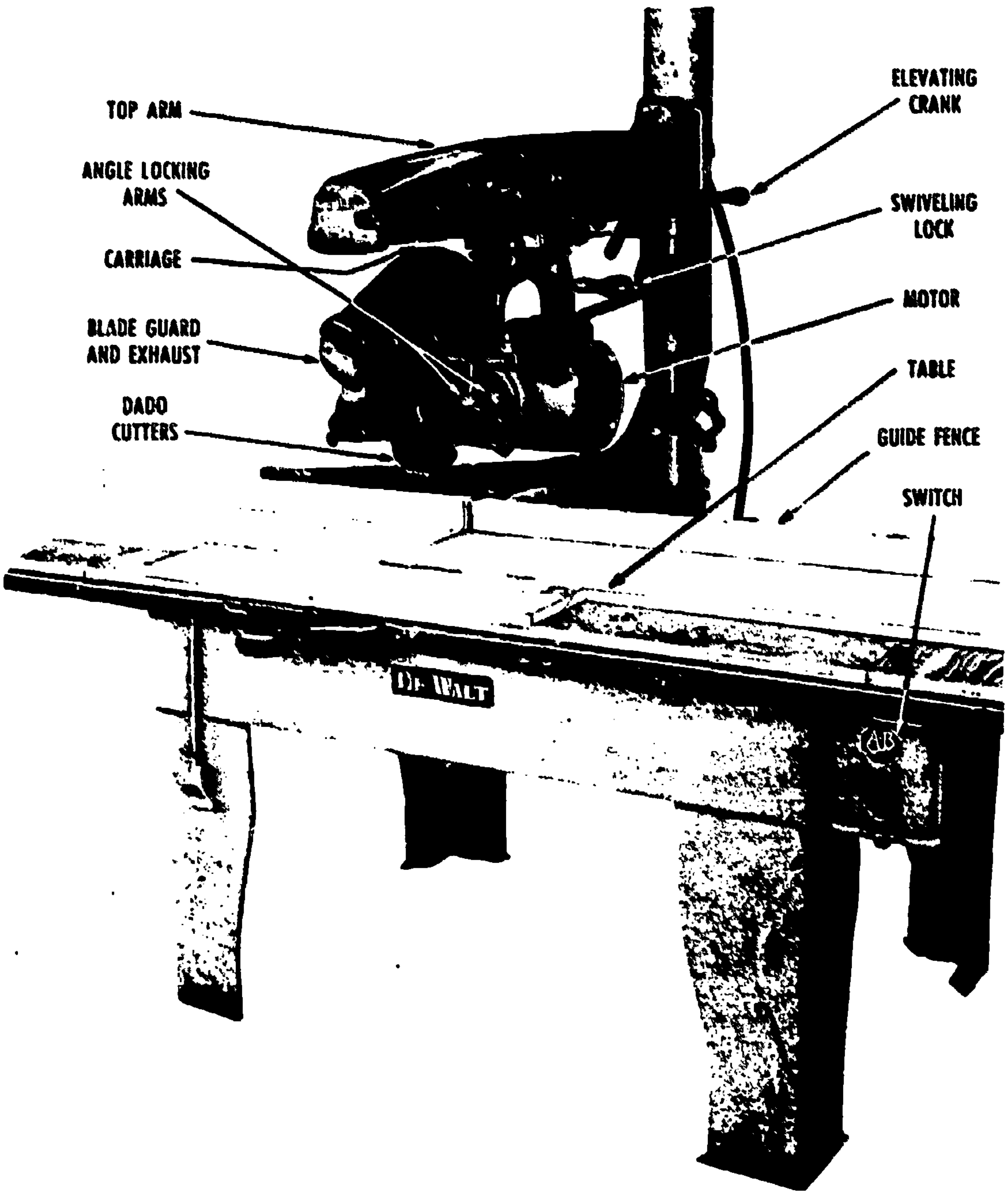
44.106

Figure 5-11. — Push sticks for ripping.



23.74

Figure 5-12. — Using the circular saw to concave the face of a stave.



44.62

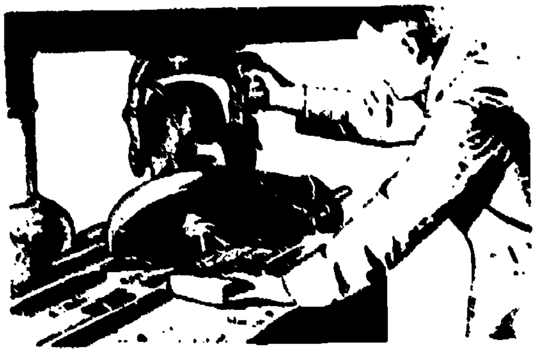
Figure 5-13.—A radial arm saw.

convenient lengths. The radial arm saw is usually selected for the initial cutting of the pattern lumber. It is especially useful in making many special cuts, such as miter, and bevel, compound miter and angle cutoff, figure 5-14. The same can also be used for shaping, grooving, rabbeting, and routing as shown in figures 5-15 through 5-19.

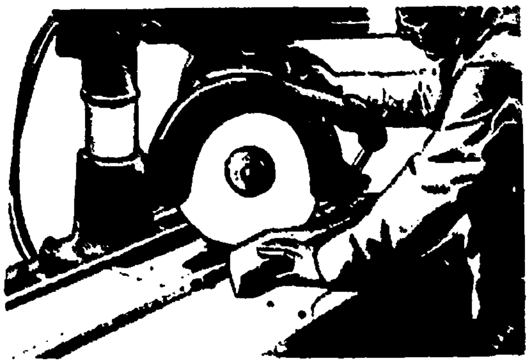
One feature of a radial arm saw is the roller arrangement ,in the top arm that permits the moving of the carriage. It is possible to move the carriage and cut through material, and to lock the arm at any angle. A handcrank enables you to raise or to lower the top arm.

Operation of Radial Saws

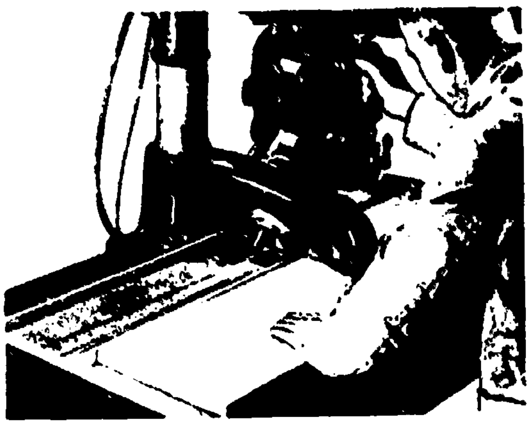
Before you operate a radial arm saw, clean all dust and dirt from the saw and table. The normal position of the blade is for the straight



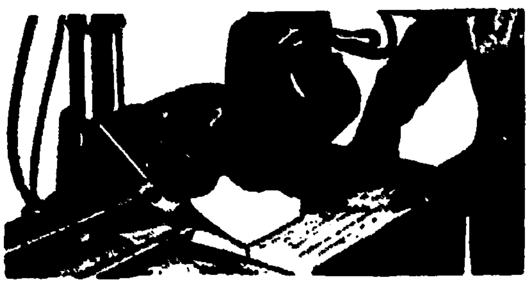
COMPOUND MITER CUTTING



MITER CUTTING



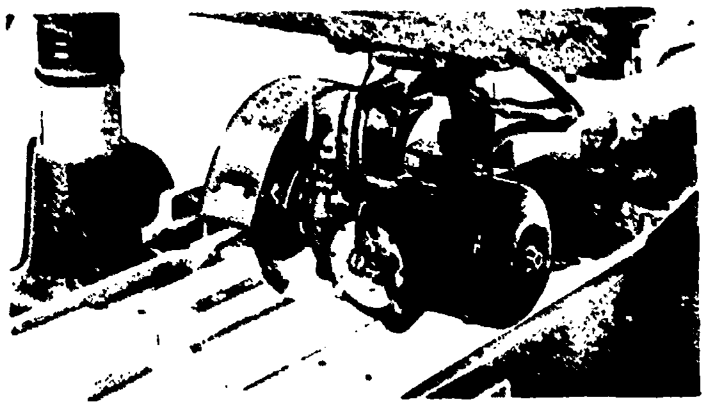
ANGLE CUT-OFF



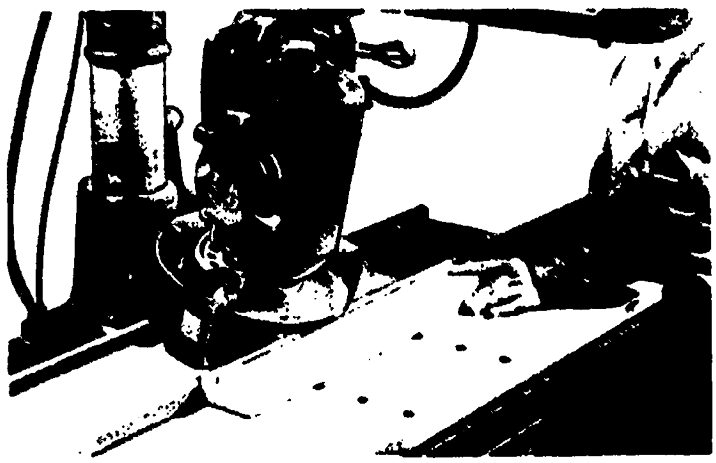
BEVEL RIPPING

44.62
Figure 5-14.—Saw cutting with the radial arm saw.

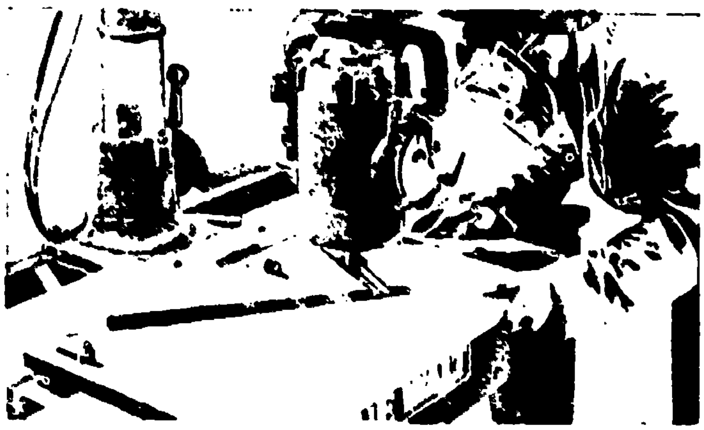
44.62(133E)E
Figure 5-15.—Shaping with the radial arm saw.



44.62(133E)C
Figure 5-16.—Grooving with the radial arm saw.



44.62(133E)D
Figure 5-17.—Rabbeting with the radial arm saw.



44.62(133E)F
Figure 5-18. — Routing with the radial arm saw.

44.62(68)A
Figure 5-19. — Crosscutting with a radial arm saw.

cutoff, where the blade is pulled from the rear to the front across the wood. The wood is placed on the table top with one edge resting against the guide fence. For ripping operations, the wood is placed flat on the table against the guide fence and is fed by hand to the blade.

The arm may be set at any desired angle for angle cutting. For ripping and ploughing, the blade may be pulled out to the end of the arm and locked in position between the guide strip and the motor. In this operation, the wood is pushed along the guide strip from the side opposite the red warning sign on the guard and into the blade. For beveling, shaping, and routing, the motor may be tilted and locked at any angle.

For straight crosscutting, place the arm of the saw at a right angle to the guide fence by setting the miter latch in the column slot at the zero position. Lock the arm with the arm-clamp handle. Place the material on the worktable, against the guide fence, and make the cut. (See fig. 5-19.) Then return the saw blade to a position behind the guide fence.

For ripping, the arm must be clamped in crosscut position. Pull the entire motor carriage to the front of the arm. Then, lift the rip latch, release the swivel-clamp handle, and revolve the motor yoke under its carriage. There are holes in the yoke to receive the rip latch and hold the motor in ripping position. Using the rip scale on the arm, locate the position you desire, lock the swivel clamp, and secure the rip lock on the arm. Adjust the safety guard so the infeed end almost touches the material. Lower the kickback device on the opposite end so the sharpened points rest on the lumber. Keep the lumber against the guide strip and feed it evenly into the saw blade. (See fig. 5-20.) Do not feed the lumber into the kickback end of the saw guard.

44.62(68)B
Figure 5-20. — Ripping with a radial arm saw.

Maintenance of Radial Saws

Periodic cleaning, greasing, and oiling of all moving parts are necessary. Each morning before starting operations with the radial arm saw, you should clean the tracks inside the arm by wiping. Occasionally, clean these tracks with a lacquer thinner to remove grease and dirt. Do not oil or grease the tracks or the roller head bearing under any circumstances. Once a month, oil the elevating screw of the column and the elevating gear shaft of the arm. A small amount of light lubricating oil should be applied once in a while to the miter and swivel latches and to the arm clamp handle. Never lubricate the motor or the roller carriage.

Safety Precautions

These are the most important OPERATING PRECAUTIONS for the radial arm saw:

1. The electrical current being used should agree exactly with the specifications on the motor.
2. All clamp handles should be properly tightened before you operate the machine.
3. For all operations, adjust the guard down to the material.
4. Before starting to cut, be sure that the wood rests against the guide strip.
5. Before changing any setup, stop the saw blade.

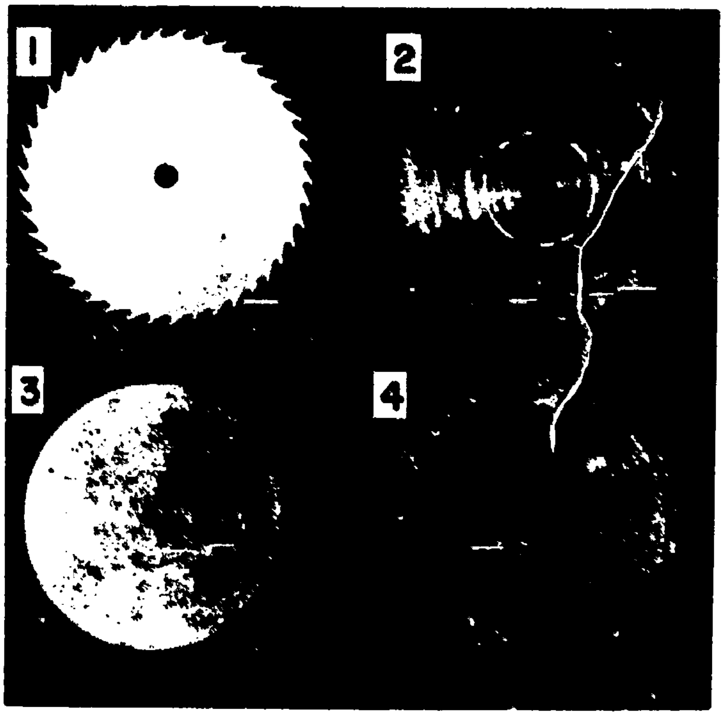
Safety Rules for All Circular Saws

1. Before starting the machine, inspect the condition and type of blade in the saw. It is extremely dangerous to attempt to use a dull blade.
2. Use a crosscut blade for cross cutting only and a rip blade for ripping only. Use the proper fence for each operation.
3. Stop the saw before adjusting the fence or guide. Lock the fence frame firmly to the saw table.
4. The height of the saw above the table should equal the thickness of the stock plus 1/8" to 1/4".
5. Before attempting to cut stock on the saw, run the stock over a jointer to establish a true straight edge from which to work.
6. Inspect the machine area for obstructions that would interfere with the passage of the stock through the saw.
7. Be sure that the exhaust system is in operation and the exhaust duct is open.
8. Always use a wood push-stick when ripping narrow or thin stock.
9. When returning stock, use a sweeping motion to the right or left; keep the stock entirely clear of the blade.
10. Secure cylindrical work in a jig designed to suit the particular needs.
11. When sizing, use two cuts, each halfway up, rather than one cut all the way through the stock.
12. Ask for help when sawing large stock.
13. Never reach over and pull work through the saw.
14. Stand to the left of the saw allowing clearance for any stock that might be kicked back. Use anti-kickback dogs.
15. Use the guard at all times unless the nature of the work does not permit guard use.
16 Do not stack material to be cut on the saw table. The pieces of stock might accidentally come in contact with the saw blade and be thrown violently at the operator.
17. All saw work must have a good firm table and fence contact. Maintain firm control of the stock at all times.
18. Inspect all surfaces of the stock for nails, screws, metal clips, or particles of embedded sand before cutting.
19. Bring the saw blade to a full stop before clearing the table of small scraps.
20. After using the saw, stop and lower the blade below the table before leaving the machine.
21. If the saw was set for angle cutting, swing it back to 90° and lower it below table level before leaving the machine.
22. Inspect the crosscut miter unit to see that it slides freely in the table groove. Lock the miter head securely in place before using.

CIRCULAR SAW BLADES

Figure 5-21 illustrates four distinct types of saw blades employed on circular saw benches. Each has a particular shape of tooth and gullet. The four types are:

1. Circular ripsaw blade, with a standard tooth arrangement that is best for general purpose ripping of both hard and soft woods. (See part A of fig. 5-22.)
2. Circular crosscut saw blade, the tooth and gullet shape illustrated in part B of figure 5-22 is best for general purpose crosscutting.



23.72(68)

1. Rip Blade
2. Crosscut Blade
3. Miter Blade
4. Combination Blade

Figure 5-21. — Circular saw blades.

3. Miter saw blade, with the cutting teeth shaped and sharpened much the same way as standard crosscut saw teeth. The precision miter saw is usually employed on a single arbor variety saw bench.

4. Combination rip and crosscut saw blade, which serves for both ripping and crosscutting. (See part C of fig. 5-22.)

The correct circular blade, properly jointed, set, gummed, and filed will cut cleanly. On the other hand, if the teeth are dull, they will merely scrape or burn their way through, leaving a rough, ragged, sawed surface; and there is the attendant danger of overheating and softening the blade. If some teeth are unevenly set, there will be marks or scratches and the roughness may require much planing for the final finishing. Sometimes a dull blade will cause the motor to stall. Some saw blades are manufactured as "hollow-ground" blades. These are usually more expensive than conventional blades but they produce a smoother cut.

Direct motor-drive saws may run at 3,600 rpm. Unless properly tensioned for this high

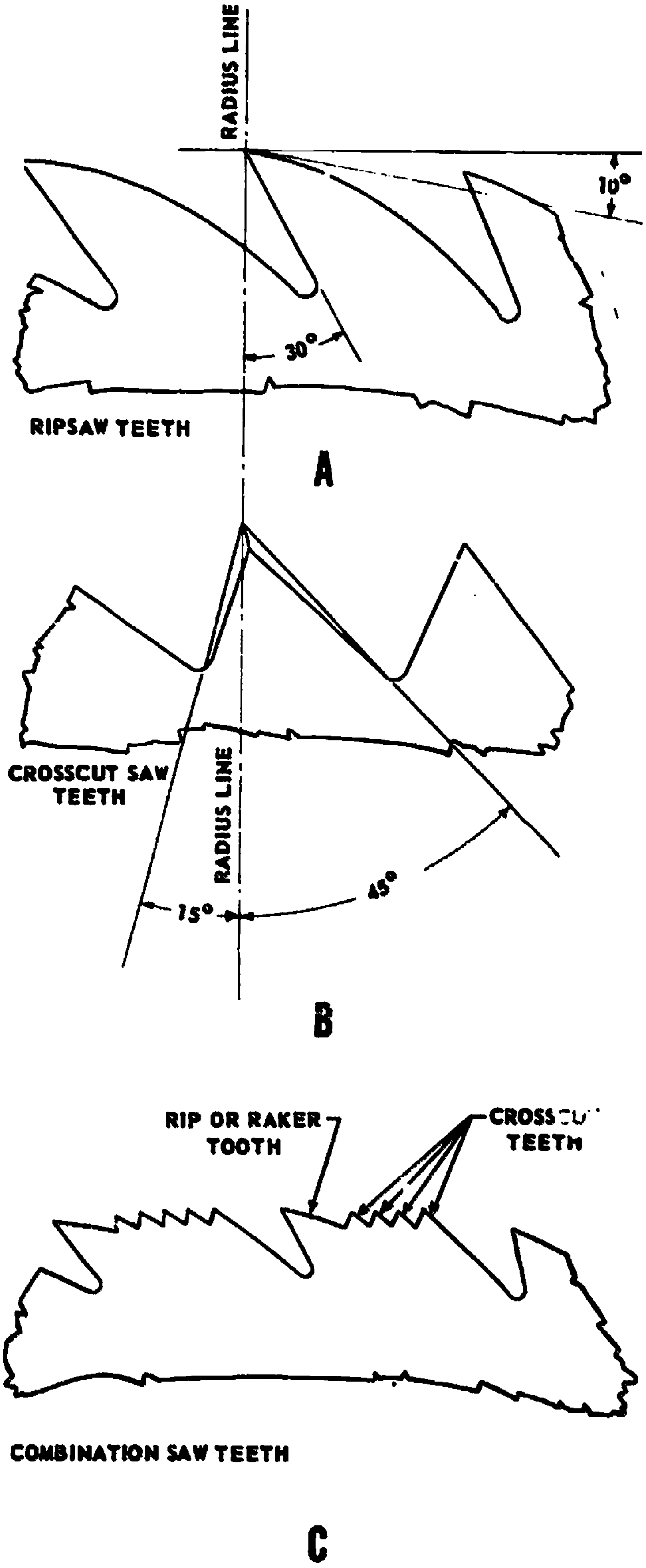


Figure 5-22. — Correct shapes of circular saw teeth. 29.15(68)

speed, the blade will not stand straight, but will vibrate and wobble. A saw blade containing high spots, ridges, bends, or twists will overheat, become distorted and burn in spots, thus impairing its temper. Portions of the blade will show black on one side, while on the opposite side the high spot will stand out, brightly polished by frictional contact in the cut.

Saw blades must be given the same care as other edged tools, such as chisels and boring bits. To give good results, a blade must be properly tensioned, jointed, set, sharpened and gummed, and protected from damage in handling or stowage.

There are several rules for the PROPER CARE of circular saw blades:

1. Keep the saw sharp.
2. Use an automatic saw filer or a circular saw filing vise and saw files to sharpen blades. Most cracks in a circular saw are caused by sharpening with a sharp-cornered file.
3. In filing, maintain the original shape of the teeth.
4. Joint the blade as often as is necessary. A blade out of round is out of balance.
5. Do not allow a blade to become coated with pitch or gum as it will cause a blade to heat in spots and ruin its usefulness. Clean with kerosene or any other approved solvent.
6. Do not overfeed the blade. Crowding a saw blade beyond capacity produces bad work and also places a strain on both the blade and motor.
7. Do not strike the teeth of a blade against the saw table or other metal objects. The saw blades are made of a steel which is soft enough to be filed; therefore, the delicate points and edges of the teeth are easily injured by contact with other metal.

JOINTING a circular saw is done when wear and repeated sharpening have caused the points on the saw to become out of round. The procedure for jointing a circular saw is as follows:

1. Obtain a piece of an old grinding wheel.
2. Secure the saw blade on the saw arbor in the reverse position (points of the teeth toward the rear of the table).
3. Adjust the saw so that the teeth extend slightly above the table.
4. PUT ON GOGGLES.
5. Start the saw, place the piece of grinding wheel flat on the table, and move it toward the revolving teeth until the higher points begin to strike the stone. Move the stone gradually further until the sound indicates that all the points are striking. Stop the saw and examine the points. When every point shows a bright spot, jointing is completed.

Gumming is done when wear and repeated sharpenings have caused the gullets to become too shallow. The first step is to lay out the shapes of several teeth on the saw as shown in figures 5-23 and 5-24. For a ripsaw (fig. 5-23), draw a circle on the saw with a diameter equal to one-half that of the saw, and draw a line from each point tangent to the circle. This line indicates the correct angle for the front of the tooth. Lay off the correct angle for the top of the backslope (10°, as shown in part A of fig. 5-22), and draw in the gullet until it looks about right. Draw a circle (the GUM LINE shown in fig. 5-23) through the bottom of the gullet and all the way around the saw, to indicate the correct gullet depths of all the teeth.

A crosscut saw is marked for gumming as shown in figure 5-24. Draw two circles on the saw, one with a diameter equal to one-quarter of that of the saw, the other with a diameter equal to three-quarters of that of the saw. A tangent drawn from the smaller circle to the

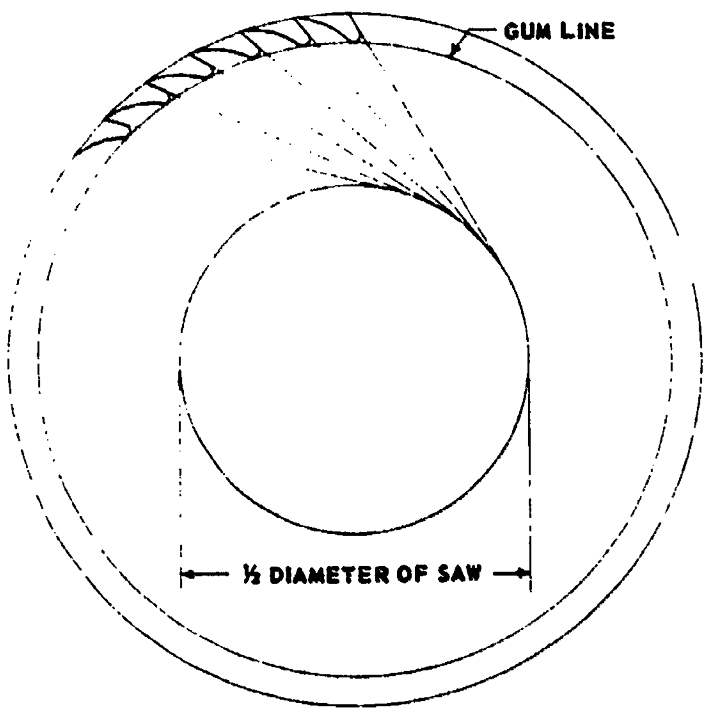
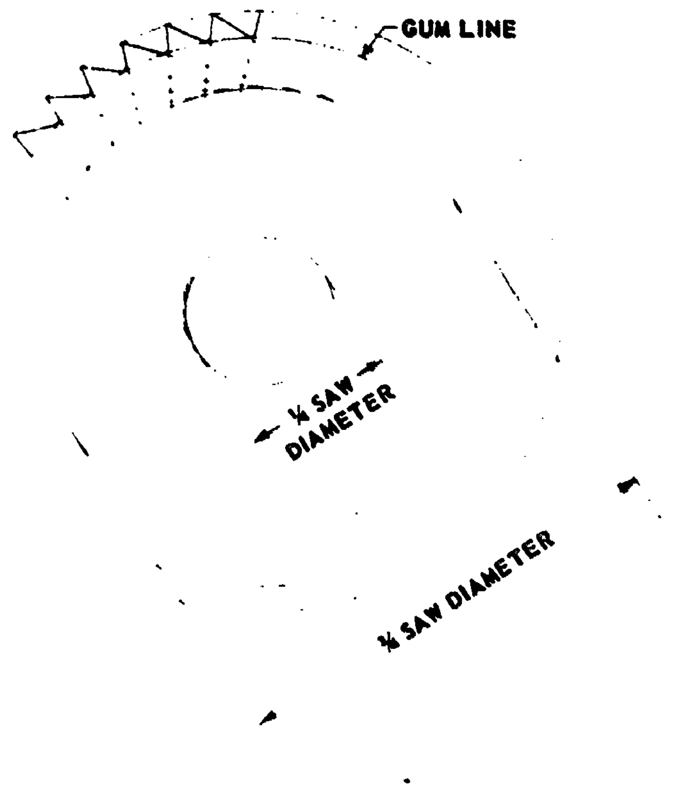
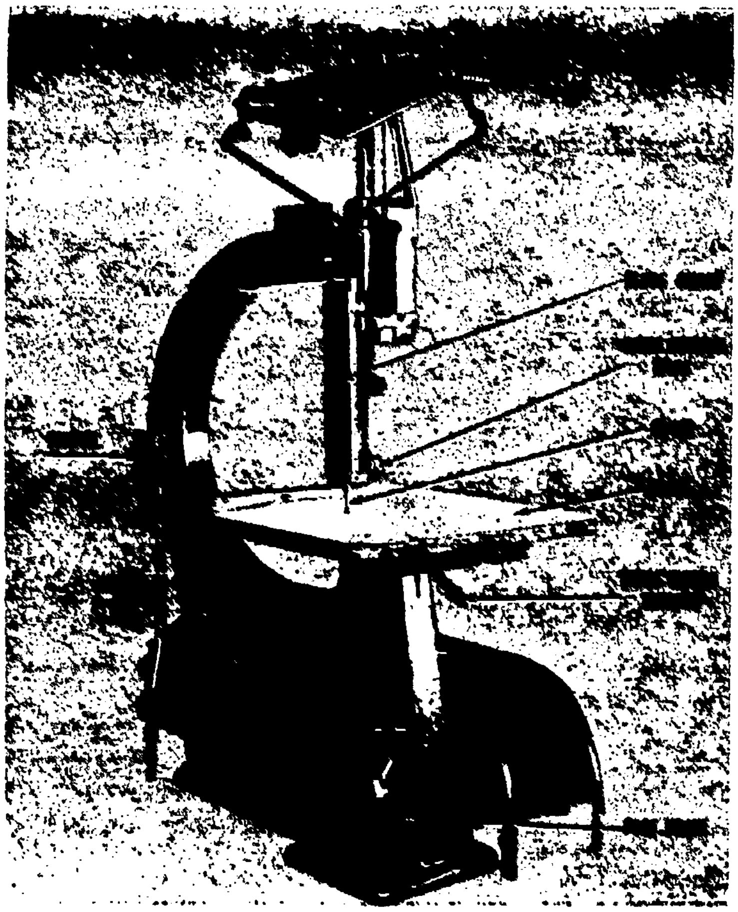


Figure 5-23. — Laying out ripsaw teeth.



68.13
Figure 5-24. — Laying out crosscut saw teeth.



68.15
Figure 5-25. — A jigsaw.

point of each tooth gives the line of the front or the tooth; a tangent drawn from the larger circle to the point of a tooth gives the line of the backslope of the tooth. Make the gum line circle large enough to run a little above the points of intersection of fronts and backslopes, to allow for a slight rounding of the gullet. A gullet which is filed to a corner has a tendency to crack at the corner.

In a combination saw the rip or raker teeth are shaped like ripsaw teeth and the other teeth are like crosscut saw teeth, as shown in part C of figure 5-22.

THE JIGSAW

The jigsaw or scroll saw, figure 5-25, has developed a great deal from its early days. The old types were usually operated by foot-power and were very crude. The modern jigsaw is a very efficient motor-driven machine used principally for cutting out enclosures.

Some models have a table that tilts right, left, and front. This permits sidewise cutting as well as straight cutting. This saw is capable of using several different blades, files, and sanding drums. It cuts stock up to 1 3/4 inches thick.

Some jigsaws have a variable speed control so that the operator may select any speed from approximately 650 to 1,700 cutting strokes per minute. The ball crank under the table controls the speed so that the blade can be run at high speed for fast, fine work; at low speed for heavy work; and at any speed between.

OPERATION OF JIGSAW

The chief advantage of the jigsaw is that internal cuts may be made by putting the blade in a starting hole. This is not easily accomplished with bandsaws.

Before the cutting is started, bore a hole in the area to be cut out. The hole must be large enough for a blade to go through easily. If a sharp curve is to be cut, select a narrow blade. Place the blade through the hole in the stock and into the jaws of the lower chuck. Tighten the clamping screw in the lower chuck until the blade is held securely. Lower the upper plunger until the saw blade can be inserted into the jaws of the chuck, then tighten the clamping screw. Test the tension of the blade by moving the saw by hand. If the blade buckles, increase the tension.

Adjust the top guide so that it is just above the stock, allowing the blade to rub gently against the rear of the slot. Now you are ready to start the machine and begin cutting. Hold down on the stock and push it steadily against the blade, cutting on the outline of the enclosure. Do not crowd the blade. When you have cut out the enclosure, stop the machine, loosen the clamping screws and take out the saw blade, then remove the stock.

SAFETY RULES

1. Jigsaw blades cut on the downward stroke only. Saw teeth face downward. Be sure that the blade is not inserted in the machine in an inverted position.
2. Select the proper size (width) of blade to suit the job, taking into consideration the thickness of the stock and the radius to be cut.
3. Adjust the saw guide as close as possible to the work to prevent the work traveling up and down with the saw blade.
4. Keep both hands firmly on the work during the entire cutting operation.
5. Do not force the blade to cut a sharper radius than it is designed to cut.
6. Stop the motor, using both the foot pedal and the pushbutton switch before attempting to clear internally cut free stock, before relocating the saw blade in the work, changing saw blades, cleaning the table surface of scrap materials, and on completion of the use of the machine.
7. Round stock may be cut on the jigsaw only when an adequate supporting jig has been provided to hold the stock firmly and to prevent its turning.

LATHES

The LATHE is without question the oldest of all woodworking machines. In its early form, it consisted of two holding centers with the suspended stock being rotated by an endless rope belt. It was operated by having one person pull on the rope hand-over-hand while the cutting was done by a second person holding crude hand lathe tools on an improvised beam rest.

The actual operations of woodturning performed on a modern lathe are still done to a great degree with woodturner's handtools. However, machine lathe work is coming more and more into use with the introduction of newly designed lathes for that purpose.

TYPES OF LATHES

The lathe is used in turning or shaping round billets, drums, disks, and any object that requires a true diameter. The size of a lathe is determined by the maximum diameter of the work it can swing over its bed. There are various sizes and types of wood lathes, ranging from very small sizes for delicate work to large surface or "bull lathes" that can swing jobs 15 feet in diameter.

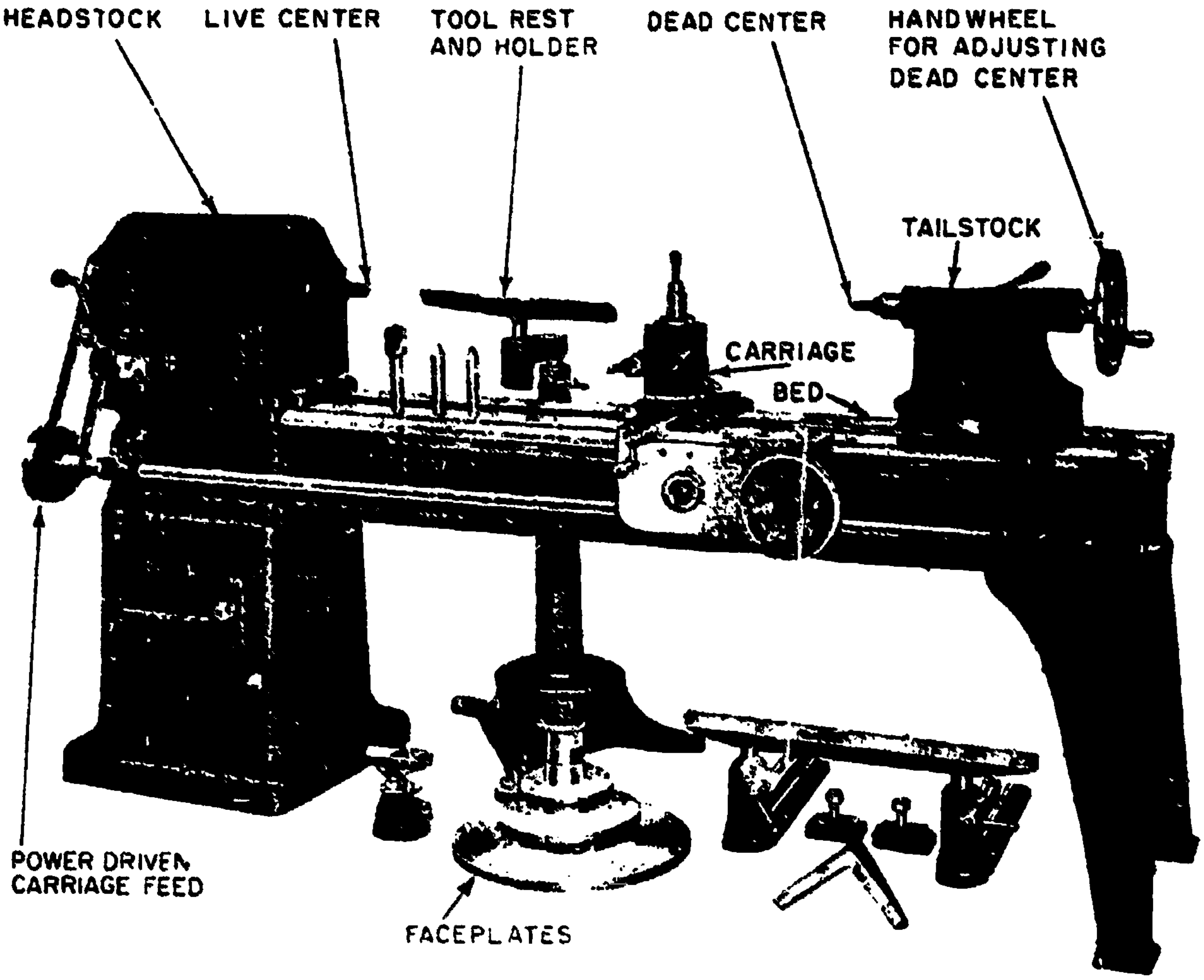
Figure 5-26 illustrates a type of lathe that you may find in your shop. It is made in three sizes to swing 16-, 20-, and 24-inch diameter stock. The lathe has four major parts: (1) bed, (2) headstock, (3) tailstock, and (4) toolrest.

The lathe shown in figure 5-26 has a bed of iron and is usually 8 or 10 feet long. It can be obtained in any other length desired. The bed is a broad flat surface that supports the other parts of the machine.

The headstock is mounted on the left end of the lathe bed. All power for the lathe is transmitted through the headstock. It has a fully enclosed motor that will give a variable-speed spindle (from 600 to 3,600 rpm). The spindle is threaded at the front end to receive the faceplates. A faceplate attachment to the motor spindle is furnished to hold or mount small jobs having large diameters. There is also a flange on the rear end of the spindle to receive large faceplates, which are held securely by four stud bolts.

The tailstock is located on the right end of the lathe and is movable along the length of the bed. It supports one end of the work while the other end is being turned by the headstock spur. The tail center may be removed from stock simply by backing the screw. The shank is tapered to automatically center the point.

Most large sizes of lathes are provided with a power-feeding carriage. A cone-pully belt arrangement provides power from the motor, and ways are cast to the side of the bed for sliding the carriage back and forth. All machines

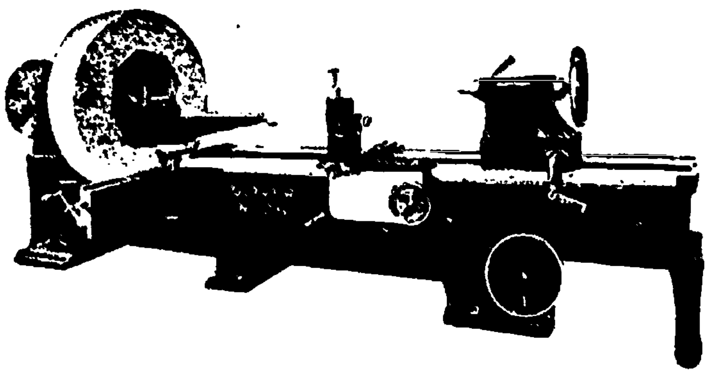


28.69(68)AX

Figure 5-26.—A woodturning lathe with accessories.

have a metal bar that may be attached to the bed of the lathe between the operator and the work. This serves as a handtool rest and provides support for the operator in guiding tools along the work. It may be of any size and is adjustable to any desired position.

The Patternmaker's large gap lathe shown in figure 5-27 is especially useful in turning large diameter work. The gap may be extended to take work of different sizes.

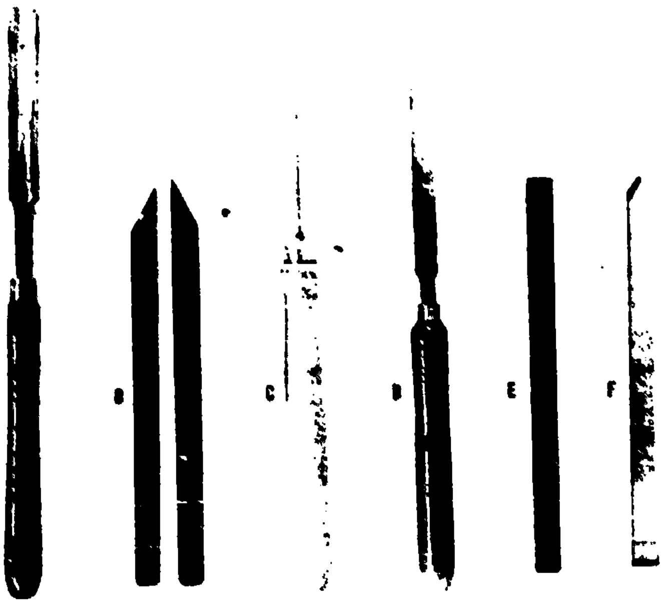


28.69(68)BX

Figure 5-27.—Patternmaker's gap lathe.

LATHE TOOLS

In lathe work, wood is rotated against the special cutting tools illustrated in figure 5-28. The special lathe tools include turning gouges;



A. Turning gauge D. Round-nose chisel
B. Skew chisels E. Square-nose chisel
C. Parting tool F. Spear-point chisel

28.66(68)
Figure 5-28. — Lathe cutting tools.

skew chisels; parting tools; round-nose, square-nose, and spear-point chisels; toothing irons; and auxiliary aids such as calipers, dividers and templates.

Turning gouges are used chiefly to rough out nearly all shapes in spindle turning. A skilled Patternmaker may use this tool for almost any lathe operation except faceplate turning. The gouge sizes vary from 1/8 inch to 2 or more inches, with 1/4-, 3/4-, and 1-inch sizes being most common.

Skew chisels are used for smoothing cuts to finish a surface, turning beads, trimming ends or shoulders, and for making V-cuts. They are made in sizes from 1/8 inch to 2 1/2 inches in width and in pairs, right-handed and left-handed.

Parting tools are used to cut recesses or grooves with straight sides and a flat bottom and also to cut off finished work from the faceplate. These tools are available in sizes ranging from 1/8 to 3/4 inch.

Scraping tools of various shapes are used for the most accurate turning work, especially for most faceplate turning. A few of the more commonly used shapes are illustrated in parts D, E, and F of figure 5-28. The chisels shown in B, E, and F are actually old jointer blades which have been ground to the required shape; the wood handles for these homemade chisels are not shown in the illustration.

A toothing iron is basically a square-nose turning chisel with a series of parallel grooves cut into the top surface of the iron. (See fig. 5-29.) These turning tools are used for rough turning of segment work mounted on a faceplate. The points of the toothing iron created by the parallel grooves serve as a series of spear-point chisels; therefore, the tool is not likely to catch and dig into the work like a square-nose turning chisel. The toothing iron is made with coarse, medium, and fine parallel grooves and varies from 1/2 inch to 2 inches in width.

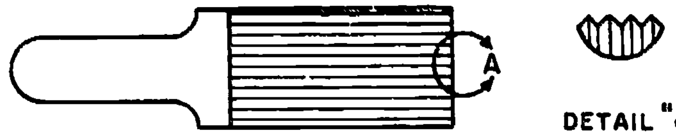
OPERATION OF THE LATHE

Lathe turning may be divided into two categories: center-to-center turning (also called between center turning and spindle turning) and faceplate turning.

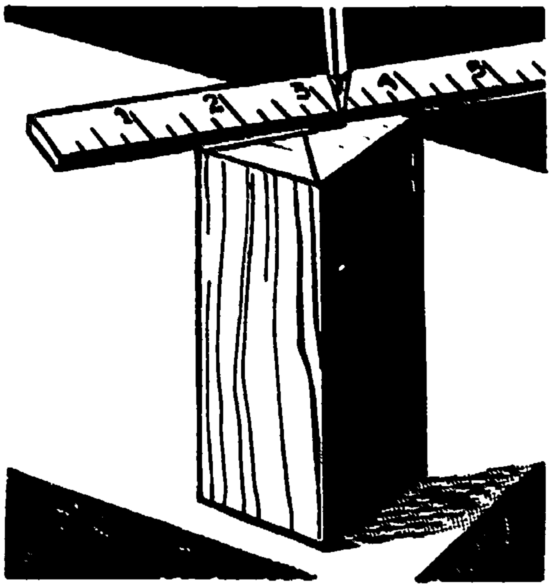
Spindle Turning

The first step in spindle turning is the preparation of the stock for centering. When working with solid or glued-up stock, cut the stock approximately square and about 1 inch longer and 1/4 inch wider than the desired finished dimensions. Draw diagonal lines from corner to corner across both ends of the stock (see fig. 5-30). The point on each end where the lines cross will be approximate center. Indent these centers with an awl, nail set, or drill.

Center one end of the stock against the headstock spur of the lathe. Tap it on the other end with a wooden mallet and seat the stock against the spur surface. Hold the stock in this position while you move the tailstock to within 1/4 inch of the other end of the stock. Clamp the tailstock to the bed by tightening the clamping



68.16
Figure 5-29. — Toothing iron lathe tool.



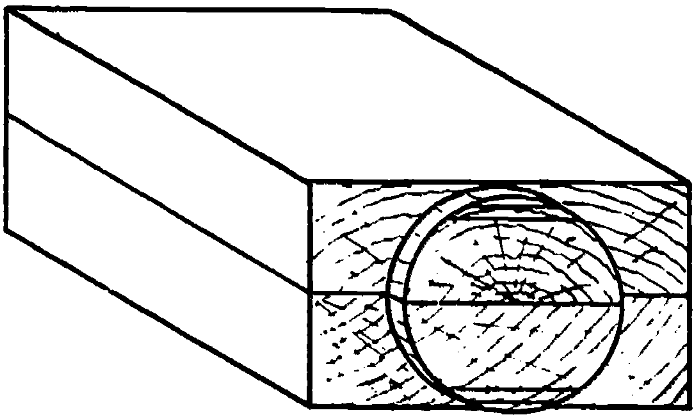
68.17
Figure 5-30. — Centering solid stock.

level. Run the tailstock spindle out and place its center point in the center hole in the end of the stock. Turn the handwheel at the rear of the tailstock and force the center point tightly against the stock end. Then back off the spindle about 1/8 turn of the handwheel and place a drop of oil or some beeswax where the wood touches the metal center. This relieves the pressure of the center against the work and allows the stock to rotate freely without end play. Tighten the spindle clamp.

When working with parted pieces it is necessary for you to check the work to make sure that the parting joint is exactly in the center. One good method of doing this is by gaging a series of lines equidistant from the parting joint on each end of the stock before the two pieces are fastened together for lathe turning. See figure 5-31.

Turn a test space about 1/8 inch long at each end of the stock to a perfect circle. If the circle coincides with two of the gaged lines — one on each side of the parting joint — the joint is exactly centered. If not, you will have to tap the stock lightly with a mallet in order to center the work in the lathe. You can also test the distance on each side of the parting joint with a pair of dividers.

After you center the work properly in the lathe, move the toolrest close to the stock and parallel to it. The toolrest should be about 1/8 inch from the work. Spin the work by hand to see that it clears the rest. Lock the toolrest holder in position. Release the clamp that holds the toolrest in the toolrest holder. Set the toolrest approximately level with, or about 1/8 inch above the centerline of the stock. Then make sure that the toolrest is securely tightened in position.



68.18
Figure 5-31. — Centering parted pieces for lathe turning.

Before starting the lathe, adjust the speed in accordance with the size of the stock. The size of the job will determine the turning speed of the lathe spindle: the larger the diameter, the slower the speed; the smaller the diameter, the faster the speed.

The recommended speed for any size of the lathe work is approximately 1500 surface feet per minute. Do not confuse surface feet per minute (sfpm) with revolutions per minute (rpm). Surface feet is the distance covered by the point of the tool on the rotating surface of the work during the interval of one minute. It is expressed in surface feet per minute.

To find sfpm, multiply the circumference of the work (in inches) by the number of revolutions per minute and divide by 12 to change inches to feet. The result is peripheral or surface feet per minute. For example, an object with a 12-inch diameter has a circumference of 37.69 inches (circumference equals diameter times 3.1416). If this object is turning at 600 rpm, the surface feet per minute will be $\frac{37.69 \times 600}{12}$, or 1884.5 sfpm. Conversely, the rpm required to obtain a given sfpm is found by dividing the product of the surface feet times 12 by the circumference of the work in inches.

After the speed adjustment has been made and the machine has been started, you are ready to cut or turn the stock with a gouge or other lathe cutting tool. For gouge work, stand with your feet about 12 or 14 inches apart and with the left side of your body a little closer to the lathe than the right side. The stance might vary for a left-handed person.

Use the gouge for reducing stock to a cylindrical shape and for making concave cuts and grooves. Hold the gouge handle securely and place the gouge on the toolrest with the handle well down. Steady the gouge with your left hand by placing the heel of the palm against the front of the toolrest. Hold the palm on the top of the gouge when making heavy cuts and under the tool for fine cuts.

Bring the gouge slowly against the revolving work at about the middle of the stock. Roll the gouge sideways to make a shearing cut with the side edge of the tool. Move the gouge slowly toward the headstock. (See fig. 5-32.) Stop when the gouge is about 1/2 inch from the end of the toolrest. Go back to the point where you started the cut and roll the gouge over and make a cut toward the left. Keep checking the dimensions frequently with a pair of calipers set at least 1/8 inch over the finish dimensions.

Be sure that the power is shut off and that the lathe has come to a complete stop before you attempt to check dimensions with calipers or templates. Repeat the right and left cuts until the stock is reduced to a cylinder. You may need to move the toolrest as the work progresses. Be sure to keep the 1/8-inch clearance so that the hand that is steadying and guiding the cutting tool will have full support at all times. Also adjust the angle of the toolrest to conform to the contour of the stock as it is being shaped.

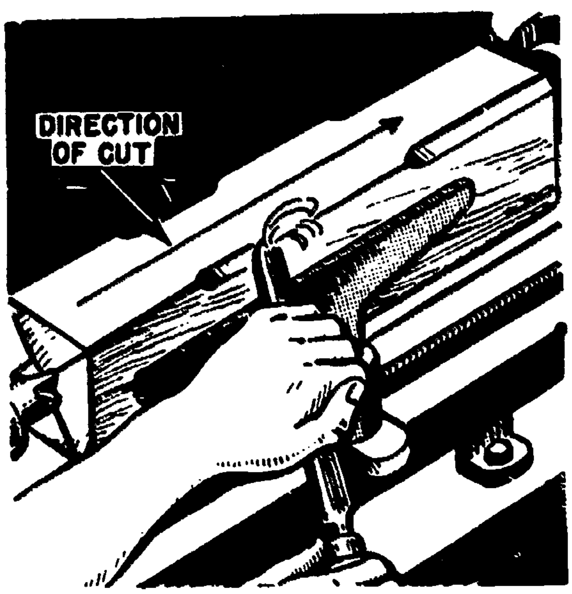
After the stock has been reduced to the approximate size and shape desired, use the skew chisel for smoothing cuts and for trimming ends and shoulders. In smoothing a straight cylindrical surface, always place the chisel flat on the toolrest before bringing it against the work. Start the cut at about the middle of the toolrest. Keep the skew chisel on the toolrest at all times while using it.

Draw the chisel back slowly, meanwhile raising the handle slightly until the heel of the bevel on the cutting edge engages the work. Keep the face of the bevel tangent to the surface of the work and hold the chisel firmly against the toolrest as you move it steadily into the cut. This position is illustrated in figure 5-33. Never allow the skew chisel point to come into the cutting position because it may dig in and ruin the turning. Move the chisel laterally to the right or left. Then reverse the chisel, cut in the opposite direction, and repeat as much as necessary.

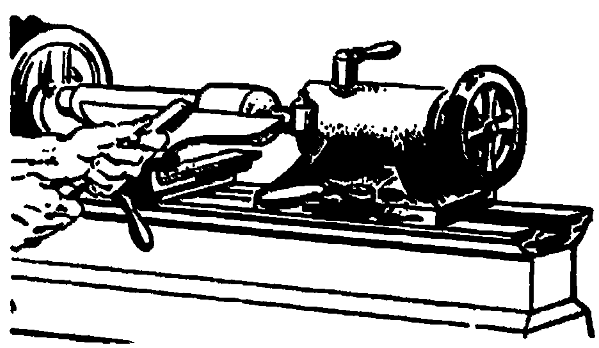
There are many other spindle cuts that you can make with the gouge, skew chisel, and other lathe cutting tools.

Faceplate Turning

Faceplate turning differs from spindle turning in the manner of mounting the stock on the lathe. In faceplate turning, the headstock spur



68.19
Figure 5-32. — Using a gouge in spindle turning.



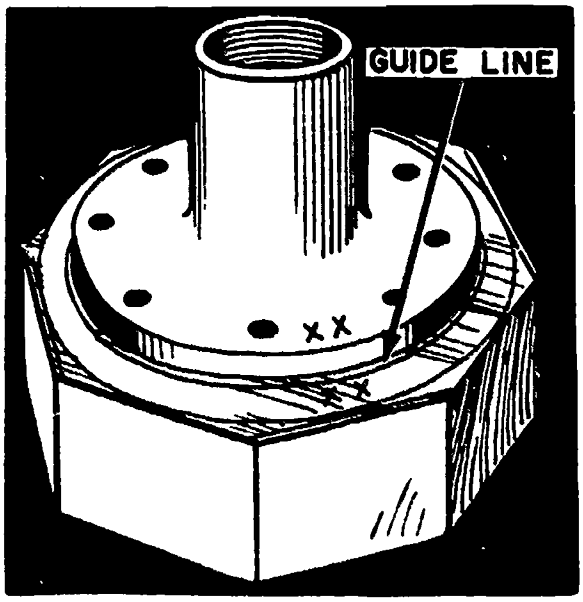
68.20
Figure 5-33. — Using a skew chisel.

is replaced by a metal faceplate. The most common method of fastening the stock to the metal faceplate is by the use of wood screws.

A faceplate of approximate size is selected and its diameter measured. Draw a circle of this size plus 1/32 inch on the working face of the stock. Center the faceplate in this circle. With a pencil, draw a few small circles on the stock through the screw holes in the plate. Also mark the plate and stock so you can place them together again at the same exact points. (See fig. 5-34.) Remove the faceplate and drill holes for the screws. Then position the faceplate and stock so they are back in their original position, and insert and tighten flathead screws of correct size.

Small stock, under 4 inches in diameter and under 2 inches in thickness, may be mounted on a screw chuck. This is a faceplate with a screw permanently fastened in its center. A 3/16-inch hole is bored in the center of the working face of the stock. The chuck screw is run into this point of the stock. Then the faceplate is screwed on the lathe spindle and the stock is ready for turning.

You may find that it is not always possible or practicable to fasten the stock to a metal faceplate. This is especially true when turning very thin, ring-shaped, or segmented stock. In these cases, the stock is fastened to an auxiliary wooden plate that is mounted on the metal plate.



68.21

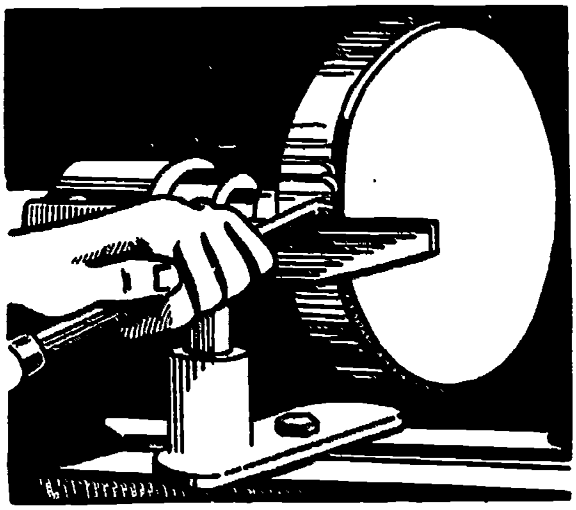
Figure 5-34. — Centering the faceplate on the stock.

The stock is centered on the wooden faceplate and fastened with screws, brads, or glue. The size and number of screws depend upon the thickness and size of the faceplate and stock. If brads are used, set them so that they will not interfere with the turning operation. Be careful after completing the turning to remove the stock with a thin chisel. If glue is used, coat the stock and clamp it in position on the faceplate; then let it dry. If you insert a sheet of paper between the wood faceplate and the stock, you will be able to separate them more easily when you are finished.

Faceplate turning also differs from spindle turning in the use of turning tools. In general, faceplate turning is accomplished by scraping instead of cutting. The toolrest is set about 1/8 inch below the center of the lathe spindle. Turn the stock a few times to see if it will clear the toolrest when it revolves.

Hold a round-nose or a spear-point tool on the toolrest as shown in figure 5-35. Slowly bring the cutting edge into contact with the moving stock and make a light initial cut. This is continued until the outer diameter is true. A safety factor to be remembered in faceplate turning is NEVER USE A GOUGE.

If the stock thickness has to be reduced, scribe a line along the outer edge to show the amount of stock to be removed. Stop the lathe; then, loosen and swing the toolrest and toolrest holder until they are parallel to the face of the stock. The toolrest should be clamped securely about 1/8 inch away from the stock, and about



68.22

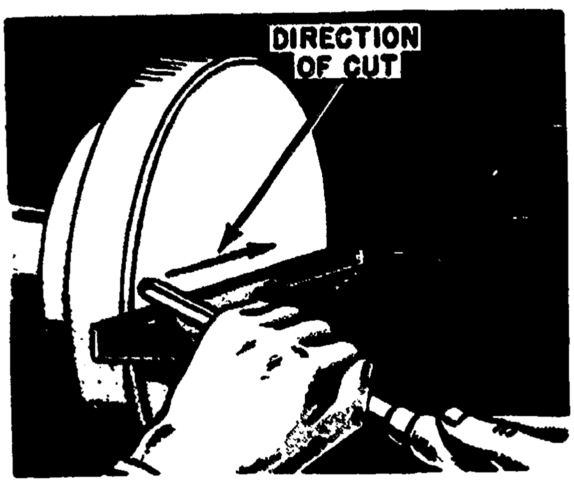
Figure 5-35. — Using a diamond point lathe tool in faceplate turning.

1/8 inch below the center. The lathe may now be started at a speed of 1,200 to 1,800 rpm.

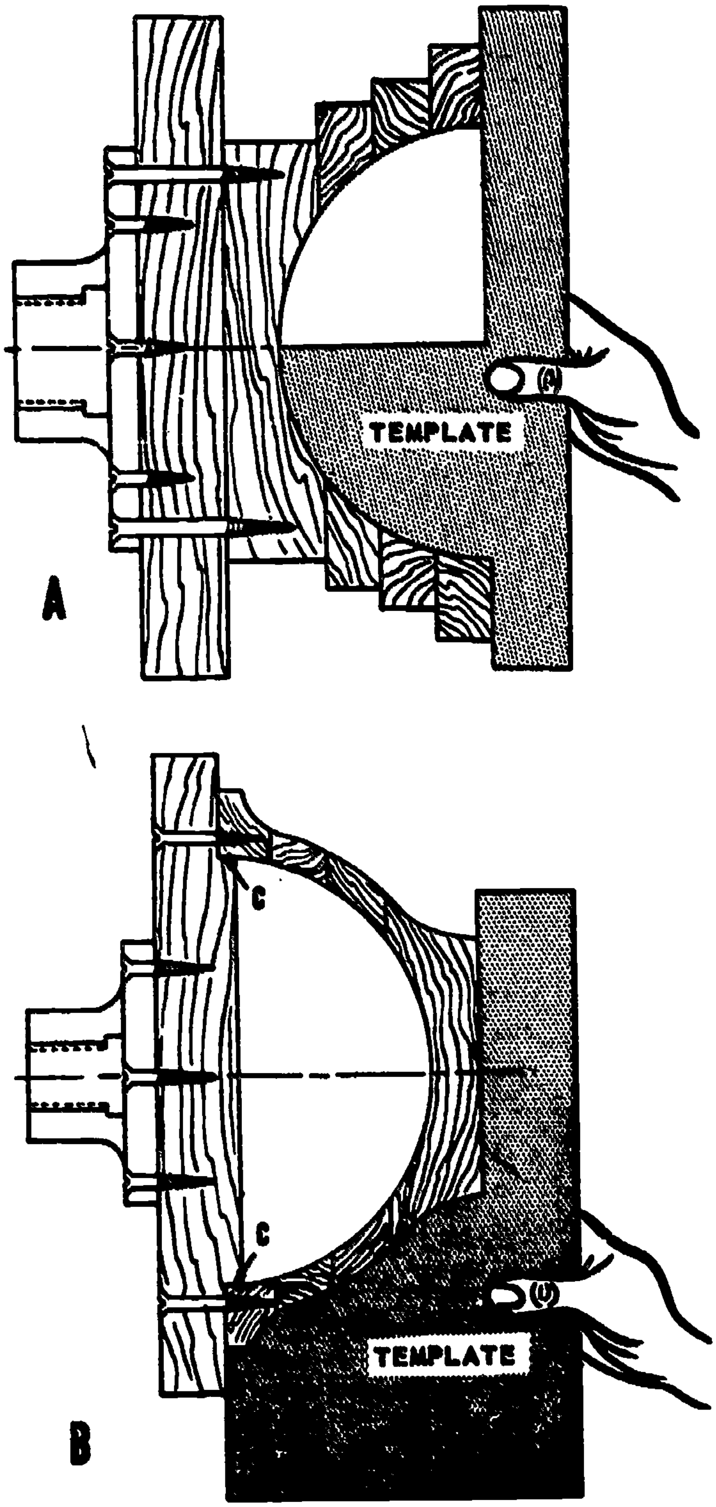
The turning tool is directed from the outer edge toward the center. (See fig. 5-36.) Do not go past the center point because centrifugal force will cause the turning tool to be thrown back at you. Light, careful cuts must be made until the waste stock has been removed to the scribed thickness guide line. Then, holding a square-nose tool horizontally against the stock, lightly cut away any remaining waste stock and smooth the surface. A square is used to test the edge and the face of the stock for squareness. Other cutting tools, especially the round-nose chisel, skew chisel, and the square-nose chisel, are best used for faceplate cutting of recesses, for scraping beads, and for turning fillets.

Templates

A template is a thin piece of material with the edge corresponding to a specific contour and used as a guide for checking purposes. Templates are used by the Patternmaker to get perfect shapes in lathe turning and in hand carving of patterns and core boxes. Templates vary in shape depending upon the particular requirements of the job. They are usually made of thin stock, cardboard, template paper, or sheet metal. No matter what material is used, templates must be made with great accuracy. Important centerlines are transferred from the layout to the template. Figure 5-37 shows the use of an inside and an outside template in



68.23
Figure 5-36.—Reducing stock in thickness.



23.84
Figure 5-37.—Using templates in faceplate turning.

faceplate turning. The edges of the templates are chalked so that you can tell where the high spots are located. Remove the stock slowly and carefully from the high spots to prevent cutting off too much stock and thereby ruining the job.

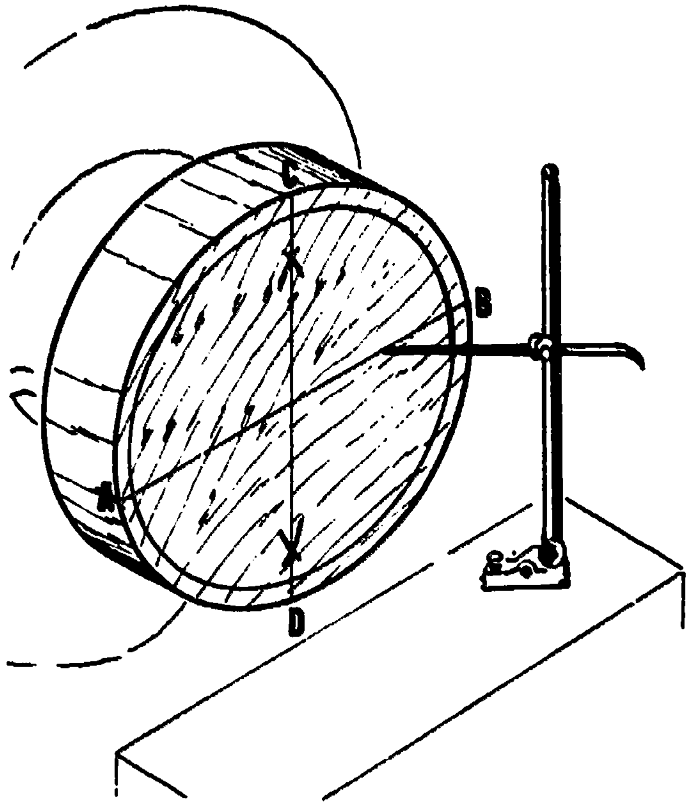
The two methods shown in figure 5-37 are not the only methods of mounting work in the lathe for faceplate turning. Very often the Patternmaker will make use of engine lathe attachments such as drill chucks (Jacobs chucks), independent, universal, or combination chucks, for centering special jobs.

Rechucking

Rechucking is the procedure used when all the surfaces of a pattern are to be turned to dimension. After completing the turning of one face of the pattern, the Patternmaker will detach the work from the faceplate and remount it in a reversed position as shown in part B of figure 5-37. This enables the Patternmaker to turn the surface that was originally against the faceplate. Great care must be exercised in centering the work properly during rechucking operations. One method of centering the work is shown in figure 5-37. Note that a recess is turned on the wood faceplate at points C of part B to provide a firm bearing surface for the rechucked pattern.

Laying Out Centerlines On A Faceplate

Scribed centerlines and construction lines will invariably be cut away during turning operations. You must, in order to maintain accuracy of workmanship, replace all centerlines after completing the turning phase of the job. You will find that it is most convenient to restore the centerlines while the work is mounted in the lathe. The procedure outlined here is suggested for laying out centerlines on faceplate work. (See fig. 5-38.)



23.85
Figure 5-38.—Laying out centerlines on faceplate work.

1. Start the work revolving on the lathe. Touch the approximate center of the work very lightly with a pencil or with one leg of a pair of dividers. The rotation of the work will cause the pointer to move in the direction of true center.
2. Stop the lathe and lock it securely in place to prevent any movement during subsequent measurements. Set up a surface gage on the flat lathe bed and adjust the pointer to the height of the true center scribed on the job in step 1.
3. Move the surface gage across the face of the work and scribe a light line at points A and B on the faceplate. Note that the measurement marks are made on the faceplate to avoid marring the face of the job.
4. Rotate the work in the lathe by hand through an arc of 180° and recheck marks A and B against the surface gage pointer. Readjust the surface gage and repeat this procedure until both points A and B coincide exactly with the surface gage pointer. Lock the gage and scribe centerline AB across the face of the work.
5. Scribe a circle on the faceplate intersecting line AB. Using dividers or trammels, bisect line AB and scribe points C and D on the faceplate.
6. Rotate the work by hand and recheck points C and D to make sure that they coincide with the surface gage pointer. Scribe centerline CD across the face of the work.
7. Before detaching the job from the faceplate it is advisable to mark its exact location on the faceplate because the job might require subsequent turning and remounting on the lathe.

The exact position of the work on the faceplate may be marked by attaching small blocks of wood to the faceplate at several points outlining the silhouette of the job.

Turning Interrupted Surfaces

Thus far we have discussed the lathe turning operation on stock which offers a continuous, uninterrupted surface to the cutting tool. For certain jobs, such as a gear wheel or a star washer pattern, the Patternmaker will be required to turn an interrupted surface. As a PM3 or PM2 you should be alert to the following dangers inherent in the turning of interrupted surfaces:

1. The work tends to grab the cutting tool.
2. The stock tends to split off at the trailing edge.
3. The limits of the stock are difficult to see.

Being aware of these dangers, you should follow and insist upon strict adherence to the following safety rules:

1. Use the toolrest as much as possible.
2. Adjust and set the compound or the toolrest for the start of the cut before turning the switch on.
3. Take very light cuts, especially when using handtools.
4. Never attempt to use calipers on interrupted surfaces while the work is in motion.

SAFETY RULES

1. Secure all adjustments before turning on power. Start lathe at the lowest speed and adjust speed to the rate appropriate to the size of the job.
2. Make one complete revolution by hand to check the clearances before starting the motor.
3. Put a drop of oil or beeswax on the dead center of the lathe before starting and repeat at various intervals as required.
4. All wood to be turned must be free from deep checks and knots.
5. Allow all glued work to dry properly before attempting to turn it in the lathe.
6. Use screws instead of nails whenever possible to attach the work to a faceplate.
7. Remove wrenches from chuck before starting the motor.
8. Always remove the toolrest before sanding.
9. Always stop the lathe before making any adjustment of the toolrest. Keep the toolrest close to the work but with sufficient clearance to avoid catching in the revolving stock.
10. Use a turning gouge for roughing down.
11. Use a wooden or rawhide mallet to force the centers deeply into the stock. Center the work properly in the lathe. (If the tailstock is equipped with a setover device, adjust and lock it at zero, before starting new work.)
12. Remove all flat spots from the work before attempting to use outside calipers.
13. Never reduce the rpm of a lathe by using the electrical controls. This may cause the faceplate to spin off the spindle with dangerous force.
14. Stop the lathe before using inside calipers.
15. Take precautions to avoid catching clothing (sleeve, necktie, etc.) in revolving jobs.
16. Use particular caution in turning interrupted surfaces to avoid grabbing.
17. Never use a turning gouge for faceplate work.

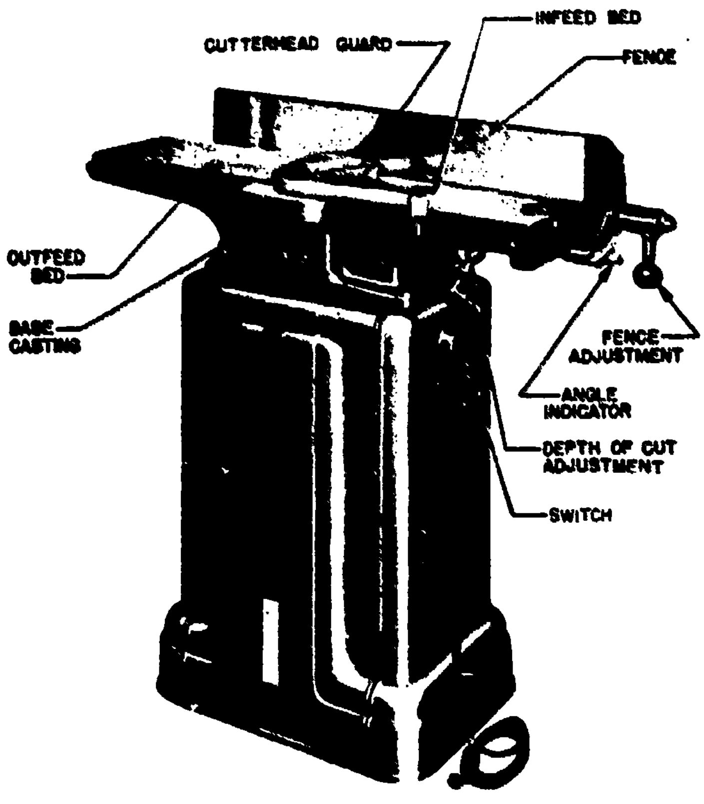
THE JOINTER

The jointer (also called hand planer and jointer) is used principally for surfacing and edging. It is also used for beveling, chamfering, rabbeting, and tapering. By jointing one face of a warped board, the jointer can make it suitable for use in patternmaking. Figure 5-39 illustrates a model which you may find in your shop.

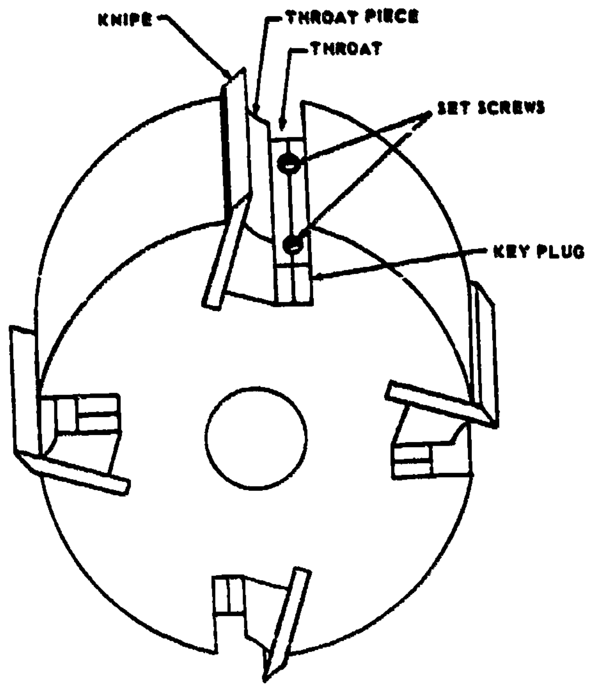
The size of the jointer is determined by the length of the cutterhead and is available as 4, 6, 12, 16, 47, or 30 inch.

The machine has a heavy, strongly ribbed bed with sliding frames to carry the table to and from a cutterhead. In the cutterhead (fig. 5-40) there are two, three, or four knives, depending upon the make of the machine. A movable fence and automatic safety guard are also provided.

Only sharp knives of equal weight should be used in the jointer. Dull knives are dangerous, and knives of unequal weight cause vibration. The knives should be set accurately to produce a smooth, even cut and should be fastened securely to prevent them from flying out. Before starting the machine, see that the tables and fence are properly set and locked.



29.138
Figure 5-39.— A 6-inch jointer.



133.73
Figure 5-40.—Four-knife cutterhead for a jointer.

OPERATION OF THE JOINTER

Before cutting pattern lumber to the desired size on the circular saw, you would normally surface the stock. Surfacing includes making one face of the stock a plane surface, straightening one edge, and making the stock uniformly thick throughout its length. A curved or irregular edge may cause binding and possible accidents.

Thin stock (below 1/4 inch in thickness) should not be faced on the jointer. Always consider the front table as 4 inches long, the throat as 4 inches long, and the rear table as 4 inches long; therefore, stock less than 12 inches long SHOULD NOT be run over ANY jointer. Working thin or short stock may cause injury and damage.

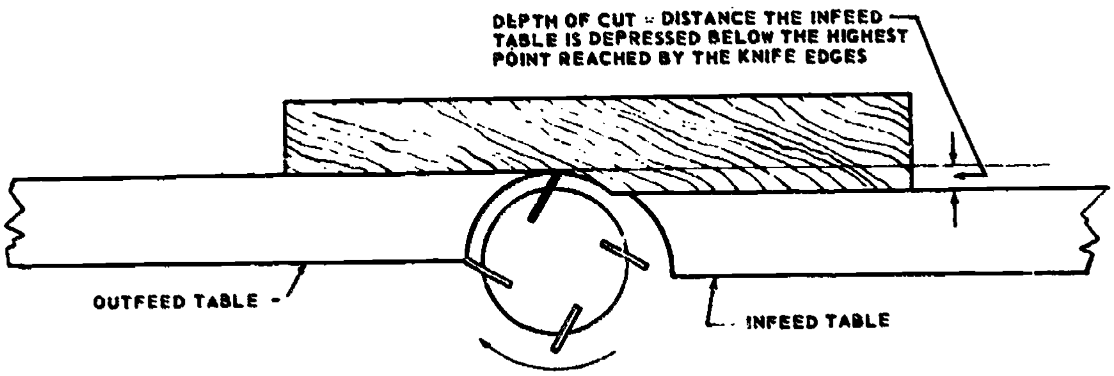
Use the jointer for surfacing one face of a board. Adjust the front table to make a 1/32-inch cut and set the fence at a right angle to the rear table, near the right-hand edge (fig. 5-41). Start the machine and wait until the cutterhead is revolving at maximum speed. Hold the stock against the fence and always use the guard. Use a push block (fig. 5-42) on the shorter pieces. It is safer and better to take several lighter cuts instead of one deep cut. Too heavy a cut may cause a kickback.

Care should be taken to feed the lumber so it will cut with the grain. As soon as the front part of the stock passes the cutterhead, hold it down on the rear table. Since the rear table determines the plane of the cut, stock must be held against it firmly to ensure a true plane.

When you have finished jointing, be sure that the power is shut off and the cutterhead has come to a complete stop before you clean off the shavings or move the fence.

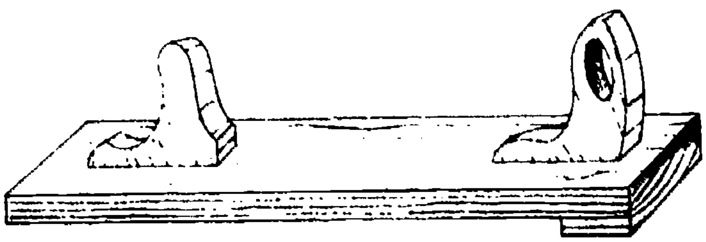
The jointer is also used for edging a board. If the edge is fairly straight, hold the board firmly against the fence and front table and push it over the cutterhead to the rear table. Repeat until the edge is perfectly flat.

When edging curved stock, pass the after end of the concave edge of the board over the cutter



133.74

Figure 5-41. — Principle of operation of the jointer.



103.35

Figure 5-42. — A jointer pushboard.

68.24

Figure 5-43. — Jointing crooked stock.

four or five times. This is illustrated in figure 5-43. Reverse the board and joint the outer end; then joint in the usual way. This permits the knives to start cutting gradually instead of jabbing into the edge and possibly splitting the board. If a board is badly warped, cut the edge approximately straight on a bandsaw and finish on a jointer.

After you have trued one face and one edge of the stock on the jointer, mark them for identification purposes. You are now ready to saw the board to size on the circular saw and to plane the board on the thickness planer to the thickness wanted.

MAINTENANCE OF THE JOINTER

The cutterhead has precision ball bearings. The model illustrated has the self-aligning, frictionless ball type which requires very little attention. Jointers made by other companies will vary in their lubrication requirements. Some models must be given careful attention, including weekly greasings. For all models, dirt is the outstanding cause of ball bearing troubles; so keep your machine clean.

The electric motor is enclosed and ventilated. Occasionally the motor should be blown out with compressed air to keep all the air ducts open. It must be lubricated in accordance with the manufacturer's instructions. The table adjusting mechanisms are usually oiled once a week.

Additional maintenance information concerning all shaving machines will be discussed later in this chapter.

SAFETY RULES

1. See that there are no obstructions beyond the table ends which may cause interruptions in the work once it is started.

2. Inspect the safety guard for free action. Keep the safety guard over as much of the cutterhead area at all times as the work will permit.

3. The correct position of the hands in jointer operation is such that at no time will they pass above the cutter blades while you are advancing the stock. Keep hands away from the front and back ends of the stock and keep the fingers from extending over the edges of the stock.

4. Make sure that the exhaust system is in operation and that the exhaust duct is open, before starting the machine.

5. Allow the motor to develop full speed before starting the cut.

6. Inspect all surfaces of the stock and remove nails, screws, paint, embedded sand, and other metallic parts that may damage the blades.

7. Adjust and lock the fence frame to expose only the required blade area for the job. Adjust and lock the guide fence in place before starting the machine.

8. Do not attempt to take more than a 1/8" cut on edge work or more than a 1/16" cut for surfacing.

9. Hold the stock down firmly and flush against the guide fence to prevent any kickback due to warpage or convex curvature in the stock. Whenever possible, keep the small finger on top of the fence while pushing stock.

10. To avoid stock tipping, only stock of recommended length should be run across the jointer. Do not attempt to surface stock shorter than 12" in length.

11. Use a push block when surfacing thin stock.

12. NEVER attempt to use the jointer to cut end or cross grain.

13. Do not crowd the knives; this overloads the machine.

14. When surfacing is completed, turn the power off and replace the guard before leaving the machine. If the guide fence was used with an angle setting, readjust it and lock it at 90° before leaving the machine. When the machine has come to a complete stop, clean all shavings from the throat.

PLANER

The planer is designed to plane or dress the surface of wood stock to a desired, uniform thickness throughout its length and width.

Some types will surface two faces as well as the two edges with one pass but the type generally found in Navy shops will surface one face at a time and is known as the single surfacer (fig. 5-44).

The size of the surfacer is determined by the maximum width that it can cut which may vary, with Navy machines, from 12 to 48 inches. The model shown in figure 5-44 will plane stock up to 24 inches wide and 8 inches thick, thus it is a 24 inch planer.

Figure 5-45 is an illustration of the basic parts of a single surfacer.

The bed of a conventional single surfacer has three sections: front table, center table, and rear table with the lower infeed and outfeed rollers mounted on either side of the center table. These rollers span the entire width of the bed with the outfeed roller about 10 inches to the rear of the infeed roller. The rollers are set from 1/32" to 1/16" higher than the tables. The bed can be raised and lowered by either a manually operated handwheel (fig. 5-44) or by a power hoist.

The upper section of the single surfacer consists of an upper infeed roller, upper outfeed roller, the cutterhead, the chip breakers, and the pressure bar.

The single surfacers used in Navy shops usually are provided with a spring loaded, sectional upper infeed roller, each section being about 1 1/2" wide. This is a much safer roller than the solid bar type as it allows for the uneven surface of rough stock and ensures contact with the stock at all times. This roller feeds the stock into the cutter and must always maintain enough pressure on the stock to prevent it from being kicked back against the operator.

The upper outfeed roller is a solid bar type and is responsible for pulling the finished stock out of the machine.

The cutterhead is usually a solid cylinder, slotted to hold three or four knives and is similar to the jointer cutterhead.

The knives in the cutterhead are balanced, matched sets. If the knives are removed from the machine for sharpening, care should be taken that they are marked and taped together to ensure that they are not mixed with another set.

Some machines are provided with a knife grinding attachment which can be mounted on top of the machine. This enables you to sharpen the knives without removing them from the cutterhead. After the grinding attachment has been used, it must be removed from most machines to allow the re-attachment of the

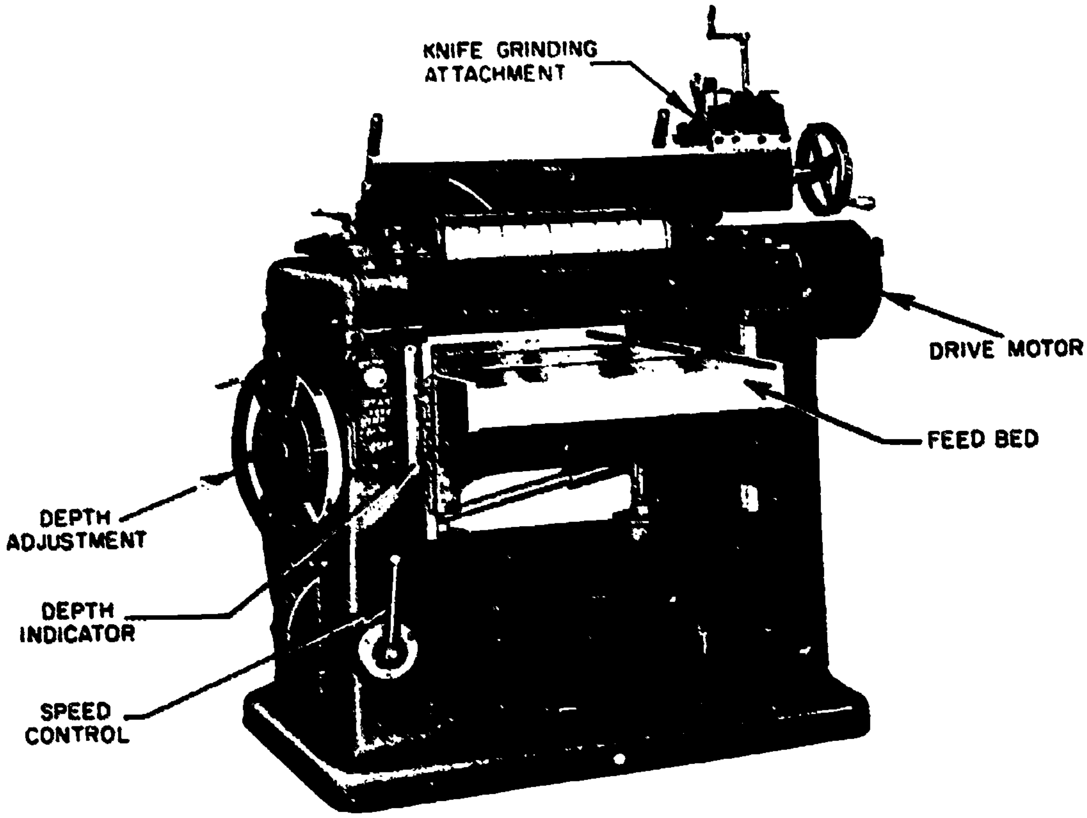


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Figure 5-44. — Single surfacer.

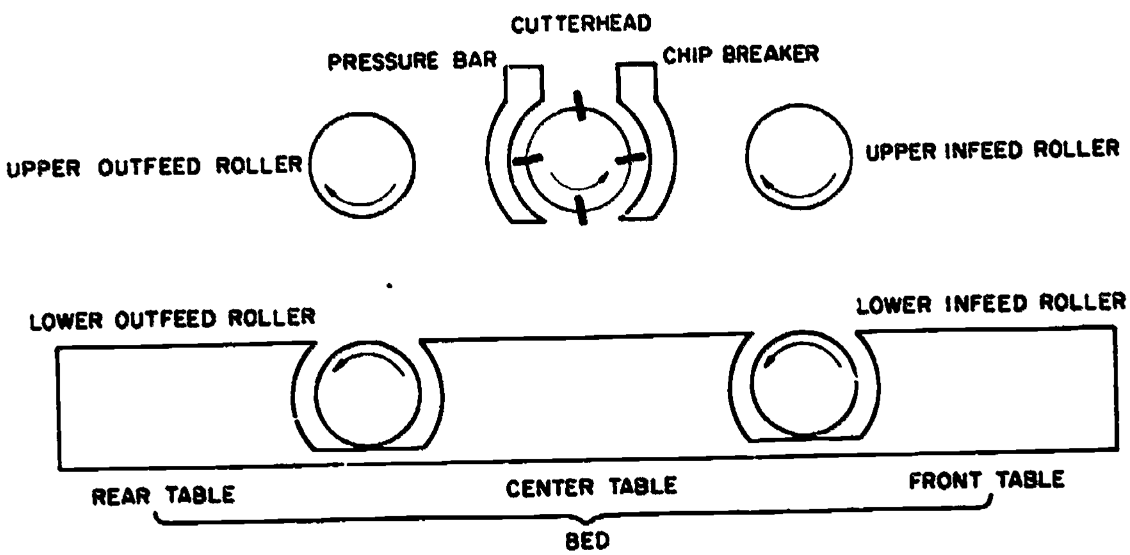

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Figure 5-45. — Basic parts of a single surfacer.

sawdust collector exhaust hood. The knife grinding attachment will be discussed later in this chapter.

The chip breakers are situated in front of the cutterhead. They are spring loaded, usually about 1 1/2" to 2" wide and extend the full length of the cutterhead. Their function is to prevent excessive chipping by pressing down on the stock and forcing the chips to break into small pieces.

Immediately behind the cutterhead is the pressure bar which also extends the complete length of the cutterhead. The pressure bar is solid and has a smooth lower face. Its function is to hold the stock firmly in place after it has been planed.

A single surfacer may have one or two motors. In the two motor machine, one motor will be a direct mounted, high speed type which drives the cutterhead at 3600 rpm. The other motor will be a variable speed type which drives the feed rollers at 0 to 60 feet per minute (fpm).

In the single motor type, the cutterhead is usually direct drive also but the feed rollers are driven by either a system of speed chains and sprockets or belts and pulleys. Both systems are variable and will usually allow for 0 to 60 fpm feed.

Some machines, usually the two motor type, will have a reverse feed feature which allows the operator to back stock out of the machine.

All planers are provided with a depth indicator scale, a depth adjustment wheel, which raises or lowers the bed, and a speed control lever or wheel which regulates the feed by fpm.

OPERATION OF THE PLANER

The lumber that is stocked by the Navy is in its rough state. It may contain staples from shipping tags, nails, screws, imbedded dirt, paint, loose knots, or a variety of other objects that could damage the machine or create a safety hazard so it is very important to inspect the stock thoroughly before surfacing it.

Since the Patternmaker needs perfectly flat stock, the next step is to obtain one true face and one true edge on the jointer. THE PLANER IS NOT DESIGNED TO STRAIGHTEN WARPED STOCK. If a warped board is passed through the machine, the rollers and a pressure bar will hold it flat but as soon as the board is released by the machine, the board will return to its warped condition.

After you have trued your stock, cut it to the desired width and about 6 inches longer than the desired length. Cutting the stock to width saves material and the additional length ensures plenty of useable stock if the stock chips out on the ends.

CAUTION: Do not try to plane stock that is less than 2 inches longer than the distance between the centers of the infeed and outfeed rollers. Stock that is too short to span both the infeed and outfeed rollers has a tendency to jump and the finished work is not smooth.

Now you are ready to plane the board to the desired thickness.

Before starting the planer, sight through it and see that there are no loose chips or foreign objects on any of the tables, measure the stock at its thickest section, adjust the bed so that the depth indicator measures 1/16" less than this measurement. One sixteenth inch is the maximum cut that may be taken on soft woods, 1/32" for hardwoods. Now set the feed indicator at 25 fpm, which is the rate of feed for average work, disengage the feed mechanism, open the exhaust vent, and start the machine. Wait until the cutterhead reaches full speed and engage the feed mechanism. Place the stock on the front table with the rough side up and the direction of the grain running with the cut (fig. 5-46). Be careful not to have your fingers alongside or under the stock. Push the stock forward and at a slight angle until it is engaged by the infeed rollers and then release it. (The slight angle helps to minimize chipping.)

68.26

Figure 5-46. — Feeding stock to a planer.

If the planer cutterhead slows, stop the feed and reset the feed control to a slower feed rate, wait for the cutterhead to regain full speed and then restart the feed mechanism.

To reduce two or more pieces of stock to the same thickness, run all the pieces, one at a time, through the planer. Then reset the machine for another cut and run them through again. This is repeated until you are ready to make the final cut. Before making the final cut, it is a good practice to run a test piece through the machine and reset until the desired thickness is obtained.

When surfacing stock for patterns, do not use a standard rule. Always use the same shrink rule that was used in developing your layout.

MAINTENANCE OF THE PLANER

It is very important to keep the planer, as well as all machines, clean. The most outstanding cause of machine breakdown is dirt. Particles will get into bearings, cling to chains, sprockets and rollers, stick to belts and cutterheads, and eventually render the machine either inoperative or inaccurate. Use compressed air to clear the machine of loose dirt and sawdust. Use a non-corrosive solvent to clean rollers, tables, cutterheads, and any other areas where dirt is stuck to a part. Never use a wire brush or sandpaper to clean tables and rollers or other polished surfaces as they scratch the surface and make it much easier for dirt to cling.

As each manufacturer's machine has different maintenance requirements, it is necessary to refer to the manufacturer's instruction booklet for specific maintenance requirements.

SAFETY RULES

1. Before starting the machine, make sure that the exhaust system is in operation and that the exhaust duct is open.
2. Sight through the machine to see that the table is clear of chips and shavings.
3. Allow the motor to come up to speed before starting the stock through the rollers.
4. Joint one surface before running stock through the planer. Measure the thickness of the stock at the greatest point to determine the maximum diameter.
5. The maximum cut for average work is 1/16".
6. If the stock jams, stop the machine and make sure that the cutters have stopped completely before lowering the table.
7. The minimum length of the stock to be surfaced should be at least 2" greater than the center-to-center distance between rollers.
8. Keep fingers above the bottom edge of the material when feeding stock into the planer. Keep hands and measuring tools off the top of the advancing lumber.
9. Stand clear of the material passing through the planer to avoid injury due to kickback.
10. Before running stock through the planer, inspect the lumber for nails, screws, loose knots, paint, and embedded sand. The presence of such materials will cause damage to the blades.
11. Feed stock into the planer so that it cuts with and not against the grain. Use the rate of speed that is appropriate for the thickness of the cut, the width of the board, and the type of lumber. If the speed is too fast, it produces a corrugated effect on the surface of the lumber.
12. Do not attempt to raise or lower the table after the cutting operation is once started.
13. Do not use a planer to cut down plywood thickness.

CARE AND MAINTENANCE OF POWER SHAVING TOOLS

The two most important factors in the care and maintenance of a jointer, surfacer, or shaper are the proper lubrication of all moving parts and the proper sharpening and adjustment of the knives and/or cutters. Dull knives and cutters deteriorate the machinery by causing it to "labor," and to "chatter" or vibrate. Besides, a dull knife or cutter on a power shaving machine is a very dangerous hazard. A dull knife or cutter tends to "catch" in the wood, and since the machine is cutting toward the operator the result of a catch is a violent throw-back of the stock toward the operator. The piece may strike the operator, but more serious than this is the fact that the operator's hands, when the piece is torn out of them, may be driven against the knives or the cutters.

The best way to sharpen the knives on a jointer or surfacer is with a KNIFE GRINDING ATTACHMENT like the one shown on the surfacer in figure 5-44. With one of these devices the knives can be sharpened without removing them from the cutterhead. The knife grinding attachment consists of a small motor-driven grinding wheel, mounted in a SADDLE which can be cranked back and forth on a steel bar called a BRIDGE. The bridge can be mounted over the cutterhead by means of a couple of BRIDGE BRACKETS. The general procedure for sharpening with a knife-grinding attachment is as follows:

Open the starting switch on the machine and lock it open. If the power line has a main switch which can be opened, open that switch as well.

Revolve the cutterhead by hand until a knife is in a position where the cutterhead LOCKING PIN can be put on. The locking pin holds the uppermost knife in correct grinding position.

Loosen the set screws until they are holding the knife only lightly, and move the knife up about 1/12 in. The best way to do this and still keep the knife level is to use a THREE-PRONGED KNIFE GAGE. This device has two prongs which fit against the cutterhead on either side of the knife, and a third prong in the center which can be set to any desired amount of protrusion of the knife edge. When the knife has been set at the desired height, tighten the set screws.

Adjust the knife edges of the other knives to the same height.

Set the grinding attachment in place, bring the grinder down to contact the bevel on the first knife, and crank the grinder back and forth over the knife several times. Take a light cut, and crank fast enough to keep the knife from overheating. Repeat on the other two knives.

When the first knife is again under the grinder, lower the grinder slightly and repeat the above procedure on all three knives. Repeat this whole process, lowering the grinder a little every time you get back to the first knife, until all nicks have been ground away and there is a perfect bevel on every knife in the cutterhead.

The next step is JOINTING the knives, which means, as in the case of a circular saw, ensuring that the knife edges form a perfect circle as the cutterhead revolves. Remove the motor from the saddle and install a JOINTING ATTACHMENT. A jointing attachment is a device with a fine whetstone attached to its lower end; the whetstone can be set so that it barely touches the knife edges. Set it so, revolving the cutterhead by hand to ensure that there is the barest contact and no more.

Start the machine and crank the jointing attachment back and forth several times over the revolving knives. Stop the machine and examine the knife edges. If they have not all been slightly touched, lower the stone just a little and repeat the process until every knife edge has been touched.

In the absence of a knife grinding attachment, the knives must be removed from the cutterhead and ground on an oilstone grinder or in some other manner.

NOTE: Extreme care must always be taken to ensure that all knives of the set weigh exactly the same after they have been sharpened.

To readjust the knives in the cutterhead of a jointer, place a builder's level or a wooden straightedge on the outfeed table and line the highest point reached by each knife edge with the lower edge of the straightedge as follows. Place the knife in the cutterhead and set the set screws up lightly. Place the straightedge over one end of the knife and raise or lower the knife until the edge barely contacts the straightedge when the cutterhead is rotated by hand. Move the straightedge to the other end of the knife and repeat the same procedure. Tighten the setscrews and make a final check for correct height at both ends of the knife. Repeat the same procedure with the remaining knives.

A flat shaper knife with a straight cutting edge is ground and whetted like a plane iron or a chisel. As is the case with a jointer or surfacer, the knives in a shaper must be exactly equal in size and weight. Three-way cutters and knives with curved edges must be sharpened "free-hand" with a small portable grinding wheel, called a "grinding pencil." The greatest care must be taken to keep pairs of knives and the cutting extensions in a three-way cutter exactly alike in size, weight, and shape.

WOODWORKING SHAPER

The SHAPER is designed primarily for edging curved stock and for cutting ornamental edges, as on moldings; but it can also be used for rabbeting, grooving, FLUTING, and BEADING. A FLUTE is a straight groove with a curved rather than a rectangular cross section. A BEAD might be called the reverse of a flute. A heavy duty shaper is shown in figure 5-47 and a light duty shaper in figure 5-48.

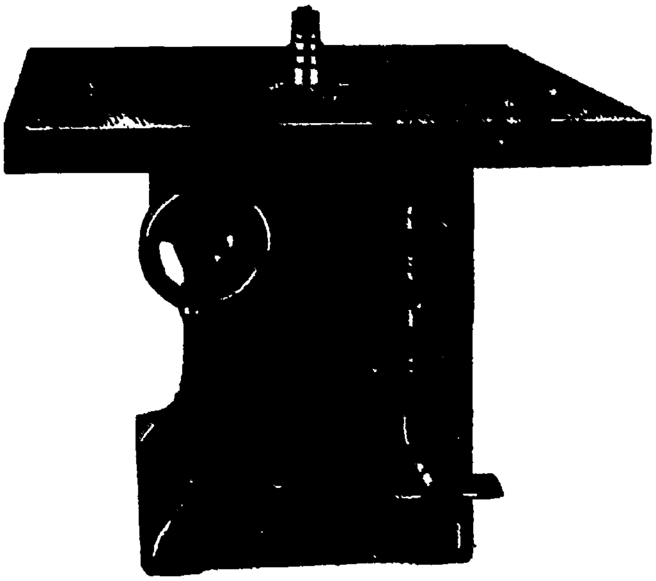

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Figure 5-47.—Wood shaper.

The flat cutter or knives on a shaper are mounted on a vertical SPINDLE and held in place by a hexagonal SPINDLE NUT. A grooved COLLAR is placed below and above the cutter or knives to receive the edge of the knives. Ball bearing collars are available for use as guides on irregular work where the fence isn't used. The part of the edge that is to remain uncut runs against the ball bearing collar, as shown in the bottom view of figure 5-49.

A THREE WING CUTTER fits over the spindle as shown in the upper view of figure 5-49. FLAT KNIFE cutters are assembled in pairs between collars. Both cutters and knives come with cutting edges in a great variety of shapes. BLANK flat knives are available which may be ground to any desired shape of cutting edge. This is done only by experienced personnel.

OPERATION OF THE SHAPER

For shaping the side edges on a rectangular piece, a light-duty shaper has an ADJUSTABLE

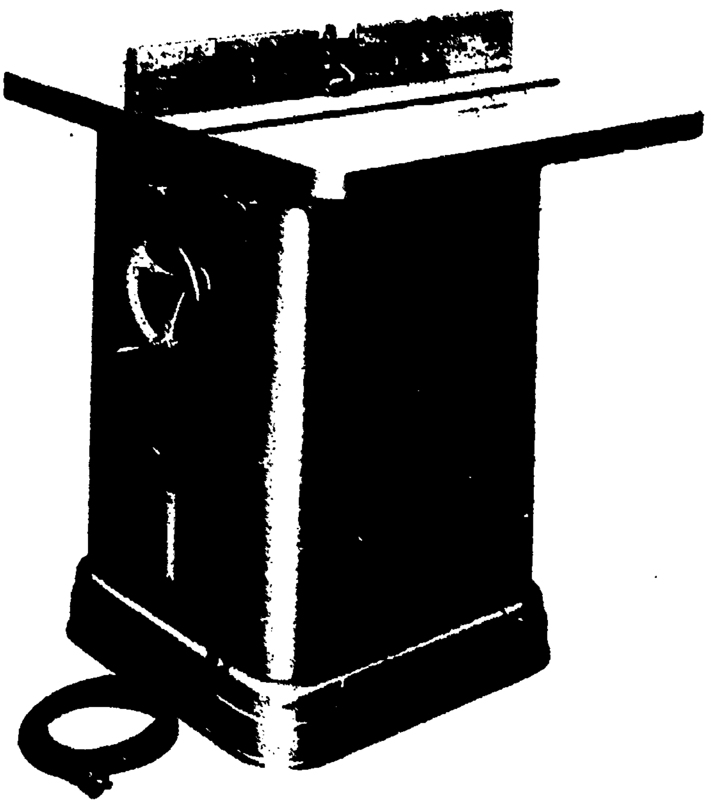

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Figure 5-48.—A light-duty wood shaper.

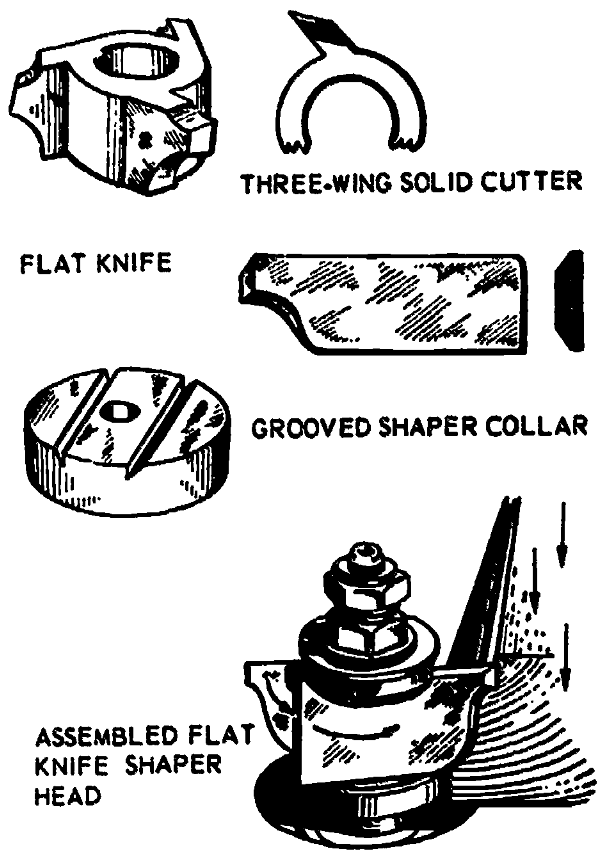

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Figure 5-49.—Three-wing cutter and flat knives for a shaper.

FENCE like the one shown on the shaper in figure 5-48. For shaping the end-edges on a rectangular piece, a machine of this type has a SLIDING FENCE, similar to the cutoff gage on a circular saw. The sliding fence slides in the groove shown in the table top.

On larger machines the fence consists of a broad straightedge, clamped to the table with a handscrew as shown in figure 5-50. A semicircular opening is sawed in the edge of the straightedge to accommodate the spindle and the cutters or knives. Whenever possible, a guard of the type shown in the figure should be placed over the spindle.

For shaping curved edges there are usually a couple of holes in the table, one on either side of the spindle, in which vertical STARTER PINS can be inserted. When a curved edge is being shaped, the piece is guided by and steadied against the starter pin and the ball bearing collar on the spindle.

Many shapers are equipped with a spindle which can run either clockwise or counterclockwise. Therefore, it is important to check the direction of the spindle rotation before starting a cut on the machine.

Like the jointer and surfacer, the shaper cuts toward the infeed side of the spindle, which is against the rotation of the spindle. Stock should therefore be placed with grain running toward the infeed side.

MAINTENANCE OF A SHAPER

Maintenance of a specific shaper should be performed in accordance with the applicable manufacturer's technical manual.

SAFETY RULES

Make sure the knives are sharp and are well secured.

If curved or irregularly-shaped edges are to be shaped, place the stock in position and check to see that the collar will rub against part of the edge which should not be removed.

Whenever the straight fence cannot be used, always use a starting pin in the table top.

Always take several light cuts instead of attempting an extremely deep cut.

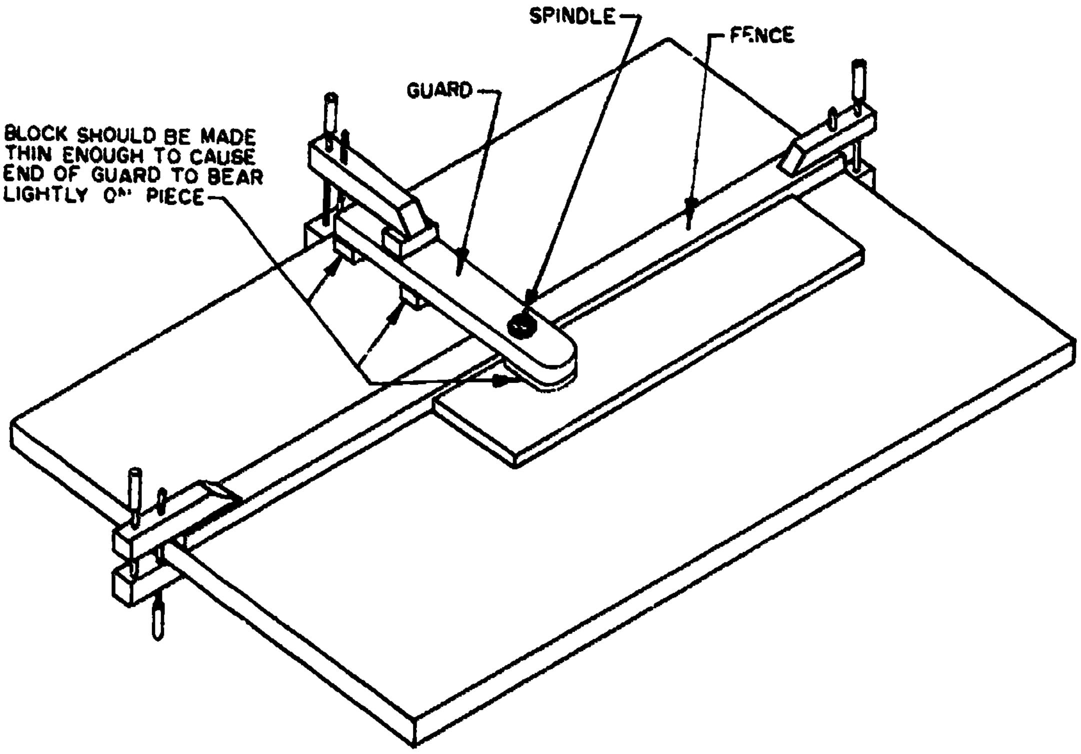

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Figure 5-50.—Shaper table, showing straightedge fence and guard.

Make sure the shaper knives rotate toward the work.

Whenever possible, always use a guard, pressure bar, holddown, or holding jig.

If possible, place the cutter on the shaper spindle so that the cutting will be done on the lower side of the stock.

NEVER BACK UP ON A CUT.

Do not attempt to shape small pieces of wood.

Check all adjustments before turning on the power.

"The spindle shaper is probably one of the most DANGEROUS machines used in the shop. Use extreme caution at all times."

THE VERTICAL BORER

In the shop, the vertical borer (fig. 5-51), which may be a drill press (fig. 5-52), is used mainly for boring holes, boring excess stock away, and planing.

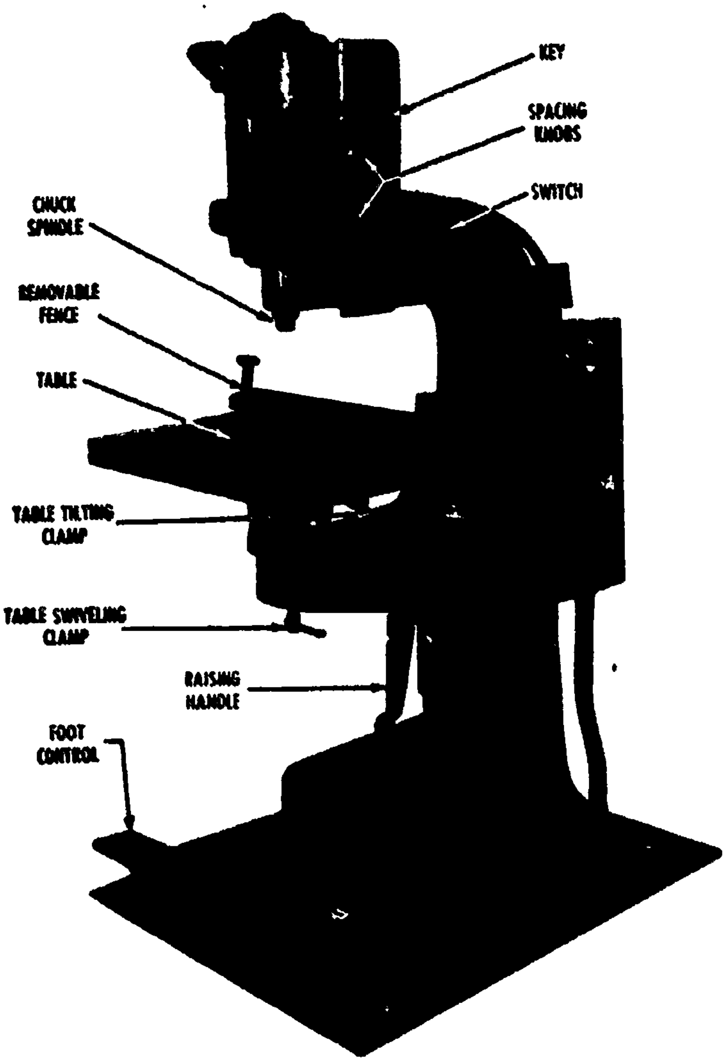

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Figure 5-51.—Single-spindle, vertical boring machine.

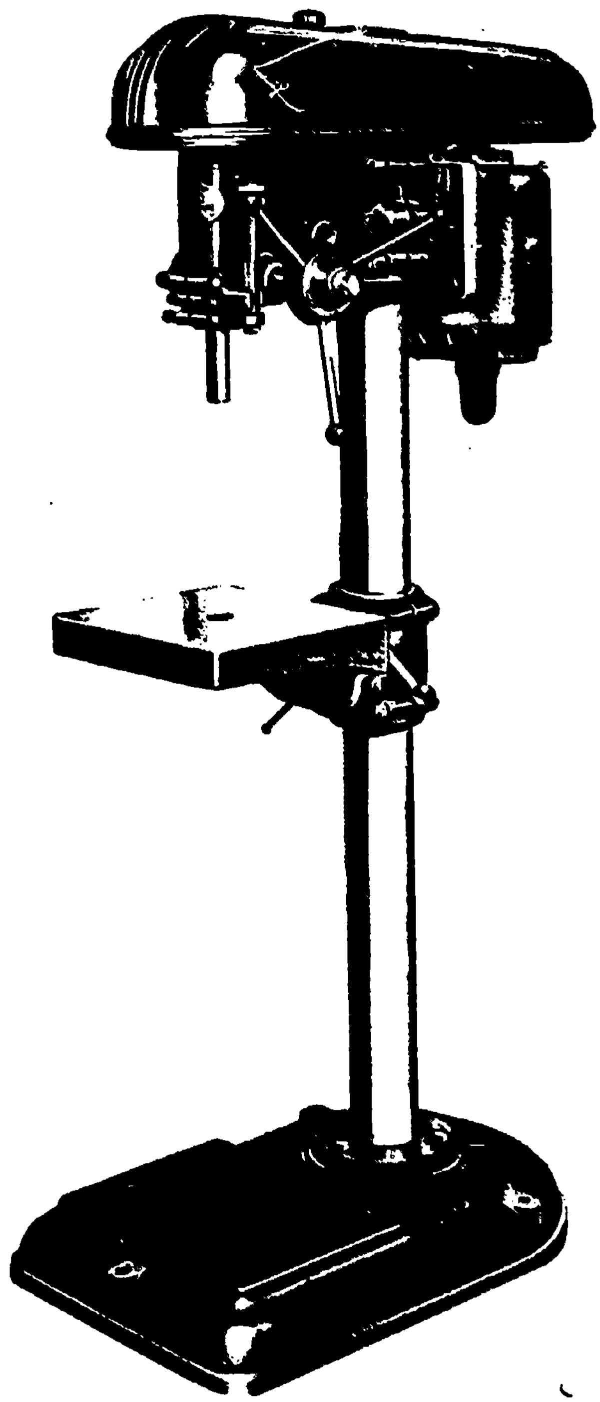

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Figure 5-52.—Drill press.

The model illustrated in figure 5-51 is a single-spindle vertical boring machine and is capable of boring holes 2 inches in diameter and 6 inches deep in the center of 36-inch stock. The table easily adjusts 12 inches in a vertical direction, swivels in a complete circle, and tilts 45 degrees. It can be raised or lowered by means of self-locking spiral gears and a slip crank. Two adjustable, holding-down fingers are fastened to each side of the column near the head, to prevent stock from climbing when the bit recedes.

An enclosed motor is mounted directly on the boring spindle. The spindle has a maximum speed of 3,600 rpm and a vertical movement of 6 1/2 inches, controlled by a foot lever. The regular boring bits range from 1/4 inch to 2 inches. A variety of cutters in different shapes and sizes is also available. An example is the fillet cutter that is made for cutting a fillet into a pattern. This cutter can also be used where it is necessary to cut a recess, level it, and leave a fillet in the corner.

Many manufacturers of drill presses and vertical boring machines are now equipping their products with shaper, router, and mortising attachments. Ordinarily these attachments are recommended for light work only. Samples of the work that can be done with some of the special cutters are shown in figure 5-53.

Before starting the motor, be sure that all the adjustments are correct and that the wrench used to tighten the cutter is not in the chuck.

There is little maintenance care needed for the vertical borer and drill press. Lubricating the motor and spindle in accordance with the manufacturer's instructions and keeping the cutting bits sharp are the two most important requirements.

The following safety rules apply to the vertical borer and drill press:

1. Remove the wrench from the chuck before turning the switch on.
2. Use a slow speed for wood bits.
3. Secure work properly before drilling or boring.
4. Do not use long bits in high speed machines.
5. Do not wear gloves while operating a drill press.
6. Always secure the machine before adjusting the table or drill head.

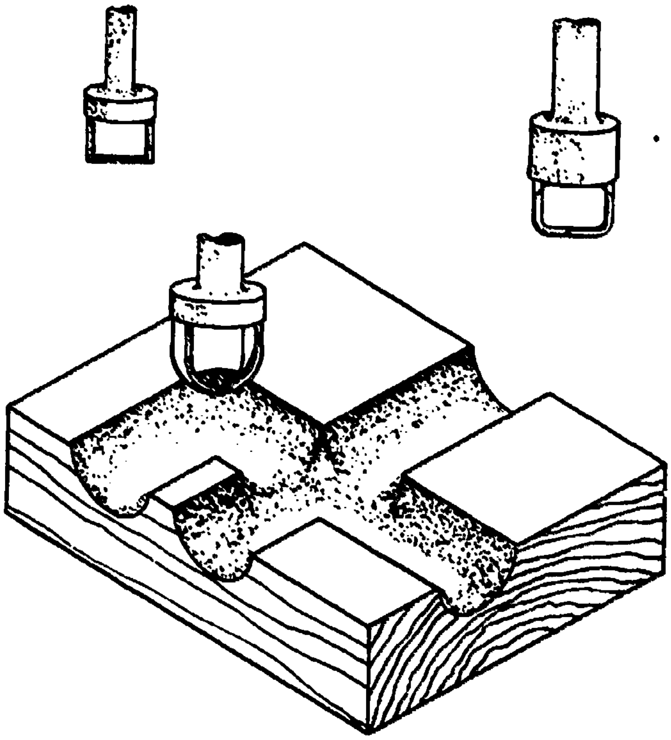

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Figure 5-53. — Special cutters.

SANDERS

Shaping wood by the use of sanding machines has become an important technique in the pattern shop of today. Two sanders are of primary importance: (1) the disk sander, and (2) the spindle sander.

DISK SANDER

The disk sander, illustrated in figure 5-54, is a great timesaver and does a more accurate job than can usually be done with handtools. It is used to smooth the end grain of stock and to put draft on pattern sides. The disk sander likewise is used to shape flat surfaces and the outsides of convex-curved faces of stock. It also sands out saw marks.

The illustrated model has a removable 15-inch metal plate disk that revolves at a speed of 1,800 rpm. Three screws secure the disk to the disk hub. Garnet paper disks are glued to the face of the disk for wood sanding.

The table of the disk sander tilts 45° down and 25° up. The handwheel and worm arrangement is self-locking at the desired angle.

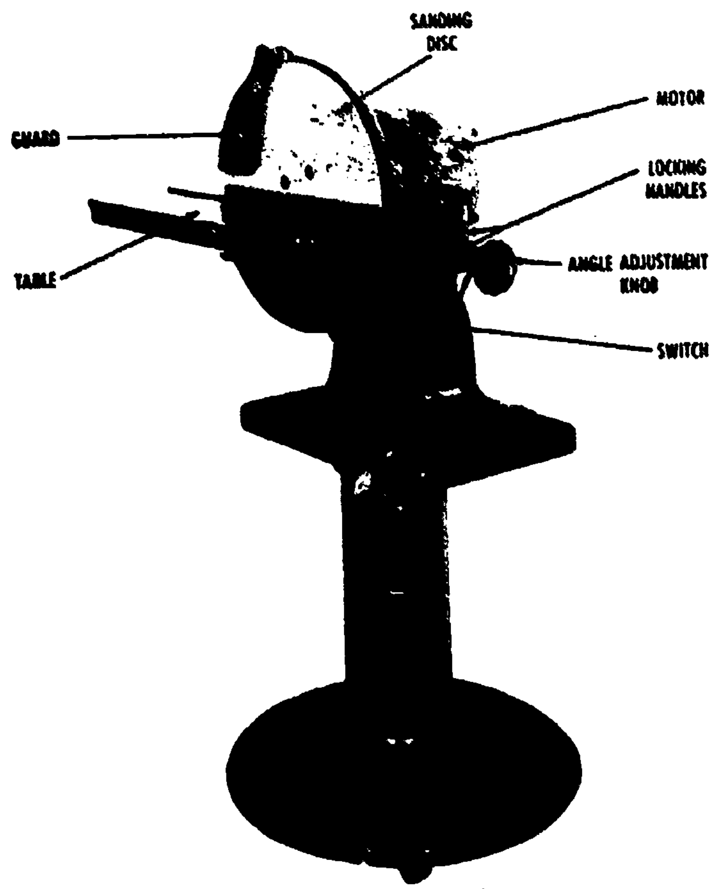

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Figure 5-54.—A disk sander.

Operation of the Disk Sander

When using the disk sander, place the stock against the right-hand side of the sander if possible. If you use the left-hand side, you most likely will get some grit and dust thrown into your face. Article 12209 of U.S. Navy Safety Precautions states that goggles and masks shall be used during sanding operations.

Be sure that the table is square or at the angle wanted before you start sanding. Also check your stock if it has been glued, and see that the glue has hardened thoroughly. Sandpaper will readily pick up fresh glue from the stock, which impairs the cutting quality of the sandpaper.

While sanding, move the stock along the disk sander so you do not hold the stock in any one place too long. This prevents the burning of the sandpaper and the grooving of the stock. Always remember to watch out for your fingers. When you have finished sanding the job, be sure that the table is set square.

Maintenance of the Disk Sander

Little maintenance care is required for the sanders. Regular oiling and greasing are most important. Also, change the sandpaper whenever it is clogged.

Safety Rules

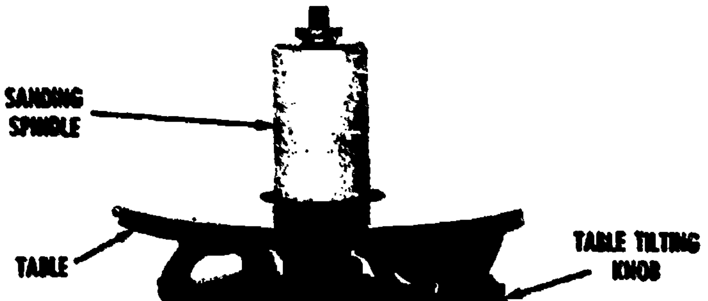
1. Determine the direction of rotation of the sander before using. Use the right side of the disk if the motion is clockwise; use the left side if the motion is counterclockwise.
2. Never allow too large a gap between the table and the disk.
3. Oscillate the work while sanding to avoid burning the stock and plugging the sandpaper.
4. Use goggles, eyeshields, and dust guards.
5. Be sure that the work is held firmly and is flat on the table before engaging the sander.
6. Place small stock in a clamping jig or other holding device to prevent burning the fingers by accidental contact with the abrasive.
7. Clean glue, grease, or paint from the surface of the stock before sanding.
8. When it is desirable to adjust the table at a sharp angle, tilt the table down rather than up to prevent the hands from being fed into the sander.
9. Always adjust the table to 90° before leaving the machine.

SPINDLE SANDER

The spindle sander, illustrated in figure 5-55, is used to sand both straight and curved inside surfaces, and outside curved surfaces that are not adaptable to the disk sander.

The spindle that revolves the sandpaper has removable drums or cylinders of various diameters. It moves in an oscillating up-and-down motion at the same time that it revolves. The sandpaper rolls or tubes are attached to the cylinder. The table is also adjustable and may be locked at different angles.

Some manufacturers make single machines that combine the features of both the disk and spindle sanders.



68.31
Figure 5-55.—A spindle sander.

THE GRINDER

A grinder for all-round use in the pattern shop is shown in figures 5-56 and 5-57. In this model, a fully enclosed motor is mounted on the cast-iron column. The motor has a double-ended shaft. At one end is an emery cone and a leather stropping wheel. The other end carries a gear and a flexible coupling that transmits power to one emery wheel and two oilstone wheels.

An automatic saturation system is provided by having an oil reservoir mounted over each oilstone wheel with the oil dripping on the inside of the wheel. Petcocks regulate the flow of oil and special wipers prevent the oil from being thrown off the wheels. The wheels are of the cup wheel type and run in ball bearings. They are 8 inches in diameter, have a 2-inch face, and have a speed of 300 rpm. One oilstone wheel is of coarse grain for rapid abrasion; the other wheel is of fine grain for putting a smooth, keen edge on a tool.

In front of the oilstone wheels is a table that tilts to any desired angle and which has a horizontal adjustment of several inches. It is fitted with a special toolholder for holding chisels and other edged tools. The holder has a screw feed arrangement for feeding the tools to the oilstones when grinding.

On the other side of the machine is an emery cone that is used for grinding gouges and irregular-shaped tools. It is 3 inches in diameter, 5 inches in length, and has a speed of 1,800 rpm. On the same shaft is a leather stropping wheel that takes away burrs and puts the finishing touches on the tools. There is also an emery wheel mounted on a ball-bearing shaft. It is 8 inches by 1/2 inch in size and is used for general dry grinding. A right-angle toolrest permits grinding on the side of the emery wheel as well as on the face.

OPERATION OF OILSTONE GRINDER

When a plane iron does not cut smoothly or easily it should be sharpened by hand on a whetstone. If there are nicks in the cutting edge, the plane iron should be ground on a power grinder. The cutting edge of the plane iron is moved back and forth as the oilstone revolves toward it. It should be ground at an angle of about 30° if it is to be used for cutting very hard wood, and at about 20° for white pine.

When the plane iron is pushed back and forth, do not exert much pressure or the edge will overheat and lose its temper. Plane irons should be examined occasionally to see that they are being ground straight and square. If the oilstone is being used, the chances of overheating and burning the steel are lessened. If a dry grinder is being used, the plane iron should be dipped in water frequently to cool it. Goggles must be worn while grinding.

Plane irons have their cutting edges ground to suit the type of work they do. The jack

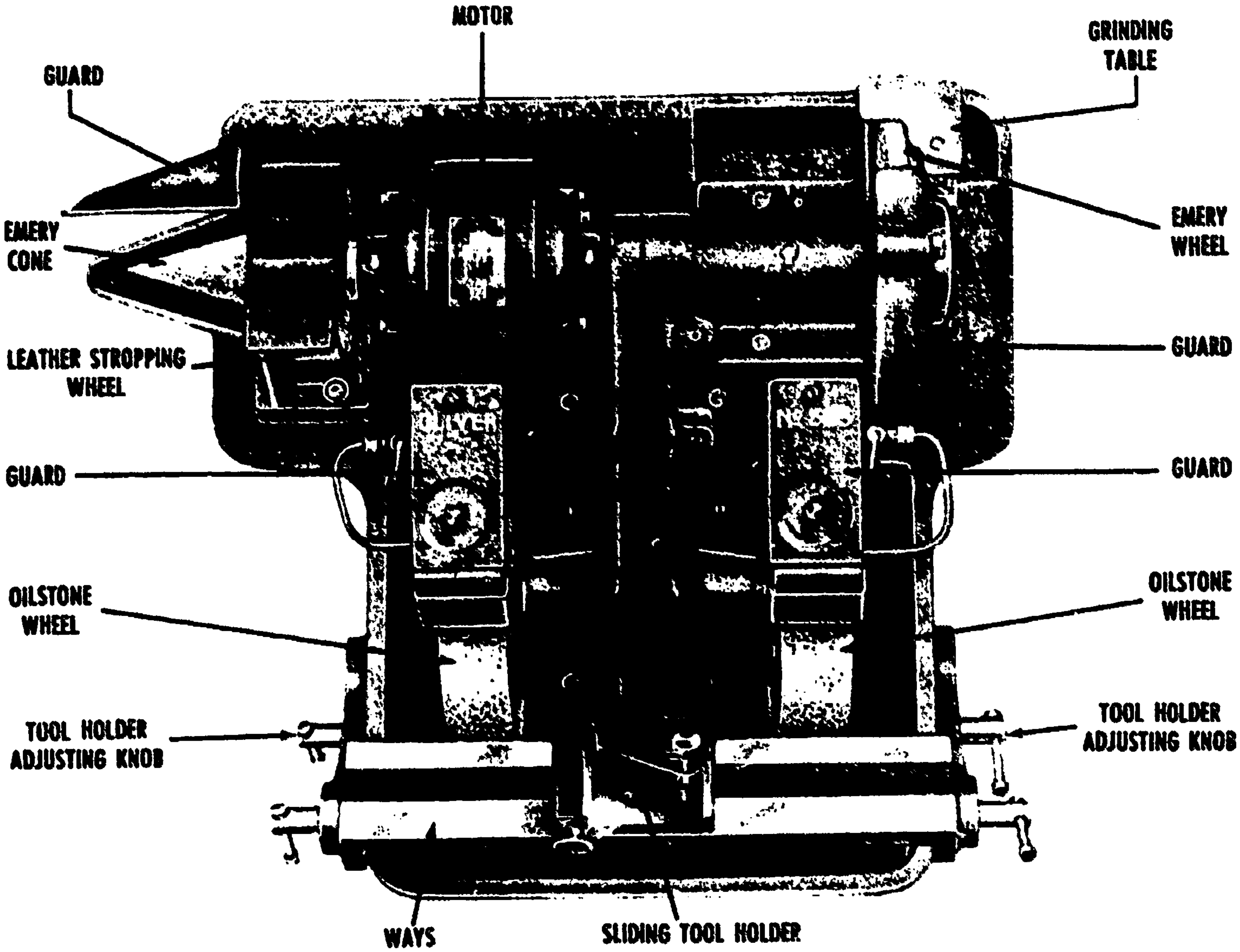


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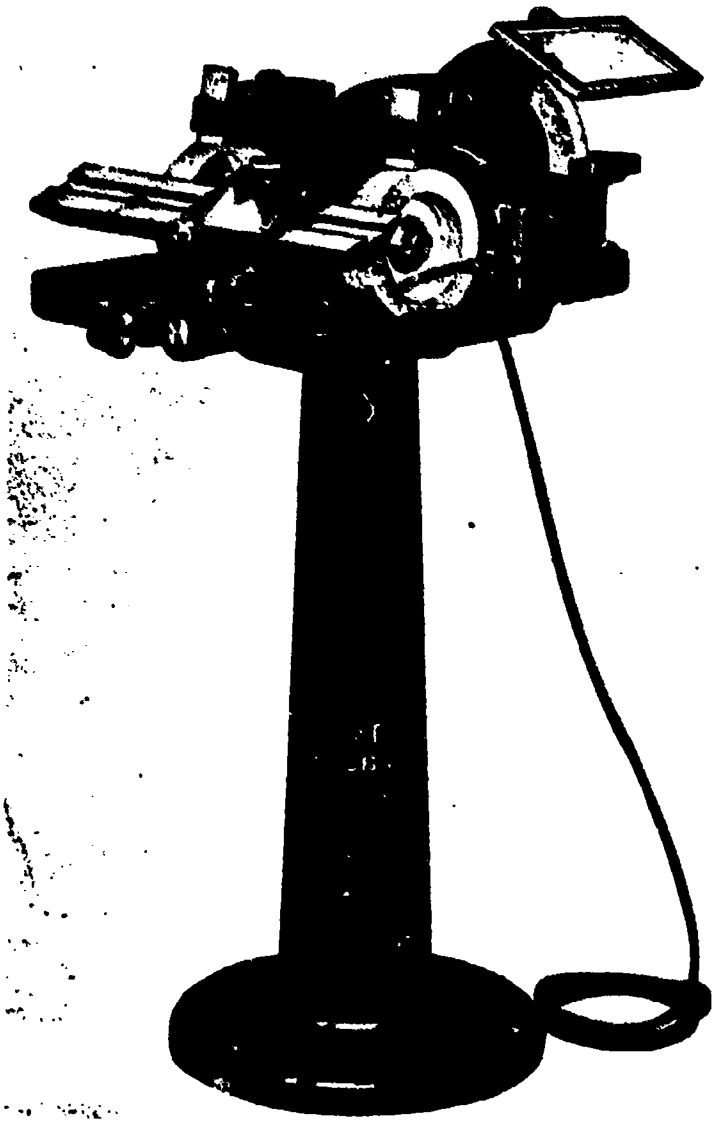
Figure 5-56. — Top view of a tool grinder.

plane irons are used to take the wind or warp out of a surface. The cutting edge should be almost straight across with only a 1/16-inch crown (fig. 5-58).

Fore planes, and jointer planes are used to produce a smooth surface. They are ground almost straight, with a 1/32-inch crown. (See fig. 5-58.)

The block plane and the smoothing plane are ground straight with the corners rounded. This is to help keep the corners from digging in and grooving the wood. The rounding of the corners is best done by hand or with an oilstone (fig. 5-58).

Whetting the plane iron to a keen cutting edge is done on a flat oilstone. Before beginning, wipe the stone clean and wet the surface with a solution of one part machine oil and one part kerosene. Hold the bevel cutting edge of the iron at about a 25° angle. Whet the plane iron in a circular motion moving back and forth across the entire length of the oilstone. This pushes the grit and small particles of steel to one side and also prevents uneven wearing of the stone. Continue whetting until a fine, wire edge is formed along the cutting edge. Turn the plane iron over and lay the back side down flat on the face of the oilstone. A few light strokes will remove the wire edge. Use the oil-kerosene solution freely



103.36
Figure 5-57.—A standard tool grinder.

on the stone. After this whetting, hone the plane iron carefully on both sides using the leather strop.

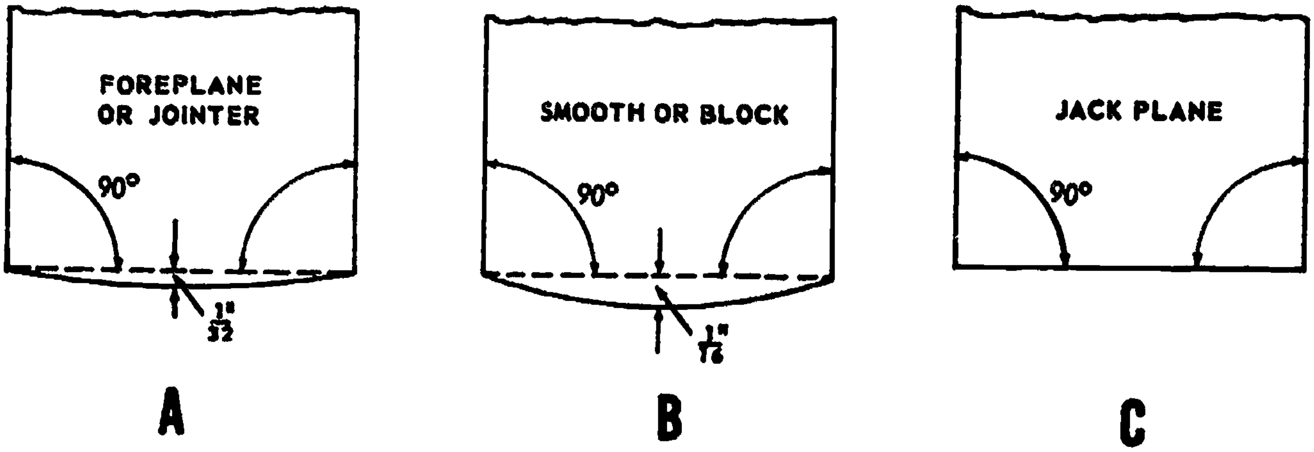
The other cutting tools require the same grinding, whetting and honing attention as that given the plane iron. The spokeshave blade, for example, is ground at an angle of 22° and then whetted and stropped. Paring chisels should be ground at about 15° and firmer chisels at about 20°.

The gouge should be ground very slowly on the core grinding wheel. The paring gouges should be ground at 15°, the inside firmer gouges at 20°, and the outside firmer gouges at 25° to 30°.

A slipstone is used for whetting the cutting edges of the gouges. The slipstone should be held low so that the gouge will not cut your hand. Move the slipstone back and forth as you press fairly hard against the cutting edge of the gouge. The slipstone is kept at the same angle as the gouge was ground. The reverse side of the gouge is also sharpened, with the slipstone held flat on the back of the gouge. The leather strop is pushed down on both the front and back of the gouge at the same grinding angle to complete the sharpening.

CARE AND MAINTENANCE OF ABRASIVE EQUIPMENT

Abrasive wheels and oilstones are very easily broken or cracked, and must be handled and stowed with the greatest care. A wheel should be given a regular RING TEST for cracks. Tap the wheel with a rubber-faced



29.12.2
Figure 5-58.—Plane-iron shapes.

hammer or mallet. A ringing sound indicates a sound wheel. A dull thudding sound indicates a cracked wheel. NEVER USE A CRACKED WHEEL.

When you are installing a new wheel, NEVER force the wheel onto the spindle. The wheel must slide easily with about 0.003 to 0.005 in. clearance. If it doesn't IT IS NOT THE RIGHT SIZE FOR THE SPINDLE.

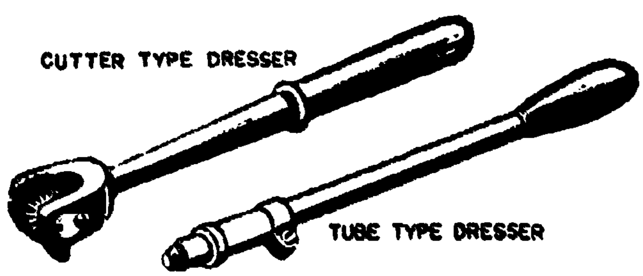
Tighten the spindle nut just enough to set the flanges firmly against the wheel. Overtightening may crack the wheel. After installing, GET YOURSELF AND EVERYBODY ELSE OUT OF THE LINE OF THE WHEEL, turn the power on, and keep clear until the grinder has run long enough to indicate that the wheel is not going to fly apart.

If a wheel GLAZES rapidly, decrease the speed of the grinder or put on a softer wheel. If a wheel LOADS rapidly (LOADING means the clogging of surface pores with the material being ground), increase the speed of the grinder or put on a softer wheel.

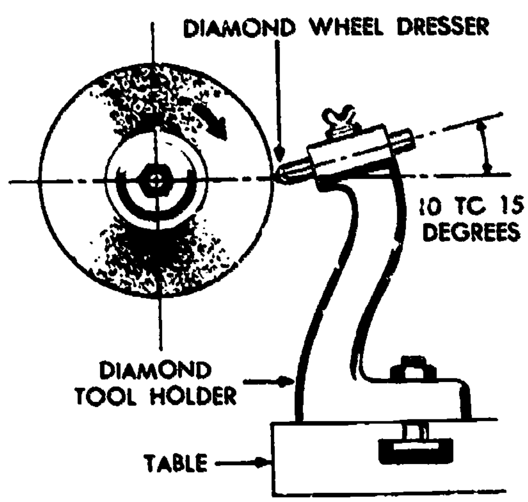
A glazed or loaded wheel should be DRESSED, and a wheel which has become out-of-round or irregular on the surface must be TRUED. The same procedure is used to cure both conditions; it is called DRESSING, and it is done with a WHEEL DRESSER. CUTTER and TUBE type dressers are shown in figure 5-59. A DIAMOND wheel dresser (which is the most effective) is shown in figure 5-60.

The procedure for dressing a wheel is as follows:

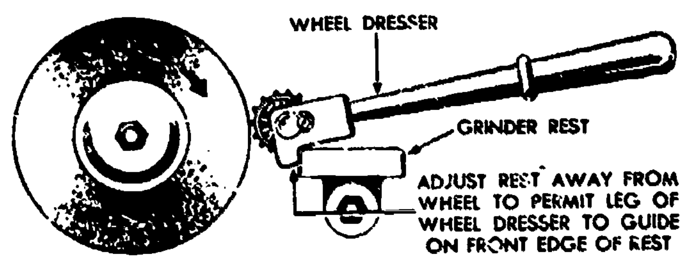
1. Adjust the tool rest to permit the wheel dresser to contact the centerline of the wheel, as shown in figure 5-61. The cutter type dresser



28.63(133E)A
Figure 5-59.—Cutter and tube type wheel dressers.



28.63(133E)B
Figure 5-60.—Diamond wheel dresser.



28.63(133D)C
Figure 5-61. — Dressing with a cutter type dresser.

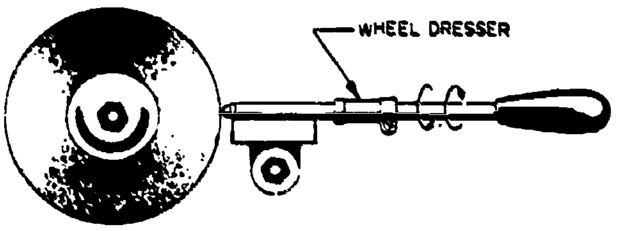
is held with the lug on the cutter against the front edge of the tool rest, as shown in the figure. The tube type dresser is held flat on the tool rest, as shown in figure 5-62.

2. Start the wheel and slowly press the dresser against the face until you feel the dresser start to "bite."

3. Move the dresser from side to side and gradually press it forward until you feel it "bite" all the way across the face of the wheel.

Do not grind against the sides or corners of a wheel unless it is absolutely impossible to do the grinding job on the face.

A grinding wheel will gradually wear down, or will gradually be dressed down, to a diameter which is much smaller than the original diameter. As the wheel becomes smaller, the speed of the grinder should be increased to allow for



28.63(133E)D
Figure 5-62.—Dressing with a tube type dresser.

the reduced speed of travel of the smaller grinding face. If the same speed is maintained for the smaller wheel, the wheel will "act soft," and it will also wear down too rapidly.

A new oilstone should be soaked in engine oil before it is used for whetting. To prevent glazing, oil should always be applied when the stone is used for whetting. The stone should be wiped clean with cloth or cotton waste after each use. A glazed or "gummed up" stone should be washed with dry-cleaning solvent or aqua ammonia. If the stone cannot be thoroughly cleaned in this manner, it should be scored with aluminum oxide abrasive cloth or flint sandpaper.

For whetting plane irons, chisels, and the like, the faces of an oilstone must be perfectly flat. An uneven face can be trued up on the side of an old grinding wheel, or by rubbing on a piece of moistened waterproof artificial abrasive paper laid on a flat, true, hard surface.

SAFETY RULES

1. Inspect the wheel for glaze, trueness, and general condition before using the machine.

2. Use safety goggles and eyeshield when grinding.

3. Keep the toolrest close to and above the center of the wheel.

4. Stand to one side of the wheel when starting the machine.

5. Do not wear gloves during grinding operations.

6. Never use a rag to hold the object that is being ground. Hold small objects securely in a jig, clamp, or other suitable holding device.

7. Never grind on the side of the wheel.

8. Always have a pot of water close by the wheel to cool off the surface being ground.

9. Never try to slow the wheel by using the bare hands. Wait until the machine coasts to a full stop.

10. Avoid grinding bronze, brass, aluminum, lead, or galvanized metal on any emery wheel. (If it becomes necessary to grind any of these soft metals, dress the emery wheel immediately after using.)

11. If the wheel has received a severe jolt, remove it for thorough inspection and test it before using.

12. Excessive vibration indicates that the wheel is out of round. Dress it immediately.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 6.

AIR DRIED LUMBER—Lumber seasoned by being permitted to dry out naturally.

CUPPING—The tendency of tangential sawed boards to curl away from the heart of the tree.

GYPSUM—Mineral from which plaster of paris is produced.

KILN DRIED—Lumber artificially dried under controlled temperature and relative humidity conditions by being placed in a specially designed enclosure called a KILN.

STOPPING OFF—Process of filling up with sand a part of a mold to eliminate that part not wanted as a part of the casting.

SWEEP—A board or template shaped to a required profile used to remove excess material from a mold or core.

SWEEP WORK—Forming molds or cores by using sweeps instead of patterns.

CHAPTER 6

PATTERNMAKING STRUCTURAL MATERIALS

As a Patternmaker, you will be working mostly with wood. Wood is not the only material from which patterns can be made. Several other materials, such as metals, plasters, and plastics, are used in patternmaking. In selecting the material from which to make patterns, you must take the following four factors into consideration:

1. Cost per casting.
2. Number of castings to be produced.
3. Foundry method to be used.
4. Design of the casting.

This chapter provides information on the classification of trees, tree growth and structure, and the cutting and seasoning of lumber. In addition, grades, sizes, measurement, defects, care and storage of wood, and wood joints are considered.

The pattern shop on a repair ship or tender rarely produces patterns for mass production work. Usually, only a few castings of a given part must be made as quickly and as economically as possible. Thus, wood is most often the material selected for Navy patterns.

Twentieth century production methods, such as those employed by the railroad, automobile, and aircraft industries, require patterns that can stand up under more demanding foundry methods. Metal has now become a standard pattern material in the heavy industries where mass production and machine molding techniques are used. In addition, new plaster and plastic materials have been developed. Different types of tools, machines, and equipment are needed for these materials. As a result, where a large number of patternmakers are employed in industry, specialization takes place and the patternmaker is designated as a wood, metal, or plaster craftsman.

Navy Patternmakers almost invariably use wood in the production of patterns. Because the Navy does not mass produce castings in its shipboard foundries, other patternmaking materials, such as metal, plaster, and plastics, are not used extensively aboard ship. However, the Navy wants you to be acquainted with these patternmaking developments.

WOOD

Trees are basically classified (according to the nature of their growth) into four general groups: (1) naked seed or needle-leafed trees, (2) two-seed or broad-leafed trees, (3) one-seed or bamboo trees, and (4) one-seed or palm trees. Wood from each group as a whole has its own characteristic qualities. However, woods from within each group vary greatly and are further classified according to the qualities of hardness, toughness, and flexibility. HARDNESS is measured by the compression which a piece of lumber can undergo when a weight or force is applied to it. The naked-seed or needle-leafed woods are generally softwoods and are easily worked with tools. Most one-seed or broad-leafed woods are hard, and some types are very difficult to work with. TOUGHNESS is the measure of strength and durability of wood. Tough wood will stand rough treatment before it will break or split. FLEXIBILITY is measured by the amount a piece of lumber will bend before breaking. Softwood is brittle, while most hardwood is flexible. Moist lumber is more flexible than dry lumber. Hardwoods do not split as easily as softwoods and seasoned lumber does not split as easily as green lumber.

Trees are classified in the lumber industry as hardwoods or softwoods. These two terms, while used extensively by carpenters and other woodworkers, are used more as a matter of convenience than as exact classification terms. In fact, this classification does not depend so much upon how hard the wood is as it does upon WHAT KIND OF LEAVES THE TREE HAD.

If the tree had broad leaves that were shed in winter the wood is classified as hardwood. If the tree had needle leaves or cones the wood is called softwood. Generally, softwood is any wood light in texture, nonresistant to warpage, and easily worked; while hardwood is any heavy, close-grained, warpage resistant wood.

This classification is somewhat confusing because some so-called softwoods are just as hard as some of the hardwoods. Also, some of the hardwoods are softer than the softwoods.

Hardwoods are used extensively in general construction and repair work because of their strength, durability, and elasticity. They are also used in making furniture, dowels, and some patterns. Among the native hardwoods are ash, birch, beech, white oak, poplar, walnut, and maple. The most commonly used imported hardwoods are mahogany, teak, and lignum vitae.

Patternmakers prefer softwoods for most patterns. Softwoods are also used as structural lumber, boat planking, shoring, and plywood. Among the native softwoods are white cedar, cypress, Douglas fir, white pine, yellow pine, and redwood.

TREE GROWTH AND STRUCTURE

Every piece of wood is made up of a number of small CELLS, the size and arrangement of which determine the grain of the wood and many of its properties. Examine a freshly cut tree stump, and you will see that the millions of large and small cells are arranged in circular RINGS around the PITH or center of the tree and are growing in a vertical direction. The large cells have thin walls and the smaller cells have thick walls. See figures 6-1 and 6-2. Rings are caused by a difference in rate of the tree's growth during various seasons of the year. In spring a tree grows rapidly and builds up a thick layer of comparatively soft, large cells, which appear in the cross section of the trunk as the light-colored annual rings (SPRING RINGS).

As the weather gets hotter during early summer, the rate of growth slows and the summer cells become darker and more closely packed and form the dark annual rings (ANNUAL RINGS). Because only these dark rings are counted when the age of a tree is being determined, many people erroneously believe that only one ring is formed each year. But actually two rings are formed each year, a light-colored ring in the spring and a darker ring in summer. The terms early wood and late wood are used with reference to the growth zones of the annual rings. Some trees, such as oak and walnut, have more distinctive rings than others. White pine, on the other hand, is so uniform that you can hardly distinguish the rings.

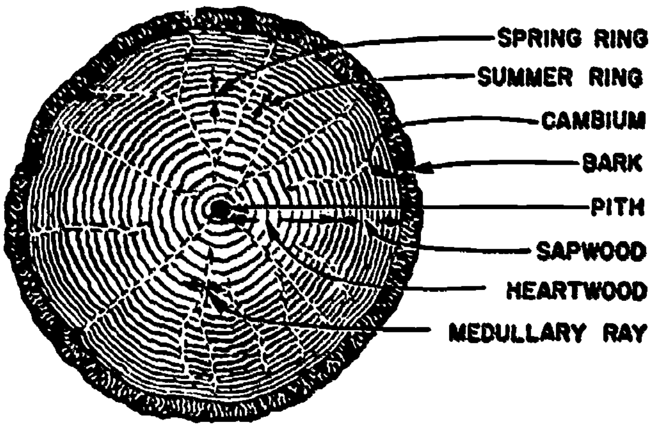


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Figure 6-1.—Cross section of a tree.

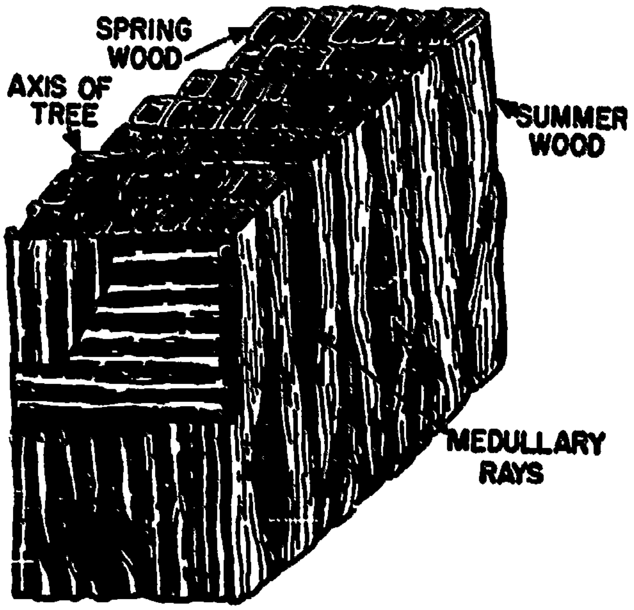

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Figure 6-2.—Structure of wood.

The SAPWOOD of a tree is the outer section of the tree between the HEARTWOOD (darker center wood) and the BARK. Sapwood is lighter in color than heartwood; but, as sapwood gradually changes to heartwood on the inside, it becomes darker. The CAMBIUM LAYER is the boundary between the sapwood and the bark. In this thin layer, new sapwood cells form. From 9 to 35 years are required to transform sapwood into heartwood, depending upon the type of tree.

MEDULLARY RAYS are radial lines of wood cells. (They are especially prominent in oak.) Their function is to accommodate horizontal movement of cell liquids. In speaking of medullary rays, THICKNESS refers to the horizontal dimension, and WIDTH to the vertical dimension.

When a tree is sawed lengthwise, the annual rings form a pattern which is called the GRAIN of the wood. A number of terms are used to describe the various wood grain conditions. If the cells of the wood which form the grain are closely packed and small, the wood is said to be FINE-GRAINED or CLOSE-GRAINED. Maple and birch are excellent examples of this type. If the cells are large, open, and porous, the wood is COARSE-GRAINED or OPEN-GRAINED, as in oak, walnut, and mahogany. When the wood cells and fibers are comparatively straight and parallel to the trunk of the tree, the wood is said to be STRAIGHT-GRAINED. If the grain is crooked, slanting, or twisted, the wood is said to be CROSS-GRAINED. The arrangement, direction, size, and color of the wood cells give the grain of each wood its characteristic appearance.

Trees differ in their rate of growth, and a slow growing tree forms a denser pattern of annual rings (and therefore a denser grain) than a fast growing tree. Therefore, wood from the slower growing trees is CLOSE-GRAINED, and wood from the faster growing trees is COARSE-GRAINED.

When a log is sawed lengthwise into boards, each saw cut moves through the annual rings at a certain angle. If the angle between the saw cut and the rings is 45° or greater, the board is said to have a VERTICAL GRAIN. If the angle is less than 45°, the board is said to have a FLAT GRAIN. If the log is fed right on through in the same position, without being turned, the first few outside boards cut off will be flat-grained; the boards cut from the center section will be vertical-grained; and the last few boards cut will be flat-grained. By turning the log in various ways between saw cuts, a log can be made to produce all vertical-grained or all flat-grained lumber.

Vertical-grained wood resists wear better than flat-grained wood of the same species. Most flat-grained wood, on the other hand, will take and hold a finish better than most vertical-grained wood. The term TEXTURE should be used to express the relative size of the pores (cells) and fibers as "coarse" and "fine" texture, "even" and "uneven" texture.

Colors of woods are difficult to describe exactly in words. For example, FLESH-COLOR is a soft shade about the color of the skin; STRAW-COLOR is a light-yellow shade of buff; CHERRY, the brown color of freshly cut cherry wood; and CHESTNUT, the color of chestnuts.

CUTTING AND SEASONING OF LUMBER

In a large lumber mill such as the ones in the Pacific Northwest, logs are processed into lumber with huge bandsaws and circular saws. There are two methods of sawing the logs—SLASH-CUTTING and RIFT-CUTTING. (See fig. 6-3.) Slash-cutting is accomplished by a series of parallel cuts. If hardwoods are being cut, the process is known as PLAIN-SAWING. If softwoods are being cut, the process is termed FLAT-GRAIN SAWING.

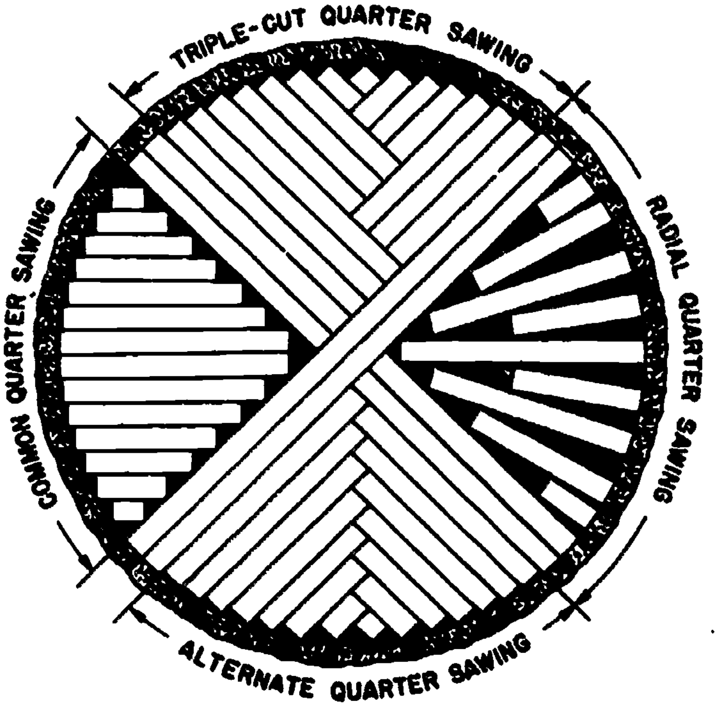

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Figure 6-3. — Four methods of quarter-sawing.

RIFT-CUT lumber is specially cut to provide edge grain on both faces. If hardwood is so cut, it is called QUARTER-SAWED lumber. If softwood is so cut, it is called EDGE-GRAIN LUMBER. When an entire log is slash-cut, several boards from near the center of the log will actually be rift-cut.

Slash-cut lumber is usually cheaper because less time is required to slash-cut a log, and there is less waste involved. Circular or oval knots appearing in slash-cut boards affect the strength and surface appearance much less than do spike knots, which may appear in rift-cut boards. If, however, a log is sawed to produce all slash-cut lumber, more boards will have knots than if the log were all rift-cut.

In order to get as many edge-grained boards as possible from a tree, the logs are first sawed into quarters as shown in figure 6-4. Then each quarter is sawed into planks by one of the four methods shown in figure 6-4, depending upon the use for which the lumber is intended. RADIAL QUARTER-SAWING will yield lumber that is stronger and will warp less than that obtained by any other method of sawing. The disadvantages, however, are that this method is more costly, takes longer, and is more wasteful of material.

After being sawed, lumber must be thoroughly dried before it is suitable for most uses. The old method—and one still preferred for some uses—was merely to AIR-DRY the lumber in a shed or in the open. This method requires considerable time—up to 7 years for some hardwoods.

A faster method of drying is known as KILN-DRYING. In this method the wood is placed in a tight enclosure, called a KILN, where it is treated with steam. The time required for drying varies from two or three days to several weeks, depending on the kind of wood, its dimensions, and the methods of steaming. Often a combination of drying methods is used; the wood is both AIR-DRIED and KILN-DRIED.

Lumber is considered dry enough for most uses when the moisture content has been reduced to about 12 or 15 percent. For pattern use, the moisture content is reduced to 5 or 6 percent. As a Patternmaker, you will soon learn to judge the dryness of a wood by its color, weight, smell, feel, and by a visual examination of shavings and chips.

Briefly, SEASONING of lumber is to remove the moisture from the millions of large and small cells of which wood is composed. Moisture (water or sap) occurs in two separate forms; FREE WATER and IMBIBED WATER. Free water is the amount of moisture the individual cells contain. Imbibed water is the moisture absorbed by the cell walls. During drying or seasoning, the free water in the individual cells evaporates until a minimum amount of moisture is left. The amount of moisture remaining is called the FIBER-SATURATION POINT. The fiber-saturation point varies from 25 to 30 percent, but for general purposes is accepted as 30 percent. Below the fiber-saturation point, the imbibed water is extracted from the porous cell walls, causing a reduction of the thickness of the walls.

Wood shrinks across the grain when the moisture content is lowered below the fiber-saturation point. SHRINKING and SWELLING of the wood cells, caused by varying amounts of moisture, change the size of the cells. Therefore, the LOWERING or RAISING of the moisture content causes lumber to shrink or swell.

The loss of moisture during seasoning causes wood to be (1) harder, (2) stronger, (3) stiffer and (4) lighter in weight.

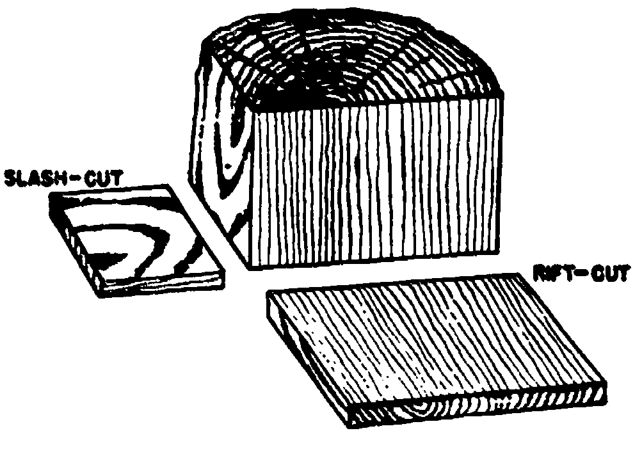

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Figure 6-4.—Slash-cutting and rift-cutting.

LUMBER DEFECTS AND BLEMISHES

A DEFECT in lumber is any flaw which tends to affect the strength, durability, or utility value of the lumber. A BLEMISH is a flaw which mars the appearance of the lumber only. A blemish which affects the utility value of the lumber (such as a blemish in wood intended for fine furniture or cabinet work) is also a defect.

You will seldom find a piece of lumber that does not have a defect or blemish of some sort. Some, are the result of decay in the growing tree while others are the result of insects, worms, and fungi, both before and after the lumber is cut. Other defects and blemishes are the result of improper seasoning. Some of the defects that may be present in freshly cut logs are shown in figure 6-5.

Probably the most common defects are knots, which occur in almost all kinds of lumber and are the result of branch growth. An INTERWOVEN KNOT is formed while the tree is alive and its annual rings are interwoven with those of the trunk of the tree. Usually an interwoven knot is solid enough and does not constitute a serious defect. If by chance the limb dies, the wood formed in the trunk of the tree makes no further connection with the limb, but grows around it. This, in turn, produces a DEAD KNOT which may be loose enough to drop out or which may be tight enough to become encased so that it will hold its shape and position when being sawed into lumber. A SPIKE KNOT, which is a long thin knot, is the result of the way the tree has been sawed.

Small solid knots are not objectionable in most of the lumber that is used aboard ship, but lumber having loose or large knots should be cut into smaller pieces to eliminate these spots in the lumber.

HEARTSHAKE is another lumber defect. This is caused by the action of the wind during the growing of the tree and causes a lengthwise separation of the annual rings. WINDSHAKE is another defect caused by the action of the wind during the growth of the tree, which causes the tree to be twisted.

A SHAKE is a separation along the lengthwise grain. It is not the same as a CHECK because it already exists when the tree is cut, while a check develops as the cut lumber dries.

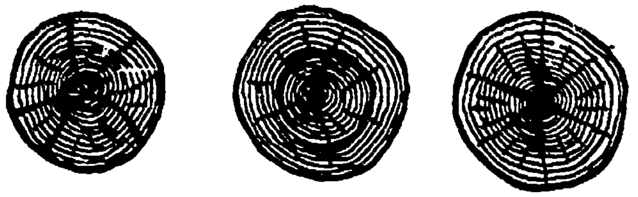

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Figure 6-5.—Defects in logs.

A CHECK is a crack or separation, usually short, which is caused by the uneven shrinking of the wood cells in seasoning. Small enclosed spaces in the wood that are filled with sap or pitch (resin) are called PITCH POCKETS.

WARP or WARPAGE is a lumber defect in which the faces of a board or timber are distorted from a true, flat, plane surface. Or in other words, lumber is twisted, bowed, or cupped. The varying amount of moisture in the wood changes the diameter of the cells of the wood, thereby causing the board to shrink or swell in width as well as in thickness, but not in length, as the cells or tubes lie in a lengthwise direction. However, redwood is one of the woods that will swell or shrink in all three directions. Warping is always the result of swelling and shrinking of the wood cells and may be understood as meaning any change or variation from a flat or plane surface of a board.

WANE is the condition of a board that is not full or true to size—one that lacks wood along corners, edges, or ends, or is partially composed of bark.

BLUE STAIN is a blemish caused by a mold fungus. It does not weaken the wood.

A BARK POCKET is a patch of bark over which the tree has grown, and which it has entirely or almost entirely enclosed.

CROSS-GRAINED lumber is lumber in which the grain does not parallel the lengthwise axis of the piece, or in which the grain spirals around the lengthwise axis.

Some of the lumber defects that are caused by improper seasoning of the lumber either by air-drying or kiln-drying are called HONEYCOMBING and CASE-HARDENING. Honeycombing is a series of checks or cracks either on the surface or in the center of the lumber caused by the stresses set up in the lumber during the drying process. If these stresses are not properly relieved, by adding moisture during the seasoning of the lumber, honeycombing will result in the dried lumber.

Case-hardening is the drying of the outside layers of cells before the cells in the center have an opportunity to dry. The surface of the board, however, cannot shrink properly until the center has shrunk, thus causing this surface to become set when expanded. Then, when the inner layers of cells become dry and are ready to shrink, the wood is stressed.

CLASSIFICATION OF LUMBER

Lumber is classified into three major use categories as follows:

YARD LUMBER grades for general building purposes where the piece is to be used as a whole.

FACTORY AND SHOP LUMBER grades where the lumber is to be cut-up in further manufacture.

STRUCTURAL material of relatively large dimension where the piece is to be used as a whole and where strength factors are definitely appraised independently of appearance factors.

An IMPORTANT EXCEPTION to this generally applicable classification according to uses is that boxes and containers are produced largely from the yard lumber grades rather than factory grades, because for this purpose clear pieces are not normally required.

LUMBER SIZES

Pieces of lumber which are less than 2 inches thick are usually called BOARDS. Pieces which are from 2 to 5 inches thick are called PLANKS or DIMENSION LUMBER. Heavier pieces are called TIMBER.

Softwoods, particularly those used for construction, are usually cut to standard thicknesses, widths, and lengths as are those hardwoods to be used for construction such as oak.

The DRESSED dimensions of a piece of lumber are always smaller than the specified size (NOMINAL SIZE). The NOMINAL SIZE is the actual size of the lumber in its rough form as it comes from the saw mill.

DRESSED lumber is lumber which has been surfaced (planed smooth) on two or all four sides. Lumber which has been surfaced on two sides is designated as S2S (surfaced on two sides); lumber which has been surfaced on all four sides is designated as S4S (surfaced four sides). Most lumber used in general construction is S4S, which most lumber used for patternmaking is nominal size. The nominal sizes and the actual dressed (S4S) dimensions of some common sizes of boards follow:

Nominal size	Dressed dimensions
1 x 6	25/32 x 5 5/8
1 x 8	25/32 x 7 1/2
1 x 10	25/32 x 9 1/2

The nominal sizes and the actual dressed (S4S) dimensions of some common sizes of dimension lumber are as follows:

Nominal size	Dressed dimensions
2 x 2	1 5/8 x 1 5/8
2 x 4	1 5/8 x 3 5/8
2 x 6	1 5/8 x 5 5/8
2 x 8	1 5/8 x 7 1/2
2 x 10	1 5/8 x 9 1/2
2 x 12	1 5/8 x 11 1/2
4 x 4	3 5/8 x 3 5/8

All softwood framing lumber, and most other softwood lumber, is cut to even-numbered-foot lengths, such as 10 ft, 12 ft, 14 ft, and so on. Hardwood is sometimes cut to odd-numbered as well as even-numbered-foot lengths.

Hardwoods to be used for cabinets, furniture, and other finish work are usually cut to specific thicknesses (in graduations of 1/4 inch) and to random widths and lengths (RWL) with a specified minimum. For example, an order for walnut would be written as 4/4 X 4 X 6 RWL. This would tell the supplier that you require material 1 inch thich (4/4), at least 4 inches wide and at least 6 feet long.

GRADING OF LUMBER

Lumber grades are based on the type and extent of defects, size of the pieces, and seasoning condition. Softwood lumber is graded for quality in accordance with American Lumber Standards set by the National Bureau of Standards for the U.S. Department of Commerce. The major quality grades, in descending order of quality, are SELECT LUMBER, (usually used for interior finish), and COMMON LUMBER, which is usually used for house construction. Each of these grades has subdivisions in descending order of quality as follows:

GRADE A lumber is select lumber which is practically free of defects and blemishes.

GRADE B lumber is select lumber which contains a few minor blemishes.

GRADE C lumber is finish item lumber which contains more numerous and more significant blemishes than grade B All of these must be capable of being easily and thoroughly concealed with paint.

GRADE D lumber is finish item lumber which contains more numerous and more significant blemishes than grade C, but which is still capable of presenting a satisfactory appearance when painted.

NO. 1 COMMON lumber is sound, tightknotted stock, containing only a few minor defects. It must be suitable for use as watertight lumber.

NO. 2 COMMON lumber contains a limited number of significant defects, but no knot holes or other serious defects. It must be suitable for use as graintight lumber.

NO. 3 COMMON lumber contains a few defects which are larger and coarser than those in No. 2 Common; occasional knot holes, for example.

NO. 4 COMMON lumber is low-quality material, containing serious defects like knot holes, checks, shakes, and decay.

NO. 5 COMMON is capable only of holding together under ordinary handling.

If you buy MILL-RUN lumber, you take everything that is sawed except the slabs (bark).

The grades of construction, standard, utility, and economy are used in some associations.

All species are covered by the grading rules and size standards of some association or grading bureau. In the case of softwood lumber, standards are set by a regional manufacturer's association. In a few cases, a softwood species growing in more than one region is graded under rules of two different associations. There is great advantage to the purchaser, whether large or small, to buy according to these association grades rather than to attempt to buy according to his own individual specifications unless the requirements are actually very unusual. Occasionally a departure from the standard grade provision is necessary to cover unusual requirements. This is best handled as an exception to a standard grade rather than as an entirely special grade.

Hardwoods are graded as firsts, seconds, selects, Number 1 common, and Number 2 common. These grades denote only the amount of clear, usable lumber in a particular piece and are established by the National Hardwood Manufacturers' Association.

The best way to buy hardwoods, for any use other than construction, is by personal inspection.

MEASURING LUMBER (BOARD MEASURE)

As applied to lumber measure, THICKNESS is the dimension between the two face surfaces, WIDTH is the dimension between two edges which are parallel to the wood grain, and LENGTH is always the dimension between two ends and is parallel to the wood grain regardless of the width dimension.

It is common practice to state the thickness dimension first and in inches, the width second (also in inches), and the length last, but in feet. Therefore, if you were told to get a 2 by 4 by 6, you would know to find a piece 2 inches thick by 4 inches wide by 6 feet long.

The standard measure for lumber is a board foot, usually abbreviated as bf or bd ft. A board foot is simply 1/12 of a cubic foot. In other words, a board measuring 1 inch thick, 12 inches wide, and 12 inches long would contain 1 bd ft. Figure 6-6 shows pieces of wood with different measurements which all contain 1 bd ft.

There are several formulas you may use to determine bd ft. The one most commonly used could be called the INCHES, INCHES, FEET method. To use it, multiply the thickness (T) in inches by the width (W) in inches by the length (L) in feet and divide the product by 12. Therefore, the formula would be written as:

$$\text{bd ft} = \frac{T'' \times W'' \times L'}{12}$$

To explain further, let's suppose that you want to determine the bd ft contained in a piece measuring 1 inch thick by 8 inches wide by

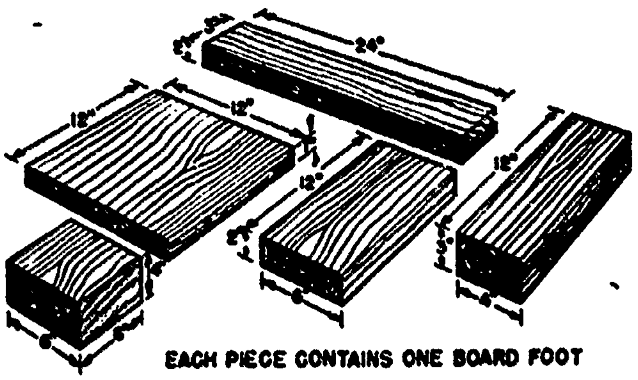

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Figure 6-6.—The board foot.

9 feet long. Using the formula, you would work it like this:

$$\text{bd ft} = \frac{T'' \times W'' \times L'}{12}$$

$$\text{bd ft} = \frac{1'' \times 8'' \times 9'}{12}$$

Since 1 multiplied by 8 equals 8 and 8 multiplied by 9 equals 72, your formula would now be reduced to 72 over 12:

$$\text{bd ft} = \frac{72}{12}$$

Now, all that is left to do is divide 12 into 72 which produces a quotient of 6. Therefore, a board measuring 1 inch by 8 inches by 9 feet will contain 6 bd ft.

When calculating board feet, a board less than 1 inch thick is counted as 1 inch. A board more than 1 inch thick is figured to the next larger 1/4 inch increment. Thus, a board having a thickness of 1 1/8 inches would be calculated as 1 1/4 inches.

Another point to remember is that board measure is calculated on the basis of the NOMINAL not the dressed dimension of the lumber.

Another common way of measuring lumber is by lineal measure. Lineal measure is simply the length measurement of a piece of lumber. Therefore, if you had a 2 x 4 x 6, its lineal measurement would be 6 feet.

This method is often used when buying dimensioned lumber for construction purposes such as 400 lineal feet of 2 x 4.

COMMON TYPES OF WOODS

Before proceeding with a discussion of wood materials used by the patternmaker, it will be helpful for you to review the sources, uses, and characteristics of the various types of common woods. This information is provided in table 6-1.

PATTERN LUMBER

Woods that have a comparatively straight close grain, that are easy to work and not given to excessive warp or shrinkage are selected for pattern work. The selection of boards containing too much moisture or pitch should always be avoided. Such boards are difficult to work, do not retain a smooth surface, and will warp or shrink excessively.

A board that contains an excess of pitch may be detected by its unusual weight. When the board is planed, large amounts of pitch may readily be seen. Although excessive moisture cannot always be detected by weight, it can at all times be seen or felt while the board is in the rough. Usually, however, excessive moisture does not show until the board has been crosscut or dressed.

Kinds of Pattern Lumber

The woods most frequently used in pattern construction are redwood, white pine, ponderosa pine, mahogany, and poplar.

REDWOOD is used extensively by pattern shops on the west coast. This wood is inferior to the better grades of sugar pine and white pine, but for all-round practical use, it answers the requirements of the average pattern job. There is an abundant supply of redwood at present, and the best grades are easily worked and quite adaptable for large pattern construction. Redwood has one peculiar property possessed by no other wood—it shrinks in length as well as in thickness and width. The name "redwood" is derived from the reddish-brown color of the wood itself. It is very closely related to and bears a marked resemblance to pine, but is much more durable when in contact with the soil or when exposed to weather.

The redwood tree grows exclusively on the west coast, being native to the coastal regions of California and the southern coast of Oregon. The age of these forest giants runs as high as 3000 to 4000 years; and they frequently grow to a height of 350 feet, with a diameter of 25 feet or greater.

WHITE PINE is the best wood for making simple patterns which will be used less than 30 times and are under 2 feet in length. This wood is smooth, straight-grained, even-grained, soft, lightweight, and although not very strong, warps very little when properly seasoned. White pine is quite easily shaped, is free from knots, and is most economical. With sharp tools, you can cut and carve white pine almost like soap, since the annual growth rings are so fine as to be almost invisible. White pine takes a good coat of shellac or glue but may be easily chipped or broken. Its color ranges from almost white to light yellowish-brown, frequently tinged with

Table 6-1.—Common Woods

Type	Sources	Uses	Characteristics
Ash	East of Rockies ..	Oars, boat thwarts, benches, gratings, hammer handles, cabinets, ball bats, wagon construction farm implements.	Strong, heavy, hard, tough, elastic, close straight grain, shrinks very little, takes excellent finish, lasts well.
Balsa	Ecuador........	Rafts, food boxes, linings of refrigerators, life preservers, loud speakers, sound-proofing, air-conditioning devices, model airplane construction.	Lightest of all woods, very soft, strong for its weight, good heat insulating qualities, odorless.
Basswood .	Eastern half of U.S. with exception of coastal regions.	Low-grade furniture, cheaply constructed buildings, interior finish, shelving, drawers, boxes, drainboards, woodenware, novelties, excelsior, general millwork.	Soft, very light, weak, brittle, not durable, shrinks considerably, inferior to poplar, but very uniform, works easily, takes screws and nails well and does not twist or warp.
Beech....	East of Mississippi, Southeastern Canada.	Cabinetwork, imitation mahogany furniture, wood dowels, capping, boat trim, interior finish, tool handles, turnery, shoe lasts, carving, flooring.	Similar to birch but not so durable when exposed to weather, shrinks and checks considerably, close grain, light or dark red color.
Birch	East of Mississippi River and North of Gulf Coast States, Southeast Canada, Newfoundland.	Cabinetwork, imitation mahogany furniture, wood dowels, capping, boat trim, interior finish, tool handles, turnery, carving.	Hard, durable, fine grain, even texture, heavy, stiff, strong, tough, takes high polish, works easily, forms excellent base for white enamel finish, but not durable when exposed. Heartwood is light to dark reddish brown in color.
Butternut .	Southern Canada, Minnesota, Eastern U. S. as far south as Alabama and Florida.	Toys, altars, woodenware, millwork, interior trim, furniture, boats, scientific instruments.	Very much like walnut in color but softer, not so soft as white pine and basswood, easy to work, coarse grained, fairly strong.

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Table 6-1.— Common Woods — Continued

Type	Sources	Uses	Characteristics
Cypress....	Maryland to Texas, along Mississippi valley to Illinois.	Small boat planking, siding, shingles, sash, doors, tanks, silos, railway ties.	Many characteristics similar to white cedar. Water resistant qualities make it excellent for use as boat planking.
Douglas Fir..	Pacific Coast, British Columbia.	Patternmaking, deck planking on large ships, shores, strongbacks, plugs, filling pieces and bulkheads of small boats, building construction, dimension timber, plywood.	Excellent structural lumber, strong, easy to work, clear straight grained, soft, but brittle. Heartwood is durable in contact with ground, best structural timber of northwest.
Elm.......	States east of Colorado.	Agricultural implements, wheel-stock, boats, furniture, crossties, posts, poles.	Slippery, heavy, hard, tough, durable, difficult to split, not resistant to decay.
Hickory.....	Arkansas, Tennessee, Ohio, Kentucky.	Tools, handles, wagon stock, hoops, baskets, vehicles, wagon spokes.	Very heavy, hard, stronger and tougher than other native woods, but checks, shrinks, difficult to work, subject to decay and insect attack.
Lignum Vitae	Central America.	Patternmaking, block sheaves and pulleys, waterexposed shaft bearings of small boats and ships, tool handles, small turned articles, and mallet heads.	Dark greenish brown, unusually hard, close grained, very heavy, resinous, difficult to split and work, has soapy feeling.
Live Oak ...	Southern Atlantic and Gulf Coasts of U.S., Oregon, California.	Implements, wagons, ship building.	Very heavy, hard, tough, strong, durable, difficult to work, light brown or yellow sap wood nearly white.
Mahogany ...	Honduras, Mexico, Central America, Florida, West Indies, Central Africa, other tropical sections.	Patternmaking, furniture, boats, decks, fixtures, interior trim in expensive homes, musical instruments.	Brown to red color, one of most useful of cabinet woods, hard, durable, does not split badly, open grained, takes beautiful finish when grain is filled but checks, swells, shrinks, warps slightly.

103.127.2

Table 6-1.—Common Woods—Continued

Type	Sources	Uses	Characteristics
Maple......	All states east of Colorado, Southern Canada.	Patternmaking, excellent furniture, high-grade floors, tool handles, ship construction crossties, counter tops, bowling pins.	Fine grained, grain often curly or "Bird's Eyes," heavy, tough, hard, strong, rather easy to work, but not durable. Heartwood is light brown, sap wood is nearly white.
Norway Pine.....	States bordering Great Lakes.	Dimension timber, masts, spars, piling, interior trim.	Light, fairly hard, strong, not durable in contact with ground.
Philippine Mahogany..	Philippine Islands	Patternmaking, pleasure boats, medium-grade furniture, interior trim.	Not a true mahogany, shrinks, expands, splits, warps, but available in long, wide, clear boards.
Poplar....	Virginias, Tennessee, Kentucky, Mississippi Valley.	Patternmaking, low-grade furniture cheaply constructed buildings, interior finish, shelving, drawers, boxes.	Soft, cheap, obtainable in wide boards, warps, shrinks, rots easily, light, brittle, weak, but works easily and holds nails well, fine-textured.
Red Cedar..	East of Colorado and north of Florida.	Mothproof chests, lining for linen closets, sills, and other uses similar to white cedar.	Very light, soft, weak, brittle, low shrinkage, great durability, fragrant scent, generally knotty, beautiful when finished in natural color, easily worked.
Red Oak...	Virginias, Tennessee, Arkansas, Kentucky, Ohio, Missouri, Maryland.	Interior finish, furniture, cabinets, millwork, crossties when preserved.	Tends to warp, coarse grain, does not last well when exposed to weather, porous, easily impregnated with preservative, heavy, tough, strong.
Redwood ..	California.	Patternmaking, general construction, tanks, paneling.	Inferior to yellow pine and fir in strength, shrinks and splits little, extremely soft, light, straight grained, very durable, exceptionally decay resistant.

103.127.3

Table 6-1.—Common Woods—Continued

Type	Sources	Uses	Characteristics
Spruce	New York, New England, West Virginia, Central Canada, Great Lakes States, Idaho, Washington, Oregon.	Railway ties, resonance wood, piles, airplanes, oars, masts, spars, baskets.	Light, soft, low strength, fair durability, close grain, yellowish, sap wood indistinct.
Sugar Pine	California, Oregon.	Same as white pine.	Very light, soft, resembles white pine.
Teak	India, Burma, Siam, Java.	Deck planking, shaft logs for small boats.	Light brown color, strong, easily worked, durable, resistant to damage by moisture.
Walnut	Eastern half of U.S. except Southern Atlantic and Gulf Coasts, some in New Mexico, Arizona, California.	Expensive furniture, cabinets, interior woodwork, gun stocks, tool handles, airplane propellers, fine boats, musical instruments.	Fine cabinet wood, coarse grained but takes beautiful finish when pores closed with woodfiller, medium weight, hard, strong, easily worked, dark chocolate color, does not warp or check, brittle.
White Cedar. . . .	Eastern Coast of U.S., and around Great Lakes.	Boat planking, railroad ties, shingles, siding, posts, poles.	Soft, light weight, close grained, exceptionally durable when exposed to water, not strong enough for building construction, brittle, low shrinkage, fragment, generally knotty.
White Oak . .	Virginias, Tennessee, Arkansas, Kentucky, Ohio, Missouri, Maryland, Indiana.	Boat and ship stems, sternposts, knees, sheer strakes, fenders, capping, transoms, shaft logs, framing for buildings, strong furniture, tool handles, crossties, agricultural implements, fence posts.	Heavy, hard, strong, medium coarse grain, tough, dense, most durable of hardwoods, elastic, rather easy to work, but shrinks and likely to check. Light brownish grey in color with reddish tinge, medullary rays are large and outstanding and present beautiful figures when quarter sawed, receives high polish.

103.127.4

Table 6-1.—Common Woods—Continued

Type	Sources	Uses	Characteristics
White Pine.	Minnesota, Wisconsin, Maine, Michigan, Idaho, Montana, Washington, Oregon, California	Patterns, any interior job or exterior job that doesn't require maximum strength, window sash, interior trim, millwork, cabinets, cornices.	Easy to work, fine grain, free of knots, takes excellent finish, durable when exposed to water, expands when wet, shrinks when dry, soft, white, nails without splitting, not very strong, straight grained.
Yellow Pine.	Virginia to Texas.	Most important lumber for heavy construction and exterior work, keelsons, risings, filling pieces, clamps, floors, bulkheads of small boats, shores, wedges, plugs, strongbacks, staging, joists, posts, piling, ties, paving blocks.	Hard, strong, heartwood is durable in the ground, grain varies, heavy, tough, reddish brown in color, resinous, medullary rays well marked.

103.127.5

red. This tree grows extensively throughout the Great Lakes region, west of Michigan. In the West, the name "white pine" is usually applied to the native sugar pine which grows extensively in northern California and southern Oregon.

PONDEROSA PINE, often mistakenly called "sugar pine" in the pattern shops of the west coast, is a comparatively recent introduction to the pattern shop. In appearance, it closely resembles the sugar pines but is not as satisfactory for pattern work. It usually warps easily, is subject to considerable shrinkage, and is more "pitchy" than sugar pines.

MAHOGANY, a wood that is more durable and harder than pine, is used when 30 to 100 castings are required. It is also used for patterns having long or thin sections or projections. This wood is strong, coarse-grained, and warps very little. It is soft enough to cut and nail easily, yet it is hard enough to stand a lot of abuse. Mahogany is often very difficult to plane or carve in the direction of the grain, but it is excellent for cross-grain carving, and will outlast pine three to one.

Several varieties of mahogany are used—Spanish mahogany from the West Indies; Honduras mahogany (also called baywood) and Mexican mahogany from Central America and Mexico; and Senegal mahogany from Africa. It is rather difficult to distinguish one variety from the others. In color, mahogany is usually reddish-brown but often varies to lighter and mottled shades.

POPLAR is used in many pattern shops. It is soft, very close-grained and straight-grained. However, because of brittleness and excessive shrinkage, as well as a marked tendency toward warping, the uses to which it may be put are limited. Poplar ranges in color from off-white to light yellow. Some species vary from light to dark green. The dark green variety often turns brown after extended exposure. The poplar tree grows extensively in the eastern part of the United States from the Gulf of Mexico north into southern Canada.

The Patternmaker occasionally works with certain other woods, of which a brief description follows.

MAPLE, principally eastern maple, is very hard and is difficult to work. It varies in color from light brown to white. Oregon maple (western soft maple) is close-grained and reddish-brown in color. This wood is used chiefly in the manufacture of furniture and tool handles. Oregon maple is also used for certain parts of patterns that are designed to endure heavy wear and tear or that are weak due to their shape or size. In addition, maple will outlast pine eight to one.

WHITE ASH is open-grained, elastic, and hard. In color it is light brown with the sapwood almost white.

BLACK WALNUT grows in the eastern part of the United States. It is very durable and very hard. When used as pattern material, black walnut will outlast pine five to one.

HICKORY is the strongest, heaviest, and toughest of all American woods. It is also quite flexible. The color of hickory varies from brown to white.

OREGON PINE (Douglas fir) is of two varieties, red and yellow. The yellow is the more valuable of the two, being hard, strong, and very durable—but difficult to work. Oregon pine is used in the pattern shop occasionally in the production of equipment.

CHERRY is brown in color, close-grained, and very hard—but warps excessively. Cherry is a little difficult to carve, but when used for small patterns will outlast pine five to one.

LIGNUM VITAE is excessively heavy, hard, and resinous. Its color varies from light yellow to dark greenish-brown—at times almost black. This wood is native to tropical America, New South Wales, and New Zealand.

TEAK is heavy, strong, and oily. Its color is quite dark. It does not shrink, crack, or warp. Teak comes from East India.

Care and Storage of Pattern Lumber

Lumber is just as much a patternmaking tool as is the saw or plane and should be considered as such. Proper maintenance must be given to lumber. Pattern lumber must be properly stowed and cared for to prevent it from becoming water-soaked, rotted, or warped. The best way to stow lumber is by stacking it on end in racks built for the purpose so that air can circulate all around the boards; this circulation dries the wood evenly and reduces warping.

Sufficient room can seldom be found aboard ship for storing lumber on end; so it must be stored in the next best manner. The generally accepted method is to store the lumber horizontally. The lumber is separated by sizes; all the 1-inch pieces together, the 1 1/2-inch pieces together, etc. In placing the lumber in racks, small strips or battens about 1 inch thick should be placed across the boards about 6 feet apart to separate the boards and form a space for the air to circulate around them. Circulation of air is important. A board that has been dressed and then laid on one of its wide surfaces, without full air circulation, will usually warp toward the exposed surface because the air absorbs the moisture from the exposed surface, but not from the underneath surface.

Usually, there is an overhead lumber storage rack in the pattern shop, but because of space limitations aboard a repair ship or tender, the bulk of the lumber is stowed in other parts of the ship. The use of overhead storage racks on the port and starboard weatherdeck passageways is a common practice.

A careful record of the pattern lumber used and on hand should be maintained. If possible, at least 3 months' supply should be on hand at all times.

MANUFACTURED WOOD PRODUCTS

LAMINATED lumber is made up of layers of wood that are glued face-to-face with the grain of adjacent layers parallel (fig. 6-7). The component parts which are glued together to make laminated lumber may be thin sliced sheets of veneer or they may be sawed boards. Plywood frequently alternates grain to give the

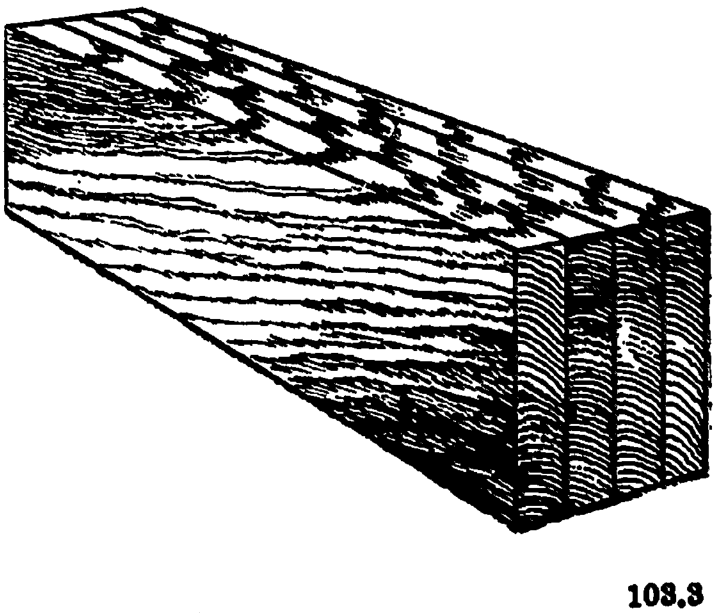

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Figure 6-7.—Laminated lumber.

member the quality of nonsplitting and stability. (Note: Plywood alternates grain each ply and laminated wood never alternates grain.)

One advantage of laminated wood is that it can be made up of unlimited thicknesses. Also, by staggering the ends of individual layers it is possible to secure members that are much longer than solid timbers.

PLYWOOD (fig. 6-8) is made up of thin layers of wood that are glued face-to-face at right angles to one another. It always has an odd number of plies—veneered stock for use in the manufacture of furniture usually having five layers. A thick layer, called the core, is in the center. The layers glued on with their grain running across that of the faces are called cross bands. The surface layers or faces are placed so that their grain runs parallel to the long direction of the panel.

Ordinarily 1/4-in. and 1/8-in. plywood (fir) has only 3 plies. Thicker plywood may have as many as 15 plies—but always an odd number. The standard size of plywood sheets is 4 feet wide by 6 to 12 feet long, though smaller and larger sizes are available. Because of the cross-grain effect, it is almost impossible to split plywood, and shrinking and swelling are negligible.

The development of special glues and other bonding materials has made possible a type of plywood highly resistant to water. It was widely used during World War II, and is still used extensively in the Navy.

There are two basic grades of plywood—interior and exterior. Most plywood produced is of the interior type. Although it can stand an occasional wetting and subsequent normal drying without losing its original form and strength, interior plywood is unreliable in wet places. Exterior type plywood will retain its original form and strength when repeatedly wet and dried and otherwise subjected to the elements. It is suitable for permanent exterior use. Most plywood is branded or stamped on the edge with the symbol "EXT." or "INTERIOR" (INT). In addition, other markings carrying more complete information are stamped on the back of the plywood sheet. A typical Douglas fir back stamp, with all symbols explained, is shown in figure 6-9.

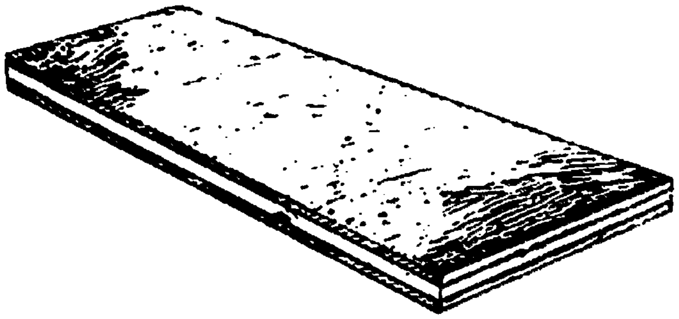

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Figure 6-8.—Plywood.

Plywood is graded by the quality of the face veneers, with A being the best and D the poorest (fig. 6-9). The grading is based upon the number of defects such as knotholes, pitch pockets, and splits, and the presence of streaks, discolorations, sapwood, shims, and patches in each face of the panel. Plywood also comes with resin-impregnated fiber faces which provide better painting surfaces and better wearing qualities.

Because of the conditions of its manufacture, plywood can generally be assumed to be dry when received. It should therefore be stored in a closed shed. For long storage a heated storage area is recommended.

Plywood is commonly solid piled. Under humid conditions, there is some tendency for edges to swell because of exposed end grain, and this swelling causes dishing, especially in the upper panels of high piles. Dishing can be minimized by placing strips in the pile at intervals. Enough strips should be used so that plywood will not bend between them. Dry 1-inch strips are suitable for supporting plywood.

FIBERBOARD conforming to Federal Specification LLL-F-321 is made of wood or vegetable fiber, and is compressed to form sheets or boards. It is available in sizes from 1/2 in. to 1 in. in thickness, 2 to 4 ft in width, and 8 ft to 12 ft in length. The boards are comparatively soft and provide good insulation and sound absorbing qualities. Fiberboard usually has a rough surface, but is also available with finished surfaces.

HARDBOARD is known by several trade names. They are all made by separating and treating wood fibers which are then subjected to heat and heavy pressure. Hardboard is available in thickness from 1/16 in. to 5/16 in. The most common size of sheet is 4 ft x 8 ft but other sizes are available. The finish may be obtained in a plain smooth surface or in any of a number of

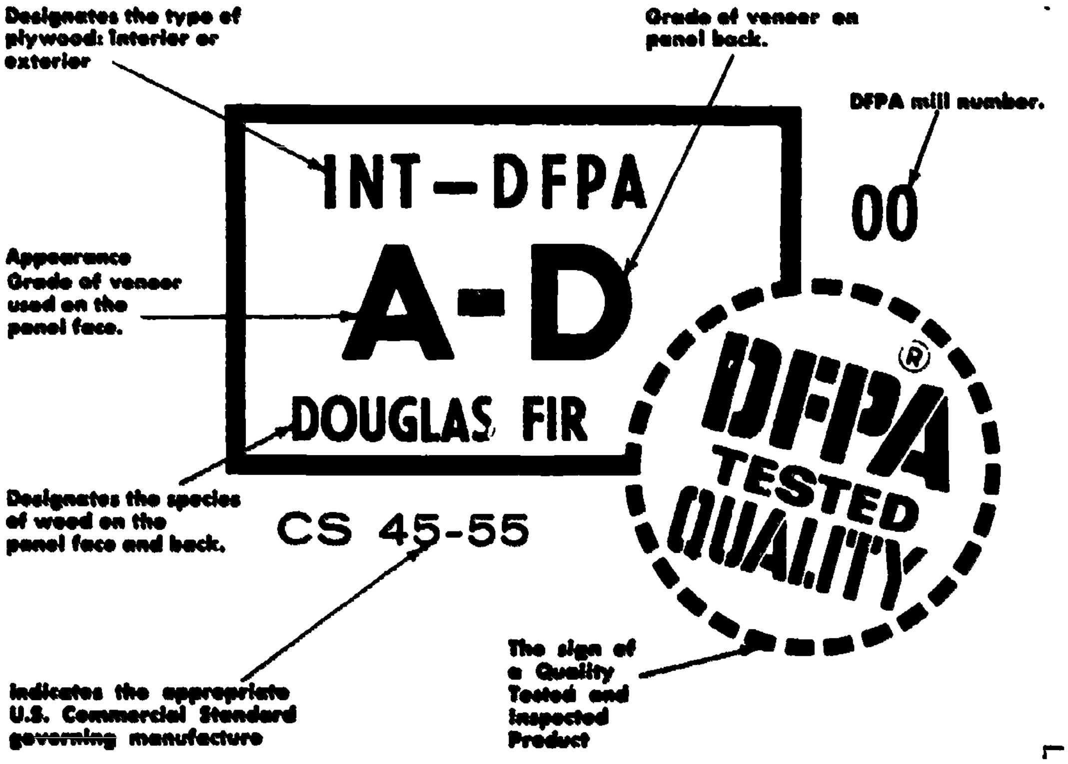

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Figure 6-9.—Typical Douglas fir back stamp.

glossy finishes, some of which imitate tile or stone. Structural type hardboard used in the Navy comforms to Federal Specification LLL-H-35. Where moisture resistance or extra strength is required, Class B treated hardboard should be used, otherwise Class A is satisfactory.

METAL

When a great number of castings is desired, or when a wood pattern might be too weak, metal patterns are the answer. Because metal patterns are more expensive than wood patterns, they are seldom used in Navy installations; that is, except for high production work. Moreover, metal patterns are heavy in weight, which, of course, limits their size. However, since metal patterns have less tendency to warp, the amount of time consumed in making repairs can be held to a minimum.

The chief advantages of metal patterns are that they are far stronger and do not warp or shrink like a wood pattern does. Because they have no coarse grains—as in wood—metal patterns tend to produce better finishes on castings. They are extremely durable, showing little evidence of wear due to the abrasive action of the molding sand even after many months of use. Metal patterns are ideal to use for the fine lines and details that are required of some types of castings. The cost of a casting produced from a metal pattern is considerably less than that of a casting made from a wooden pattern. Metal patterns can be made to conform to the working drawing to within 0.001 inch, thus ensuring a more accurate casting. In addition, less draft is required, better draws from a mold can be made, and greater detail pickup can be obtained, thus resulting in a more sound casting.

TYPES OF METALS USED FOR PATTERNS

The Patternmaker decides the kind of metal or alloy to be used in making a metal pattern, considering the size of the pattern and the degree of sharpness required of the small details. The metals usually preferred for patterns are aluminum, brass, and iron. Aluminum is used most because it is the lightest of the three metals and does not tend to rust or corrode. In metal pattern work of a general nature, aluminum may be alloyed with zinc for both hardness and lightness. At times, the aluminum pattern may be supplemented by steel, brass, or white metal sections.

Brass and iron are used when added strength is needed, and at times when aluminum is not available. Brass patterns draw well from molding sands and are used frequently for small objects. When iron is used, the casting is filed, ground, machined to size and shape, and then allowed to rust slightly. After a sufficient amount of rust has accumulated, the casting is sanded and given a light coat of shellac. The shellac fills up the pores in the metal, making a smooth surface.

FORMS OF METAL PATTERNS

Metal patterns are made in a variety of forms. The most common form is known as a HAND PATTERN which will make one casting per mold. This type of pattern is used when a limited number of castings is required and the general pattern shape and dimensions do not permit the use of a wooden pattern to hold the proper tolerances. An example of this type of pattern is the deck drain pattern or a special type of hatch dog.

When a large number of castings is required, it is possible to increase the production of these castings by metal patterns that are soldered to a common runner. This type of pattern, called a MULTIPLE or GATED PATTERN, is connected to the runner by means of a gate. In most cases, the patterns, runner, and gates can be mounted on a matchboard or mounted in a pattern frame that can be rammed up the same as a matchboard. Figure 6-10 illustrates metal patterns mounted on metal match plates. The gates of this type of pattern are known as BRANCH GATES or PATTERN CONNECTIONS. The best example of this type of pattern is the hatch dog and eye-bolt.

When the parting line of a gate of patterns is irregular, so that it is impossible to mount the patterns on a flat plate (matchboard), they can be mounted on a PATTERN FRAME that fits the flask pins. The gate of patterns can be suspended on the frame by the use of STOP-OFFS. Upon withdrawal of the pattern frame from the drag half of the mold, the stop-off portion of the mold cavity is filled in with sand prior to closing. Another way is to take the gate of patterns to the foundry and have an aluminum plate cast with the patterns, runners and gates attached. This type of match plate is called a CAST-IN PLATE.

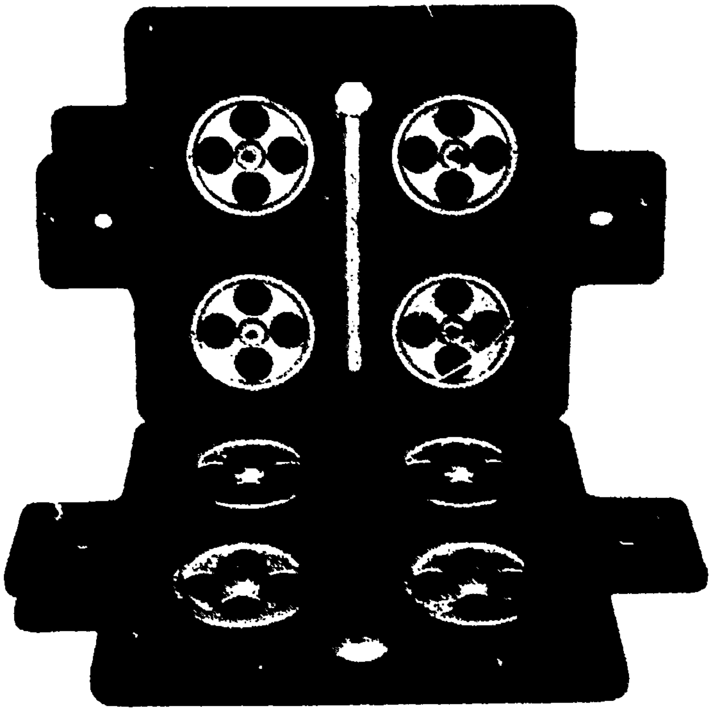

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Figure 6-10. — Metal patterns mounted on metal match plates.

Casting a cast-in plate in a shipboard foundry will require that the Patternmaker and the Molder work together in deciding the proper parting line of the gate of patterns. The thickness of the pattern plate will be determined by the size of the job.

Core boxes of intricate design that are to be used over and over again are often made of metal. The parting surface of the core box will withstand harder use if the box is made of metal. Certain types of core boxes would require a master pattern to be made and a casting made from it. The casting is finished by machining or hand scraping. When the core box is of a simple design, it may be made from solid stock by milling, drilling, or a turning process, or by a combination of these processes.

Aluminum is used in core boxes when the shape is such that it would be difficult to machine and must be hand scraped to size.

Brass and bronze are used in core boxes when there are small narrow pockets and thin walls and where the sides of these partitions must be very smooth so that the core can be removed without breaking.

GYPSUM CEMENT

During World War II, there was a great demand for quick tooling methods requiring speed, accuracy, and extensive contouring of patterns. As a result, the use of gypsum cement molds increased in use. Presently, wood and metal are still the most commonly used pattern materials aboard repair ships and tenders. Inasmuch as modern foundry requirements and procedures have stimulated research for new pattern materials, gypsum cements can be applied to many common job shop practices used by the Navy Patternmaker.

The skilled Patternmaker should have a knowledge of some of the techniques of working with plaster and some of the specialized applications of gypsum cement to patternmaking. Some of the advantages of using gypsum cement patterns are that gypsum cement:

1. Saves time in patternmaking because certain patterns may be more easily and quickly made of plaster than of wood.

2. Retains the accuracy and stability of dimensions under varying temperature and humidity conditions.

3. Is adaptable to complex contours and intersections. to irregular and intricate shapes, to multiple patterns mounted on match plates, and to producing sectional dies from full-scale mockups.

4. Requires a comparatively small investment in tools and shop equipment. The inventory problem is simplified because a pattern of almost any size can be made from gypsum cement. The cement comes in powder form and is stored in bags.

5. Has the advantage of dependable uniformity, provided the mixing is done in strict accordance with the manufacturer's instructions.

6. May be used to help check the accuracy of inaccessible parts of wood patterns and core boxes. For example, to check the metal thickness of a particular pattern, pour gypsum cement into each half of the core box. Place the two halves together face to face, in the process known as "booking" or "squeezing out." Finally, check or compare the dimensions of the plaster core against those on the layout board.

The use of plaster in patternmaking does have LIMITATIONS such as:

1. It is a messy process. You may overcome this disadvantage by developing neat work habits, by using clean utensils and equipment, and by following the manufacturer's instructions for mixing.
2. It produces a fragile pattern. You may partially overcome this disadvantage by using any one or a combination of the following materials for reinforcement: hemp, sisal, manila rope, wire mesh burlap, muslin, wood (as exterior reinforcements only), and metal inserts.
3. It is not applicable to all types of patterns. However, your experience on the job will help you to decide when to use plaster in patternmaking.
4. It requires absolute accuracy in making the templates and in attaching them to the screeding sled.

PLASTER PATTERNS

The most commonly known form of gypsum cement used in pattern construction is plaster of paris. This is only one of many forms of gypsum; in recent years a great variety of plaster types have been formulated which have special properties that meet the varying requirements of patternmaking.

Plaster is made from a finely ground, calcined material mineral (gypsum rock) processed to obtain a uniform product in powdered form. The calcination (dehydration) and additional processes are carefully controlled to produce a gypsum cement having predetermined ranges of strength, hardness, period of plasticity, and expansion. Super strength plasters are referred to as alpha gypsum cements or better known to the patternmaker as hard plasters.

CHARACTERISTICS OF PLASTER

In working with plaster you should be familiar with these three characteristics (1) COMPRESSIVE STRENGTH, (2) PERIOD OF PLASTICITY, and (3) VOLUME AND TEMPERATURE CHANGES. Compressive strength is the term used to define the amount of pressure per square inch required to break down the hardened plaster. The period of plasticity is the period of time between the thickening and setting stages of the plaster-water mixture. Volume and temperature changes take place in the hardening and setting stages and have a definite effect on the strength of the pattern. In general, these characteristics are somewhat controlled by the addition of extra water to the powdered gypsum.

Compressive Strength

High compressive strength of a plaster pattern gives breakage resistance. The increase of water in the plaster-water ratio results in a decrease in compressive strength of the finished pattern. As varying degrees of the normal consistency (amount of water required to mix 100 parts of the plaster by weight to a standard fluidity) of the slurry are required in forming patterns from plaster, it is essential that you follow the manufacturer's recommendations for the plaster-water ratio.

Chemically, 18 pounds of fresh water will convert 100 pounds of dry plaster to a solid mass. But, more water is necessary to produce a free-flowing slurry, so that excess water is always present in a freshly set mass of plaster.

Period Of Plasticity

To form a fluid, pourable, free-flowing mass known as a "slurry", the water and dry ingredients should be mixed in the correct proportions. This slurry first thickens, then hardens, and finally sets. It is during these stages that the plastic mass can be formed by hand, screened with templates, and/or reinforced with fiber hemp, sisal, wire mesh, burlap, or muslin.

With experience you will learn to distinguish between the different stages which occur during the period of plasticity and to utilize each stage to the best advantage. For example, using the mixture in the controlled flow stage eliminates the need for molds or "boxing-in" which will be necessary when the mixture is used in the free-flowing stage. In addition, different areas of the pattern will require different degrees of plasticity, because as the plastic period progresses, the cement gains strength or body, and can be built up to the contours required. The period of plasticity ranges from 15 to 30 minutes, depending upon the type of gypsum cement used.

Volume and Temperature Changes

As the free-flowing slurry changes to a solid mass, certain volume and temperature changes occur. These changes begin at the initial setting and consist of setting expansion and thermal expansion.

The setting expansion, which is very slight but positive and permanent, enables the cement to free itself from the surfaces on which it sets. This expansion, characteristic of all gypsum cements, makes gypsum cement best for reproducing fine detail. The pattern or model should be removed at the setting expansion stage because the plaster will be at its high point of expansion, which makes withdrawal easier.

In addition to the normal setting expansion, there is a slight temporary expansion caused by the heat generated by crystallization. This temporary expansion, called the thermal expansion, recedes with the loss of heat.

SHOP EQUIPMENT

In making gypsum cement patterns and models, it is necessary to have the proper equipment. Shop equipment for working gypsum is comparatively inexpensive. The size and type of work being done will determine the equipment needed. Special handtools are essentail to produce a good job. A large percentage of these tools can be manufactured in the shop.

A list of basic shop equipment and supplies needed for plaster work includes:

Flat scrapers—one smooth edge, one saw-toothed edge.

Kidney scrapers—one smooth edge, one saw-toothed edge. Figure 6-11 shows scrapers of various shapes and sizes that may be used.

Spatulas—various sizes.

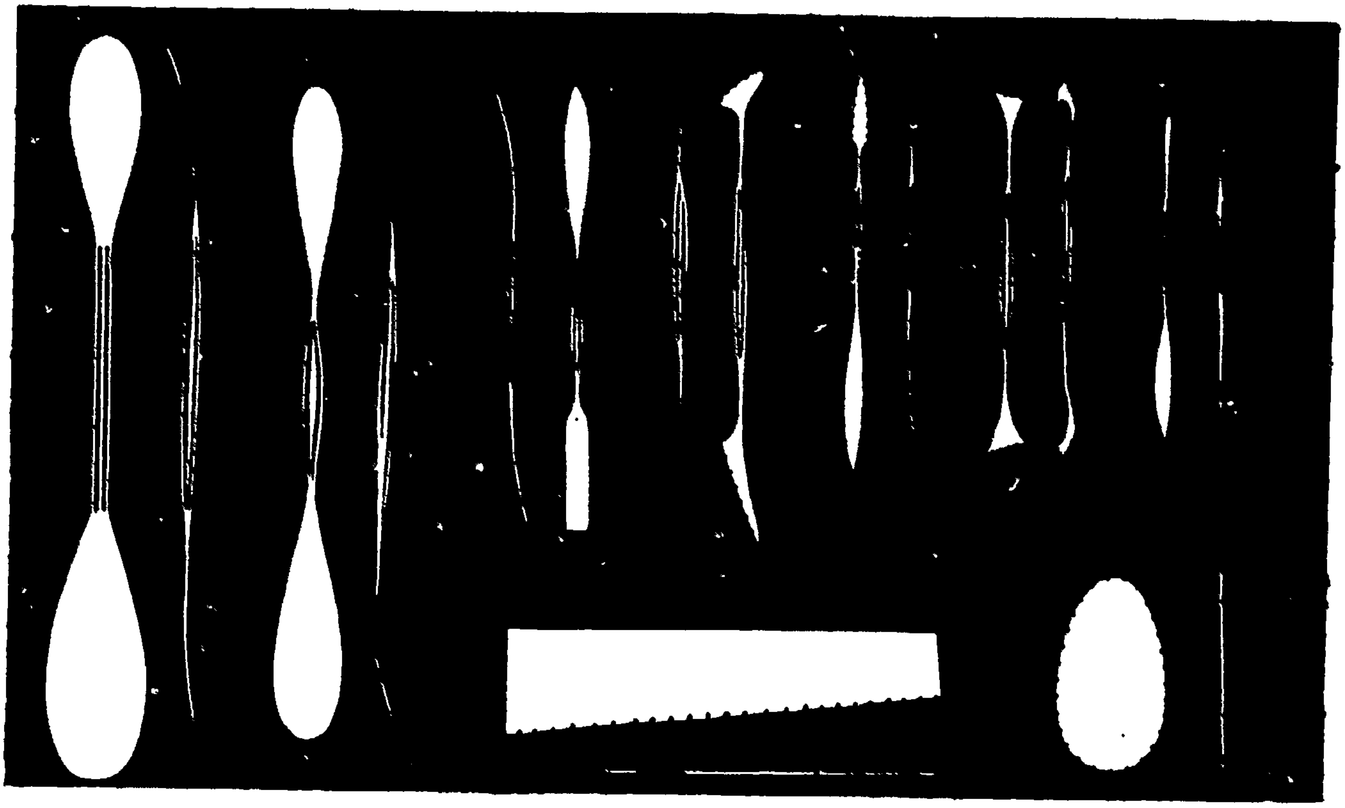
Handsaws—large tooth and wide-set.

Hand planes—size to be determined by job.

Carving tools—as needed.

Files—for forming metal templates.

Workbenches—The entire work surface should be flat and made of plate glass, marble, slate, or treated hardwood. The size of the job being made governs the height of the bench. The main body of the work should be in as convenient a position as possible. Iron benches can be used, but the rust resulting from moisture must be removed constantly. Granite surface plates are highly recommended as table tops. The plates, available in many sizes (large and



23.134X

Figure 6-11. — Tools used in shaping gypsum cement.

small), provides an extremely accurate working surface which is usually within 0.0001-inch. All benches should have straight edges so that more accurate work can be performed.

Water — for mixing of cement and washing hands frequently. Hot and cold water should be available for temperature control.

Mixing equipment — power or hand operated, depending on the amount of plaster work produced.

Mixing bowls — semispherical in shape, made of spun or stamped stainless steel, copper, or brass, or made of rubber. They should be flexible enough to be sprung to remove any set cement. Rubber mixing bowls are most useful for this purpose.

Sealers — shellac and lacquers for sealing the pores of plaster surfaces.

Scales — for weighing water and dry ingredients in controlled mixing.

Reinforcing Materials

Various materials are used to add strength and reinforce gypsum cement. The type of material to be used is governed by the nature of the work. Metal products used are pipe, solid rod, hardware cloth, expanded metal, and wire mesh. Fiber products also used are burlap, muslin, tree moss, long fiber, hemp, and sisal.

Reinforcing materials are added during the period of plasticity and become a part of the plaster body.

Wood should never be embedded in the plaster for reinforcement. The moisture of the plaster will cause swelling of the wood and result in distortion or cracking of the plaster form.

Parting Compounds

To allow for releasing the plaster from the pattern and for movement of the plastic (free-flowing) mass, a separating or parting agent must be used. A properly selected sealer-parting agent combination prevents moisture from the fluid mass penetrating into the pores of the pattern or mold, and allows free movement of the set plaster as it expands during the setting and thermal expansion.

A satisfactory parting agent meets the following requirements:

1. It prevents adhesion of the plaster to the pattern or mold.
2. It protects and lubricates the surfaces of the pattern.
3. It spreads evenly to provide a uniform film.
4. It must not react to the surface of the pattern or the plaster.

The most commonly used separating or parting agents used in plaster work are:

1. STEARINE (one part stearic acid to four parts of kerosene). The stearic acid should be melted and the kerosene added while stirring constantly; stir until a uniform mixture is obtained. NOTE: When adding kerosene to stearic acid be sure to take proper precautions for any fire hazard. Stearine is the most commonly used parting agent and is the only parting agent used with glue-based molds.
2. Petroleum jelly (Vaseline) may be used if two parts of kerosene are blended with one part of jelly. The blending should be done very carefully. The release is applied as a thin coat, and should be brushed out well.
3. Spirits of Camphor diluted in alcohol may be used for fine detail reproduction. The evaporation of the alcohol leaves a uniform deposit of camphor on the surface of the mold.

Parting qualities of any of the parting compounds can be improved by adding 1/2 cup of powdered mica to each quart of release.

MIXING AND POURING OF PLASTER

You must follow the manufacturer's instructions in preparing the mixture because the ratio of water to cement used affects the density, hardness, strength, and resistance to abrasion of the set gypsum cement. Weigh the cement and measure or weigh the water carefully to make certain that you are using the proper proportions of each constituent. (Remember that one pint of water weighs approximately one pound.) Tepid water at about 70°-75° F is most satisfactory. Cold water (below 50° F) results in hard casts which may crack or prove difficult to carve. Warm water (160°-180° F) accelerates the setting time but may result in soft casts which are likely to crumble. It is important to use clean mixing utensils and equipment because the presence of old, set cement and foreign materials will accelerate the "setting" of the new mix and will change its entire period of plasticity.

The gypsum cement should be sifted or sprinkled evenly over the surface of the water. Avoid dropping handfuls of the cement into the water at one time as this will result in the formation of lumps. Allow the plaster to soak undisturbed from 2 to 5 minutes depending upon the quantity being mixed, so that it may absorb the water thoroughly. Stir the mixture gently below the surface to reduce drawing air and trapping bubbles in the mixture. Continue stirring until the mixture is free from lumps and of the proper consistency. A proper consistency has a smooth texture and the appearance of heavy cream. When using a mechanical mixer, time the soaking and mixing operations very carefully because excessive stirring accelerates the setting of the cement.

Once the mixture is made, water or dry ingredients must not be added. Adding water will cause the mixture to become chalky and will result in reduced strength; adding dry ingredients will cause lumping and will change the period of plasticity. Excessive mixing and overworking should be avoided as it accelerates the set of gypsum cement.

To make a female mold from a master pattern, manufacture a frame large enough to accommodate the pattern. Secure the pattern upon a flat surface to prevent the pattern from floating or shifting during the setting of the plaster. Run a small fillet between the pattern and the molding board to prevent plaster from running under the pattern.

Place the frame around the pattern and secure to the molding surface. Seal the joint between the frame and the molding surface to prevent any plaster run-out.

Coat the inside of the frame, the molding surfaces of the bottom board, and the pattern surfaces with a parting agent, brush out well to prevent the plaster from sticking to the pattern. Pour the plaster carefully, from one side of the mold only, in order to avoid air pockets. Vibrating or jarring the mold helps to release any trapped air. To avoid seams in the cast, additional pourings should be made before the preceding mixture begins to set. CAUTION: If gypsum cement is allowed to set undisturbed, it will form a glazed surface. This glazed surface must be roughed with a wire brush before additional cement is applied to ensure a good bond.

The mold is allowed to stand until the plaster begins to set. CAUTION: Difficulty may arise in drawing the pattern from the mold if removal is delayed until after the high point of the setting expansion has been reached, because thermal expansion will set in. To prevent this difficulty, remove the pattern from the mold as soon as the plaster is hard enough, and before it has had time to develop heat. A good practice for checking the right time for removal of the pattern is to touch the plaster. When no plaster film sticks to the finger, it is time to take the mold apart and remove the pattern. After removal of the pattern, the mold is left undisturbed for the complete setting and cooling. Molds are usually constructed so that they can be disassembled quickly when it is time to remove the cast. After drying, the plaster mold is sanded lightly and finished with several coats of thin shellac.

The reproduction of the master pattern is accomplished by (1) pouring plaster into the female mold, (2) striking off the excess at the parting line, (3) allowing the plaster to set, and (4) removing the mold from the pattern using air or a bridge arrangement.

STORAGE OF GYPSUM CEMENT PATTERNS

Although gypsum cement patterns are dimensionally stable under high or low humidity conditions, they should not be subjected to freezing temperature as long as free water is present.

Patterns which are not properly supported in storage may become distorted. If models or patterns are mounted upon materials such as plywood which are affected by moisture, the patterns are subject to the movement of the base.

Flat slabs or patterns should be stored by standing them on end. If patterns must be stored lying flat, the surface upon which they rest must be flat. If the surface is not flat, wedges or blocks must be used at intervals to provide sufficient support. The shape and weight of the pattern determines the type of support necessary to prevent distortion.

Any sheltered, unheated or heated space which protects the pattern from weather is satisfactory for permanent storage, provided the patterns are placed so they cannot directly absorb water. Temperatures in the storage room should not exceed 125° F.

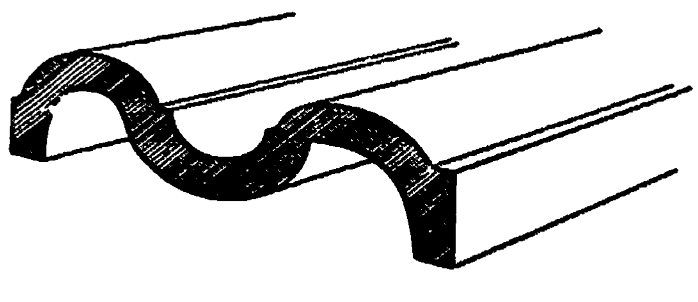
PLASTER APPLICATIONS

There are four principal methods of making gypsum cement patterns: run work, turned work, box or rod turning, and built-up work. Each method is suitable for a particular type of pattern. The Patternmaker must determine which method is most suitable.

Run Work

The run work method is useful for screeding straight molding, square, rectangular, or oblique shapes. The straight molding job used here as an example of run work is shown in figure 6-12. Note that figure 6-12 shows a double-faced mold. A first run will be required to serve as a follow board or support for the pattern. You will need two templates: one to give you the contour of the face, and the other to give you the contour of the back of the pattern. The template is a piece of metal which is cut to the shape indicated on the blueprint and layout. It is then used as a tool to screed or form the gypsum cement to the desired shape or contour. The thickness or gage of the metal used in the template depends upon the hardness of the cement to be used. For the hardest types of cement, 16 gage is usable; for the softest, 27 gage, half-hard brass is satisfactory. Figure 6-13 shows the template for the back of the pattern mounted in place on the screeding sled. The function of the sled is to support, guide, and steady the template as it is pushed through the plastic mass.

Grease the top of the workbench so that the sled will slide smoothly without chattering. The workbench should be flat, have straight edges, and be made of marble, slate, polished plate glass, or treated hardwood. Mix the gypsum cement and allow it to "cream" slightly before placing it on the bench in front of the template. Anchor the mix to the bench by allowing some

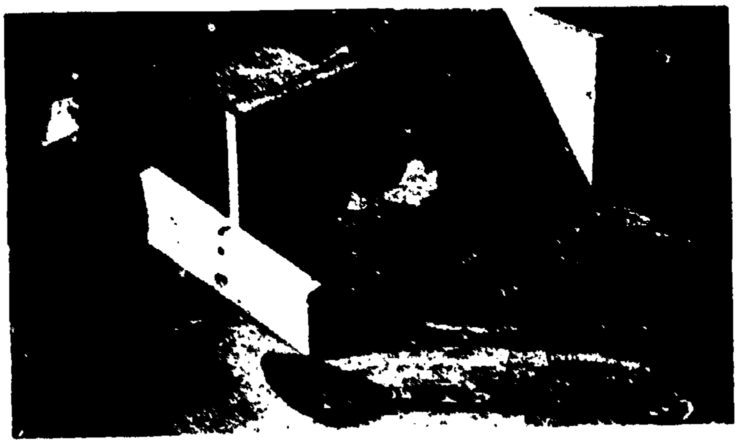


23.135X

Figure 6-12. — A straight molding pattern.

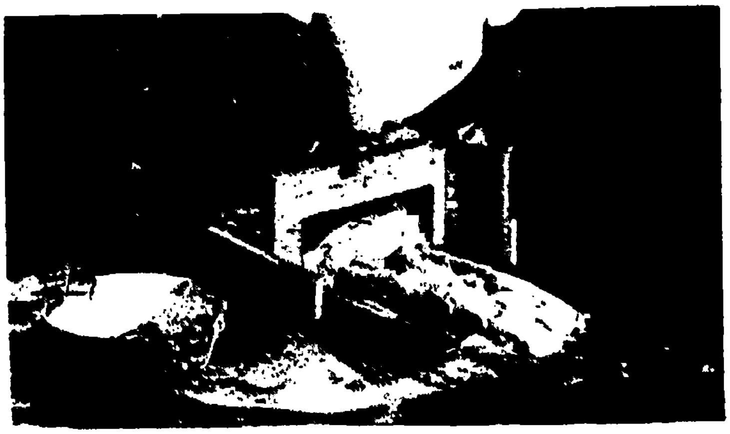
of the cement to lap over the end of the bench or by pressing modeling clay against the cement at a number of points. Push the sled and template firmly through the mass of the cement, in one direction only, as shown in figure 6-14. CAUTION: Do not build up too great a mass for the template to remove at any one time. It is better to build up gradually by applying additional mixes of ceme... small quantities after each screeding. After you have pushed the sled and template through once, lift the sled, clean the template, and scrape off the waste cement. Add more cement to fill in the voids. Return the sled to the starting position on the bench and repeat the screeding. Repeat this procedure as often as necessary until the resulting pattern for the follow board is perfectly smooth. Shellac the follow board and apply a parting compound over the shellac. Change the template and continue the screeding as shown in figure 6-15. Use as many mixes as the size of the job requires.

The completed pattern can be cut to length, carved, mitred, or further fabricated in any desired manner. One word of caution: Gypsum cement should never be carved unless it is moist. If it is dry, it will chip ahead of the carving tool making it impossible to produce a smooth cut. The completed pattern and follow board when shellacked and baked dry are ready for use. (See fig. 6-16.)



23.136X
Figure 6-13. — The screeding sled setup for run work.

23.138X
Figure 6-15. — Spreading a new mix on the follow board.



23.137X
Figure 6-14. — Screeding the mix.

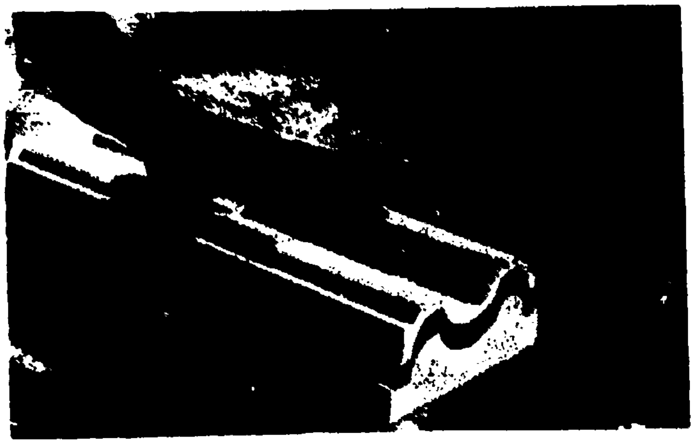


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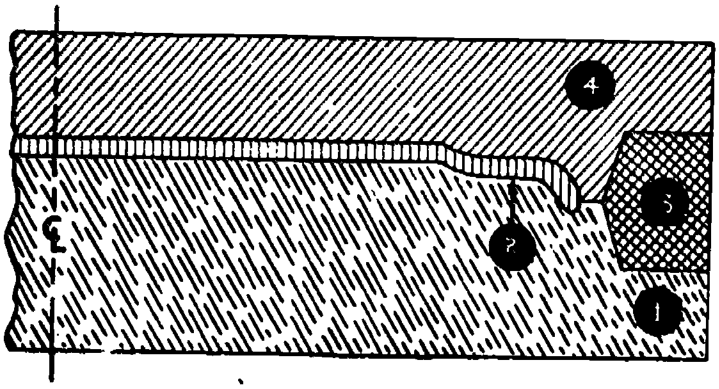
Figure 6-16. — The completed pattern and follow board.

Circular Turning

Circular turning is a method of producing circular shapes such as wheels and disks, by rotating the template around a center post. In order to produce a perfectly symmetrical pattern, you must use great care and accuracy in scribing the centerline on the template and in centering the pivot plate. To produce the pattern from the drawing shown in figure 6-17, four templates are required, one for each part of the pattern.

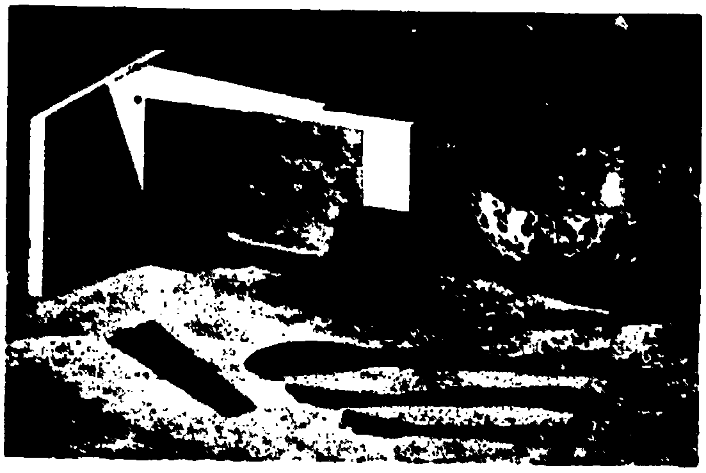
Place a center post in a hole in the workbench. The post should have a running thread with a double nut for height adjustment. The pivot point at the top must be absolutely rigid and should be set higher than the top of the pattern to be made, so that the template will clear the pattern as it is rotated around the pivot point. Cover the threads with oil or grease to avoid getting cement into them. Refer to figure 6-18 which shows the equipment required. It is possible to work to accuracies of 0.005 inch provided the equipment and templates have been accurately made.

Follow the same procedure in mixing and handling the gypsum cement for circular turning as was described for run work. Figures 6-19 through 6-24 illustrate steps in the turning of circular shapes. (See fig. 6-17.)



23.140X
Figure 6-17.—The drawing of a circular shaped pattern.

23.142X
Figure 6-19.—Rotating the sled with firm and even pressure in the screeding of part 1 of the pattern.



23.141X
Figure 6-18.—Equipment required for circular turning.

23.143X
Figure 6-20.—Applying the parting compound and changing the template.

23.144X
Figure 6-21.—Spreading additional cement for the screeding of part 2 of the pattern. (The thin gap between the top of part 1 and the template indicates that part 2 is a thin disk.)

23.145X
Figure 6-22.—Adding additional cement for the screeding of part 3, the spacer ring.

23.146X
Figure 6-23.—Changing the template and spreading additional cement for the screeding of part 4.

23.147X
Figure 6-24.—Separating the parts of the completed pattern. (Fill in the holes in the center with cement and carve away the excess.)

Box or Rod Turning

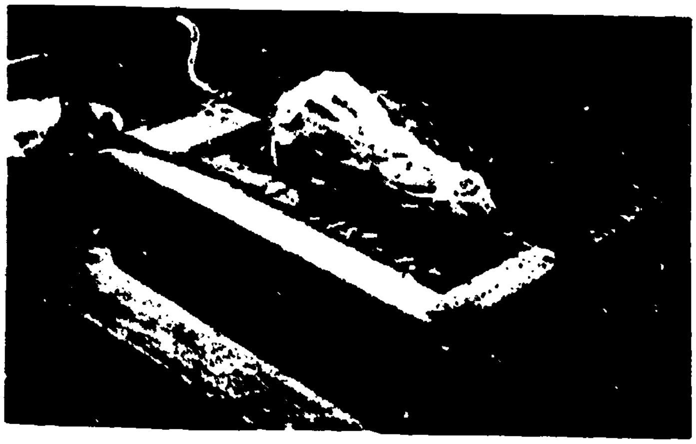
This is a method of producing cylindrical or similar shapes by forming the cement on a rod which is rotated horizontally on journals in a box. These shapes require more experience in the handling of plaster or gypsum cement than the other methods. As you rotate the rod, the excess cement is screeded by means of a stationary template attached to the box. Note that in this method you rotate the work rather than the template. You must align the centerline of the turning rod perfectly with the centerline on the template. This is a difficult part of the job because the true center on the template must be cut away to allow for the radius of the turning rod. Fasten the template board to furring strips on the inside of the box so that the template will be at the centerline height of the pattern. (See fig. 6-25.)

The turning rod is wrapped with twine to provide a bond between the rod and the cement. Fasten a metal bar crosswise on the rod to provide additional support for the cement at the greatest diameter of the pattern.

Mix a small batch of cement at below normal consistency and spread it along the rod forming a body to which subsequent mixes may be applied. Do not apply too much cement at one time because its own weight will cause it to sag away from the rod and break the bond between the cement and the rod. If this happens, you will not be able to rotate the pattern and you will have to start over again. Figure 6-26 shows the build-up of the main body of the pattern. Note that none of this first mix touches the template.

Apply additional mixes at normal consistency and screed the pattern by rotating the work slowly. This fills in the voids and gives the final finish to the pattern. (See fig. 6-27.)

23.148X
Figure 6-25.—Preparing the equipment for box or rod turning.



23.149X
Figure 6-26.—Preparing a firm foundation for subsequent mixes.

Remove the finished pattern from the box by lifting it out with the rod as shown in figure 6-28. Remove the rod by twisting and pulling. The pattern now is ready for final shellacking.

Built-Up Work

This method is useful in making patterns in which irregular shapes or combinations of shapes are required. The sections of the composite pattern may be glued together with burnt shellac. Building-up is also useful in making patterns which require the aid of lofting templates. The

23.150X
Figure 6-27.—Applying an additional mix to fill in the voids and to give final finish to the pattern.

23.151X
Figure 6-28.—The finished pattern is removed from the box by lifting it out with the rod.

lofting templates are set up in their specified positions and are held in place with the aid of jigs. The gaps or spaces between the templates can be spanned by using fiber reinforced gypsum cement slabs. See figures 6-29 through 6-34 which illustrate some of the basic steps in built-up work.

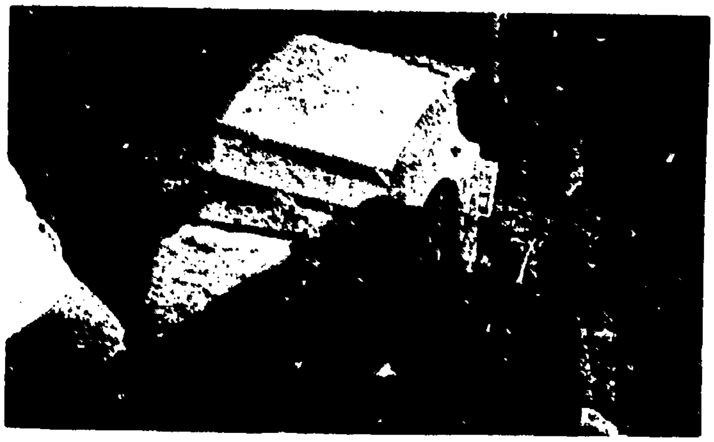
Spread fiber strands of uncarded long hemp over the bench and apply a layer of gypsum cement, pressing it firmly into the fiber as shown in figure 6-29. Saw the reinforced slab into sections of appropriate size for the job. (See fig. 6-30.) Bend and tack the slabs into place with gypsum cement to span the gap and to fit between the templates. Dip fiber bats into the cement mix and spread them evenly over the slabs to reinforce the pattern. (see fig. 6-31.) Build up the body to within 1/4 inch of the finished template line and spread a finish layer of cement over the surface with a spatula. (See fig. 6-32.) Avoid any wavy surfaces by scraping in various directions with the saw-toothed edge of a scraper as shown in figure 6-33. Finish the pattern by planing, carving, sandpapering, and shellacking. (See fig. 6-34.) If additional support is needed, wire mesh, expanded metal, and metal rods can be used. When using wire, wrap it with dipped hemp to furnish a mechanical bond between the wire and the gypsum cement. If wood-bar reinforcements are used as supports

23.152X
Figure 6-29.—Preparing a fiber reinforced gypsum cement slab.

23.154X
Figure 6-31.—Reinforcing the slabs with fiber bats dipped into cement.

23.153X
Figure 6-30.—Cutting the reinforced cement slab to size.

23.155X
Figure 6-32.—Applying the finish layer of cement.



23.156X
Figure 6-33.—Using a scraper to smooth the finish layer of cement.

23.157X
Figure 6-34.—The final finish is produced by planing, carving, sandpapering, and shellacking.

for the finished pattern, tie them onto the work with hemp fiber, after the setting expansion has taken place, to avoid warpage. Kiln dried wood is recommended, and should never be imbedded in the cement because moisture will swell the wood and distort the pattern. All wood reinforcements should be given at least three coats of lacquer before being tied to the pattern. Spraying with molten metal has also been found to be successful in overcoming the fragility of plaster patterns.

Metal reinforcing rods, pipes or tubing may be bolted or welded together to form a structural support. Steel pipes and tubing that have been bent and welded should be normalized to relieve strains or stress that may occour during fabrication. When metal reinforcements are used, they are tied to the pattern with fiber hemp bats impregnated with gypsum cement or plaster.

EXPANSION CEMENTS FOR SHRINKAGE COMPENSATION

The use of high expansion cements for the fabrication of expanded patterns has been recognized as one of the outstanding tooling developments for gypsum plasters in recent years.

Medium high expansion cement is a material compounded to give a uniform expansion of a pattern in all directions, equal to the shrinkage of zinc alloys and aluminum. While it is possible to achieve expansion values from 1/16 to 1/4 inch per foot by the quantity of water used in the mix, the amount of expansion can be controlled by the proper water to plaster ratio. Medium high expansion cements are somewhat stronger and harder than regular high expansion cements and are colored yellow for identification.

High expansion cement is compounded to give the highest setting expansion of any gypsum cement. The expansion characteristics are utilized to expand the pattern uniformly over and beyond the limits that may be obtained with medium high expansion cements.

Under the proper conditions, double shrinkage may be compensated for in one single expansion. The expansion values of high expansion cements are controlled in the same manner as are those of the medium high expansion cements. However, the ranges are from 1/8 to 5/16 inch per foot.

Expansion cements can be used to provide for shrinkage allowance when the dimensions of the original pattern need to be increased uniformly, or where the same pattern is to be used for different metals. A cement such as this has many uses, especially in metal patternmaking. For example, wood matchboards can be converted to cast pressure plates where extra shrinkage allowance is needed. Conventional foundry patterns can be converted to metal equipment for shell molding. Core driers can be produced directly from a plaster cast of the core. A number of other uses of expansion gypsums will become apparent after one becomes familiar with the characteristics of these cements.

Pattern Conversion

When converting a pattern from one shrinkage allowance to another, expansion cements can be useful. For example, a globe valve pattern with a bronze shrinkage allowance can be easily and economically changed to a steel shrinkage allowance.

Prepare the surface of the pattern for easy removal from the plaster, making sure that no indentations on the pattern surface will create back-draft. The pattern must be sealed with several coats of a very thin lacquer. After the lacquer has thoroughly dried, a thin film of stearic acid-kerosene mixture should be applied and brushed out. All excess parting agents must be removed to ensure a hard face, free from separation runs.

Because the amount of expansion is controlled by the water-gypsum ratio, the water and dry ingredients must be accurately weighed to obtain the desired degree of expansion.

The accompanying chart may be used for calculating the proper water-gypsum ratio and the maximum expansion for high and medium high expansion cements. Maximum results of expansion for either cement can be obtained when clean fresh water, at a temperature of 70° to 75° F, is used.

Gypsum (lbs)	Water (lbs)	Maximum Expansion (inches per foot)
Medium High Expansion Gypsum Cement		
100	48-50	0.062
100	45-47	0.127
100	43-44	0.171
100	41-42	0.203
High Expansion Gypsum Cement		
100	50-52	0.125
100	47-49	0.187
100	44-46	0.250

The expansion values listed can be increased 10-15 percent by using clean fresh water at 120° to 130° F.

After the cement and water have been weighed the cement should be mixed in the same manner as ordinary plaster of paris. During the mixing you will note that the mixture will be on the heavy side and will not flow freely. This is a characteristic of all expansion cements; when expansion cements are poured they must be forced or tamped into place over the pattern or mold surface.

The initial set will occur shortly after the mixture loses its water gloss. Careful attention should be given to the progress of the setting action to determine when the cast has set. As soon as practicable, remove the plaster cast from the pattern so that unhindered expansion may take place.

Place the cast on a well lubricated flat surface to permit free movement of the plaster mass as it grows or expands. The flat surface on which the cast is placed should be at room temperature so that chilling of the cast will not retard the calculated expansion of the cast.

The cast is allowed to expand undisturbed for 2 or 3 hours. During the growth or expansion period, the cast will shed water, froth, and have a sour smell. This is a natural reaction of all expansion cements.

Medium high expansion cements have been found to be dimensionally stable for 3 or 4 days after the desired expansion has been achieved. Since high expansion cements expand for several hours (maximum expansion after 10 or 12 hours), it is necessary to check the growth during the period. If the cast reaches the desired size before the maximum expansion has been achieved, a cast of low expansion cement can be made from the expanded mold to produce a pattern with the exact dimensions required.

Core Driers

Core driers are required to support cores during baking. The procedure used to produce a core drier pattern using expansion cements is to cast a core of high expansion cement. The core is cast from the core box, removed, and allowed to expand. A mixture of low expansion plaster is poured over the expanded core and allowed to set. The cast is removed and the drier pattern is cut away on the back side to a uniform thickness to reduce weight. All surfaces are sealed and lacquered as required for reproduction of metal core driers in the foundry.

PLASTICS

Plastics cover a wide field, but in patternmaking, the thermosetting phenolic resin plastics have become most popular. These resins change from a liquid to a solid state when heated.

This chemical action (polymerization) hardens the plastic into an insoluble mass. The principal advantages of these resins are that (1) they are cast without pressure, and (2) patterns made from them have stability and unusual natural finish characteristics. Plastic patterns also are easily cleaned and easily removed from a sand mold. When a large production job calls for more than one pattern, plastic patterns are often less costly than wood or metal patterns. Figure 6-35 illustrates a plastic pattern mounted on a matchboard for machine molding.

Resins available for pattern work usually contain the ingredients needed for polymerization. Phenol and formaldehyde, or phenol and aldehyde, are the principal elements in the commercial blends. When these elements are mixed with a "catalyst" or "accelerator," a chemical action is set up and polymerization results. This accelerator is generally a soda-and-acid solution. The resins, in liquid form, must be kept in closed containers at a temperature lower than 50° F. But, before being mixed for pouring, they must be brought to room temperature (70° F to 75° F).

Each manufacturer of resin supplies the accelerator, together with adequate instructions for mixing the ingredients. The mixture is stirred until all ingredients are thoroughly blended. A uniform color is the best indicator of a complete mix.

The mixture is stirred slowly to minimize the formation of air bubbles. If bubbles are trapped below the surface of the mixture, allow it to stand undisturbed from 15 to 30 minutes. The surface of the mixture should then be skimmed several times prior to pouring.

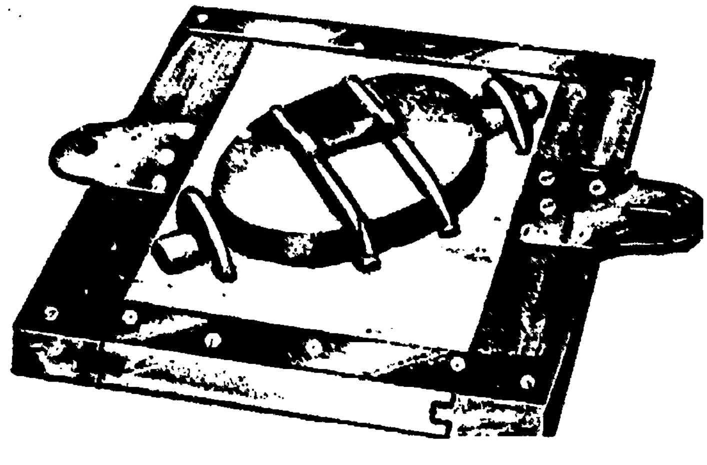


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Figure 6-35. — Plastic pattern mounted on a matchboard.

The mold is generally made from plaster, wood, plastic, or acid-resisting metals. If a non-acid proof metal is used, the mold should be coated with shellac, lacquer, or Tygon paint. The mold surfaces that will contact the liquid resins must be finished, smoothed, and coated with a protective parting agent. Bayberry wax and beeswax (both diluted with gasoline) are suitable parting agents. The mold is heated before the resins are poured into it.

The resins are poured slowly so that air pockets do not form. The resins are then allowed to set at room temperature. This setting is the first part of the curing cycle. Light castings are allowed to set for about 4 hours; heavier castings for a longer period. After the resins become opaque and gelatinous, they are baked until hard and solid.

Baking is the second part of the curing cycle. Electric or gas ovens with controllable heat adjustments are required. The baking temperature is important and must be watched closely. Most castings are baked at 140° F for 4 hours. Some of the heavier castings require as much as 8 to 10 hours for baking.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 7.

CHEEK — The section or sections of a flask lying between the drag and cope.

COURSES — Alternate layers or thicknesses of material in a pattern, each individual layer being a course.

CUTTING SHELLAC — Dissolving shellac in alcohol.

DRAW PLATE — Metal plate set into a pattern to facilitate its drawing.

DRAW SCREW — A rod which can be screwed into a pattern to act as a handle for drawing the pattern from the mold.

DRAW SPIKE — A pointed rod of iron or steel driven into a wooden pattern to act as a handle for withdrawing the pattern from the sand in the mold.

FAN CONSTRUCTION — Form of stepped-up work with the grain of the wood radiating from a common center.

FLASK—Frame consisting of two or more sections made of wood or metal and used to enclose the sand in which a mold is formed.

FLASK PINS—Pins and corresponding sockets on the joint of the sections of a flask to permit their separation and registering.

FOLLOW BOARD—Board having its surface formed so as to support a pattern and to create its parting line in the mold.

LAGGING—The fastening of narrow lags or strips about headers or batten foundations that are so shaped as to follow a line parallel to the finished contour of the pattern.

LAMINATED CONSTRUCTION—Building up in a series of courses a pattern structure of strips or segments with the alternating end joints occurring midway between those of the preceding course.

LOOSE PIECE—Part of a pattern so attached that it remains in the mold and is drawn into and then from a large mold cavity after the body of the pattern is drawn.

LUG—An earlike projection that is frequently split as the clamping lug on the tailstock of a lathe.

MOLDING BOARD — Board reinforced with cleats having a true surface upon which a pattern is laid for the ramming of the drag.

ONE PIECE PATTERN—Solid pattern but not necessarily made from one piece of stock.

RAPPING—Jarring a pattern to loosen it from the sand preparatory to drawing it out of the sand.

SKELTON PATTERN—A framework representing the interior and exterior form and the metal thickness of the required casting.

SOLID PATTERN—A one piece pattern (not parted).

SPLINE—A thin strip inserted into a groove to strengthen the work or to reinforce a joint.

SPOT FACING—Truing, by machining, a circular bearing surface about a hold in a casting. It does not affect a pattern.

SPOT GLUING—Securing two pieces of material together, temporarily, with a spot of glue.

STEPPED-UP—So called because the material, when it is fastened together, resembles steps.

CHAPTER 7

PATTERN CONSTRUCTION TECHNIQUES

In pattern construction, it is normally necessary to build up the pattern from several layers of wood. In doing this, you must use the correct gluing, reinforcing, and aligning techniques to secure strong pattern joints. After the pattern is completed "in the rough," it must be sanded smooth as a preparatory measure prior to finishing the pattern. Fillets are added to the pattern and are used to eliminate sharp corners on the pattern which tend to cause structural weakness in the resulting mold and casting.

Pattern letters, figures, and insignia are placed on patterns to aid in identifying the pattern parts. In addition, the pattern is finished with various colors of a pattern covering called a color code. The pattern covering protects the surface of the pattern from the moisture of the molding sand. The color coded parts of the pattern aid the Patternmaker and Molder in assembling the completed pattern and mold. Rapping and lifting plates are used by the Molder in withdrawing the pattern from the sand mold.

This chapter discusses a few of the important techinques that are applicable in general to all patternmaking work. Specific procedures for making various kinds of patterns are discussed in later chapters of this training manual.

WOOD JOINERY

One of the most important skills that must be mastered by the Patternmaker is the art of WOOD JOINERY. Wood joinery, in patternmaking, could be described as the art of combining two or more pieces of material into one for the purpose of increasing dimensions, strength, or for the indexing of one piece to another such as the seat for a loose piece of a pattern.

Wood joinery includes the manufacture of wood joints and the various devices used to fasten them together such as glue, nails, etc.

A pattern is only as strong as its weakest point which can be the joints if they are made incorrectly or the wrong type of joint is used for a particular application. On the other hand, the pattern joint will be the strongest point of the pattern if the joint is made properly, the correct joint used, and a suitable glue is applied properly.

Usually, only the simple wood joints are used in patternmaking. These include the BUTT and LAP joints. However, there are times when a particular job will require the use of a more complex joint. You will also be called upon to make wooden flasks for the foundry, cabinets, picture frames, shipping boxes, etc. Therefore, you, as a Patternmaker, must have a broad knowledge of wood joinery.

STANDARD JOINTS

There are four simple standard methods of joining wood stock edge to edge. These are the PLAIN BUTT, DOWEL, TONGUE AND GROVE, and SPLINED EDGE joints shown in figure 7-1.

The plain butt joint is the simplest method and the one most often used by the Patternmaker.

The dowel joint is usually a plain butt joint that has been given greater strength (reinforced) by the use of wooden dowels. Dowels can also be used to reinforce other joints such as the miter and half lap.

A rule to remember when choosing a dowel for edge to edge application is; the dowel diameter should be equal to 1/3 of the thickness of the edges to be joined. Thus, 3/4 inch thick stock would require a 1/4 inch dowel.

The tongue and grove joint is a stronger joint than the butt or dowel and is most often used in wood flooring.

The splined edge joint is a variation of the tongue and groove and is easier to make as two matching grooves and a separate spline are used in the place of the tongue. There is very

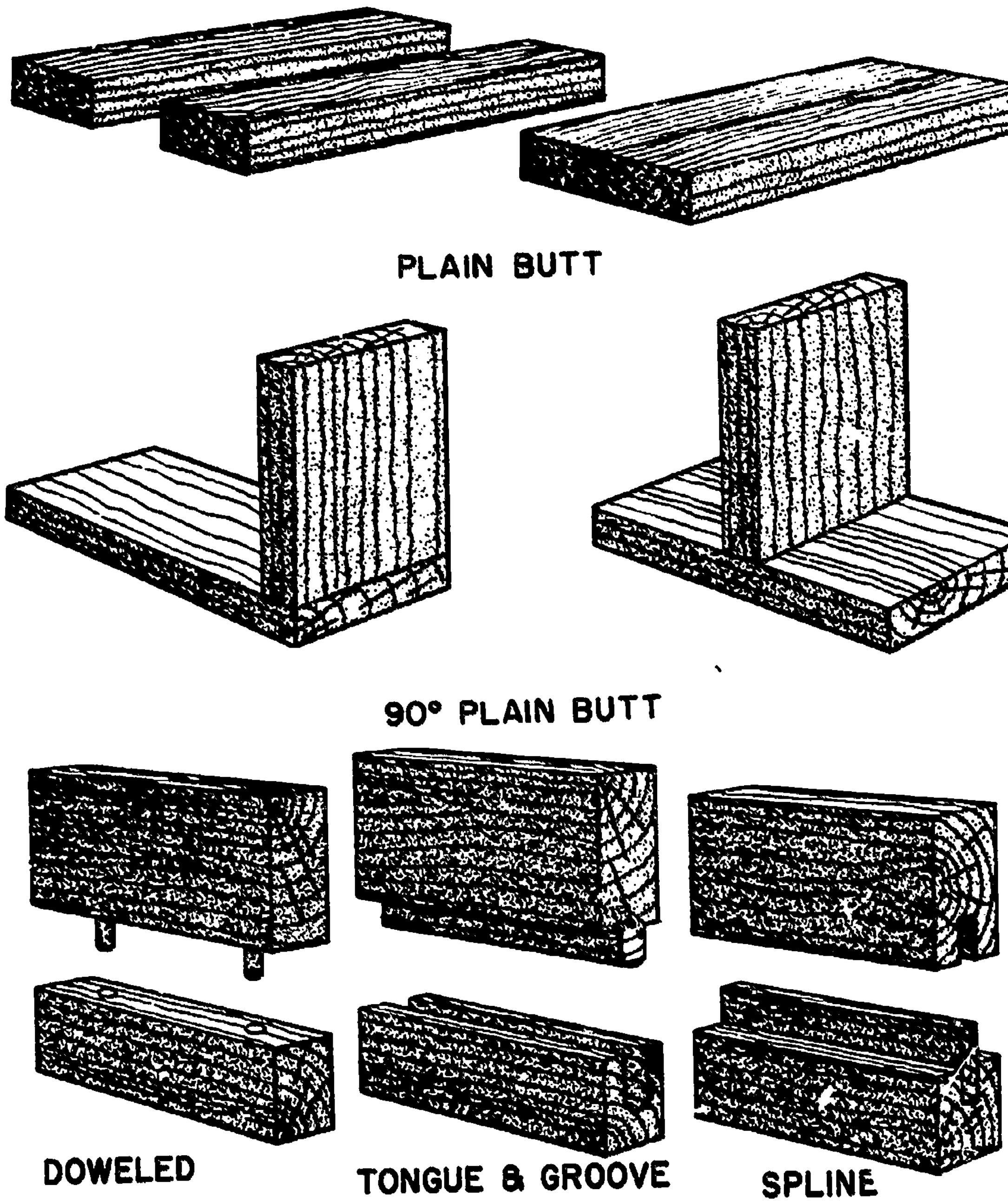


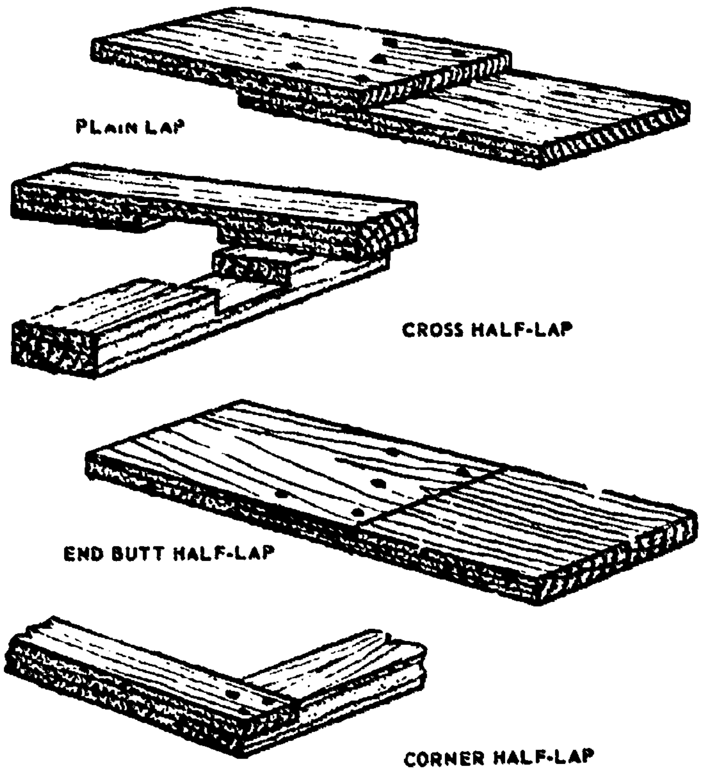
Figure 7-1.—Edge joints. 68.37

little strength gained if the grain direction of the spline is parallel to the edges as shown in figure 7-1. However, a great deal of strength is gained when the grain direction of the spline is perpendicular to the edges.

As a general rule, the thickness of both the spline and tongue should be 1/3 of the material thickness. The width of the spline should be equal to twice the material thickness while the tongue width should be the same as the thickness. Thus, 3/4 inch stock would require a spline measuring 1/4 inch thick and 1 1/2 inch wide or a tongue measuring 1/4 inch thick by 3/4 inch wide.

Lap Joints

Lap joints are shown in figure 7-2. The PLAIN LAP joint is used extensively in all kinds of construction, particularly that which



68.38.2
Figure 7-2. — Lap joints.

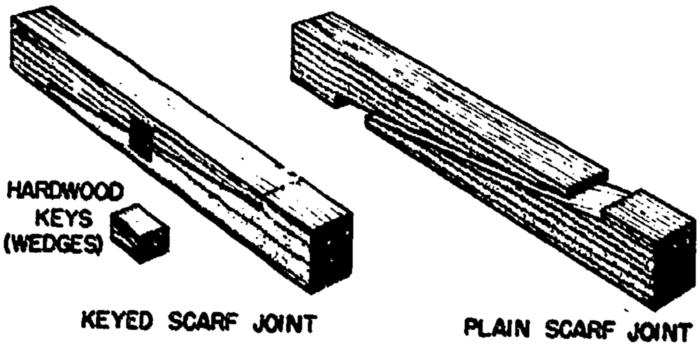


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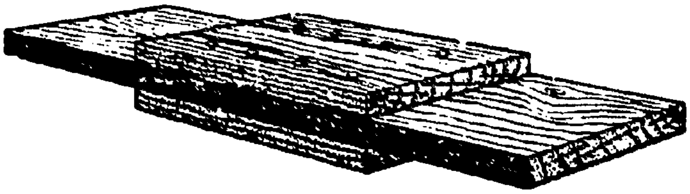
Figure 7-3. — Typical scarf joints.



68.38.1
Figure 7-4. — End butt joint with fishplates.

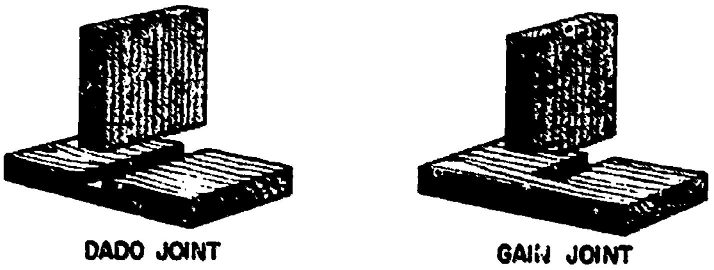
does not require a good appearance. The END BUTT HALF-LAP is not as strong as the plain lap joint, but has a better appearance and requires less space. The CORNER HALF-LAP is used for framing of buildings, boxes, and cabinets, and in many other types of construction. The CROSS LAP joint can be used in patternmaking to join the spokes of a wheel pattern.

The SCARF JOINT is a special type of lap joint that is used for joining heavy timbers. (See figure 7-3.) For repair purposes, a slope of 1 in 12 is recommended, that is, the cut should slant through the length of a piece a distance of 12 inches for every inch of depth or width.

The end butt joint with FISHPLATES (fig. 7-4) is useful for joining short members to make long pieces. It has the disadvantage of being bulky. The fishplates can be secured with nails, screws, rivets, or bolts.

Dado, Gain, and Rabbet Joints

The PLAIN DADO JOINT (fig. 7-5) is often used in making cabinets and shelves. It is usually



103.9
Figure 7-5. — Dado and gain joints.

cut with a dado head (cutters) which fits the mandrel of a circular power saw, but you can also make this cut by hand with a backsaw or tenon saw, and finish it with chisels. This joint may be glued, nailed, or fastened with screws.

The GAIN JOINT (fig. 7-5) is a special kind of dado which is used when appearance is an important factor. Dadoes and gains are both cut across the grain of the wood.

RABBET JOINTS are often used in conjunction with dadoes. They may be cut either across the grain or with the grain (fig. 7-6). Rabbets can be made with the circular saw dado head or blade or, to a more limited extent, with the jointer. They can also be cut by hand with special rabbeting planes.

Dovetail Joints

Cabinetmakers and other skilled wood craftsmen make frequent use of the dovetail joint in their work. (See figure 7-7.) It is most often used in joining the corners of furniture drawers and chests since its locking features make it an excellent joint for this type of construction. Such joints are usually made with blind dovetails, so that they are not visible from the outside of the furniture.

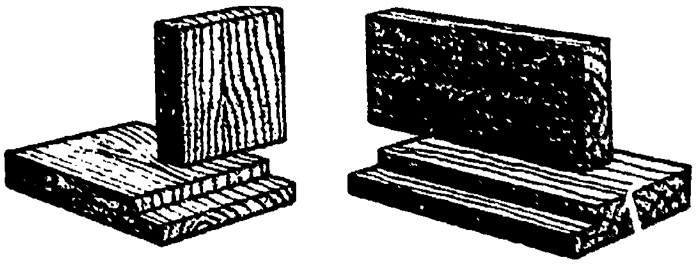


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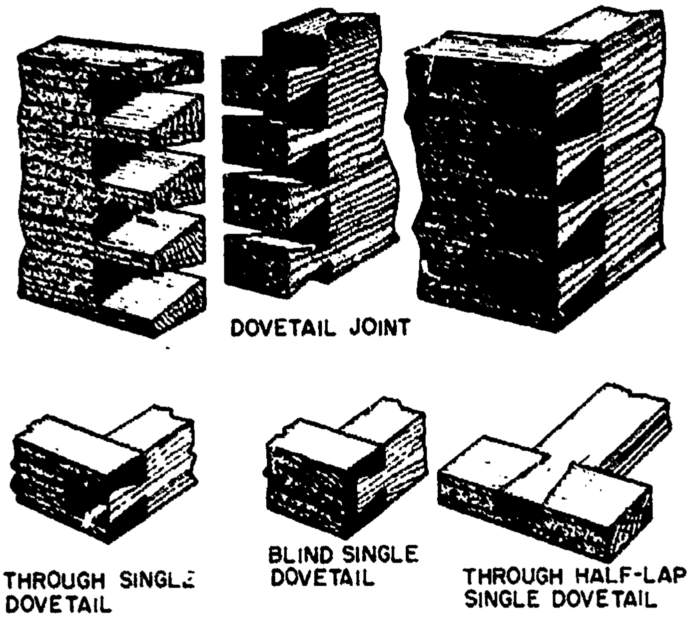
Figure 7-6. — Rabbet joints.



103.11

Figure 7-7. — Dovetail joints.

Single dovetails and half dovetails are used for heavier construction where locking joints are required. The single dovetail (DOVETAIL KEY) is also an excellent joint to use when attaching a loose piece to the body of a pattern.

Dovetails must be laid out with accuracy. Use a sharp knife edge for marking, rather than a pencil, and a T-bevel to lay out the angles. You can saw out with a tenon saw and finish the work with chisels.

Box Corner and Miter Joints

Many commercial packing boxes and chests are made with the box corner joint. (See fig. 7-8.) This joint can be used to advantage in making filing cabinets and boxes. It can easily be cut on the circular saw with special dado heads.

The miter joint (fig. 7-9), usually two 45° angle cuts, is used for picture frames, boxes, screen doors, panel frames, and other frames. Miter joints are fastened with nails, brads, corrugated fasteners, clamp nails, and are usually glued.

The spline miter is an improvement over the plain miter and can be cut quickly with the circular saw and dado head. Other miters require more work and are usually used only on special jobs.

Coping Joints

When matching inside corner joints between molding trim members, this joint shapes the end of the abutting member to fit the face of the other member. Figure 7-10 shows a coping joint.

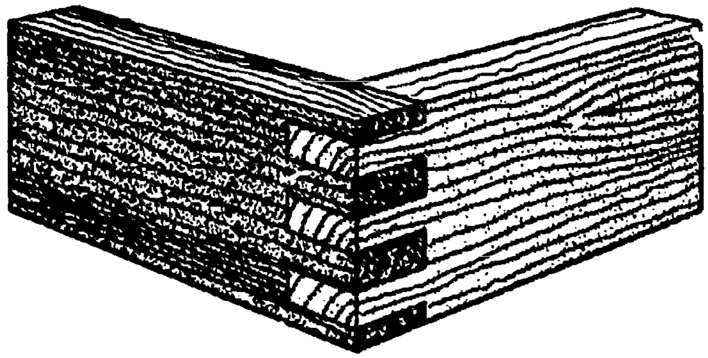


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Figure 7-8. — Box corner joint.

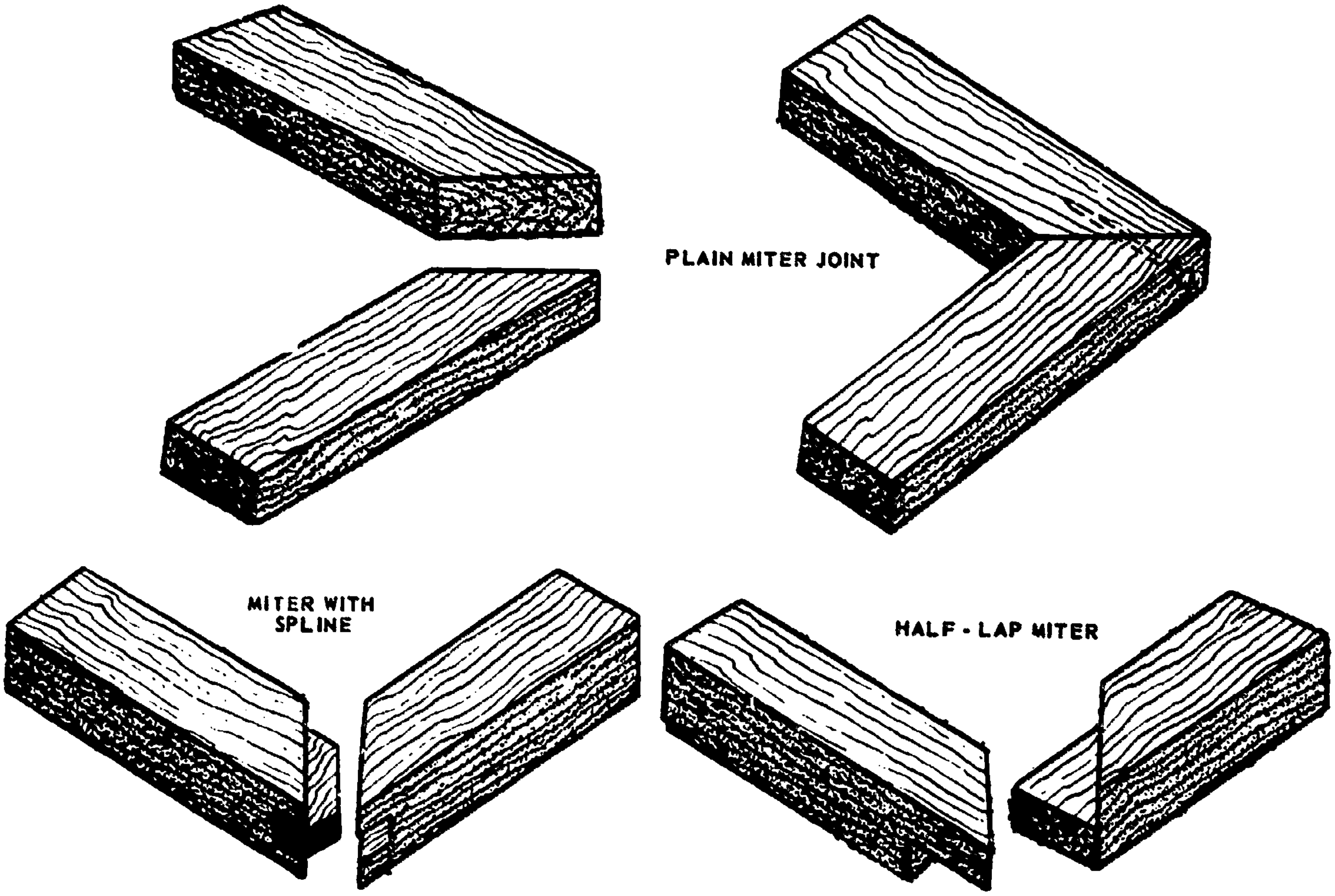

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Figure 7-9.—Miter joints.

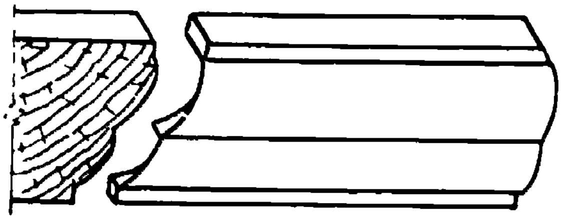

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Figure 7-10.—A coping joint.

Mortise and Tenon Joints

Good furniture usually is made with a number of mortise and tenon joints. (See fig. 7-11.) This joint is assembled with glue and is much stronger than it appears to be. It can be wedged, split, or offset. You can't go wrong with mortise and tenon joints if they are properly designed and accurately fitted. The slip tenon joint can be used the same way as a miter or corner half-lap joint. It should be glued together and can be further secured with dowels, screws, bolts, or nails.

LAYING OUT AND CUTTING JOINTS

The basic skill in woodworking is the art of joining pieces of wood to form tight, strong, well-made joints. The two pieces which are to be joined together are called MEMBERS, and the two major steps in joining are (1) the layout of the joints on the ends, edges, or faces of the members, and (2) the cutting of the members to the required shapes for joining.

Cutting joints accurately requires that the stock used be square and true. This is usually done with machines, using a surface planer to obtain uniform thickness, a jointer for truing

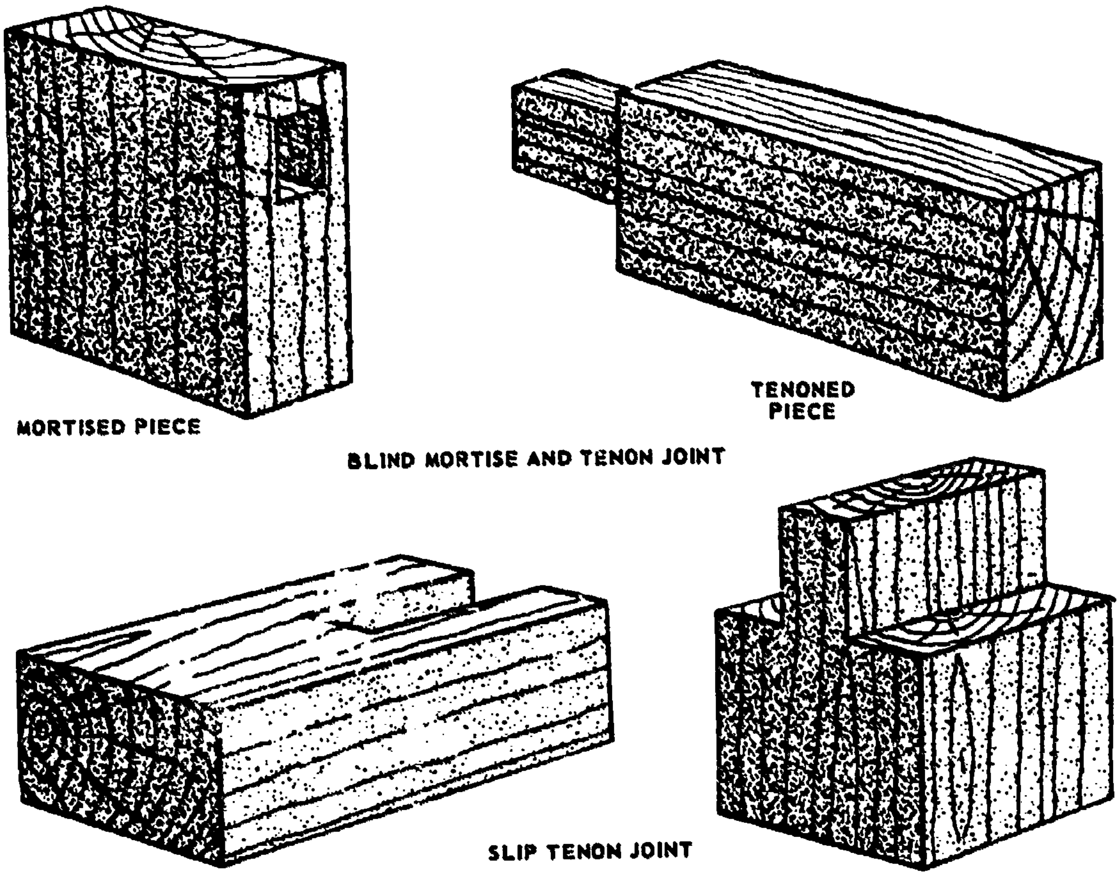

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Figure 7-11. — Mortise-and-tenon and slip-tenon joints.

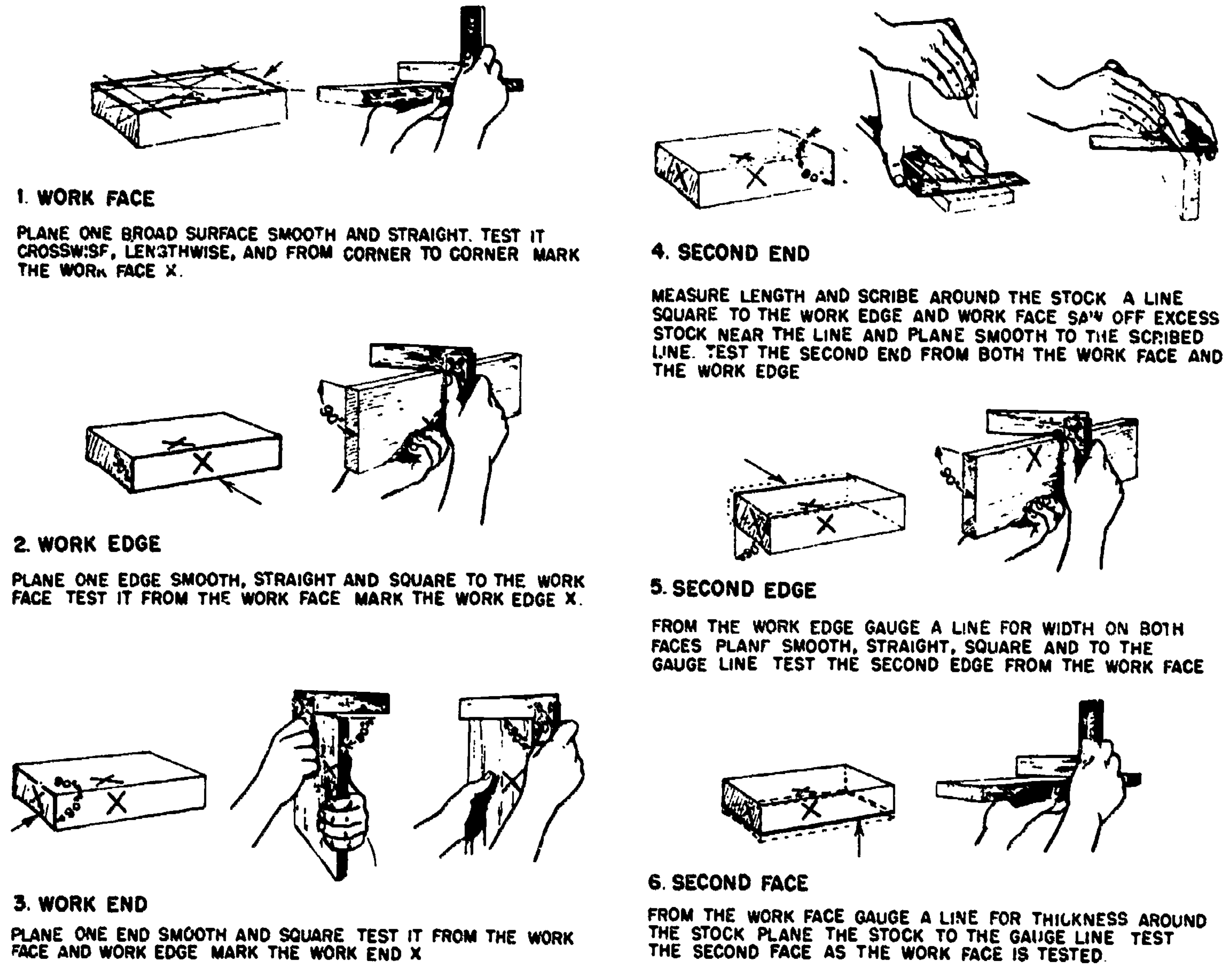
the edges, and a table or overarm saw for squaring the ends and cutting to the desired length. In a great many cases however, you will be required to perform such operations by hand. Therefore, planing and squaring a small board to dimensions is what you might call the first lesson in woodworking. Like a good many other things it looks easy until you try it. The six major steps in the process are illustrated and described in figure 7-12; practice them until you can get a smooth, square board with a minimum of planing.

The chief instruments for laying out joints are: the try, miter, or combination square; the T-bevel; the marking or mortising gage; and a scratch awl, sharp pencil, or knife for scoring lines. For cutting joints by hand, the backsaw, dovetail saw, coping saw, and various chisels and planes are essential.

All the joints which have been mentioned in this chapter can be cut either by hand or by machine. Whatever the method used, and whatever the type of joint, always remember the following important rule: To ensure a tight joint, always cut on the WASTE SIDE of the line, never on the line itself. Preliminary grooving ON THE WASTE SIDE of the line with a knife or chisel will help a backsaw to get a smooth start.

Half-Lap Joints

For half-lap joints the members to be joined are usually of the same thickness, and the following discussion is based on the assumption that this is the case. The method of laying out and cutting an end-butt half-lap or a corner half-lap is as follows: For the end butt half-lap, measure off the desired amount of lap from the end of each member and square a line all the way around at this point. For the corner half-lap, measure off the width of a member from the end of each member and square a line all the way around. These lines are called SHOULDER lines.



44.108

Figure 7-12. — Planing and squaring to dimensions.

Next, select the best wide surface of each member and place it upward. Call this surface the FACE of the member, call the opposite surface the BACK. Mark the face of each member plainly. Next set the marking gage to one-half the thickness and score a line (called the CHEEK LINE) on the edges and end of each member, from the shoulder line on one edge to the shoulder line on the opposite edge. Be sure and gage the cheek line from the face of each member. The reason for this is that, if you gage from both faces, the faces will come flush after the joint is cut, regardless of whether or not the gage was set to exactly one-half the thickness. Too much waste cut from one member will be offset by less cut from the other. On the other hand, if you gage from the face of one member and the back of the other, and the gage happens to be set to more or less than one-half the thickness, the faces will be out of flush by the amount of the error. A rule of first importance for half-lap joints, then is: Always gage the cheek line from the face of the member.

Next make the SHOULDER CUTS by sawing along the shoulder line down to the waste side of the cheek line, sawing from the BACK of the lapping member and from the FACE of the lapped member. Clamp a piece of wood along the starting groove to steady the saw.

The CHEEK CUTS (sometimes called the SIDE CUTS) are made next, along the WASTE SIDE of the cheek line. Clamp the member in the vise so that it leans diagonally AWAY from you. With the member in this position you can see the end and the upper edge, and when the saw reaches the shoulder line on the upper edge, it will still be some distance away from the shoulder line on the edge you can't see. Reverse the member in the vise, and saw exactly to the shoulder line on that edge.

Completing the shoulder cut will detach the waste. When both shoulder cuts have been made, the members should fit together with faces, ends, and edges flush, or near enough to it to be brought flush by a little paring with the chisel.

A cross half-lap joint between members of equal cross-section dimensions is laid out and cut as follows: If the members are of the same length and they are to lap each other at the mid-point, place them face-to-face with ends flush, and square a center line all the way around. To test the accuracy of the center calculation, turn one of the members end-for-end. If the center lines still meet, the center location is correct.

Put the best wide surfaces up and mark each face plainly. Lay off one-half the width of a member on either side of the center lines and square shoulder lines all the way around. Again check for accuracy by turning a member end-for-end. If the shoulder lines meet, the layout is accurate. Next, gage one-half the thickness of a member FROM THE FACE OF EACH MEMBER and score check lines on the edges, between the shoulder lines. Next make the shoulder cuts, sawing from the BACK of the lapping member and from the FACE of the lapped member.

In this type of joint the waste must be chiseled out rather than sawed out. To make the work of chiseling easier, remove as much stock as possible with the saw first, by sawing a series of kerfs between the shoulder cuts. In chiseling, make a roughing cut first, down to just above the cheek line, with a firmer chisel and mallet, holding the chisel bevel down. Then finish off the bottom with a paring chisel, holding the chisel bevel up. For fine work, smooth the bottom with a router plane if you have one.

End half-lap joints may be cut with the circular saw by the method described later for cutting tenons. Equipped with the dado head, the circular saw can be used to cut both end half-lap recesses and cross half-lap recesses. For an end half-lap recess, proceed as follows: set the dado head to protrude above the table a distance equal to one-half the thickness of a member, and adjust the fence so that when the end of the member bears against it the dado head will cut on the waste side of the shoulder line. Place the member against the universal gage, set at 90° to the fence, and make the shoulder cut. Then take out the remaining waste by making as many recuts as necessary, each made with the member moved a little less than the thickness of the dado head to the left.

For a cross half-lap recess, proceed as follows: set the dado head so that its height above the table is equal to one-half the thickness of a member, and adjust the ripping fence so that when the end of the member is placed against it the dado head will cut on the waste side of the left-hand shoulder line. Make the shoulder cut. Then reverse the piece end for end and repeat the same procedure to make the opposite shoulder cut. Take out the remaining waste between the shoulder cuts by making as many recuts as necessary, each made with the member moved a little less than the thickness of the dado head to the left.

Grooved Joints

A GROOVE is a three-sided recess running with the grain. A similar recess running across the grain is called a DADO. A groove or dado which does not extend all the way across the piece is called a STOPPED GROOVE or a STOPPED DADO. A stopped dado is also known as a GAIN (fig. 7-5).

A two-sided recess running along an edge is called a RABBET (fig. 7-6). Dados, gains, and rabbets are not, strictly speaking, grooves, but joints which include them are generally called GROOVED JOINTS.

Grooves on edges and grooves on faces of comparatively narrow stock can be cut by hand with the plow plane. The matching plane will cut a groove on the edge of one piece and a tongue to match it on the edge of another. A dado can be cut by hand with the backsaw and chisel, by the same method used to cut a cross half-lap joint by hand. Rabbets on short ends or edges can be sawed out by hand with the backsaw.

A long rabbet can be cut by hand with the rabbet-and-fillister plane as follows: First be sure that the side of the plane iron is exactly in line with the machined side of the plane;

then set the width and depth gages to the desired width and depth of the rabbet. BE SURE TO MEASURE THE DEPTH FROM THE EDGE OF THE PLANE IRON, NOT FROM THE SOLE OF THE PLANE. If you measure from the sole of the plane, the rabbet will be too deep by the amount that the edge of the iron extends below the sole of the plane. Clamp the piece in the vise, hold the plane exactly perpendicular, press the width gage against the face of the board, and plane down with even, careful strokes until the depth gage prevents any further planing.

A groove or dado can be cut on the circular saw as follows: lay out the groove or dado on the end wood (for a groove) or edge wood (for a dado) which will first contact the saw. Set the saw to the desired depth of the groove above the table, and set the fence at a distance from the saw which will cause the first cut to run on the waste side of the line that indicates the left side of the groove. Start the saw and bring the piece into light contact with it; then stop the saw and examine the layout to assure that the cut will be on the waste side of the line. Readjust the fence if necessary. When the position of the fence is right, make the cut. Then reverse the piece and proceed to set and test as before for the cut on the opposite side of the groove. Then make as many recuts as are necessary to remove the waste stock between the side kerfs.

The procedure for grooving or dadoing with the dado head is about the same, except that in many cases the dado head can be built up so as to take out all the waste in a single cut The two outside cutters alone will cut a groove 1/4 in. wide. Inside cutters vary in thickness from 1/16 to 1/4 in.

A stopped groove or stopped dado can be cut on the circular saw, using either a saw blade or a dado head, as follows: If the groove or dado is stopped at only one end, clamp a STOP BLOCK to the rear of the table in a position that will stop the piece from being fed any further when the saw has reached the place where the groove or dado is supposed to stop. If the groove or dado is stopped at both ends, clamp a stop block to the rear of the table and a STARTING BLOCK to the front. The starting block should be placed so that the saw will contact the place where the groove is supposed to start when the infeed end of the piece is against the block. Start the cut by holding the piece above the saw, with the infeed end against the starting block and the edge against the fence. Then lower the piece gradually onto the saw, and feed it through to the stop block.

A rabbet can be cut on the circular saw as follows: The cut into the face of the piece is called the SHOULDER cut and the cut into the edge or end the CHEEK cut. To make the shoulder cut (which should be made first), set the saw to extend above the table a distance equal to the desired depth of the shoulder, and set the fence a distance away from the saw equal to the desired depth of the cheek. Be sure to measure this distance from a saw tooth SET TO THE LEFT, or AWAY FROM the ripping fence. If you measure it from a tooth set to the right, or toward the fence, the cheek will be too deep by an amount equal to the width of the saw kerf.

Make the shoulder cut first. Then place the face of the piece which was down for the shoulder cut against the fence and make the cheek cut. If the depth of the shoulder and the depth of the cheek are the same, the cheek cut will be made with the saw at the same height as for the shoulder cut. If the depth of the cheek is different, the height of the saw will have to be changed to conform before the cheek cut is made.

By using the dado head, you can cut most ordinary rabbets in a single cut. First, build up a dado head equal in thickness to the desired width of the cheek. Next, set the head to protrude above the table a distance equal to the desired depth of the shoulder. Clamp a 1-in. board to the fence to serve as a guide for the piece, and set the fence so that the edge of the board barely contacts the right side of the dado head. Set the piece against the universal gage (set at 90°, of course), hold the edge or end to be rabbeted against the 1-in. board, and make the cut.

On jointers, a RABBETING STRIP on the outboard edge of the outfeed table can be depressed for rabbeting. The strip is outboard of the end of the cutterhead. To rabbet on a jointer, you depress the infeed table and the rabbeting strip the depth of the rabbet below the outfeed table, and set the fence the width of the rabbet away from the outboard end of the cutterhead. When the piece is fed through, the unrabbeted part feeds onto the rabbeting strip.

Various combinations of the grooved joints are used in woodworking. The well-known TONGUE-AND-GROOVE joint is actually a combination of the groove and the rabbet, the tongued member simply being a member which is rabbeted on both faces. In some type of panel work, the tongue is made by rabbeting only one face; a tongue of this kind is called a BARE-FACED tongue. The DADO and RABBET JOINT shown in figure 7-13 is another joint which is often used in making boxes, drawers, and cabinets.

The HOUSED LOCK JOINT shown in figure 7-14 is a type of dado and rabbet joint. Note, however, that the rabbeted piece is reversed and that the dadoed piece extends beyond the rabbeted piece. This joint is used extensively in the pattern shop for manufacturing special wooden foundry flasks. The dadoed piece is extended to form handles for the flask.

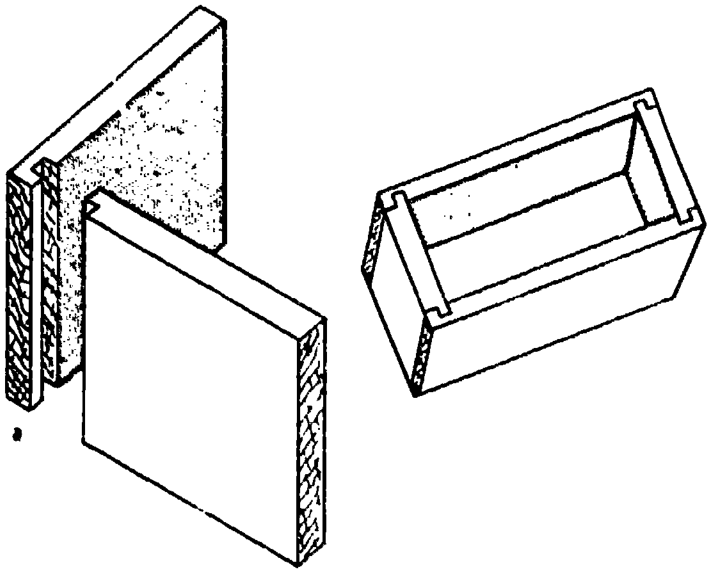


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Figure 7-13. — Dado and rabbet joint.

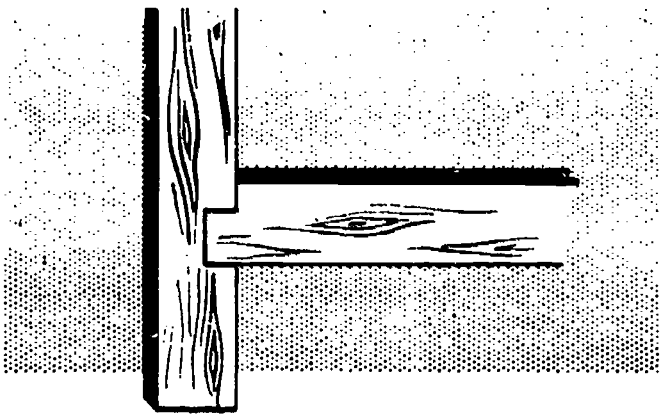

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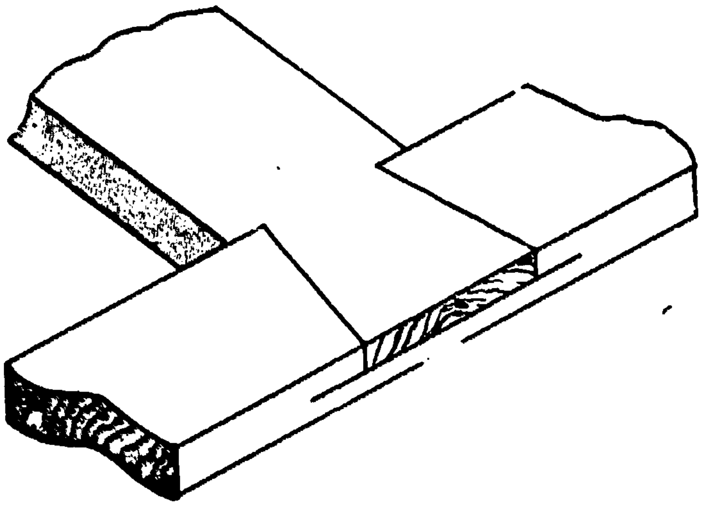
Figure 7-14. — Housed lock joint.

Dovetail Joints

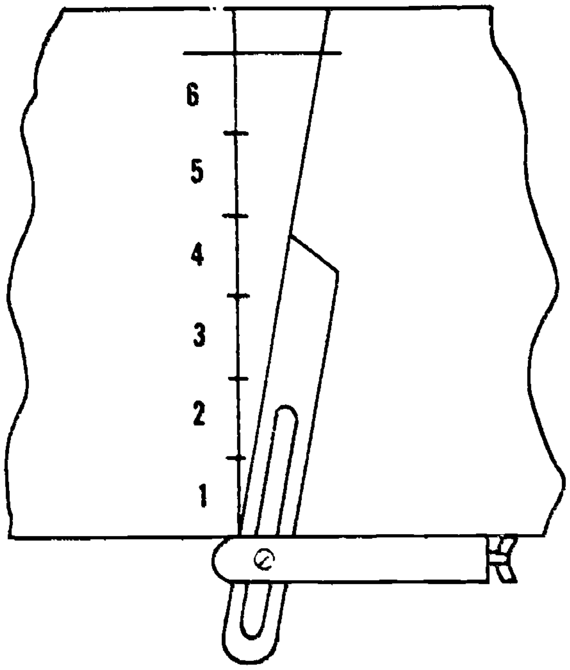
The DOVETAIL JOINT (fig. 7-7) is the strongest of all the woodworking joints. It requires a good bit of labor, however, and is therefore used only for the finer grades of furniture and cabinet work, where it is used principally for joining sides and ends of drawers.

In the dovetail joint, one or more PINS on the PIN MEMBER fit tightly into the openings between two or more TAILS (or, in the case of a single dovetail joint, between two HALF-TAILS) on the TAIL MEMBER. A joint containing only a single pin is called a SINGLE DOVETAIL JOINT; a joint containing two or more pins is called a MULTIPLE DOVETAIL JOINT. A joint in which the pins pass all the way through the tail member is a THROUGH dovetail joint. A joint in which they pass only part way through is a BLIND dovetail joint.

About the simplest of the dovetail joints is the HALF-LAP DOVETAIL joint shown in figure 7-15. This joint is first laid out and cut like an ordinary end half-lap, after which the end of the lapping member is laid out for shaping into a dovetail as follows: Set the T-bevel to 10°, which is the correct angle between the vertical axis and the sides of a dovetail pin or tail. You can set the bevel with a protractor or with the protractor head on the combination square. If you don't have either of these, use the method shown in figure 7-16. Select a board with a straight edge, square a line across it, and lay off an interval of appropriate length,



133.85
Figure 7-15. — Dovetail half-lap joint.

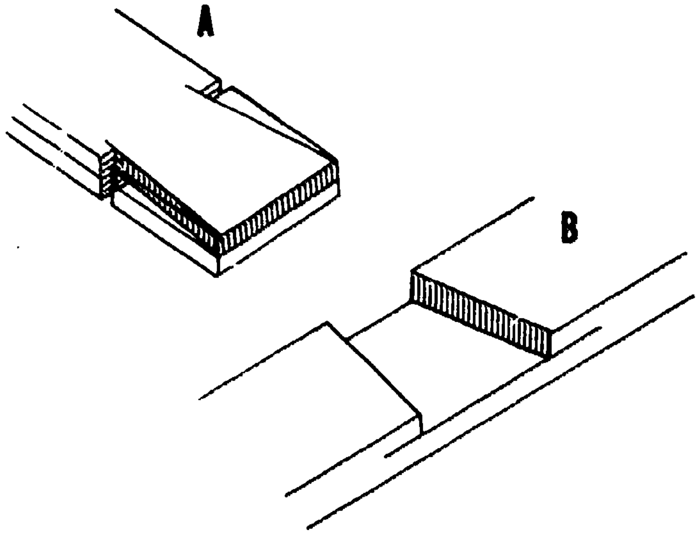


103.16
Figure 7-16.—Laying off 10° angle for dovetail joint.

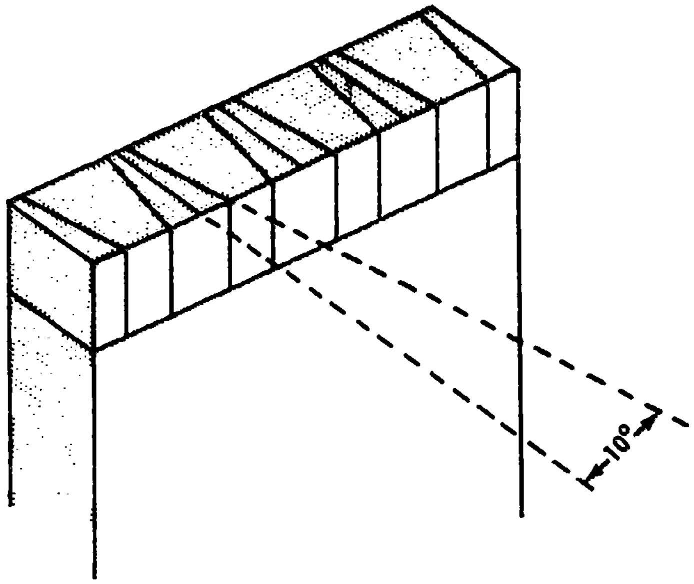
6 times on the line as shown. From the sixth mark lay off the same interval perpendicularly to the right. A line drawn from this point to the starting point of the first line drawn will form a 10° angle with that line.

Lay off this angle from the end corners of the lapping member to the shoulder line, as shown in figure 7-17, and saw out the waste as indicated. The lapping member now has a dovetail on it. Place this dovetail over the other member, in the position it is supposed to occupy, and score the outline of the recess. Then saw and chisel out the recess, remembering to saw on the WASTE side of the lines.

For a through multiple dovetail joint, the end of the tail member is laid out for cutting as shown in figure 7-18. A joint in which the pins and tails are the same size is the strongest type of dovetail, but for ease in cutting, the pins are usually made somewhat smaller than the tails, as shown. Determine the appropriate number of pins and the size you want to make each pin. Lay off a half-pin from each edge of the member, and then locate the center lines of the other pins at equal intervals across the end of the piece. Lay off the outlines of the pins at 10° to the center lines, as indicated. Then measure back from the end of the member a distance equal to the thickness of the tail



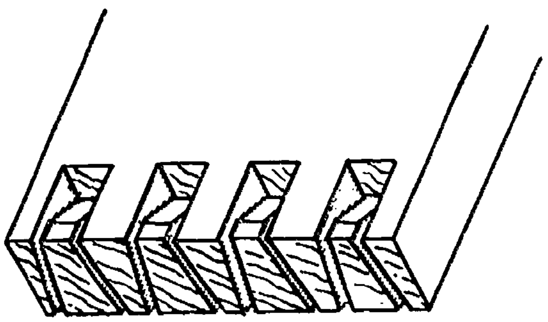
103.17
Figure 7-17.—Making a half dovetail joint.



103.18
Figure 7-18.—Laying out pin member for through-multiple-dovetail joint.

member, and square a line all the way around. This line indicates the bottoms of the openings between the pins.

Cut out the pins by sawing on the waste sides of the lines and then chiseling out the waste. Chisel half-way through from one side, as shown in figure 7-19; then turn the member over and chisel through from the other side.



103.19
Figure 7-19. — Chiseling out waste in a through-multiple-dovetail joint.

When you have finished cutting out the pins, lay the tail member flat and set the ends of the pins in exactly the position they are to occupy. Score the outlines of the pins, which will, of course, also be the outlines of the tails. Square lines across the end of the tail member, and saw and chisel out the waste between the tails just as you did the waste between the pins.

Box Corner Joint

With the exception of the obvious difference in the layout, the BOX CORNER JOINT (fig. 7-8) is made in just about the same manner as the through multiple dovetail joint.

Miter Joints

A MITER JOINT (fig. 7-9) is made by MITERING (cutting at an angle) the ends or edges of the members which are to be joined together. The angle of the miter cut is one-half of the angle which will be formed by the joined members. In rectangular mirror frames, door casings, boxes, and the like, adjacent members form a 90° angle, and the correct angle for mitering is consequently one-half of 90°, or 45°. For members which will form an equal-sided figure with other than 4 sides (such as an octagon or a pentagon), the correct mitering angle can be found by dividing the number of sides the figure will have into 180 and subtracting the result from 90. For an octagon (8-sided figure), the mitering angle is 90 minus 180/8, or 67-1/2°. For a pentagon (5-sided figure), the angle is 90 minus 180/5, or 54°.

Members can be end-mitered to 45° in the wooden miter box and to any angle in the steel miter box (by setting the saw to the desired angle) or on the circular saw (by setting the universal gage to the desired angle). Members can be edge-mitered to any angle on the circular saw, by tilting the saw to the required angle.

Since abutting surfaces of end-mitered members do not hold well when they are merely glued, they must usually be reinforced. A satisfactory type of fastener for a joint between end-mitered members is the SLIP FEATHER, a thin piece of wood or veneer which is glued into a kerf cut in the thickness dimension of the joint. Saw about half-way through from the outer to the inner corner, apply glue to both sides of the slip feather, and push the slip feather into the kerf. Clamp tight with a handscrew and allow the glue to dry. After it has dried, remove the handscrew and chisel off the protruding portion of the slip feather.

A joint between edge-mitered members may be reinforced with a SPLINE, a thin piece of wood which extends across the joint into grooves cut in the abutting surfaces. (A spline for a plain butt edge joint is shown in figure 7-1.) The groove for a spline can be cut by hand, by laying out the outline of the groove, removing the major part of the waste by boring a series of holes with a bit of suitable size, and smoothing with a mortising chisel. The best way to cut a groove, however, is on the circular saw, as described earlier, in this chapter.

Coping Joints

Inside corner joints between molding trim members are usually made by butting the end of one member against the face of the other. Figure 7-20 shows the method of shaping the end of the abutting member to fit the face of the other members. First saw off the end of the abutting member square, as you would for an ordinary butt joint between ordinary flat-faced members. Then, miter the end to 45° as shown in the first and second views of figure 7-20. Then, set the coping saw at the top of the line of the miter cut, hold the saw at 90° to the lengthwise axis of the piece, and saw off the segment shown in the third view, following closely the face line left by the 45° miter cut. The end of the abutting members will then match the face of the other member as shown in the fourth view.

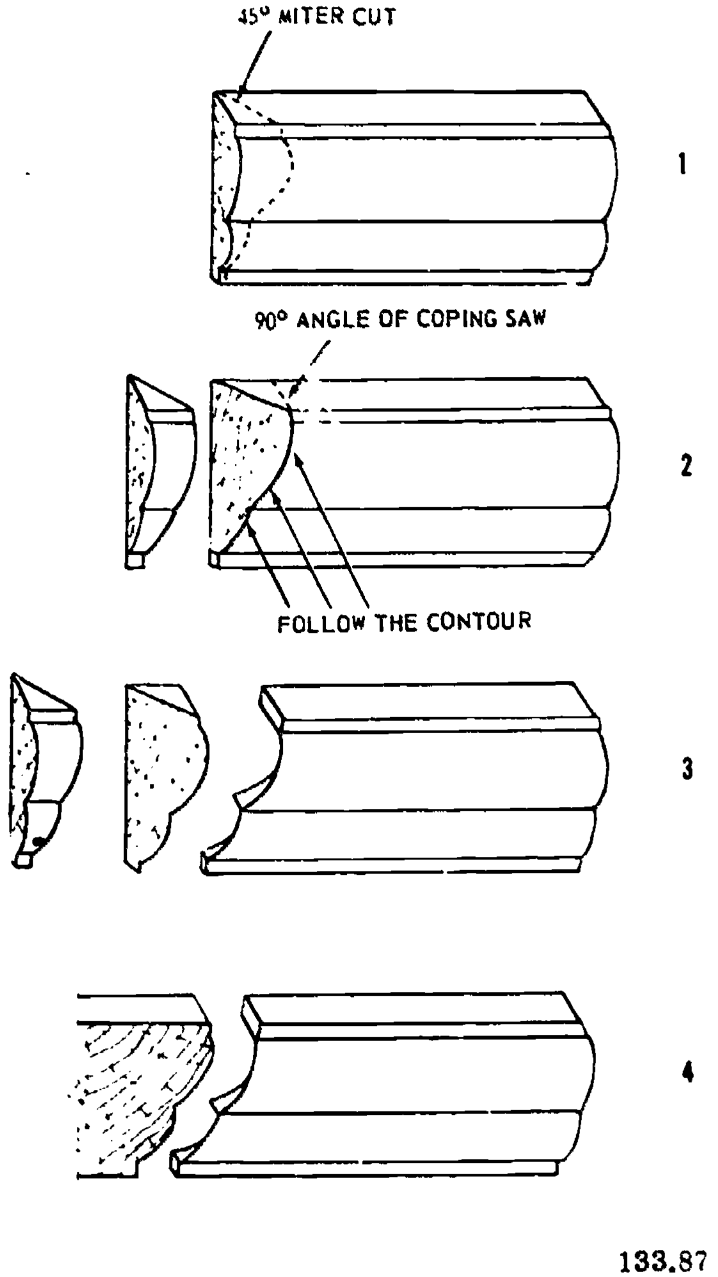


Figure 7-20. — Making a coping joint.

Mortise-and-Tenon Joints

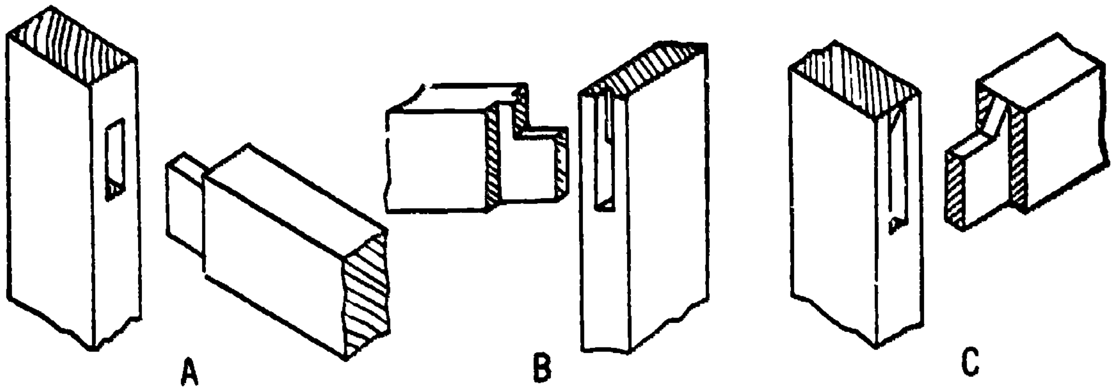
The MORTISE-AND-TENON joint is the most important and most frequently used of the joints used in furniture and cabinet work. In the BLIND mortise-and-tenon joint (fig. 7-11) the tenon does not penetrate all the way through the mortised member. A joint in which the tenon does penetrate all the way through is a THROUGH mortise-and-tenon joint. Besides the ordinary STUB joint (fig. 7-21 and view A, fig. 7-21), there are HAUNCHED joints (view B, fig. 7-21) and TABLE-HAUNCHED joints (view C, fig. 7-21). Haunching and table-haunching increase the strength and rigidity of the joint.

The layout procedure for an ordinary stub mortise-and-tenon joint is as follows: MARK THE FACES OF THE MEMBERS PLAINLY. Lay off from the end of the tenon member the desired length of the tenon, and square the SHOULDER LINE all the way around. Then lay off the total width of the tenon member on the mortise member as shown in figure 7-22.

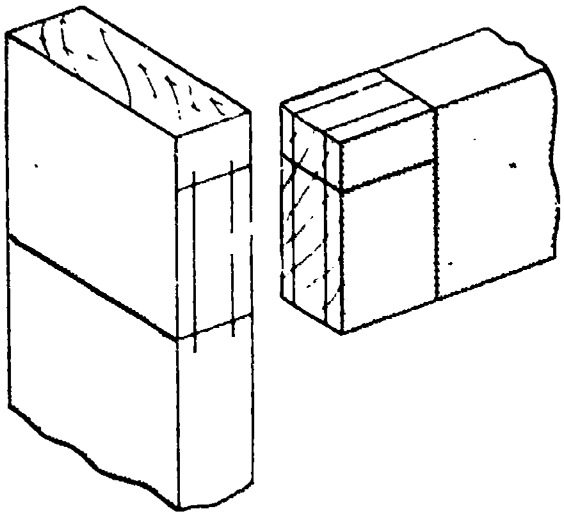
Determine the thickness of the tenon, which is usually between one-third and one-half of the thickness of the mortise member, and set the points on the mortising gage to this dimension. Adjust the block so that the points will score a double line on the center of the tenon member, as shown in figure 7-22. If the faces of the members are to be flush, use the same gage setting to score a double line on the mortise member, remembering to gage from the FACE of the member. If the face of the tenon member is to be set back from the face of the mortise member (as is often the case with table rails and the like), the mortising gage setting must be increased by the amount of the set-back. Remember, however, that the setting of the POINTS remains the same. Last, lay off from the end of the mortise member and from the appropriate edge of the tenon member the amount of end-stock which is to be left above the mortise, as indicated also in figure 7-22, and square lines as shown. For a SLIP TENON joint like the one shown in figure 7-11, you wouldn't need this last phase of the layout.

Tenons can be cut by hand with the backsaw, by the same method previously described for cutting corner and end half-lap joints. Mortises can be cut by hand with the mortising chisel. As in the case of a spline groove cut by hand, you can remove the major part of the waste by boring a series of holes with a twist drill of diameter slightly smaller than the width of the mortise. For a blind mortise-and-tenon joint use a depth gage or a wooden block to prevent the drill from boring below the correct depth of the mortise.

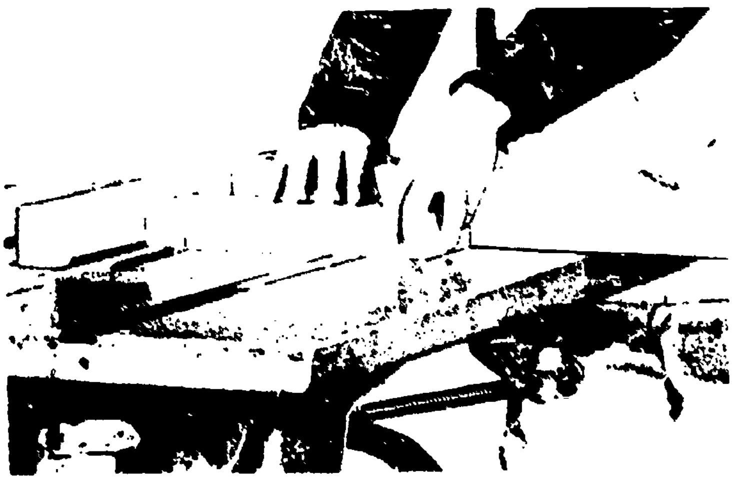
Tenons can be cut with the circular saw as follows: To make the shoulder cuts (which are made first), set the saw the depth of the shoulder above the table and set the ripping fence the length of the tenon away from the saw. Remember to measure from a saw-tooth SET TO THE LEFT. Make the shoulder cuts as shown in figure 7-23.



103.20
Figure 7-21. — A-stub, B-haunched, and C-table-haunched mortise-and-tenon joints.



103.21
Figure 7-22.—Layout of a stub mortise and tenon joint.



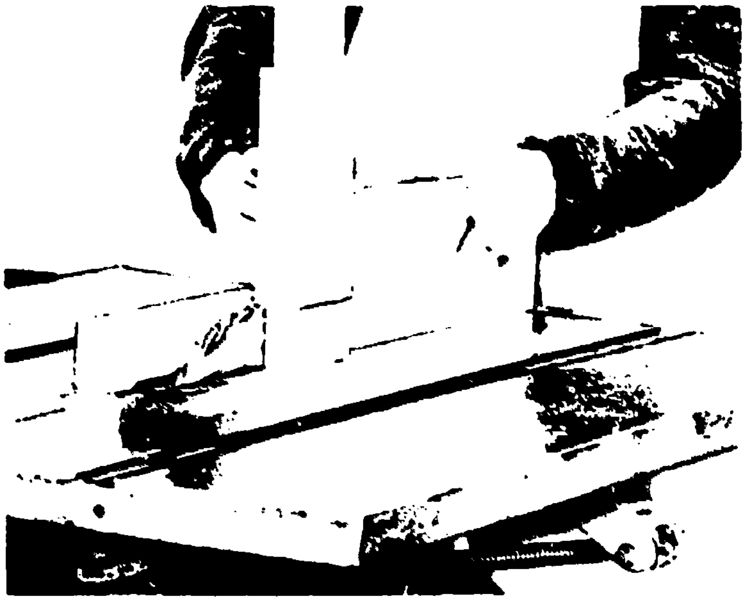
103.22
Figure 7-23.—Cutting a sq.are shouldered tenon.

Set the saw the depth of the cheek above the table, set the fence the width of the shoulder away from the saw, and make the cheek cuts as shown in figure 7-24. To steady the stock against the fence, use a FEATHER BOARD like the one shown clamped to the table. The angled end of the feather board has a series of long kerfs sawed in it, so that the board can bear pretty hard against the stock and still allow it to be fed through without binding. To maintain the stock upright, use a PUSH BOARD like the one shown in figure 7-24.

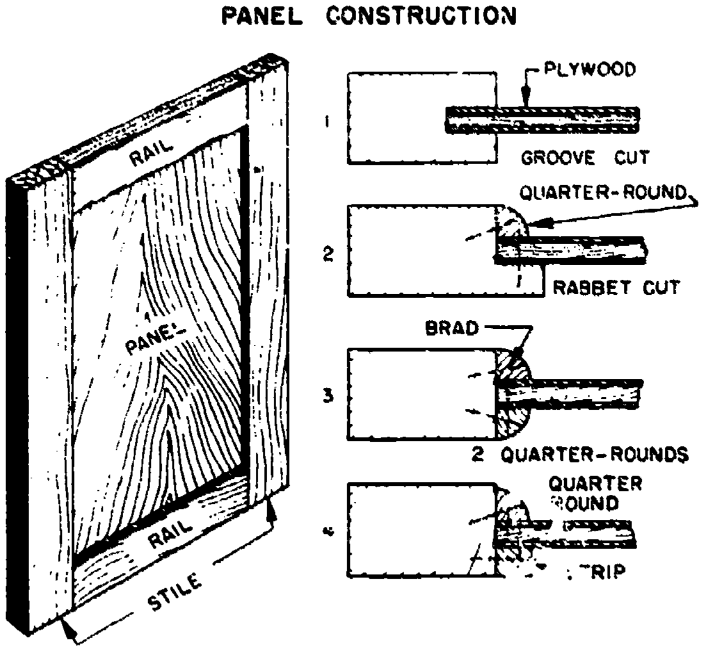
Tenons can also be cut with the dado head by the same method previously described for cutting end half-lap joints. Mortises are cut mechanically on a HOLLOW-CHISEL MORTISING MACHINE.

The cutting mechanism on this machine consists of a boring bit encased in a square, hollow steel chisel. As the mechanism is pressed into the wood, the bit takes out most of the waste while the chisel pares the sides of the mortise square. Chisels come in various sizes, with corresponding sizes of bits to match.

Mortise-and-tenon joints are fastened with glue, and with additional fasteners as required. One or more wood or metal dowels may be driven through the joint.



103.23
Figure 7-24.—Using feather board and push board to steady stock when cutting tenon cheek.



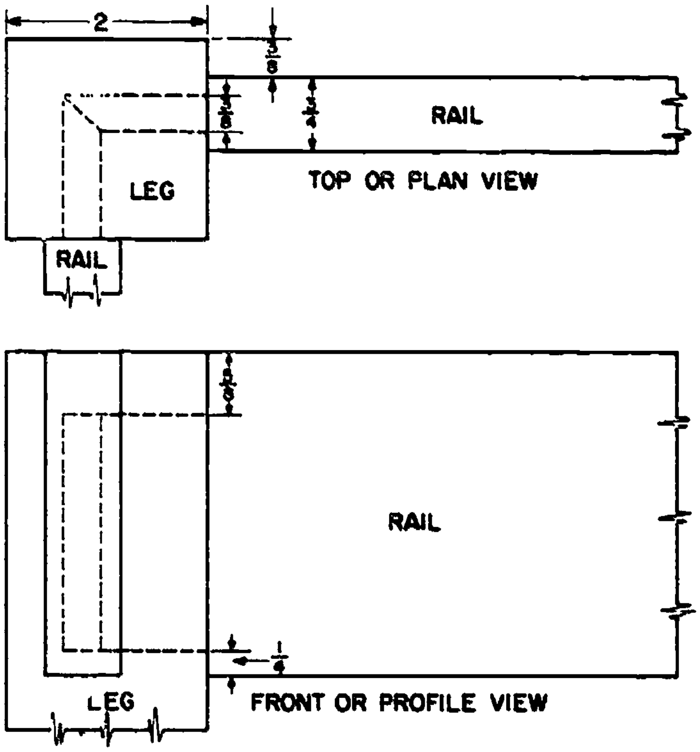
103.25
Figure 7-25.—Panel construction.

JOINT APPLICATIONS

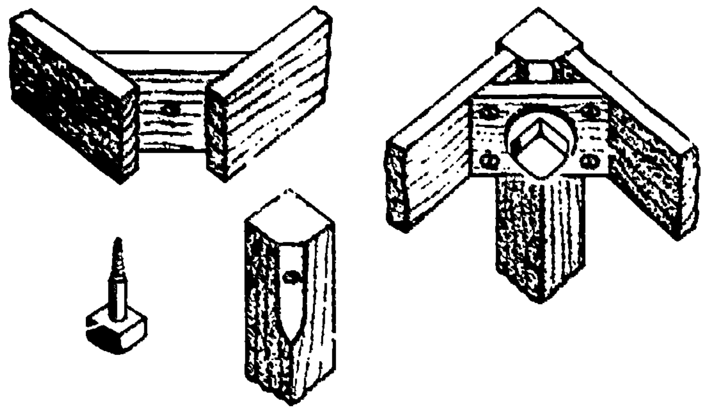
Plywood panels are often installed in frames to make parts of doors, partitions, bulkheads, tables, desks, cabinets, lockers, drawers, bulletin boards, and blackboards. The panels can be installed by a number of methods. Four of the commonly used methods are shown in figure 7-25. Notice in figure 7-25, views 1 and 2, how a groove and a rabbet are used to set the panel into the rails and stiles. The rails and stiles may be jointed by using dowels, miter joints, half-lap joints, or mortise and tenon joints. Fir plywood of 1/4" thickness is used more than any other material for panel construction.

One standard method of making a table is illustrated here (figs. 7-26, 7-27, 7-28, 7-29, and 7-30). Desks are made in much the same manner but with the addition of panels and more drawers.

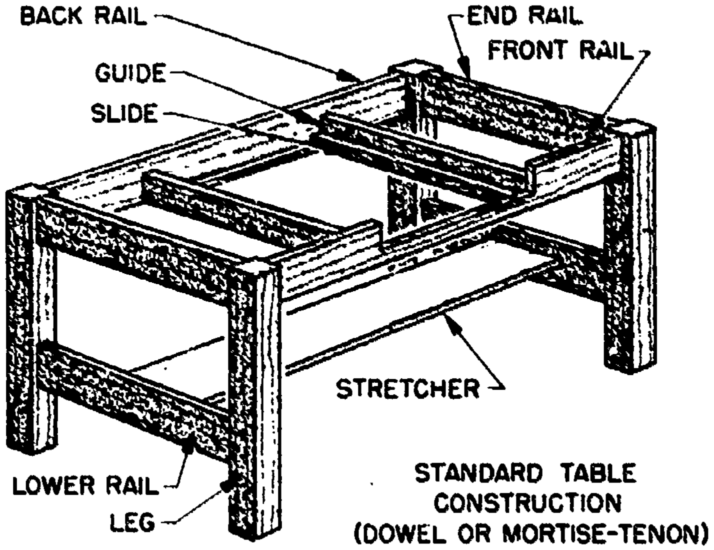
Mortise and tenon joints are used to join the table rails to the legs and to secure the stretcher to the lower end rails. An alternate method of securing the legs to the rails is by means of corner plates and lag screws. With the latter method the legs can be tightened easily when they become loose and they can be removed easily for storage or moving.



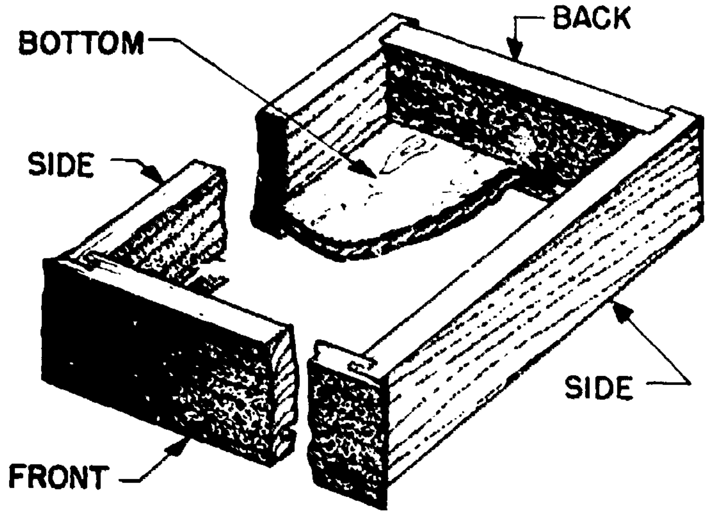
103.26
Figure 7-26.—Mortise-tenon layout and design.



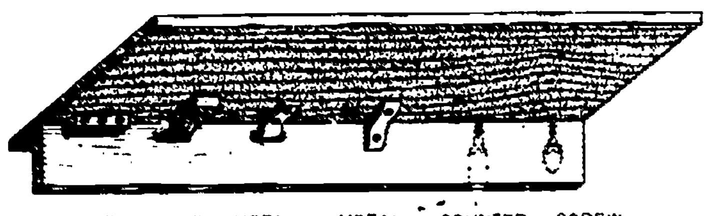
103.27
Figure 7-27. — Corner butt joint for table legs.



103.30
Figure 7-30. — Standard table construction.



103.28
Figure 7-28. — Simple drawer construction.



103.29
Figure 7-29. — Securing rails to table tops.

DRAWERS for tables and desks can be made by the method shown in figure 7-28. It is easier to make drawers by this method than it is to make them with dovetail joints. However, the dovetail joints are better and can be used on special jobs made of fine cabinet woods. Blind dovetails should be used for the front corners of drawers made for such furniture.

TABLE TOPS are usually fastened to the upper rails by one of six standard methods shown in figure 7-29. You will probably use the cleat more than any of the others. The cleat is screwed to the rail first so that it is about 1/16 inch below flush. Then the screws going into the top will pull the top down tight and snug.

FASTENING MATERIALS

There are many materials used for fastening wood together. These include NAILS, SCREWS, BOLTS, SPECIAL FASTENERS, and GLUE.

Glue

Although the carpenter very seldom uses it, glue is the most often used fastening material used by the Patternmaker, furniture maker, and cabinet maker.

Glue is the oldest, strongest, most durable and neatest of all other means of fastening wood together. Furniture, built hundreds of years ago by craftsmen of ancient Rome and Egypt, was assembled with glue and still exists today in many of our museums. In most cases, the glued joints of these pieces of furniture were put together with such a high degree of skill and craftsmanship that it takes close scrutiny and a practiced eye to discover them.

These ancients possessed the same high degree of skill and craftsmanship in wood joinery that you must attain as a Patternmaker, for the quality and strength of a pattern depend upon the quality of its glue joints.

TYPES OF GLUE.—Certain glues may be preferable for specific species of woods, since there is no all-purpose glue that meets all requirements. The various glues set, harden, or cure in different ways such as:

1. Evaporation of the solvent in the glue, such as in animal or soybean glues.
2. Polymerization or condensation under heat and pressure as in thermosetting resin glues.
3. Cooling as in thermoplastic glues.
4. Coagulation as in blood albumin glues.

In selecting any glue for a particular purpose, there are several points that should be considered: (1) the length of time it will remain in a usable condition, (2) the rate of setting of the glue joint, (3) the water resistance of the set glue, (4) the staining properties of the glue, and (5) the dulling effect it has on handtools. Any one or a combination of these points may be the deciding factor in the selection of a glue. Basically, there are two methods of using glue: hot and cold. Glues may be classified according to their composition, such as (1) animal, (2) fish, (3) vegetable starch, (4) vegetable protein, (5) casein, (6) blood albumin, (7) urea resin, (8) phenolic resin, and (9) vinyl resin.

The best grade of ANIMAL GLUE is the HIDE glue which is made from hide clippings, sinews, horns, and other waste parts of beef cattle. The next best grade is BONE glue. This is made from the bones of beef cattle. The better grades of animal glue are usually amber in color and quite transparent. Animal glue is produced in large, thin sheets which are usually broken into chips or ground to powder before being shipped. The chips are used in large shops where a great quantity of glue is used each day. The powder is used when small quantities are needed in a hurry. The chips or powder must be soaked in water and cooked before use. This class of glue sets and hardens by evaporation and must be used while it is hot.

FISH GLUE is made from the bones, sinews, and heads of fish and is kept to a proper consistency by the addition of acetic acid. It is used where the work of assembling parts is slow and time is not a factor in turning out the job. This type of glue, however, is seldom used in the Navy because it is not as strong nor as reliable as hot glue. Fish glue is usually made in liquid form; it is applied cold and has a disagreeable odor. Fish glue sets and hardens by evaporation.

CASEIN AND VEGETABLE glues are cold glues. Both are powders which are mixed with cold water to form a creamy mixture. This mixture is allowed to set for a short time to allow the water to become thoroughly absorbed by the glue. It is then ready for use. Both casein glue and the vegetable glues set and harden by evaporation.

Vegetable glue is of two types: PROTEIN, made from soybeans, and STARCH, made from the root of the cassava (tapioca) plant. It is used in some veneering work. It is NOT satisfactory for wood joints.

Casein glue is made fr milk and sold in powdered form. Compar with vegetable and animal glues, casein is generally considered to be water-resis .

BLOOD ALBUMIN glue i uperior to casein glue in water resistance, b it requires very expensive equipment for its application. It is seldom used, because it requires hot pressing and has a relatively low dry strength. The powdered type is dissolved in water, usually with some toxic ingredients to inhibit mold or fungus growth. The liquid type requires an addition of caustic soda to convert it for use. Blood albumin glue sets and hardens by coagulation.

UREA RESIN glue is a synthetic compound which may be obtained either in powder form or as a solution. Compared with casein glue it is little if any better in durability or water resistance. It is a hot or cold working glue; is soluble in water, may be catalyzed at room temperature (70° F) or hot pressed at 250° F. Urea resin glues set and harden by the condensation of the resin.

PHENOLIC RESIN glue is marketed in various forms, as a dry film, a dry powder, or a solution. In general, it is highly durable under the most extreme exposure conditions. It is resistant to attack by micro-organisms, withstands continuous soaking in fresh or salt water, and is, as a rule, as durable as wood itself. It is a cold working glue but requires a curing temperature of 150° F to 325° F. The phenolic resin glue sets and hardens by condensation and is waterproof. When used as a bonding adhesive in exterior or marine plywood it is considered more durable than wood itself.

VINYL RESIN glue is a synthetic, termoplastic, white liquid which requires no mixing or heating prior to use. This glue is ready for immediate use and can be applied at room temperatures above 50° F. The initial setting of the glue requires less than 30 minutes and for ordinary work a strong bond will occur in less than 1 hour. In addition, this glue is compounded to provide a minimum amount of wear to cutting tools as well as to have a glue line that is practically colorless. For general pattern construction, vinyl resin glue has replaced all glues that require heating, cooking, or mixing prior to use.

POINTERS ON USING GLUE.—Each type of glue must be prepared and used in a special manner if you are to get the strongest possible joint. Instructions are always given on the label of the container. Study these carefully before attempting to use any glue. There are certain general principles, however, to be followed in the application of all glues.

Phenolic resin glue should be kept in cool storage. The glue manufacturer marks on each shipment the recommended storage temperature and the period of time that the glue can be held in storage. You should not permit the glue to become heated above the recommended storage temperature for any appreciable length of time. If you do, some curing action results and the glue may become thickened to such an extent that it cannot be properly mixed and spread on the lumber to be glued.

Phenolic glue must also be protected from freezing temperatures (32° F or less). At such low temperatures some ingredients may settle out of the glue and be difficult to remix.

The wood should be warm but not hot. If the wood is cold, the glue adjacent to the wood will be chilled and will set before it has properly penetrated the pores of the joint. If the wood is hot, the water in the wood will be expelled causing the joint to warp. It is well also to have the glue room warm to avoid the dangers of chilling.

Be sure to squeeze or rub excess glue out of a joint before applying pressure. Pressure should always be applied as quickly as is consistent with good workmanship after the spreading of the glue. This prevents the glue from setting before the excess can be squeezed out.

The greater the pressure, the stronger will be the joint, provided the pressure does not become great enough to crush the wood and injure the pores. If possible, the pressure should be at least 100 psi. It is almost impossible to squeeze out too much glue. Theoretically the bond should consist only of the interlaced threads of glue passing [illegible] the pores in one piece to the pores in the other. Clamps may be used to produce this pressure, but they do not distribute the pressure even. In order to get a joint with maximum strength, you should use two plates.

Good results cannot be obtained from gluing operations unless extreme care and attention are given to the preparation of glue. All precautions taken when gluing up material are wasted if the glue is not in excellent condition. No end of trouble is encountered when glue joints fail during the process of constructing a job. Sometimes a job will hold up until it is completed, then fail during use in the foundry because of the poor condition of the glue. By using only the best grade of glue, and by following a few simple directions, much loss of time and waste of energy can be averted.

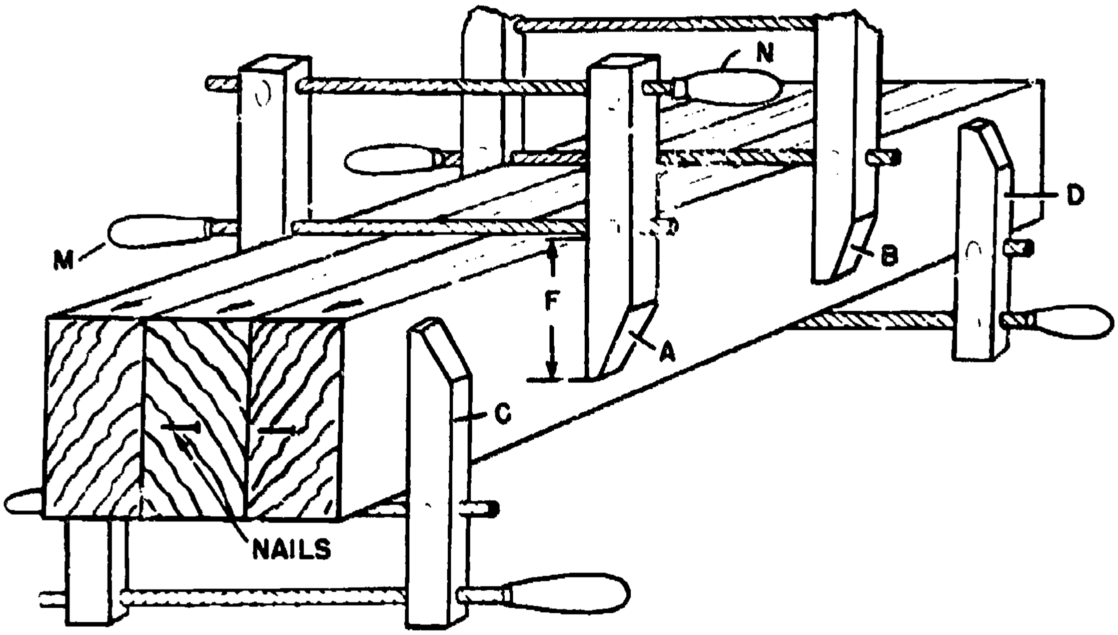
METHODS OF APPLYING GLUE.—When the need arises for thicker or wider material than that immediately available, it will be necessary to build up material to the required dimensions by gluing a number of pieces together. Two principal methods are employed for the gluing up of stock; face-to-face gluing and edge-to-edge gluing.

In FACE-TO-FACE GLUING, first determine the sizes of stock needed. Then decide which thickness and width of the stock on hand will produce the required size. Measure and remove enough lumber from the rack to do the job. Saw the lumber to the required lengths. Dress one face and one edge of each piece of material on the jointer. Dress the material to proper thickness in the planer. Rip the pieces to the proper width in the circular saw. (NOTE: Woodworking machine operation is explained in chapter 5 of this training manual.) Plane the surfaces to be glued together with a jointer or hand plane until the surfaces are smooth and true. Start a finish nail at each end of all but one piece of material. Adjust the hand clamps to an approximate jaw opening by laying the stock on the bench and fitting each clamp loosely over the stock. Then place them in a spot where they can be easily reached. Place the stock in the desired gluing position. Have the piece in which no nails have been driven, lying face up. Apply a good coat of glue to the surface of the piece of stock lying face up. Place one of the other pieces of stock face to face with the glued surface (with the nails pointing down), and rub back and forth or in a circular motion. At the same time, exert as much down pressure as possible. This spreads the glue evenly throughout the joint and excludes any air bubbles. In addition, a certain amount of glue is driven into the pores of the wood, and the glued surfaces are brought closer together; this reduces the amount of "drawing up" to be done when the clamps are applied. Line the two pieces up and set the nails in each end sufficiently to hold them together. The nails are used to hold the stock together until the clamps can be put in place and to prevent sliding of the pieces when the clamps are being tightened. Repeat the preceding gluing operations until all pieces have been assembled.

Then lay the material on its side in the position shown in figure 7-31; note how pieces are alternated in relation to the annual ring growth of lumber. The warpage of each piece will tend to offset the warpage of the one next to it if this arrangement is followed. Also, arrange the pieces so that the grain of their respective surfaces runs in the same direction; otherwise, difficulties may arise later when the job is being dressed to proper thickness. Planing with the grain on one part of the surface may prove to be the wrong direction for an adjacent area. After proper arrangement, use some system of marking the pieces of stock so that they will not be disarranged during the gluing up process.

Place clamp A (fig. 7-31) in a position so that when the clamps are all in place the space between them will be practically equal throughout the length of the material. Keep the lower clamp spindle M at least 1/2 inch above the surface of the material. Tighten up on spindle M and release spindle N until a fair amount of pressure is obtained on that part of the jaws near M. Next turn spindles M and N until the entire face of the jaw F is exerting an even pressure on the face of the material. Use sufficient force to squeeze excess glue freely from the joints of the glued up stock and draw all joints closely together.

Place clamp B on the job. Adjust and tighten it according to directions given for clamp A. Clamping the midsection of the material first will give the excess glue which is squeezed out of the joint more outlets. As each clamp is added, the glue is forced along, as well as out of, the joint. If the ends are clamped first, a considerable volume of glue is trapped which can



68.42

Figure 7-31.—Face-to-face gluing.

only be squeezed out by the application of enormous pressure. This is especially true when gluing up wide pieces of material. If the stock is being glued up on sawhorses, clamps C and D can be placed and adjusted from the bottom side of the job. The stock is then turned completely over on a table or bench, so that it rests on the ends of clamps A and B. Clamps C and D can then be placed and adjusted from the top in the same manner as clamps A and B were put on the job.

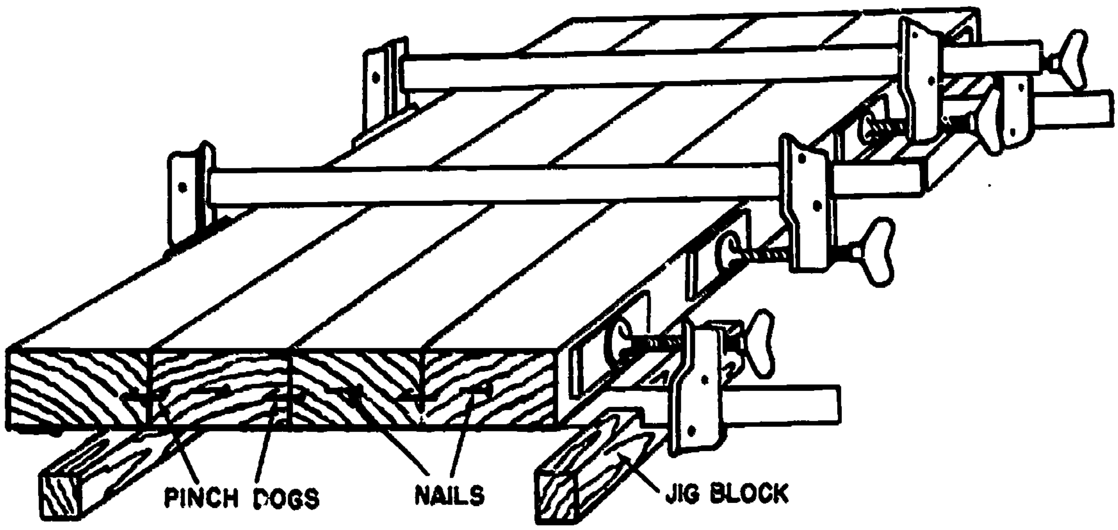
Examine the job carefully to see that all the clamps are properly set on the job, and that all the glued joints have been properly drawn up. Remove the job to a convenient spot where it will be out of the way until needed. If the job is left on the sawhorses until the glue has hardened, the excess glue which has been squeezed out of the joints may cause the job to stick to the sawhorses. Clean all waste glue from the top of the bench or sawhorses. When the glue has jelled, remove most of it with a glue scraper; then wipe the surface with a piece of cloth or waste which has been dipped in hot water. If the job is "rush", the clamps may be removed in 4 hours. However, there is no guarantee that the joints will not open up if the clamps are removed so soon. More satisfactory results will be obtained if the clamps are left on the job for at least 12 hours, but this will depend mainly on the type of glue used. Construction of the job should be planned to provide for good results in gluing operations.

The EDGE-TO-EDGE METHOD of gluing up stock is employed for two purposes: it is used most frequently to obtain material which will be relatively thin in comparison with its width, but which will not be susceptible to excessive warpage. Occasionally, this method is also used to glue up material which has to be wider than any on hand.

In edge-to-edge gluing, select, dress, and rip the material in the same manner as described for face-to-face gluing.

Start nails in the ends of each piece of stock except one, for the same purposes as described in the previous section on face-to-face gluing. Set the clamp jaw openings to suit the width of the assembled pieces of stock, allowing for the placing of blocks on the edges of the material to prevent marring by clamp jaws. Make two jig blocks for each of the bottom clamps (fig. 7-32) to hold the clamps upright during the gluing operations. Note that the pieces are arranged so that the annual ring growth will tend to offset warpage. Be sure that the direction of the grain is the same in all the pieces to be glued.

Place glue on the edges of the boards to be jointed. Rub the stock together to spread the glue evenly and to force out any air bubbles. Hold the work in place by driving the nails into each end of the stock as shown in figure 7-32. If some of the ends of the joints tend to open up in spite of the nails and before the clamps can be applied, pinch dogs may be used temporarily to hold the boards together. Immediately put the middle clamps in place with



68.43

Figure 7-32. — Edge-to-edge gluing.

the blocks in front of the jaws. Adjust and tighten them. Then adjust and tighten the clamps on the ends, removing all excess glue.

Inspect the clamps every few hours to make sure that they are not causing any warping of the stock. If you notice any of the edges pulling away from another before the glue has dried, readjust the clamps so that equal tension is applied throughout. In general, clamping and the application of pressure should start in the center of the work and worked toward each end, or started at one end and worked toward the other end.

Combined with glue — other fastening materials such as nails, brads, dowels, and corrugated fasteners are constantly being used in pattern construction. Many of the materials used in patternmaking are the same as those found in other woodworking trades. However, the Patternmaker may or may not use these materials in the same manner as other woodworkers. For example, in temporary fastening of pattern members, brads, nails, and corrugated fasteners may be used instead of wood screws. Wood screws may be combined with glue and paper in parted pattern turning. Dowels may be used for the alignment of parted patterns and of loose pattern components.

The fasteners used most frequently by the Patternmaker are nails, brads, wood screws, dowels, and corrugated fasteners. A description of these fasteners is given in the following paragraphs.

Nails and Brads

There are many types of nails, all of which are classified according to use and form. The wire NAIL so called because it is made from steel wire, is round-shafted, straight, pointed, and may vary in size, weight, size and shape of head, type of point, and finish. There are a few general rules to be followed in the use of nails. For maximum holding power, a nail whatever the type, should be at least three times as long as the thickness of wood it is intended to hold. Two-thirds of the length of the nail is driven into the second piece for proper anchorage while one-third provides the necessary anchorage of the piece being fastened. Nails should be driven at an angle slightly toward each other and should be carefully placed to provide the greatest holding power. Nails driven with the grain do not hold as well as nails driven across the grain. A few nails of proper type and size, properly placed and properly driven, will hold better than a great many driven close together. Nails can generally be considered the cheapest and easiest fasteners to be applied. In terms of holding power alone, nails provide the least; screws of comparable size provide more, and bolts provide the greatest amount.

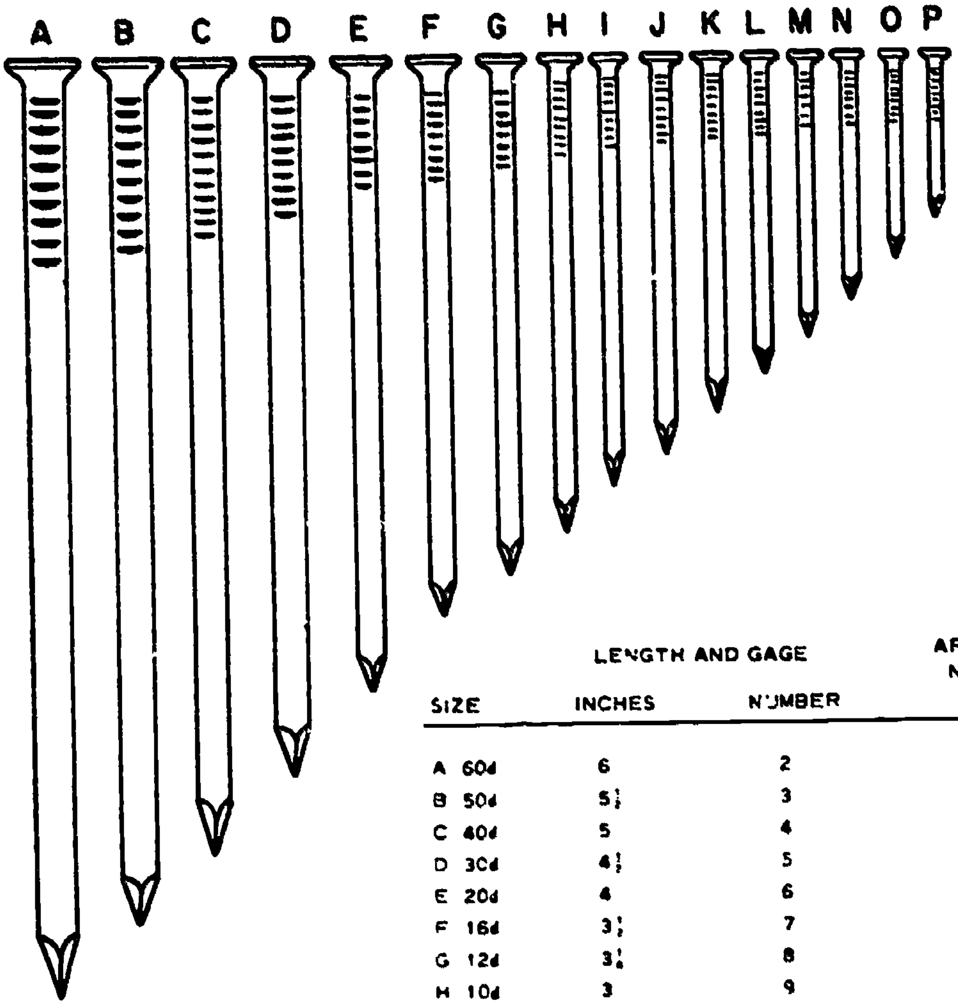
NAIL SIZES are designated by the use of the term PENNY. This term designates the length of the nail (1 penny, 2 penny, etc.), which is the same for all types. The approximate number of nails per pound, varies according to the type and size. The wire gage number varies according to type. Figure 7-33 provides the information related to the term penny for each of the type of nails referenced to in this section. The d adjacent to the numbers in the Size column is the accepted abbreviation of the word penny as used in nail sizing and should be read 2 penny, 3 penny, etc.

The COMMON WIRE NAIL (view A, fig. 7-34) has a flat head and ranges in size from 2d (1 inch long) to 60d (6 inches long). THE BOX NAIL (view B, fig. 7-34) has the same length per penny size as the common wire nail, but has a lighter head and small diameter. Both the common wire and box nail are generally used for structural carpentry where appearance is not important.

THE FINISHING NAIL (view C, fig. 7-34) is made of finer wire than either the common wire or box nail. However, its length, related to penny size, is the same. The finish nail has a small head which may be set below the surface of the wood into which it is driven leaving only a small hole which may be smoothly puttied or waxed over. It is used where appearance is important such as for interior and exterior carpentry, cabinetmaking, and patternmaking.

The DUPLEX NAIL (D, fig. 7-34) is a temporary fastener meant to be removed. For this reason, it is made with two heads. The lower head, or shoulder, is provided so that the nail may be driven securely home to give maximum holding power while the upper head projects above the surface of the wood to make its removal simple.

The WIRE —GAGE BRAD (view E, fig. 7-34) may be obtained in several gages for the same length of brad; it ranges in length from 3/8 inch to 6 inches. It is therefore the most suitable brad for pattern work. Remember that for brads



COMMON WIRE NAILS

SIZE	LENGTH AND GAGE: INCHES	LENGTH AND GAGE: NUMBER	APPROXIMATE NUMBER TO POUND
A 60d	6	2	11
B 50d	5 1/2	3	14
C 40d	5	4	18
D 30d	4 1/2	5	24
E 20d	4	6	31
F 16d	3 1/2	7	49
G 12d	3 1/4	8	63
H 10d	3	9	69
I 9d	2 3/4	10 1/4	96
J 8d	2 1/2	10 1/4	106
K 7d	2 1/4	11 1/2	161
L 6d	2	11 1/2	181
M 5d	1 3/4	12 1/2	271
N 4d	1 1/2	12 1/2	316
O 3d	1 1/4	14	568
P 2d	1	15	876

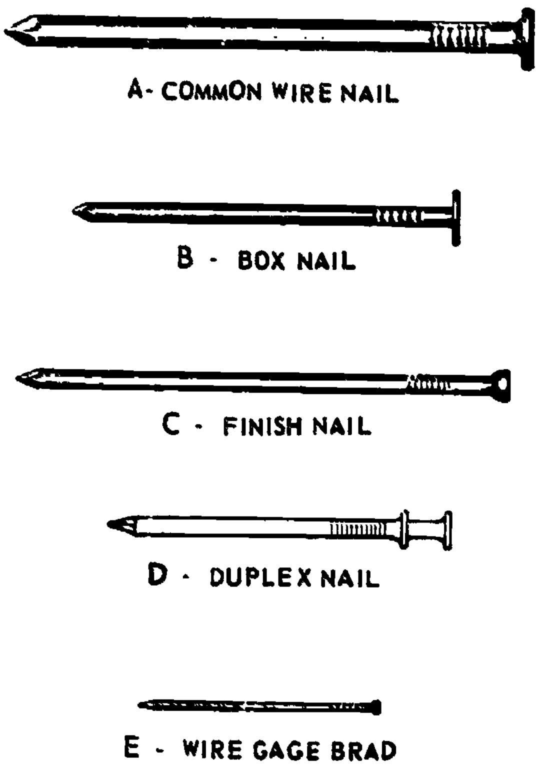
29.121

Figure 7-33. — Types of nails and nail sizes.

the higher the gage number, the smaller the body diameter. Its size is identified according to "length and wire gage"; for example, "1 — 12" means 1 inch long and made of 12-gage wire (0.105 inch). While "1 1/2 — 15" means 1 1/2 inches long and made of 15-gage wire (0.072 inch).

Wood Screws

The use of wood screws, rather than nails, as fasteners may be dictated by a number of factors. These may include the type of material to be fastened, the requirement for greater holding power than could be obtained by the use of nails, the finished appearance desired, and the fact that the number of fasteners that can be used is limited. The use of screws, rather than nails, is more expensive in terms of time and money but is often necessary to meet requirements for superior results. The main advantages of screws are — they provide more holding power; can be easily tightened to draw



29.121(68C)
Figure 7-34. — Nails and brads.

the items being fastened securely together; are neater in appearance if properly driven; and may be withdrawn without damaging the material. The common wood screw is usually made of unhardened steel, stainless steel, aluminum, or brass. Unhardened steel or brass screws are normally used in the pattern shop. The steel may be bright finished or blued, or zinc, cadmium, or chrome plated. Wood screws are threaded from a gimlet point for approximately 2/3 of the length of the screw and are provided with a slotted head designed to be driven by an inserted screwdriver.

WOOD screws as shown in figure 7-35 are designated according to head style. The most common types are: FLATHEAD, OVALHEAD, and ROUNDHEAD, both in slotted and phillips heads. To prepare wood for receiving the screws, bore a pilot hole the diameter of the screw to be used in the piece of wood that is to be fastened (fig. 7-36). Then bore a smaller, starter hole in the piece of wood that is to act as anchor or hold the threads of the screw. The starter hole is drilled with a diameter less than that of the screw threads and to a depth 1/2 or 2/3 the length of the threads to be anchored. The purpose of this careful preparation is to assure accuracy in the placement of the screws, to reduce the possibility of splitting the wood, and to reduce the time and effort required to drive

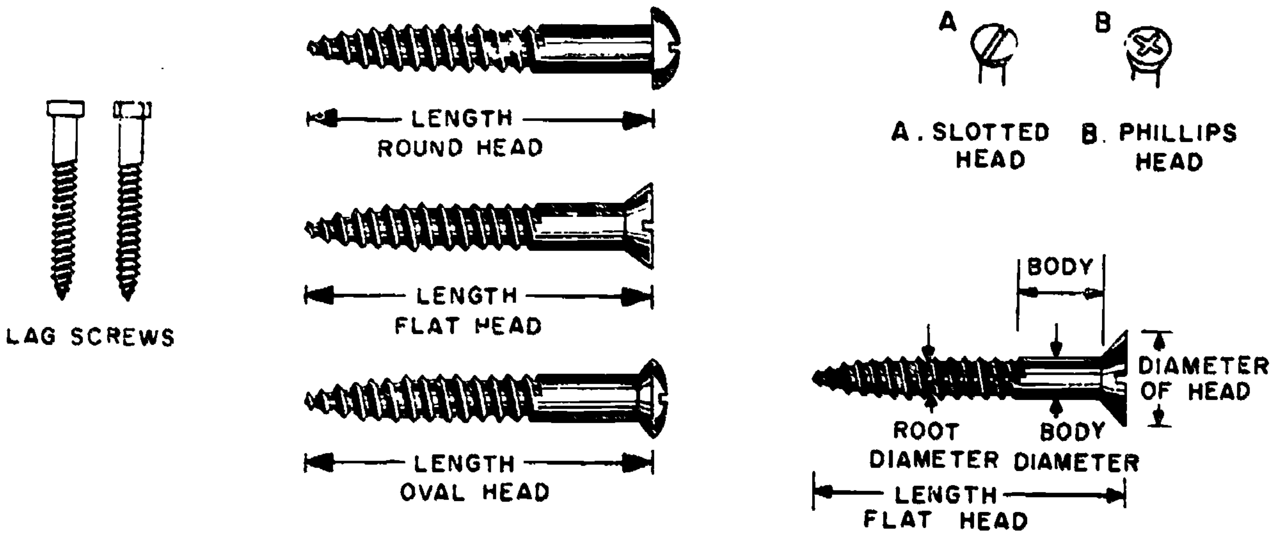


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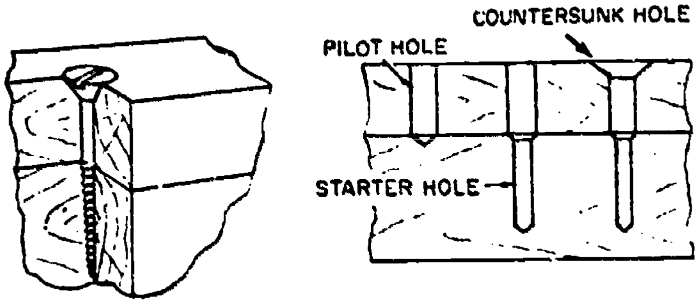
Figure 7-35. — Types of wood screws and nomenclature.



29.123

Figure 7-36. — Sinking screw properly.

the screw. Properly set slotted and phillips flathead and ovalhead screws are countersunk sufficiently to permit a covering material to be used to cover the head. Slotted roundhead and phillips roundhead screws are not countersunk, but are driven so that the head is firmly flush with the surface of the wood. The slot of the roundhead screw is left parallel with the grain of the wood.

The proper name for LAG SCREWS (fig. 7-35) is LAG BOLT, wood screw type. These screws are often required in construction building. They are longer and much heavier than the common wood screw and have coarser threads which extend from a cone or gimlet point slightly more than half the length of the screw. Squarehead and hexagon head lag screws are always externally driven, usually by means of a wrench. They are used when ordinary wood screws would be too short or too light and spikes would not be strong enough. For sizes of lag screws, see table 7-1.

Wood screws come in sizes which vary from 1/4 inch to 6 inches. Screws up to 1 inch in length increase by eighths, screws from 1 to 3 inches increase by quarters, and screws from 3 to 6 inches increase by half-inches. Screws vary in length and size of shaft. Each length is made in a number of shaft sizes specified by an arbitrary number that represents no particular measurement but indicates relative differences in the diameter of the screws. Proper nomenclature of a screw as illustrated in figure 7-35 includes the type, material, finish, length, and screw size number which indicates the wire gage of the body, drill or bit size for the body hole, and drill or bit size for the starter hole. Tables 7-2 and 7-3 provide size, length, gage, and applicable drill and auger bit sizes for screws; table 7-1 gives lengths and diameters of lag screws.

Dowels

Dowels are used by Patternmakers to assemble and hold the loose parts of the pattern in proper relation to each other while the pattern is being rammed up in the mold. They are frequently used to reinforce glued joints and delicate parts of a job. WOODEN DOWELS are round wooden pins that are made by a special dowel machine equipped with revolving cutters.

The best wooden dowels are made from straight-grain maple or birch. The diameters commonly used in the shop are: 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, 7/8, and 1 inch. See figure 7-37.

Table 7-1. — Lag Screws

Lengths (inches)	Diameters (inches)			
	1/4	3/8, 7/16, 1/2	5/8, 3/4	7/8, 1
1	x	x		
1 1/2	x	x	x	
2, 2 1/2, 3, 3 1/2, etc., 7 1/2, 8 to 10	x	x	x	x
11 to 12		x	x	x
13 to 16			x	x

133.342

Table 7-2. — Screw Sizes and Dimensions

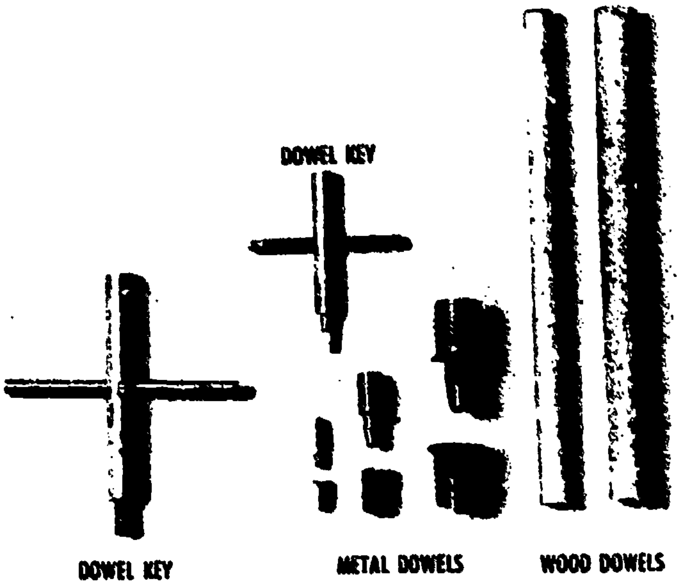
Length (in.)	Size numbers																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	24
1/4	x	x	x	x																		
3/8	x	x	x	x	x	x	x	x	x	x												
1/2		x	x	x	x	x	x	x	x	x	x	x	x									
5/8		x	x	x	x	x	x	x	x	x	x	x	x		x							
3/4			x	x	x	x	x	x	x	x	x	x	x		x		x					
7/8			x	x	x	x	x	x	x	x	x	x	x		x		x					
1				x	x	x	x	x	x	x	x	x	x		x		x		x	x		
1 1/4					x	x	x	x	x	x	x	x	x		x		x		x	x		x
1 1/2					x	x	x	x	x	x	x	x	x		x		x		x	x		x
1 3/4						x	x	x	x	x	x	x	x		x		x		x	x		x
2						x	x	x	x	x	x	x	x		x		x		x	x		x
2 1/4						x	x	x	x	x	x	x	x		x		x		x	x		x
2 1/2						x	x	x	x	x	x	x	x		x		x		x	x		x
2 3/4							x	x	x	x	x	x	x		x		x		x	x		x
3							x	x	x	x	x	x	x		x		x		x	x		x
3 1/2									x	x	x	x	x		x		x		x	x		x
4									x	x	x	x	x		x		x		x	x		x
4 1/2													x		x		x		x	x		x
5													x		x		x		x	x		x
6															x		x		x	x		x
Threads per inch	32	28	26	24	22	20	18	16	15	14	13	12	11		10		9		8	8		7
Diameter of screw (in.)	.060	.073	.086	.099	.112	.125	.138	.151	.164	.177	.190	.203	.216		.242		.263		.294	.320		.372

133.343

Table 7-3. — Drill and Auger Bit Sizes for Wood Screws

Screw size No		1	2	3	4	5	6	7	8	9	10	12	14	16	18
Nominal screw		.073	.086	.099	.112	.125	.138	.151	.164	.177	.190	.216	.242	.268	.294
Body diameter		5/64	3/32	3/32	7/64	1/8	9/64	5/32	11/64	11/64	3/16	7/32	15/64	17/64	19/64
Pilot hole	Drill size	5/64	3/32	7/64	7/64	1/8	9/64	5/32	11/64	3/16	3/16	7/32	1/4	17/64	19/64
	Bit size											4	4	5	5
Starter hole	Drill size		1/16	1/16	5/64	5/64	3/32	7/64	7/64	1/8	1/8	9/64	5/32	3/16	13/64
	Bit size														4

133.344



68.44
Figure 7-37.—Dowels and dowel keys.

Table 7-4.—Drill Sizes for Metal Dowels

Dowel No. Size	Dowel Diameter (Inches)	Drill Size (Inches)
0	7/64	1/8
1	11/64	3/16
2	3/16	1/4
3	7/32	5/16
4	5/16	7/16
5	13/32	9/16
6	17/32	3/4
7	13/16	1

68.188

METAL DOWELS, especially of brass, are used quite frequently. They are not easily damaged. They also eliminate the inconvenience caused by the swelling of wooden dowels which have absorbed moisture from the molding sand. One type of metal dowel is shown in figure 7-37.

Metal dowels are self-centering—the lower portion of the threaded end is designed to find its own center in the bored hole and hold the dowel to its center as the threads cut their way into the wood. The depth of the thread tends to keep the dowel tight, giving the male and female parts a fit within a tolerance of 0.001 inch.

The metal dowel is easily inserted or removed from drilled holes in the pattern. DOWEL KEYS are used for this purpose. (See fig. 7-37.)

Table 7-4 lists the dowel number size, diameter of the dowel pin, and the recommended drill size to be used.

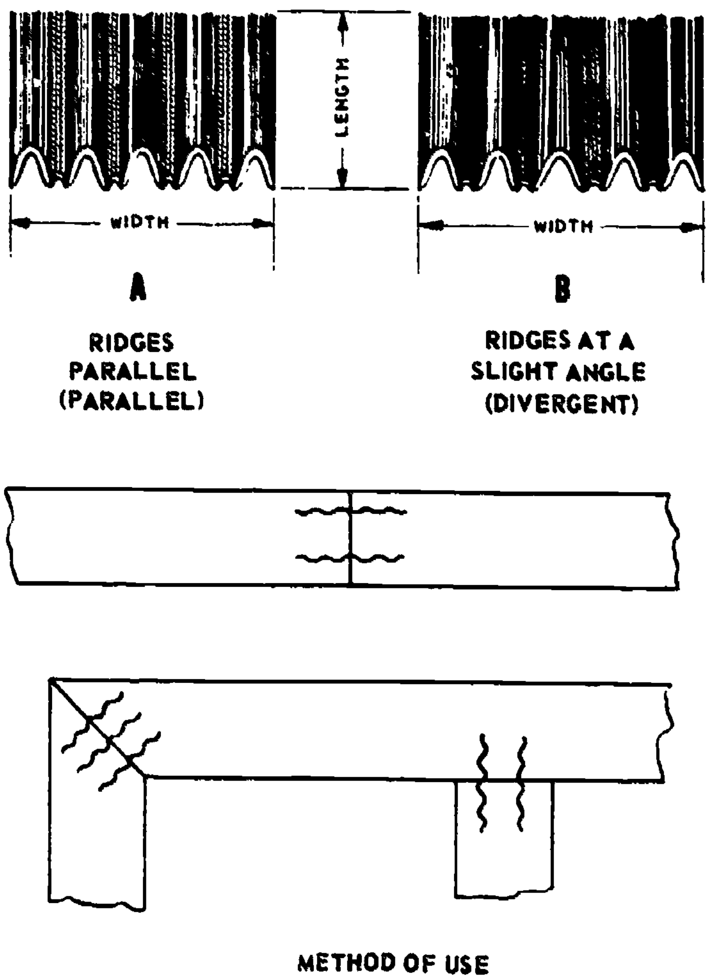
Corrugated Fasteners

Corrugated fasteners are made from sheet metal of 18 to 22 gage with alternate ridges and grooves; the ridges vary from 3/16 to 5/16 inch, center to center. One end is cut square, the other is sharpened with bevel edges creating a sawtooth effect. There are two types of corrugated fasteners, PARALLEL and DIVERGENT. (See fig. 7-38.) The parallel type has the ridges running parallel. The divergent type has the ridges running at a slight angle away from the square edge. The angle creates a tendency to compress the material since the ridges and grooves are closer together at the top than at the bottom. Corrugated fasteners are made in several different lengths and widths. The width varies from 5/8 inch to 1 1/8 inches, while the length varies from 1/4 to 1 inch. In addition, they are also made with different numbers of ridges, ranging from 3 to 6 ridges per fastener.

FINISHING THE PATTERN

After a pattern is constructed and before it receives its final protective pattern coating, it must be sanded to remove tool marks and ridges. Fillets must be added, identification markings must be included, and rapping and lifting plates must be set into the pattern.

The procedure followed to complete patterns may vary depending upon the job requirements. The sequence of steps which may be followed to complete a pattern are discussed in the following sections.



68.45(68C)
Figure 7-38.—Corrugated fasteners and their uses.

SANDING MATERIALS

After a pattern is constructed, it must be sandpapered smooth in order to remove the ridges and marks left by the cutting tools. However sanding must be done with care so as to not remove the construction lines and centerlines. Final finishing of a pattern is very important because it gives the pattern a hard, smooth finish that is resistant to the warping effects of moisture and heat, and to abrasion. It also helps the Molder to draw the pattern away from the sand mold cleanly.

Two types of SANDPAPER are used in the pattern shop: (1) quartz or flint, and (2) garnet. The first type is made from crushed quartz rock and the second from crushed garnet ore. Both sandpapers are made by applying hot glue to one side of a tough paper, and then sprinkling the abrasive material on top of the glue. Garnet paper is harder and more durable.

Sandpapers are graded according to the coarseness or fineness of the abrasive particles that are used. The grade is marked by a number on the back of the sandpaper. Different grades are used to indicate grit size for flint and garnet papers. The various grades in each type are listed in the accompanying chart:

GRADE	USES	GRIT SIZE Garnet	Flint
Very fine	Cabinet finishing	9/0	---
		8/0	---
		7/0	---
		6/0	4/0
		5/0	3/0
Fine	Finish sanding	4/0	2/0
		3/0	0
		2/0	1/2
Medium	Rough sanding	0	1
		1/2	1 1/2
		1	2
		1 1/2	---
Coarse	Disk sanding	2	---
		2 1/2	2 1/2
		3	3

Grit sizes of garnet paper above 4/0 and flint paper above 2/0 are used for cabinet work. However, the pattern shop usually stocks no finer grade than number 4/0. The sandpaper for hand use comes in sheets about 9 by 11 inches. For machine sanders, it comes either in rolls or already cut to fit the machine.

The proper storage of sandpaper is important for good performance. It should never be stored in a damp place or in a place where it might become too dry. Moisture tends to loosen the abrasive material, while excessive dryness tends to make the paper too brittle.

HAND SANDING

Sanding of finished surfaces of cabinet and jointer work is usually done with the run of the grain to avoid scratches that might spoil the natural appearance of the grain. A large portion of pattern material, however, is sanded across the grain to produce a surface that is both smooth and even. This applies in particular to material such as redwood and some of the pines used in the pattern shop. These woods possess a marked difference in hardness between the soft and hard portions of their annual ring growth. When sanding is done with the run of the grain on wood of this type, the abrasive on the sandpaper tends to remove the softer portion of the grain quite rapidly in the form of microscopic shreds. The harder grain portions offer more resistance to the abrasive, frequently being so tough that they are barely affected. Instead, they tear the abrasive from the paper, and this loose material in turn attacks the softer portions as the sandpaper is pushed back and forth over the surface. This often produces a "washboard" surface that is very unsatisfactory for the face of a pattern.

When the same woods are sanded across the grain, the abrasive material rapidly cuts tiny chips out of the hard fiber walls, somewhat in the manner of thousands of small saw teeth all cutting at once. The entire abrasive face of the sandpaper is evenly dulled, and cannot remove the soft grain portion any faster than the reduction of the hard fibers will permit. This action produces a smooth and fairly even surface that is quite suitable for a pattern finish.

For sanding flat surfaces, select a sheet of sandpaper that is just coarse enough to dress the surface free of tool marks without cutting the surface too rapidly. Best results are obtained in the use of sandpaper if you bend a sheet over the sharp edge of a table or board and tear it into four equal parts. Since a sheet of sandpaper is too large for the average-size job, tearing it into four parts saves much unnecessary waste.

Make a sandpaper block and fold one of the pieces of sandpaper around it. Sand the surface by moving the block back and forth across the grain with long strokes; at the same time, move along the surface from one end of the material to the other. Do not sand in one spot; instead, try to remove an equal amount from all parts of the surface during each sanding motion. With the bench brush, brush the surface free of wood dust and loose abrasives. Examine the surface to see if all tool marks have been removed. If not, repeat these sanding operations until the desired results are obtained. Select a sheet of fine sandpaper for finishing the surface. Complete sanding the surface with the fine grade of sandpaper, and brush the surface clean with the bench brush.

When sanding straight narrow edges, sand with the grain of the wood. There is a tendency to impart a rocking motion to the sanding block when cross-grain sanding is being done on narrow edges; the rocking motion produces a rounded surface.

When sanding concave surfaces, use a round-faced block. Do as much cross-grain sanding as conditions will permit. Select a sheet of sandpaper of suitable coarseness, tear it into four equal parts, and wrap one piece around the curved side of a sanding block. Start each sanding stroke at the top edge of the concave surface and push toward the bottom. Do not sand on the back stroke, because you may pass over the edge and knock the corner over. Clean the surface with the bench brush occasionally, examining for tool marks. Finish the surface with a fine grade of sandpaper.

In sanding irregular surfaces, the usual procedure is to tear the sandpaper sheet into quarters. Fold each quarter as shown in figure 7-39 to obtain three separate surfaces. As one surface of the paper becomes dull, the paper can be turned over until the entire piece has been used. The paper is held during sanding as shown in figure 7-40. This method of sanding is used for surfaces for which a sandpaper block is unsuitable. Exercise care to avoid sanding too long in one spot and thereby altering the dimensions of a job.

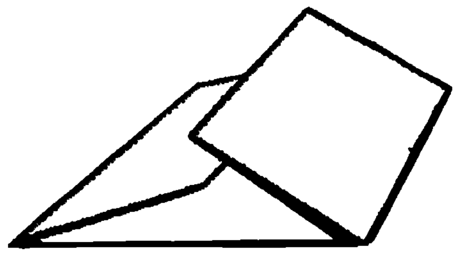


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Figure 7-39. — Folded sandpaper.

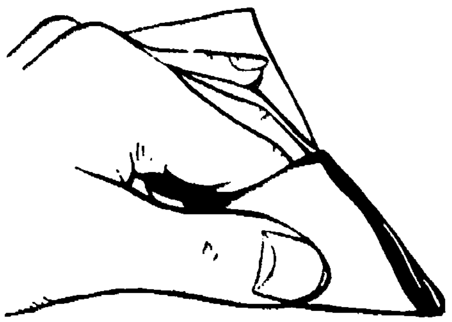

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Figure 7-40. — Holding folded sandpaper.

One method of finish sanding frequently employed after sanding with a folded sheet of sandpaper, is to tear off a narrow strip of sandpaper and use it in shoe-shine fashion. This should be done with a fine grade of sandpaper, about 3/0 or 4/0, when finishing small jobs. Coarser grades may be used on larger work.

In sanding shellacked surfaces, either of these sanding methods may be used as conditions warrant. However, most sanding of shellacked surfaces is done by using sandpaper folded as shown in figures 7-39 and 7-40.

The principal purpose of sanding a shellacked surface is to remove any roughness that may be present, without removing the shellac. The pressure exerted on the sandpaper should never be greater than that necessary to obtain satisfactory results. Also, as fine a grade of sandpaper as the job will permit should be used.

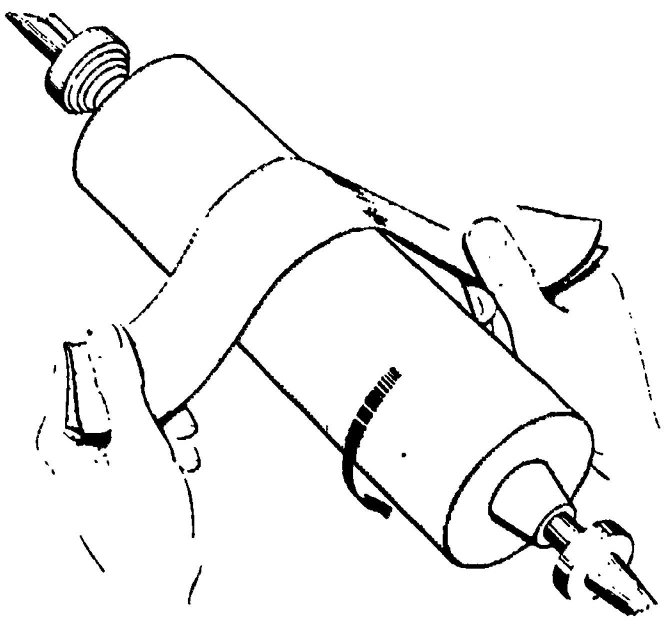
Examine a shellacked surface to see if it is fully dry before attempting to sand it. Select a sheet of sandpaper of proper grade for the job to be done. Tear the sheet into four equal parts, and fold one piece as shown in figure 7-39. Hold the folded sandpaper as shown in figure 7-40. Sand the surface very lightly at first, increasing pressure as conditions may require. Use strokes that are as long as possible and do not "dabble" in one spot. Examine the surface frequently to see if the desired results are being obtained. Do no more sanding than is necessary to produce a smooth surface. Also, examine the sandpaper frequently to see if any part has become gummed with shellac. If it has, do not use that part of the sandpaper any longer because it will scratch the surface of the job.

LATHE SANDING

Excessive sanding of work in a lathe should be avoided or the dimensions of the job may become too greatly altered. The job should be carefully turned to a smooth finish so that only minor sanding is necessary to finish the surface. The speed of the lathe should be well regulated during sanding operations in order to avoid burning. A fine grade of sandpaper should be used (3/0 or 4/0) on the average-size job. Dulled, fine sandpaper (4/0) should be used on very small work. Always remove the toolrest from the lathe before sanding a job.

For most lathe sanding jobs, use 3/0 or partially worn sandpaper. If the job is small, use a half sheet; if fairly large, use the whole sheet. Fold the sheet twice, and start the lathe at about medium speed. Apply the sandpaper lightly (fig. 7-41) and keep moving it along the surface of the job. Do not let the sandpaper stay in one spot. When sanding the ends of the job, use a narrow strip of sandpaper, folding it between your fingers in the shape of the surface to be sanded. Then hold it lightly against the stock, and rotate it at the proper angle so that all angles, edges, or shoulders retain their designed shapes. (See fig. 7-42.)

In sanding a concave faceplate pattern, start by tearing a suitable piece from a sheet of 4/0 sandpaper. Fold it over twice. Bend the paper a few times to make it pliable, so that it can take



68.48

Figure 7-41.—Sanding a lathe job.

the shape of the concave surface. Start the lathe at about medium speed. Sand the job as illustrated by figure 7-43. Do not knock off the sharp corners on the face of the bend.

You will find that electric sanders are useful for smoothing stock, and for putting draft on the sides of patterns. Be alert when operating a machine sander so you will not cut off too much stock and ruin your work.

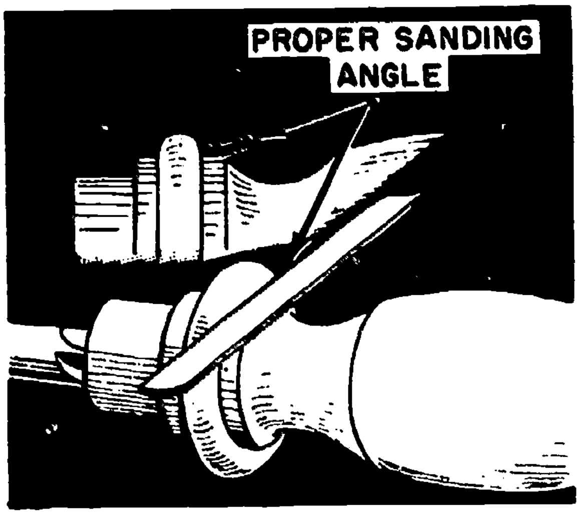


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Figure 7-42. — Sanding at an angle.

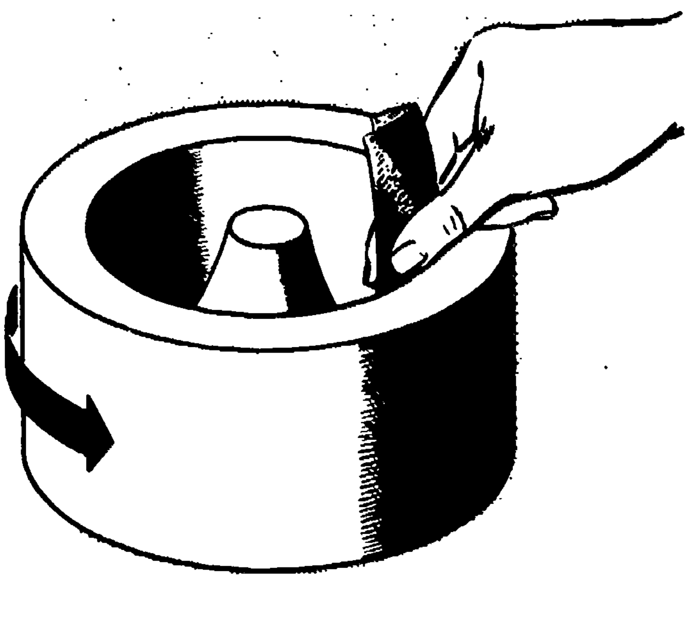

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Figure 7-43. — Sanding a concave faceplate pattern.

FILLETS

FILLETS are concave connections or corner pieces that are used to eliminate sharp corners on patterns. They are designed to provide additional strength on the finished casting by relieving the strains and stresses that are created in the shrinking of the metal as it cools. The use of fillets also helps to eliminate sharp edges of sand that are likely to be loosened and to fall when the pattern is withdrawn.

Types of Fillets

By far the strongest and most satisfactory fillet is that turned or carved from the pattern stock on the pattern itself. Others in the order of their importance are the glued-on wooden fillet, the leather fillet, and the wax fillet. Fillet irons, pattern letters and figures, and rapping and lifting plates are illustrated in figure 7-44.

GLUED-ON WOODEN FILLETS may be classified as either STRUCK fillets or PLANTED fillets. A struck fillet is made from rectangular stock, glued in place, and carved to shape. See part A of fig. 7-45. A planted fillet is made of previously shaped stock that is glued or affixed in place. (See part B of fig. 7-45.) Note that on planted fillets, the sides are cut to slightly more than 90° to permit the feather edge of the fillet to adhere tightly to the pattern. In addition, the back corner (heel) is trimmed to allow for the glue or shellac which might prevent close adhesion. Wood fillet stock may be purchased in sizes ranging from 1/4 inch to 2 inches.

LEATHER FILLETS may be classified as planted fillets. These fillets are frequently used to fill in sharp corners occurring at the intersection of irregular shapes and also for shaping to curves. Some additional pliability may be obtained from this type of fillet by moistening the face of the leather and by working and flexing the leather in the hands.

Leather fillets range in size from a 1/16-inch radius to a 1-inch radius. (See fig. 7-46.) An approximate method of measuring leather fillet stock is to measure from the point of the angluar face to the edge of the fillet.

WAX FILLETS are occasionally used for small fillets and for filling up holes made by brads and screws. They may be purchased in sizes of 1/16 "round" (diameter) to 3/4-inch radius. (See fig. 7-47.) WAX fillets may be classified as planted fillets, but the term PRESSED is generally applied to wax fillets.

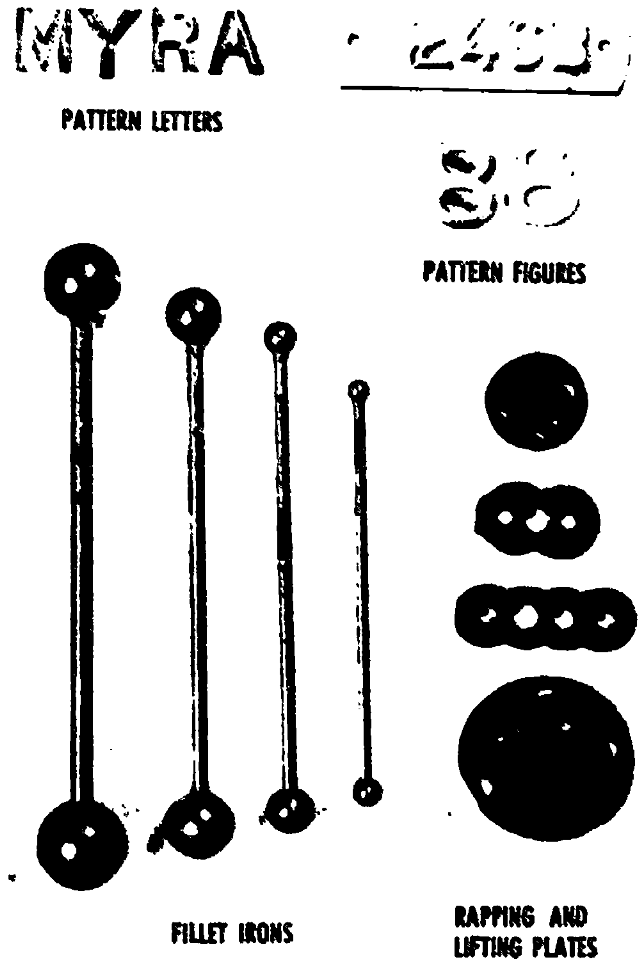

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Figure 7-44.—Fillet irons, pattern letters, and rapping plates.

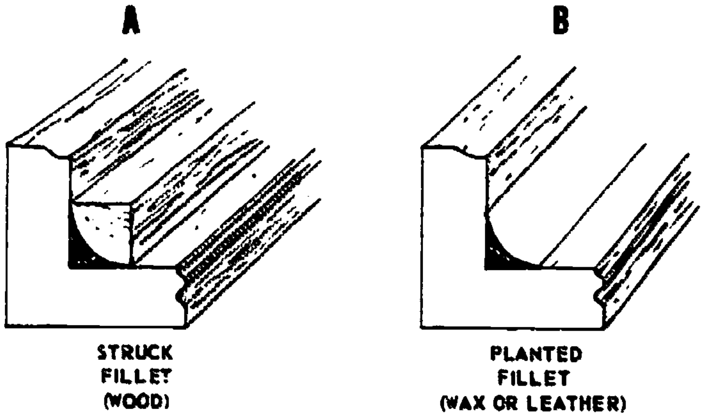

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Figure 7-45.—Struck and planted fillets.

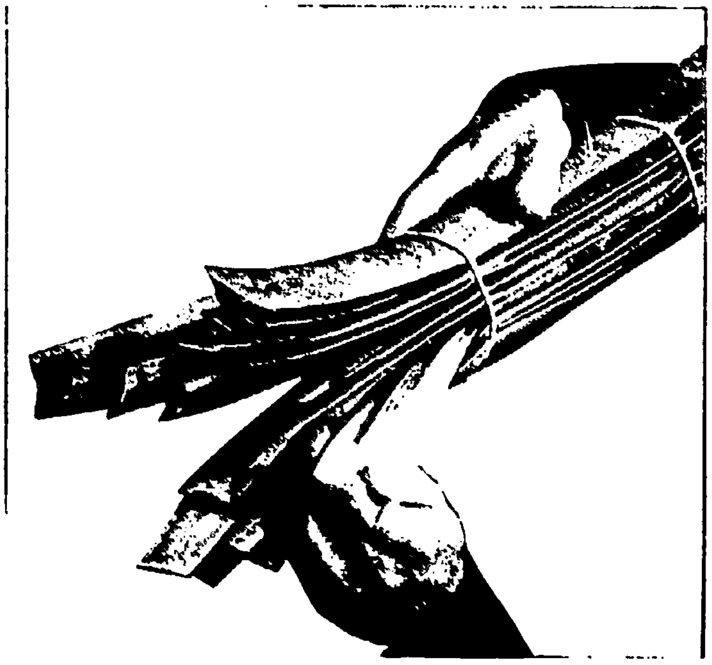

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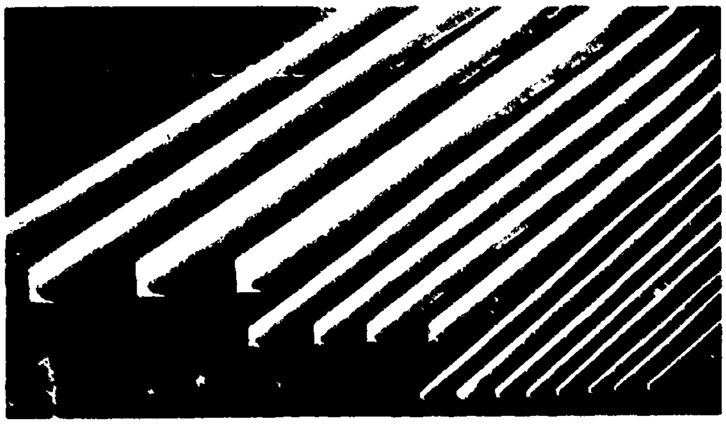
Figure 7-46.—Leather fillets.



68.54X
Figure 7-47.—Wax fillets.

A leather or wax fillet may be forced or molded (pressed) into place by a FILLET IRON. When used for wax filleting, the iron is heated slightly over an alcohol lamp. The spherical ends of the fillet iron are of different diameters. A full set of irons provides spheres ranging from 1/8 inch to 1 inch in diameter (in 1/16-inch increments). The irons should be kept clean at all times. To remove shellac from them, use a rag moistened in alcohol. To remove glue, use a rag soaked in hot water.

Running in Leather Fillets

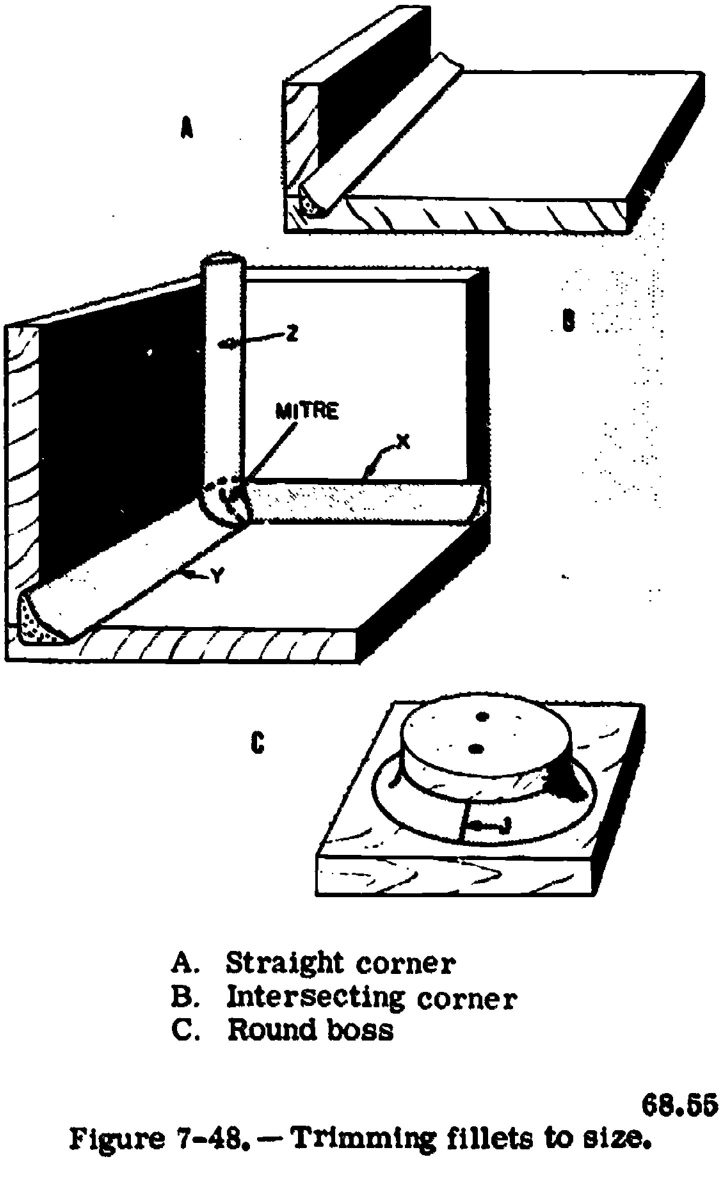
Leather fillets are usually run on patterns when speed of production rather than durability of the pattern is the important consideration. They are frequently used in job shops and aboard repair ships when relatively few castings are to be made from a pattern. The cutting of leather fillets and the methods used to secure the fillet in place are discussed in the following paragraphs.

Cutting Leather Fillets

The first step in running leather fillets is to cut each fillet to the rough length. For a straight corner, cut the fillet slightly longer than the corner it is to be run in. (See part A of fig. 7-48.) The overhanging ends are trimmed with a sharp knife or paring chisel after the fillet is secured to the job and the shellac or glue has set.

For an intersecting corner (part B of fig. 7-48), the bottom fillets have their corner ends trimmed to form a miter joint where they meet. These fillets (X and Y) are run first. The vertical fillet (Z) has its corner end trimmed to a rounded feather edge or "fade out." It is run last. All are cut slightly longer than required, then trimmed flush with the pattern edges later.

For a round boss, the length of fillet is measured roughly by wrapping it snugly around the boss and marking the joint with knife cuts. See J of part C of fig. 7-48. The fillet should be kept long enough to completely encircle the boss; then if it is too long after being run in place, the excess can be trimmed off with a bench knife.



A. Straight corner
B. Intersecting corner
C. Round boss

68.55

Figure 7-48. — Trimming fillets to size.

Occasionally you will find leather fillets which are stiff and not pliable. This condition can be improved by soaking the fillets to be run with glue in cold or lukewarm water; those to be run with shellac may be brushed with alcohol.

After you have trimmed the fillets to size, you are ready to continue.

Methods of Securing Leather Fillets

Two methods are employed to secure leather fillets to a pattern. One method is to use shellac as an adhesive agent and the other method is to glue the fillets to the job.

The first method is considered the better of the two. The shellac does not set as rapidly as the glue; therefore, more time can be taken during the operation to obtain the best possible results. Also, fillets that are shellacked are not so readily loosened by exposure to moisture as those attached to a pattern with glue. More time is required to run fillets with shellac; for that reason, glue is sometimes used on rush jobs or on patterns which will be used only once or twice. Fillets to be secured with shellac are usually run on the job after the first coat of shellac has been applied to the pattern. When glue is used, the fillets must be run before any shellac is applied because the glue will not adhere properly to a shellacked surface.

A good rule to determine which method of securing leather fillets to use is "Glue to wood and shellac to shellac." This means use glue to fasten leather fillets to bare wood and use shellac to fasten leather fillets to shellacked surfaces.

SHELLACKED METHOD.—Shellacked fillets are usually run on a pattern after the first coat of shellac has been applied to the pattern surface. Sometimes, only that portion of the pattern to be filleted is shellacked at this time; the remainder of the job is shellacked later. Lay the trimmed fillets on the workbench or a piece of board with the angular faces up. Apply one coat of shellac to all the fillets and allow several minutes for drying. Keep repeating the applications until the fillets will absorb no more shellac—allowing several minutes between coats—and until a sticky surface is obtained. Usually three coats are sufficient.

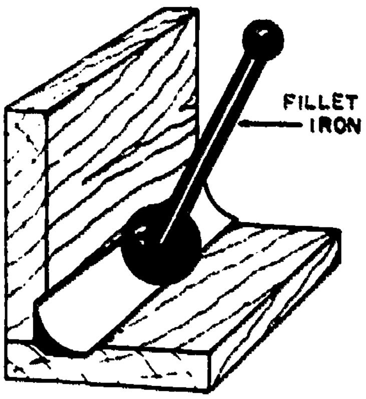
Hold a fillet at one end and apply the shellacked face to the corner. Dip the end of the fillet iron into alcohol. Iron the fillet well into place, and continue ironing until the fillet is set securely.

Dip the fillet iron into alcohol frequently and wipe the end clean with a piece of waste soaked in alcohol. After the fillet is in place, wipe excess shellac from the face and the surrounding area with a piece of waste moistened in alcohol. Run all fillets as rapidly as possible. Allow the fillets to become well set before doing any final trimming that may be necessary.

GLUED METHOD.—The glued fillet operation is slightly different from the shellacked fillet operation. Lay the trimmed fillets face down on the workbench with the angular face of the fillet up. Apply a coat of glue to the angular face of the fillet to be run first. Apply only the minimum of glue needed to hold the fillet to the pattern. Glue is not applied to a fillet until just before time for it to be run. If glue is applied on all fillets at the same time, it will chill and set before you can run them in place. Always work rapidly during this operation.

Immediately after applying the glue, lift the fillet off the bench by one end and place it "glue face" to the corner where it is to be located. Use the correct size of fillet iron and iron the fillet well into the corner. See fig. 7-49. Keep ironing until the fillet sets securely in place.

Clean the fillet iron frequently with a piece of waste dipped in hot water. Wipe excess glue off the face of the fillet and the surrounding pattern surface with a moist piece of clean waste. Do any necessary trimming with a bench knife and paring chisel after the glue has set.



68.56

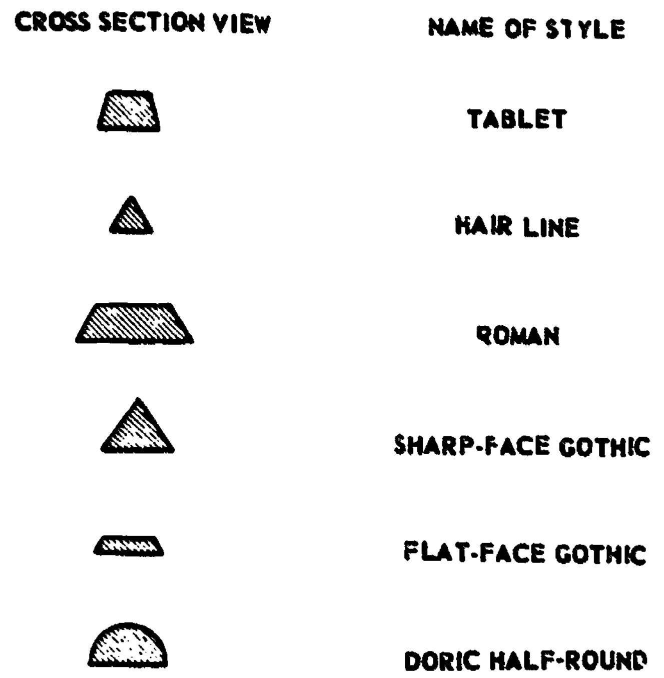
Figure 7-49.—Ironing a fillet.

PATTERN LETTERS, FIGURES, AND INSIGNIA

Pattern letters, figures, and insignia are placed on patterns to identify the casting or the pattern. They are also useful in the indexing and storing of patterns. The most common method is to put raised letters and figures on the pattern. The letters and figures may be obtained in various sizes, styles, and metals. The letters and numbers most commonly used are cast from an alloy of lead and tin, white metal, lead, aluminum, or brass. Some metal letters are made with points, sprigs, or spurs on the back so that they can be driven into a wooden board or riveted to a metal plate. Others are made without points and may either be shellacked to wood or soldered or sweated to metal. The sides are made with plenty of draft so that the letters will pull away from the sand freely and cleanly. Figure 7-50 shows the cross-section views of a few representative styles that are in common use.

Another method employs a special machine to emboss the letters and figures on strips of aluminum, zinc, or brass. These strips are then shellacked or tacked on the pattern. (See fig. 7-44.)

When ordering pattern letters from a pattern supply house, consider the manufacturer's system of packing them in assortments called FONTS. A font is an alphabet of letters with more of certain frequently used letters such as the vowels A, E, I, O, and U, and fewer of the little used consonants such as Q, X, and Z. A font is composed of the quantity of each letter which experience has shown will be needed in comparison to the frequency with



68.57
Figure 7-50. — Cross-section views of styles of pattern and tablet letters.

which other letters in the alphabet will be needed.

THE NUMBER OF A's FURNISHES THE KEY TO THE SIZE OF THE FONT. Notice in table 7-5 under the 10-A Font that there are ten of each of the letters A, I, N, O, R, S, and T; while there are 12 E's (20 percent more). With this in mind, you can approximate the amount of characters included in ANY font because the proportions are similar for all fonts regardless of their size. Although fonts vary, the size is always indicated with some marking such as 10A, 15A, 25A, 50A, 100A, etc.

RAPPING AND LIFTING PLATES

Rapping and lifting plates are devices provided on patterns to prevent splitting when the patterns are rapped for loosening prior to being drawn from the sand. They are also helpful to the Molder in lifting the pattern out, especially if it is large.

The plates are of various sizes and designs. They have one or more smooth holes into which a rapping bar is placed and struck. They also have one or more threaded holes into which a lifting pin is screwed to lift the pattern from the mold. See fig. 7-44.

When rapping or lifting plates are used, they are set below the surface of the pattern and fastened with screws.

PATTERN COATINGS

With the exception of the final checking of the pattern, the application of a pattern finish is the last step in the completion of a pattern. Because it is a very important step, the Patternmaker must know about pattern coatings materials and their application.

When you have completed the pattern and its core box, the surface of the pattern must be covered with some material which will render it hard, smooth, and resistant to the moisture of the molding sand. In addition, the pattern finish should make the pattern easier to withdraw from the mold.

Many types of pattern coatings are manufactured, such as pure shellac, lacquer based coatings or plastic resins. Keep in mind that a pattern coating used on patterns for one foundry may not be suitable on patterns for another, due to the differences in conditions, and the methods and materials used in different foundries. However, satisfactory results can be obtained by experimentation to select the most desirable pattern coating.

To be successful for foundry use, a pattern coating must:

1. Flow evenly and adhere to previously applied coats without lifting them.
2. Have a minimum drying time between coats.
3. Not raise the grain, which would require sanding between coats.
4. Not blister after application.
5. Not be brittle and chip off, but must be elastic enough to expand and contract without cracking or checking.
6. Dry over wax fillets in approximately the same time it dries over wood.
7. Be resistant to oil and greases.
8. Resist the heat and moisture and the abrasive action of the foundry sands.

To help you properly identify pattern coatings, a brief discussion of the various coatings and their application is given in the following sections.

Table 7-5. — Pattern Letter Fonts

	10-A	15-A	25-A	50-A	100-A		10-A	15-A	25-A	50-A	100-A
CHARACTERS	FONTS					CHARACTERS	FONTS				
A	10	15	25	50	100	Y	4	10	15	40	80
B	4	10	15	40	80	Z	3	8	10	25	30
C	7	10	20	40	100						
D	6	10	20	40	80	(TOTAL CHARACTERS)	169	295	500	1055	2110
E	12	15	30	50	120						
F	5	10	15	40	80						
G	5	10	15	40	80						
H	6	10	20	40	100	NUMERALS					
I	10	15	25	50	100						
J	4	10	15	40	80	1	4	10	15	50	40
K	4	8	10	25	70	2	3	8	10	40	30
L	7	10	30	40	80	3	3	8	10	40	30
M	6	10	20	40	100	4	3	8	10	40	30
N	10	15	25	50	80	5	3	8	10	40	30
O	10	15	25	50	100	6	3	8	10	40	30
P	6	15	15	50	80	7	3	8	10	40	30
Q	3	8	10	25	40	8	3	8	10	40	30
R	10	15	25	50	100	9	3	8	15	50	30
S	10	15	30	50	100	0	5	13	10	40	50
T	10	15	25	50	100						
U	6	10	20	40	60	(TOTAL NUMERALS)	33	87	110	420	330
V	4	8	15	25	60						
W	4	10	15	40	80						
X	3	8	10	25	30	TOTAL	202	382	610	1475	2440

68.189

Shellac

SHELLAC is used on patterns more than any other protective material because of its ability to dry rapidly and to contract. It forms a smooth, hard surface, which is essential to the easy drawing of a pattern from the molding sand. Shellac also seals the pores of the wood of the pattern against taking up moisture from the damp sand used in the foundry.

Shellac may be purchased for use in the pattern shop in two forms: dry flake shellac and liquid shellac. In Navy shops, it is purchased in the dry state for convenience in handling and storage. It comes in the form of very thin, small flakes of a bright amber color. Flake shellac should be stored in a cool, dry place and kept tightly covered so that dirt and wood chips will not get into it. Only enough shellac is prepared at one time as is needed for a short period. The preparation and storing of shellac are very important in obtaining a good pattern finish.

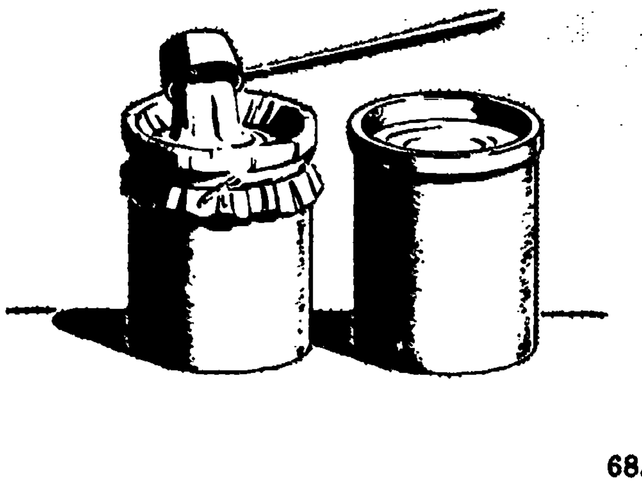
To mix shellac, fill a glass container or earthenware crock about three-quarters full with shellac flakes. Add denatured (ethyl) alcohol until it stands about 1/2 inch above the flakes. One gallon of denatured grain alcohol is needed for three or four pounds of flakes. The use of wood (methyl) alcohol or other solvents is not advisable since such solvents retard the proper drying of the shellac and affect its durability.

The mixture should be stirred and then allowed to stand for a day or more. Every few hours it should be stirred until all the flakes are dissolved.

Liquid shellac should never be stored in metal containers or it will become discolored. It should be kept in a cool place where the sun will not strike the container. After the flakes have dissolved thoroughly, strain the mixture. With string, tie two or three layers of gauze sheets or cheesecloth over the mouth of an empty crock. (See fig. 7-51.) Slowly strain the shellac into the empty crock, using a copper dipper to transfer the mixture. Copper is less susceptible to attack from the solution than most metals and will not discolor the shellac. The straining removes most of the foreign matter and grit. Drain the first crock to within one-half inch of the bottom and discard the remainder. This portion contains grit and other foreign bodies that will pass through the cloth if an attempt is made to strain it. Remove and discard the gauze. Place the dipper in a container of alcohol to prevent shellac from accumulating on it and hardening. Place a cover over the crock to keep it clean and to prevent the alcohol from evaporating.

When filling individual shellac pots from the prepared supply, use the copper dipper. When finished, place the dipper in the container of alcohol; do not leave it in the full crock of shellac. Always replace the cover on the crock. If the shellac is found to be somewhat foggy or discolored, it may be CLEARED by the addition of a very small amount of oxalic acid crystals (1 teaspoonful for each 2 or 3 quarts). If it is too thick, thin it by adding a small amount of alcohol and stirring until the proper consistency is attained.

Although care is needed in the preparation of shellac, it is equally important that the shellac be kept in suitable containers that will give it proper protection when it is not being used. Many designs of shellac pots are made; however, the principal object, regardless of design, should be to keep the contents tightly covered and clean at all times. Shellac should be strained through gauze or cheesecloth when being poured into a shellac pot.



68.58

Figure 7-51. — Straining shellac.

Good shellac should be a light golden yellow or orange color and very transparent. It should be fairly thin (much thinner than paint) and free of dirt or wood chips.

Shellac prepared in this way is known commercially as "orange shellac," but in the shop it is commonly called "yellow shellac." Pigments can be added to the shellac to make it red or black for use in indicating certain details of the pattern. If pigments are added, the shellac must be thinned with alcohol to make it brush smoothly.

Shellac brushes should be of good quality bristles. Brushes used are from 1 inch to 2 1/2 inches wide, depending on the size of the work being done. The brushes in use should be suspended in the shellac but not left standing in the shellac pot. Standing will bend the bristles and eventually ruin the brush. Brushes not in use should be carefully washed out in alcohol and stored away from dust and dirt.

Before you start to shellac a pattern, inspect the surface to make sure that all sanding has been completed and that all glue has been removed from the face of the pattern. Wood surfaces should be thoroughly sandpapered to a smooth finish and brushed or blown free of all dust before shellac is applied. Inspect the shellac pots to see if the shellac needs thinning or clearing. If the shellac contains any foreign matter, throw it out and refill the pots with clean shellac.

The first coat of shellac applied to a pattern should be the natural uncolored shellac. If black or red shellac is applied on the first coat, the solution tends to run along the grain of the wood in much the same manner that ink spreads over the surface of a blotter, the lines of demarcation between the different colored shellacs will not be clear-cut.

Dip the brush into the shellac and remove the surplus by drawing the bristles over the dowel crossbar at the top of the shellac pot. Apply the shellac to the job with long strokes of the brush and with the brain whenever possible. Shellac dries quickly and must be applied rapidly. Shellac spreads more uniformly if applied with the grain. Avoid overlapping previous applications and brush the shellac out to a smooth surface. Always pass the brush in an outward direction from the job, or else the sharp edges will scrape shellac from the brush and create an accumulation that will drip or run down the edge of the work.

Allow the shellacked job to dry for about one hour. Fill in all nail holes, screw holes, etc. Inspect the job carefully to see if all the shellac is dry. The job will feel rough due to a slight raising of the soft-grain portion of the wood surface. The soft wood cells absorb some of the alcohol in the shellac and swell. Also, a certain amount of dust particles from the surrounding atmosphere settles on the surface of the work.

Sandpaper all shellacked surfaces. After all sanding operations have been completed, brush the job off thoroughly with the bench brush. The job is now ready to have its different parts shellacked according to their respective colors. First, shellac all parts of the job that are to be yellow and allow them to dry. Next, shellac all parts that are to be black. Last, shellac the red parts. Where one color leaves off, be careful to make a neat, true line of demarcation. Ragged lines spoil the appearance of the work. Be careful not to slop the shellac on the job. Keep the work neat at all times. Do a thorough job when shellacking the pattern, especially if it is to be used with synthetic sands in the foundry.

As many coats of shellac can be added as are desired; however, each coat should be allowed to dry thoroughly and be carefully sanded before the next coat is applied. Usually three coats of shellac are sufficient. After applying the final coat of shellac, allow it to dry thoroughly. Then, tear a sheet of 4/0 sandpaper into four equal pieces. Dull one of the pieces. Very lightly rub each shellacked surface to remove any signs of roughness. Brush the job off carefully with the bench brush. Rub all surfaces thoroughly with a clean piece of waste or soft cloth.

When shellacking hardwood patterns the shellac should be much thinner than that used on redwood and pine. Hardwood does not absorb as much of the shellac as the softer woods absorb, so that the shellac has a tendency to pile up and produce an irregular, gummy surface.

Lacquer and Synthetic Plastic Resin

Although shellac for many years has been the accepted standard protective coating for patterns, lacquers and synthetic plastic resins have come into use recently. It is claimed that these new coatings are superior to shellac because they produce a surface that is smoother, harder, and more resistant to moisture. There is also less of a tendency for foundry sand to stick to lacquer and plastic coatings.

LACQUER is available in various colors and can be applied to the pattern by spraying, dipping, or brushing. Several thin coats are better than a single thick coat. If wax fillets have been used on a pattern, you must coat them with shellac before applying the lacquer. If they are not coated, the wax will prevent the lacquer from hardening and will cause the sand to stick to the pattern. Lacquer solvents evaporate very quickly; and you must remember to add thinner from time to time. Most of the lacquer solvents are flammable and toxic, and appropriate safety precautions must be taken to prevent fire and to provide adequate ventilation.

SYNTHETIC PLASTIC RESIN coatings are said to be ideal for wood patterns that are designed for prolonged and hard usage in the foundry. Patterns to be coated with plastics must be made from well-seasoned lumber and must be sanded smooth. Wax fillets must not be used. A filler or undercoat of lacquer is desirable before applying the plastic. The desired coloring pigment is usually added to the lacquer filler coat. Sand the filler coat smooth and then apply the plastic resin. Follow the manufacturer's instructions in mixing the plastic resin, catalyst, and thinner. Each coat must be air-dried and then baked in an oven at 140° F for 2 hours before applying the second coat. Two or three coats are usually applied. If well-seasoned lumber has been used in the construction of the pattern, the curing of the resin in the oven will have no harmful effects. Shellac must not be used as an undercoat because it will blister under the heat required to cure the plastic resin coating.

PATTERN COLOR CODES

In order to designate certain parts of the pattern, the practice of painting the patterns various standardized colors have been adapted. The coloring of the various parts of the pattern prevents embarrassing and costly mistakes in the foundry; the Molder can tell at a glance what the molding routine should be. In addition, the coloring is used as an aid in getting all of the pattern parts properly assembled. For example, one color may be used to represent that part of a pattern which, when cast, will be in the "as-cast" condition. Another color may be used to show other parts representing the core prints or projection(s) for the openings of a hollow casting.

Standard Pattern Color Code—1932

One method of standardizing the pattern color code has been prepared and adopted by the American Foundrymen's Society (formerly the American Foundrymen's Association). This color code has been approved and recommended for Navy use by the Naval Ships Systems Command. This color code known as the STANDARD PATTERN COLOR CODE—1932 is illustrated in figure 7-52 and is as follows:

1. Black—identifies surfaces to be left unfinished.
2. Red—identifies surfaces to be machined.
3. Alternating red and yellow diagonal stripes—identifies seats of and for loose pieces.
4. Yellow—identifies core prints and seats for loose core prints.
5. Alternating black and yellow diagonal stripes—identifies stop-offs.
6. (Optional)—A white line may be used for the indication of any change in the direction of draft.

This pattern color code has been adopted as standard practice by the Joint Committee on Pattern Standardization, which is sponsored by the American Foundrymen's Society and consists of official representatives from various national organizations. This standard was approved as the American Tentative Standard B-45, 1—1932 by the American Standards Association, and as Commercial Standard CS 19-30 by the Bureau of Standards, U.S. Department of Commerce.

Tentative Standard Pattern Color Code—1958

Another method of standardizing the color code is the TENTATIVE STANDARD PATTERN COLOR CODE which may be adopted for new patterns. All new patterns should be painted in accordance with the standard practice adopted as of 1958 by the Pattern Colors Committee, Pattern Division, American Foundrymen's Society. This standard, illustrated in figure 7-53 is as follows:

1. Clear coating—identifies unfinished casting surfaces, the faces of core boxes, and the pattern or core box parting faces.
2. Red—identifies surfaces to be machined.
3. Aluminum—identifies seats of and for loose pieces.
4. Black—identifies core prints and seats for loose core prints.
5. Green—identifies stop-offs.

(Optional)—A white line may be used for the indication of any change in the direction of draft.

Molder's Blueprint

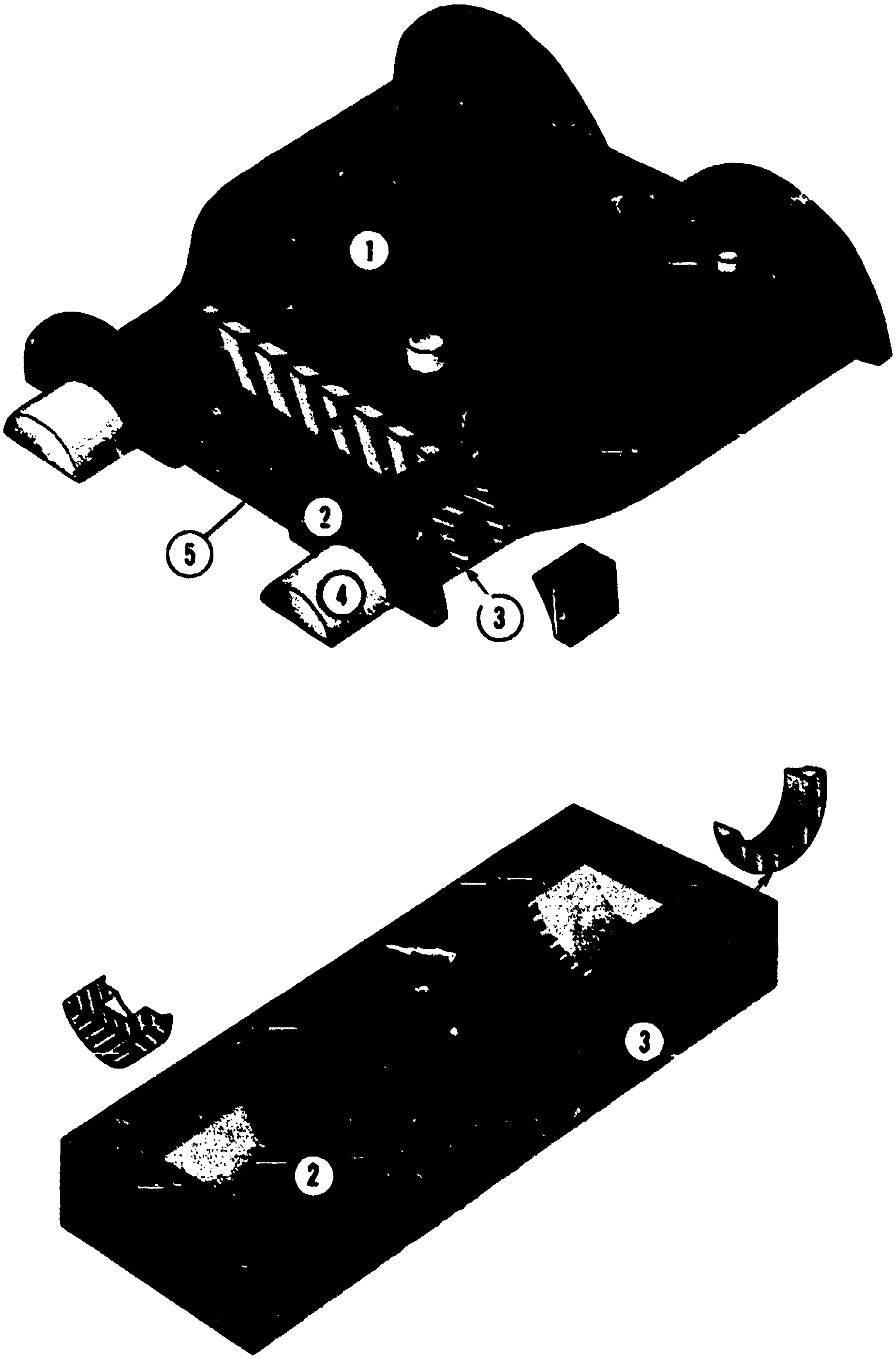
Places where cores will cut through to the exterior of the casting, as well as the core outline on the joints of parted patterns, are indicated by the same pattern color as are core prints. This is called the MOLDER'S BLUEPRINT and should be included as standard practice. Painting the parting surfaces in this manner will prevent the possibility of positioning cores end for end and will eliminate costly mistakes.

METHODS OF CONSTRUCTING PATTERNS

As a PM3 or PM2, you must be proficient in the use of handtools and power tools; however, your real success will depend on your ability to utilize different methods of construction. Making a pattern that can be used as a tool by the Molder to produce a sound, usable casting, requires that you be familiar with all styles of construction. In addition, you must have the necessary knowledge of foundry work to construct a pattern so that there will be no waste time in the foundry, and so that the casting will be as nearly perfect as can be expected. The ability to construct the pattern develops with practice and experience, as does skill in the use of tools.

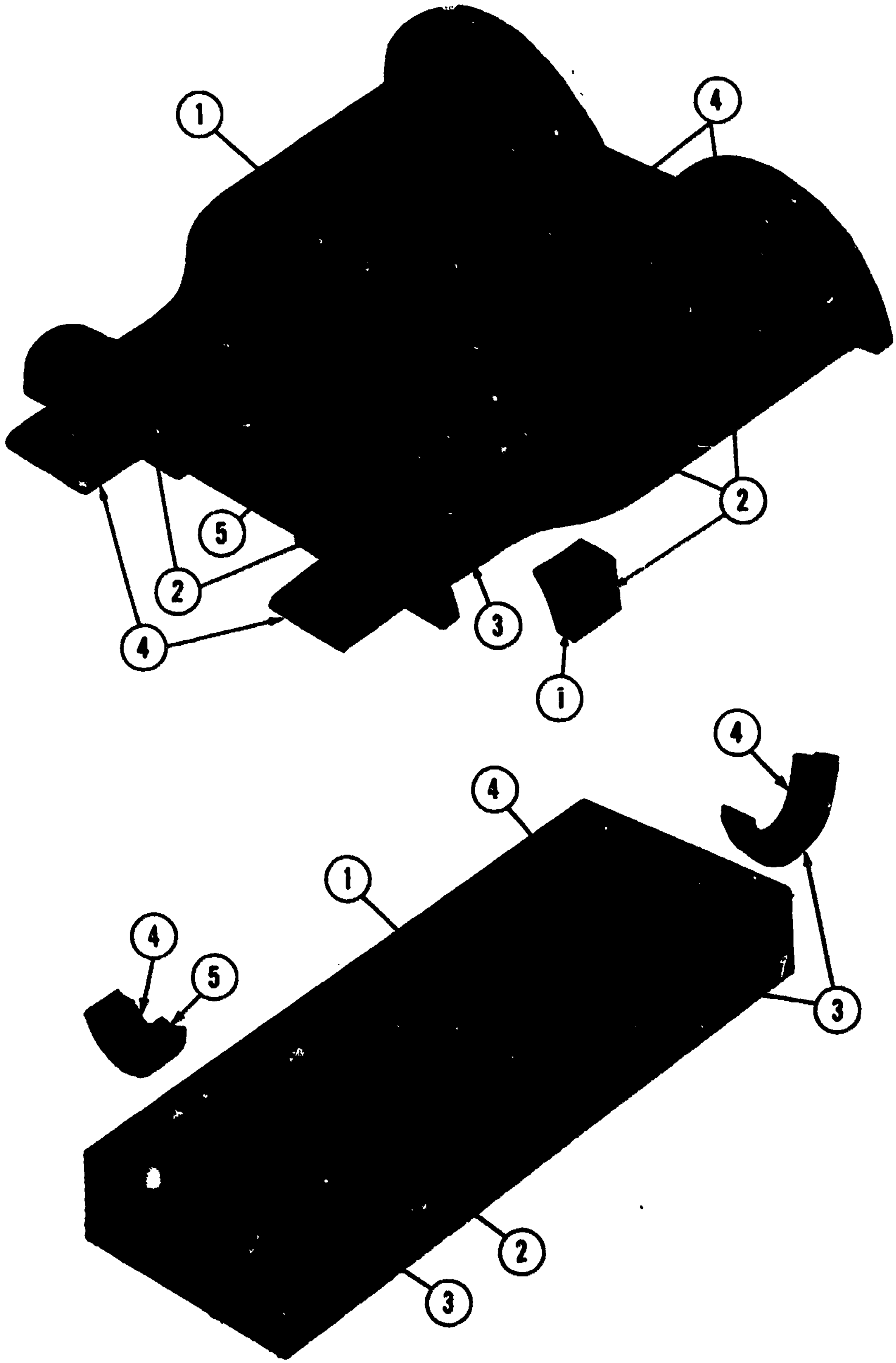
In pattern construction, careful consideration must be given to the direction of the grain in the wood in order to:

1. Minimize end grain or short grain.
2. Obtain a pattern of maximum strength.



C102.1.1X

Figure 7-52. —Standard Color Code—1932.



C102.1.2X

Figure 7-53.—Tent·.tive Standard Color Code—1958.

3. Utilize the direction of grain to counteract the warpage of adjacent pieces.
4. Avoid cutting or planing against the grain during the actual construction.
5. Provide a smoother draw from the mold.

The actual construction of the pattern is determined by the number of castings to be made from it, or its proposed use. Some of the methods of pattern construction are:

1. SOLID CONSTRUCTION (fig. 7-54).—A pattern shaped from one piece of pattern material.

2. ONE PIECE BUILT-UP CONSTRUCTION (fig. 7-55).—A pattern not necessarily made from one piece of wood. It can be a series of pieces formed to make a certain shape, but the pattern will be in one piece.

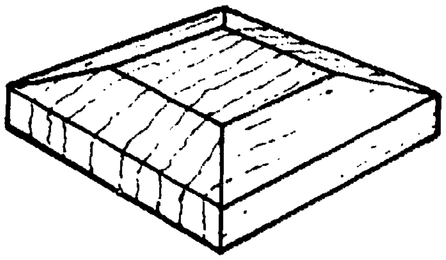
3. PARTED CONSTRUCTION (fig. 7-56).—A pattern made in two or more parts. (Collapsible patterns fall under this category.)

4. SEGMENTAL CONSTRUCTION (fig. 7-57).—A pattern built up in a series of courses (segments) with the alternating end joints arranged midway between those of the preceding course.

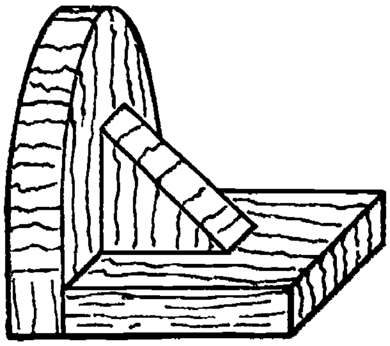
5. STAVED CONSTRUCTION (fig. 7-58).—The attaching of staves to polygonal headers in the building of cylindrical bodies. It is also used for semicircular cavities.

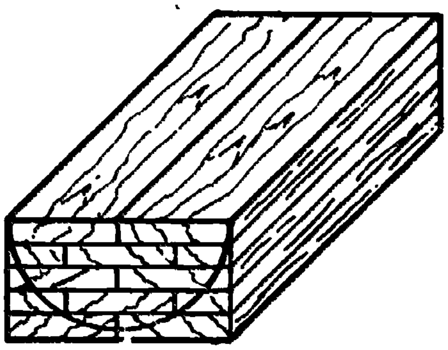
6. LAGGED CONSTRUCTION (fig. 7-59).—The fastening of narrow strips about batten foundations so shaped as to follow a line parallel to the contour of the pattern.

7. STEPPED-UP CONSTRUCTION (fig. 7-60).—So called because the material, when fastened together, resembles steps.

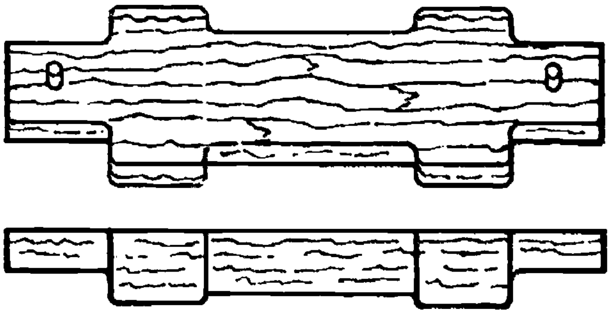


68.190
Figure 7-54.—Solid construction.

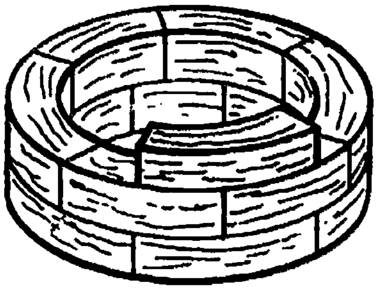




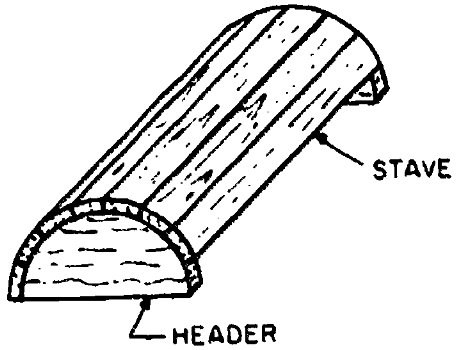
68.191
Figure 7-55.—One piece built-up construction.



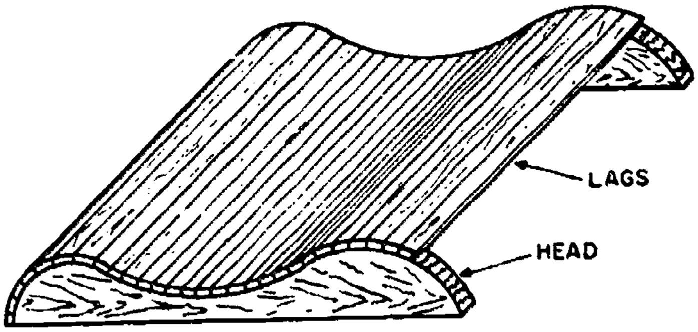
68.192
Figure 7-56.—Parted construction.



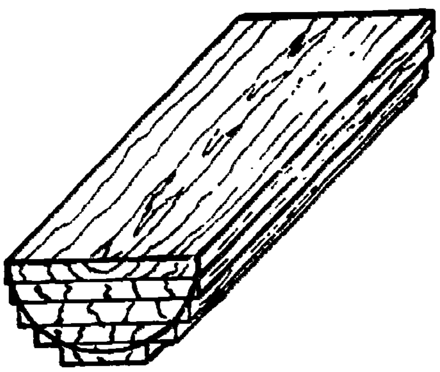
68.193
Figure 7-57.—Segmental construction.



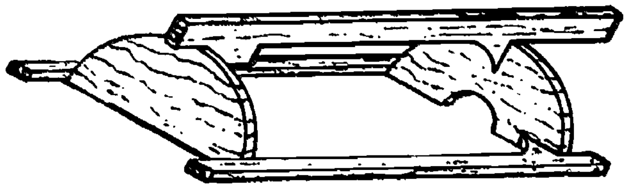
68.194
Figure 7-58. — Staved construction.



68.195
Figure 7-59. — Lagged construction.



68.196
Figure 7-60. — Stepped-up construction.



68.197
Figure 7-61. — Skeleton construction.

8. SKELETON CONSTRUCTION (fig. 7-61). — Is a framework representing the interior and exterior shape and the metal thickness of the required casting.

9. FAN CANT CONSTRUCTION (fig. 7-62). — Form of stepped-up work with the grain of the wood radiating from a common center. Used in the construction of propellers when the diameter is less than 4 feet.

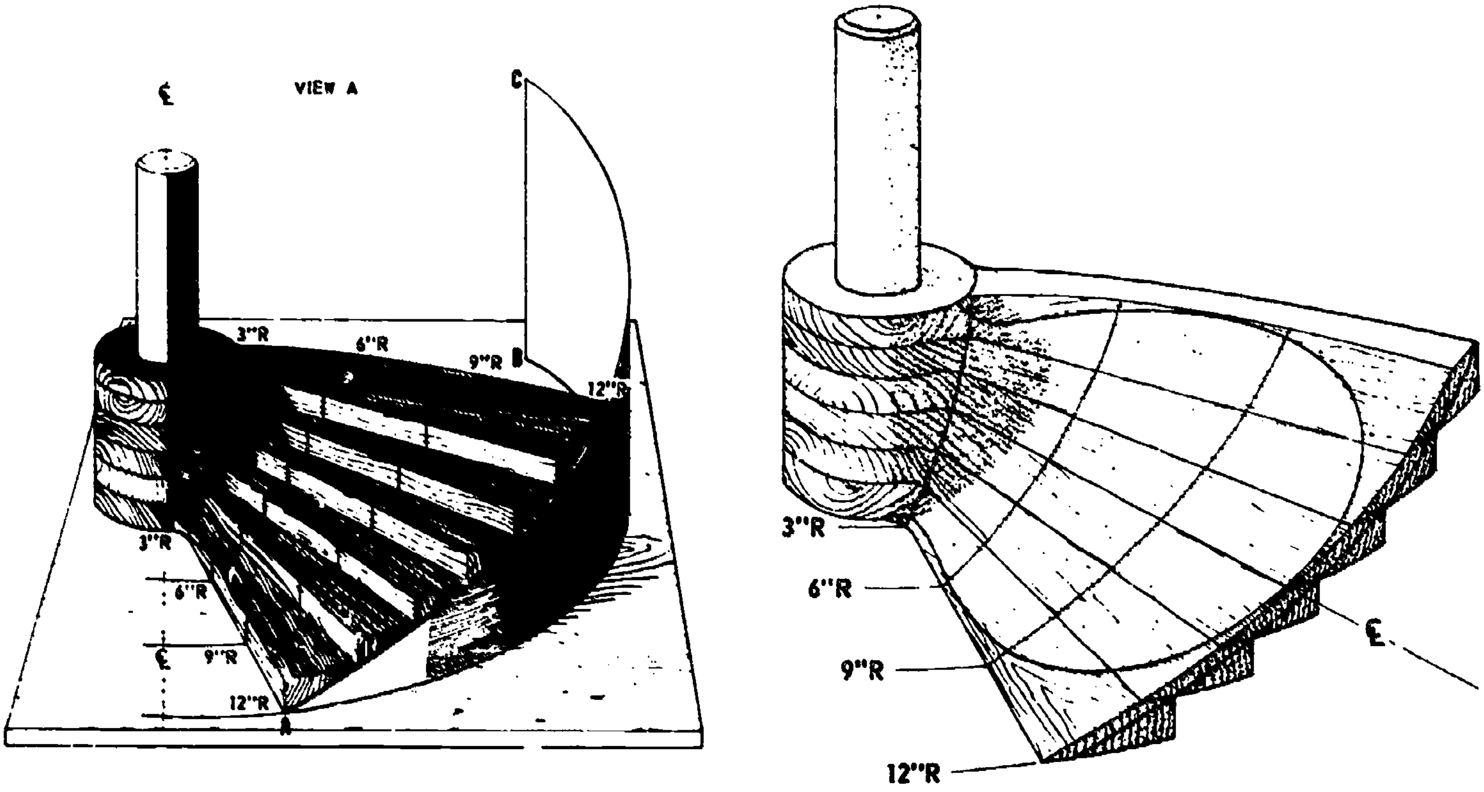
10. CROSS CANT CONSTRUCTION. — Form of stepped-up work with the grain of the wood running in a transverse direction. Used in the construction of propellers when the diameter is more than 4 feet.

The various construction methods and techniques for the different types and kinds of patterns are discussed in various sections throughout this training manual.

CONSTRUCTING WOODEN FLASKS

As a PM3 or PM2, you must be familiar with the design and methods for making pattern flasks for the foundry.

A FLASK is a metal or wooden boxlike frame in which the mold for a casting is made. It may be rectangular, trapezoidal, or round in shape. Most molds require at least two flask sections so that the mold can be opened to remove the pattern. The upper section is called the COPE; the lower section is called the DRAG. In three-part flasks, the middle section between the cope and the drag is known as the CHEEK. Each flask section is made to fit perfectly with its mating section or sections by the alignment of the flask pins with the flask pin holes. There are many flask designs available, but the standard flask section used by the Navy is the



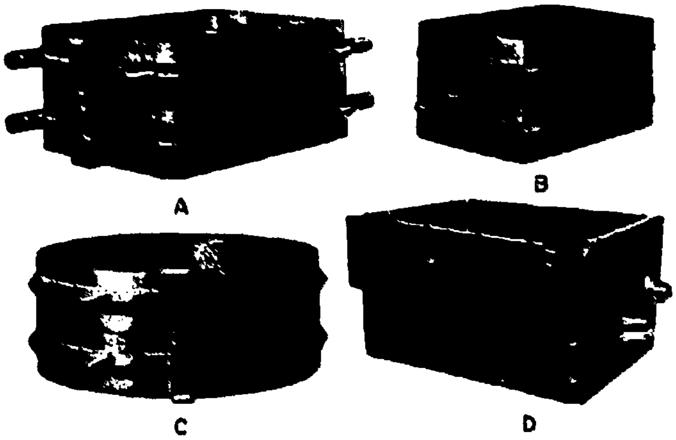
23.111:.112

Figure 7-62.—Fan cant construction.

interchangeable type. In other words, the individual flask sections can be used interchangeably as either cope, drag, or cheek sections. Flasks may be used in either bench, machine, or floor molding procedures. Most commercial flasks are made of cast iron, aluminum, or pressed steel, and are equipped with two or more lifting handles for ease of manipulation in lifting off, rolling over, and closing the cope. For very large or special floor molds, the flask sections are usually fabricated out of plate steel stock bolted, riveted, or welded together. These very large flasks are equipped with one or two trunnions at each end for convenience in attaching a crane, hoist, or chain-fall.

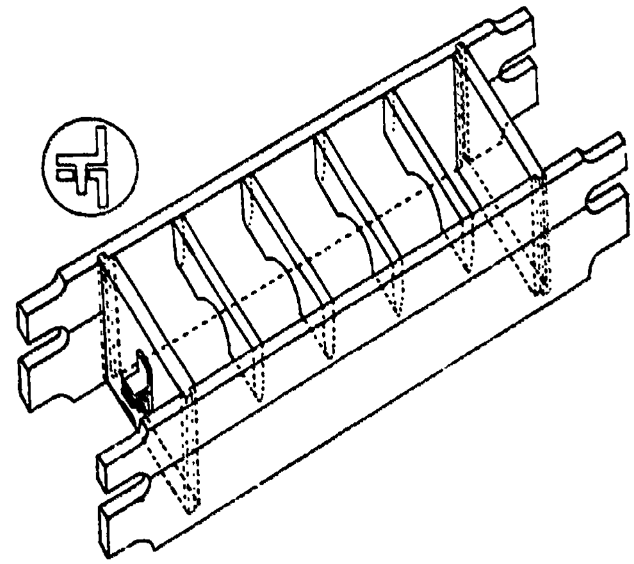
The flasks shown in figure 7-63 are typical of those available in Navy foundries. The flask in view A is the standard two-man, double-lug, interchangeable flask. This type is used almost exclusively by Navy Molders. A one-man, single-lug flask is shown in view B; a circular flask in view C; and a wooden snap flask in view D. The steel flasks shown in views A, B, and C are much alike in appearance and use; snap flasks (view D) are a bit different and warrant additional discussion.

SNAP FLASKS are wooden or metal boxlike frames made with hinges at one corner and with latches at the opposite corner. Snap flasks are always made in sets: that is, the cope and drag sections are not interchangeable, and the cope depth is usually greater than that of the drag. After the mold is rammed, the latches are opened, the flask is spread apart, and is lifted off the mold. A wooden box or a lightweight metal SLIP-JACKET is slipped over the mold. Weights are placed on top of the cope. The slip-jackets keeps the mold from crumbling under the weight of molten metal and the pressure which develops as the casting is poured. The weights tend to act as clamps in holding the several parts of the mold together and in preventing metal run-out at the parting line. Snap flasks are used extensively in production foundries because they eliminate the need for a large number of small standard flasks. By using a snap flask and slip-jackets, a Molder can ram up a large number of molds with one flask. As the poured castings solidify, the



102.12X

Figure 7-63. — Molding flasks.



23.223X

Figure 7-64. — A wooden flask.

slip-jackets may be removed and slipped over the next line of molds to be poured.

Because of limited shipboard stowage facilities only those flask sizes considered essential are available. However, from time to time a flask larger than the standard 30" by 30" by 8" flask may be necessary. The Patternmaker will then be called upon to build the special flask for the particular molding job. In deciding upon the methods of construction, the Patternmaker will take into consideration the materials available; the size, shape, and weight of the casting; the kind of metal to be poured; the space allowance for the gating and risering systems; the number of times the flask is to be used; and the flask accessories required such as flask pins, bars, and lifting handles.

The flask must be made strong enough to withstand the rough usage it will get in the foundry. Wooden flasks are made with dado or housed lock joints and are often reinforced with metal supports and tie bars. Fir, yellow pine, white pine, or oak are the kinds of wood used in flask construction. Oak is usually used for extremely heavy castings. Yellow pine or fir is more frequently used in wooden flask construction because of its relatively low cost and great durability. (See fig. 7-64.)

A wooden flask is made with the sides extending beyond the two ends a distance of 6 to 8 inches. These extensions serve as handles for the Molder, in lifting off and closing the cope. For large flasks that are to be handled by crane or hoist, two trunnions are fastened to the flask at opposite ends. The Patternmaker will also aid the Molder by constructing such accessories as molding boards, bottom boards, wedges, riser heads, and flask bars necessary for the specific molding job for which the flask is to be used.

JIGS

In building patterns, there will be many occasions when you will have to call upon your own experience and ingenuity to devise and construct a means of holding a particular odd or circular shaped pattern member in order to cut or shape it, scribe lines on it, or position one pattern member to another. The means that you devise is called a JIG.

A jig, as used in patternmaking, could be described as any device used to mechanically maintain the correct position between one piece of work to another or a piece of work and a tool.

When constructing a jig, the points to consider are:

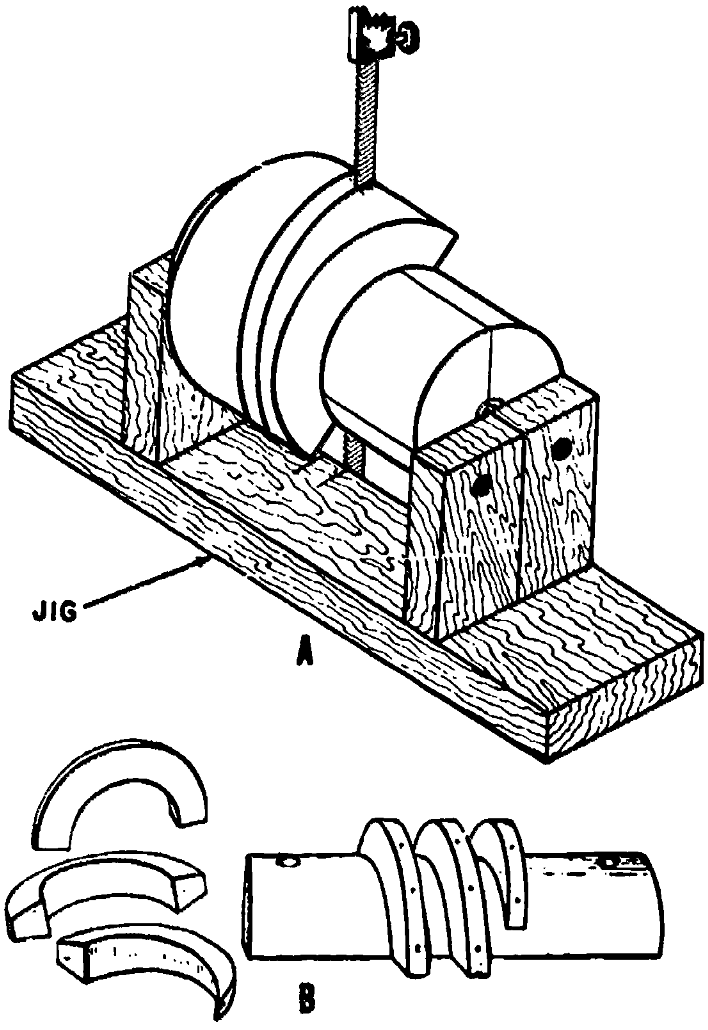
1. The jig must hold the pattern member in such a way that the member cannot shift or change position.

2. The jig must not damage the pattern member.
3. The jig must be made accurately so that the desired precision can be attained.
4. The jig must be safe to use.

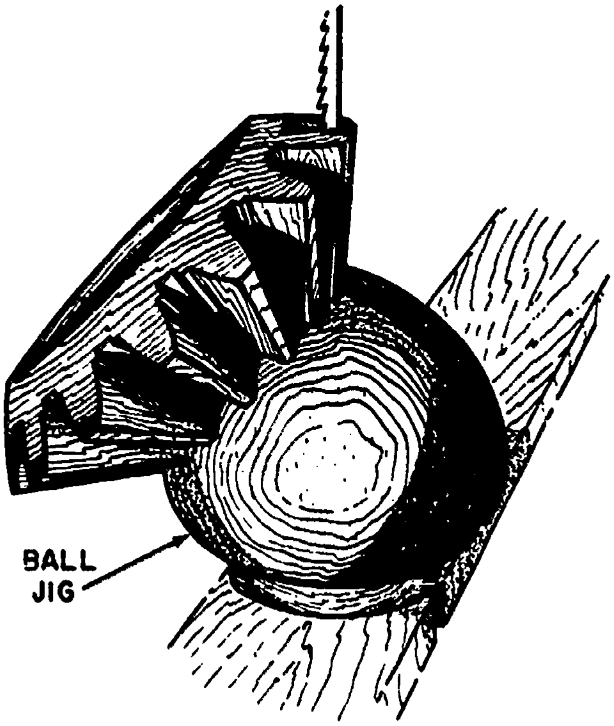
Figures 7-65 and 7-66 illustrate two types of jigs.

The jig template is a combination template and jig. Any jig that has the outline of a cut to be made scribed on its surface or supports a separate template is called a jig template.

Figure 7-67 illustrates one type of jig template.



23.130X
Figure 7-65.—Shaping the worm gear thread by using a jig and bandsaw.

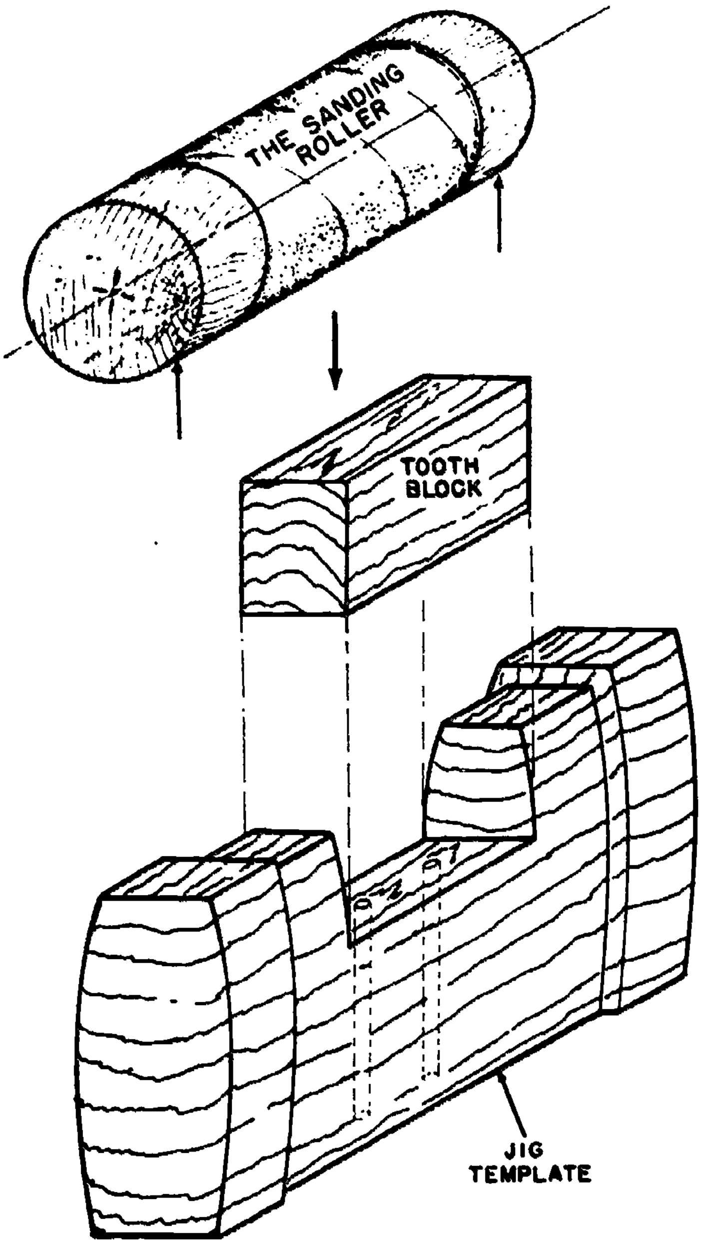


23.126X
Figure 7-66.—Using a ball-shaped jig and band-saw to shape bevel gear teeth.

PATTERNS FROM OLD CASTINGS

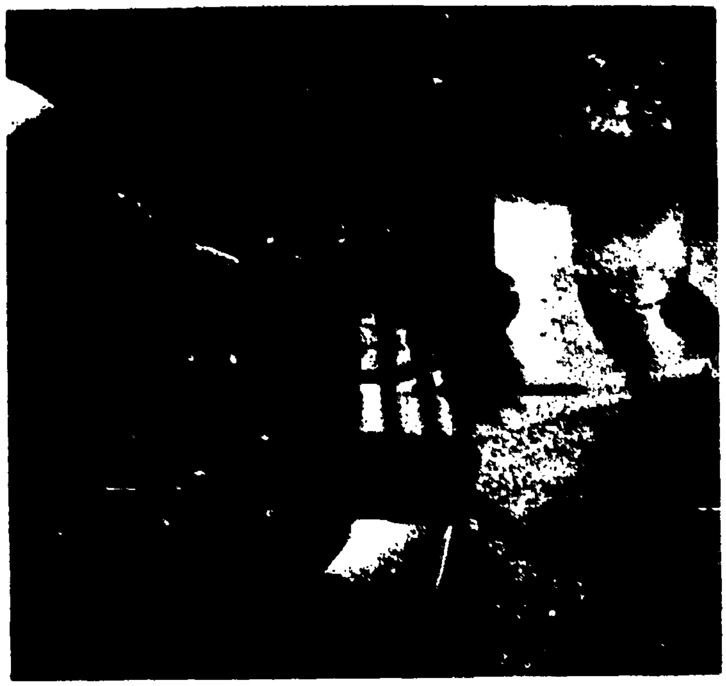
There may be emergencies when time will not permit the making of a new pattern. On such occasions, the old casting may be used as the pattern. Additional material must be added to the old casting to allow for the shrinkage of the metal in order that the new casting will not be too small. Plastic lagging material is supplied in sheets for this purpose. (See fig. 7-68.)

Before applying the lagging material, the surface of the old casting is cleaned and smoothed. Then, the sheet lagging material is cut into pieces and immersed in a solvent known as methyl-ethly-ketone. As soon as these pieces become very pliable and sticky, they are applied to the casting. They will shape very easily, even on the irregular surfaces, with pressure from the fingers.



23.124
Figure 7-67.— Jig template and sanding roller for shaping gear teeth.

When the ketone has evaporated, the lagging material will adhere firmly to the casting. The lagging material shrinks in thickness after dipping and drying. If a greater thickness is desired on a surface, additional layers of lagging material may be applied to the original layer. When dry, the outer surface of the lagging material is relatively hard and may be sanded and lacquered to a smooth surface.



68.97X
Figure 7-68.— Application of plastic lagging material.

CAUTION: Methyl-ethyl-ketone is highly flammable, volatile, and toxic. Use it in a well ventilated area. Avoid prolonged or repeated contact with skin and avoid breathing the vapors. Be sure to take the proper precautions to eliminate the hazards of fire and explosion.

In addition to applying plastic lagging material to the old casting to compensate for the shrinkage of the metal, the old casting must be prepared as follows:

1. All surfaces are to be clean and smooth so that they will draw from the sand.

2. Small holes such as tapped and drilled holes are to be filled.

3. Missing parts or surfaces are to be built in.

4. Machined surfaces are to be built up.

5. Core prints (if necessary) are to be added and core boxes provided.

CHAPTER 8

SHOP MATHEMATICS

Mathematics is as important to you as a Patternmaker as are manual skills and good tools. It is a universal language that enables you to understand measurements and values written by a foreign speaking designer as well as those written by an English speaking designer.

As a PM, you will constantly be working with fractional measurements, calculating quantities of materials, and developing geometric outlines just to mention a few of the applications for mathematics that you will encounter.

This chapter is not meant to be a complete text in shop mathematics. Instead, it is a review of the basic mathematical knowledge you will need as a PM3 or PM2 and a guide to some of the applications of that knowledge.

Tables of weights, measures, and equivalents are useful references when solving many of the mathematical problems you will encounter as a Patternmaker. Tables 8-1, 8-2, 8-3, and 8-4 are referenced at appropriate points within this chapter; other tables (Tables 8-5 through 8-9) with which you should be familiar are located at the end of this chapter.

If you desire further study of mathematics, you can obtain the following manuals through your Information and Education Office:

- Mathematics Vol. 1, NAVPERS 10069-C
- Mathematics Vol. 2, NAVPERS 10071-B
- Mathematics Vol. 3, NAVPERS 10073-A
- Engineering Aid Programmed Mathematics, Part 1, NAVPERS 94469-1
- Engineering Aid Programmed Mathematics, Part 2, NAVPERS 94469-2
- Engineering Aid Applied Mathematics Workbook, NAVPERS 94470
- General Mathematics for Construction Ratings, NAVPERS 94415
- PREP-TEXT Mathematics Series, Volumes 1 through 8, NAVPERS 93492-1 through 93492-8.

FUNDAMENTALS OF MATHEMATICS

A broad definition of the term Mathematics is; that science which deals with the relationships which exist between quantities and operations, and with methods by which these relationships can be applied to determine unknown quantities from given or measured data. The fundamentals of mathematics remain the same no matter to which field they are applied. Mathematics has been divided into a number of different branches. You will be principally concerned with four of these branches; ARITHMETIC, ALGEBRA, GEOMETRY, and TRIGONOMETRY.

Arithmetic is that branch of mathematics which deals with the simple computation of real numbers by using addition, subtraction, multiplication, and division.

Algebra is a branch of mathematics in which letters and symbols are used in place of numbers or values to construct equations in accordance with established mathematical rules.

Geometry is that branch of mathematics which investigates the relations, properties, and measurement of solids, surfaces, lines, angles, graphs, etc.

Trigonometry is the study of the properties of triangles and of trigonometric functions and their applications.

COMMON FRACTIONS

Common fractions are used extensively in patternmaking as most of your measuring devices, such as the standard rule and the shrink rule, are divided into common fractional increments, i.e., 1/2", 1/4", 1/8", etc.

The common fraction can be defined as a simple method of dividing a whole number or object into any number of equal parts such as dividing one inch into four equal parts or dividing a line into four equal parts. These equal parts would then be defined as increments of one fourth and we would know that four increments would equal the whole number or object. Any part less than the whole would be written as a common fraction such as 1/4" or 3/4". It can also be said that a fraction is an indication of division.

The common fraction contains two parts: the DENOMINATOR and the NUMERATOR. The denominator shows into how many equal parts the whole is divided and the numerator shows the number of these equal parts that are being considered.

Example: $\frac{5}{8}$ Numerator / Denominator

Some common fractions have EQUIVALENT fractions. Equivalent fractions are fractions that are equal in value.

Example: 4/8 = 2/4 = 1/2

When a fraction has been changed to an equivalent fraction with smaller numbers in the numerator and denominator, it has been reduced to lower terms.

To reduce 2/8 to its lowest terms, divide both the numerator and the denominator by 2 which is the largest COMMON DIVISOR to both the denominator and the numerator. When a fraction cannot be reduced any further, it has been reduced to its lowest terms.

Example: $\frac{2}{8} \div \frac{2}{2} = \frac{1}{4}$

To raise a fraction to higher terms, simply multiply both the denominator and the numerator by the same number.

To add fractions with the same denominator, add the numerators but leave the denominator the same.

Example: 3/8 + 1/8 + 1/8 = 5/8

To add fractions that have different denominators, change the fractions to equivalent fractions having the same denominator and then add the numerators and place the sum over the denominator.

Example: 1/4 + 5/16 = ?
1/4 = 4/16 therefore
4/16 + 5/16 = 9/16

In addition, as well as subtraction, having a COMMON DENOMINATOR is an essential factor. A common denominator of several fractions is any number that can be exactly divided by their denominators. You should always use the smallest possible number for the denominator. This is called the LEAST COMMON DENOMINATOR.

To find the least common denominator, take the largest denominator and proceed in multiples of that denominator until you find the smallest number that is divisible by the smaller denominators. Therefore, the least common denominator for 2, 4, and 10 would be 20.

To subtract fractions having different denominators, change the fractions to equivalent fractions having a common denominator and then subtract the numerators and place the difference over the common denominator.

Example: 3/4 - 3/16 = ?
3/4 = 12/16 therefore,
12/16 - 3/16 = 9/16

A fraction in which the numerator is equal to or larger than the denominator is an IMPROPER FRACTION. Examples of improper fractions are 21/6, 8/8, and 5/4.

A number that is made up of a whole number and a PROPER FRACTION (a fraction where the numerator is always less than the denominator) is called a MIXED NUMBER. Examples of mixed numbers are 1 3/4, 2 1/2, and 8 3/16.

In order to change an improper fraction to a mixed number or a whole number, divide the numerator by the denominator and write the whole number that results. If there is a remainder, put it over the denominator and write the resulting proper fraction next to the whole number.

Example: 25/6 = 4 1/6 or
25 ÷ by 6 = 4 1/6

To change a mixed number to an improper fraction, change the whole number to an equivalent fraction and then add the equivalent fraction to the fraction in the mixed number.

Example: 3 5/8 = ?/8
3 x 8 = 24 + 5 = 29 therefore,
3 5/8 = 29/8

To multiply fractions, place the product of the numerators over the produc he denominators and reduce the resulting fractions to its lowest terms.

Example: 2/3 x 3/4 = ?

$$2 \times 3 = \frac{6}{}$$
$$3 \times 4 = \frac{}{12} \text{ therefore,}$$
$$2/3 \times 3/4 = 6/12 \text{ or } 1/2$$

In order to multiply a proper or an improper fraction by a whole number, multiply the numerator of the fraction by the whole number and place the product over the denominator.

Example: 11 x 7/8 = ?
11 x 7 = 77 therefore,
11 x 7/8 = 77/8 or 9 5/8

To multiply a mixed number by a whole number, either change the mixed number to an improper fraction and multiply by the whole number or consider the mixed number as the sum of a whole number and a proper fraction and multiply each part by the whole number, then add the products.

Example: 1 7/8 x 3 = ?
15/8 x 3 = 45/8 or 5 5/8

DECIMAL FRACTIONS

The decimal fraction is just as important to you as a Patternmaker, as are common fractions, as most blueprints are dimensioned in decimal fractions.

A decimal fraction is a fraction whose denominator is 10 or some power of 10 such as 100, 1,000, or 10,000. Thus, 7/10, 12/100, and 125/1,000 can be written as decimal fractions.

Decimal fractions use the decimal point to take the place of the denominator of the common fraction.

Example: 7/10 = .7
and
12/100 = .12

In a decimal fraction, the number of digits after the decimal point indicates the number of zeros in the denominator of the equivalent common fraction.

Example: .7 (one digit) = 7 tenths or 7/10
.19 (two digits) = 19 hundredths or 19/100
.005 (three digits) = 5 thousandths or 5/1000

In order to add decimal fractions, the only rule to remember is that the decimal points must be in line. Otherwise, they are added as in columns as in any other simple addition problem.

Example: 105.1256 + 7.15 + 12.625 = 124.9006 or,

```
105.1256
  7.15
 12.625
--------
124.9006
```

When subtracting decimal fractions, the same rule applies.

Example: 4.83 - 2.75 = 2.08 or,

```
 4.83
-2.75
-----
 2.08
```

When multiplying decimal fractions, write the numbers as in multiplying whole numbers. It is not necessary to have the decimal points in line.

The total number of places in the product must be equal to the number of decimal places in the multiplicand plus the multiplier.

Example:

Multiplicand	39.744
Multiplier	.5
Product	19.8720

When dividing by whole numbers, the quotient must contain as many decimal places as the decimal fraction that was divided (dividend).

```
                     .0031  Quotient
Example: Divisor  62).1922  Dividend
                      186
                        62
                        62
```

When dividing by decimal fractions, the divisor must be converted to a whole number. This is done by moving the decimal point to the right. You must also move the decimal point in the dividend the same number of digits.

Example: .35) .1922 would be changed to

35.) 19.22 and

.279) 680.588 would be changed to

279.) 68058.00

Always carry your division computations out one more digit than you need and then round off the result. If the last number is 5 or more, add 1 to the preceding number. If the last number is less than 5, leave the preceding number unchanged.

To explain further, let's suppose that you require an answer in thousandths (.000). In order to round off to thousandths, you will carry your division out to ten thousandths (.0000) and then round off as explained in the preceding paragraph.

Example: 5 or more
.7857 rounded off to the nearest thousandth would be .786.

Less than 5
.7853 rounded off to the nearest thousandth would be .785.

When converting a decimal fraction to a common fraction, simply write the decimal fraction as a common fraction (.75 = 75/100) and reduce the resulting common fraction to its lowest terms which in this case would be 3/4.

Common fractions can be converted to decimal fractions by dividing the denominator into the numerator.

Example: $\frac{5}{16}$ 5 Numerator equals $16\overline{)5.0000}$ = .3125 or
16 Denominator

$\frac{5}{16} = .3125$

PERCENTAGE

Percentage can be defined as the expression of numbers in terms of hundredths. The sign used to indicate percentage is % and is called the PERCENT sign. There are three terms applied to percentage problems: BASE, RATE, and PERCENTAGE. The number upon which the percent is calculated is the BASE, the amount of the percent is the RATE, and the result of the calculations made with the base and rate is called the PERCENTAGE. For example, 2% of $125.00 equals $2.50. The rate of 2%, $125.00 is the base, and $2.50 is the percentage.

Percentage is calculated as a decimal fraction. Therefore, the rate must be converted to a decimal fraction. For example, 2% and 25% would be converted to .02 and .25 respectively. A rate of 100% would be written as 1.00, 225% as 2.25, etc.

In order to find percentage, convert the rate to hundredths and multiply the base by the rate.

Example: 8% of $240.00 = $19.20 or

```
 $240.00  (base)
     .08  (rate)
 -------
  $19.20  (percentage)
```

Example: 125% of $16.55 = $20.69 or

```
 $16.55
   1.25
 -------
$20.6875  rounded off to $20.69
```

In order to find the base when the percentage is known, divide the percentage by the rate. Thus, if 4% yielded a return of $4.00, how much money was originally invested?

(rate) $4\%\overline{)\$4.00}$ = base (percentage) or

$.04\overline{)\$4.00} = 4\overline{)400.00}$ = 100.00 (base) therefore,

base equals $100.00

To find the rate when the base and the percentage are known, you must divide the base into the percentage. Thus, if $100.00 yielded a return of $4.00, what was the rate of return?

(base) $\$100.00\overline{)\$4.00}$ = rate (percentage) or

$10000.\overline{)400.00}$ = .04 (rate) therefore,

rate = 4%

A mathematical definition of the term "equation" must be understood in order to progress, without confusion, into more complex mathematics.

The term, equation, comes from another term, equate, which means; to make equal. Therefore, we can say that an equation is a mathematic comparison of equal values. The formula for finding the circumference of a circle is an equation with letters and a symbol substituted for numbers which states that C (circumference) equals π (Pi or 3.1416) times D (diameter) or, $C = \pi D$.

This formula tells us that if we were to multiply the constant by a known diameter (D), the product of our multiplication would equal the circumference (C) of that particular circle. Therefore, C is an equal value to πD.

Another way to look at an equation would be to compare it to a simple balance scale such as the one in view A of figure 8-1.

The fulcrum (balance point) of the scale is the same as the equal sign of an equation. Now, if we add the value "C" to one side of the scale, as in view B of figure 8-1, our scale is out of balance. In order to balance the scale, we must add the equal value of πD as in view C of figure 8-1.

Notice, that in order to balance the scale, we had to add equal values to both sides. If we were to subtract from either side, our scale would, again, be out of balance. Therefore, we would have to subtract an equal value from the opposite side in order to re-balance the scale. The point of this is, that if anything is done to one side of an equation, it must also be done to the other side in order to keep the equation in balance.

POWERS AND ROOTS

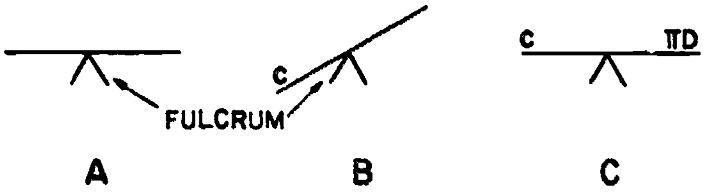
The power of a value, which can be a number or a letter symbol, indicates a process of multiplication and is always identified by a number, in small print, placed at the upper right of the BASE number or letter symbol.

Example: 3^3
R^2

The number in small print is called an EXPONENT which tells you how many times the base value is to be multiplied by itself.

Example: $3^3 = 3 \times 3 \times 3$,
$3^3 = 9 \times 3$
$3^3 = 27$

The exponent ^{2} is called the SQUARE and the exponent ^{3} is called the CUBE. We could say



68.219
Figure 8-1.—Balancing an equation.

three cubed or the cube of three and it would be understood that the base number three is to be taken to the third power (3) as in the above example.

The process of determining ROOT is the inverse of raising a base number to a power and is indicated by a symbol called the RADICAL SIGN. The number contained in the radical sign is the RADICAND and the number in small print situated to the upper left of the radical sign is called the INDEX.

Example: $\sqrt[3]{27}$
radical sign = $\sqrt{\quad}$
radicand = 27
index = ^{3}

In the example above, you are looking for the cube root of the radicand 27, in other words, the base number that can be multiplied by itself three times and equal the radicand. In this case, the base number is 3 or you could say that, the cube root of 27 is 3.

If the index number is ^{5}, then you would solve for the base number that can be multiplied by itself five times and equal the radicand.

Example: $\sqrt[5]{3125} = 5$ or inversely
$5^5\ (5 \times 5 \times 5 \times 5 \times 5) = 3125$

If no index number is present, then it is understood that you must solve for SQUARE ROOT; the base number that can be multiplied by itself to equal the radicand.

Example: $\sqrt{9} = 3$ or inversely
$3^2\ (3 \times 3) = 9$

The steps of procedure for EXTRACTING (solving) square root are:

1. Start at the decimal point and, working in both directions, separate the number into two digit groups.

Example: $\sqrt{1849}$
$\sqrt{21.4826}$

If, on either side of the decimal point, there is an odd number of digits, add a zero at either end of the number.

Example: $\sqrt{71243.695}$ would become
$\sqrt{071243.6950}$

2. Place the decimal point in the quotient directly above the decimal point in the radicand.

Example: $\sqrt{18\,49.}$

$\sqrt{21.48\,26}$

3. Find the largest number whose square is equal to or less than the first group of digits. This number is the first digit of the quotient. Write this number above the first digit group.

```
             7.
Example:  √54.61 21
```

4. Write the square of tl › number under the first digit group.

```
             7.
Example:  √54.61 21
           49
```

5. Subtract the square of the number from the first digit group and bring down the next digit group.

```
             7.
Example:  √54.61 21
           49
            561
```

6. Double the first digit of the quotient and write the sum just to the left of the results of step 5. This number is called the TRIAL DIVISOR.

```
             7.
Example:  √54.61 21
           49
       14 | 561
```

7. Determine how many times the trial divisor will divide into all but the last digit of the remainder and write this number in the quotient above the second group of digits and also to the right of the trial divisor.

```
             7. 3
Example:  √54.61 21
           49
      143 | 561
```

8. Multiply the new trial divisor by the last digit of the quotient (143 x 3) and subtract the product from the remainder. Bring down the next pair of digits.

NOTE: 14 will divide into 56 exactly 4 times. However, if 4 were added to the trial divisor, making the trial divisor 144, the product of 144 x 4 would be l›rger than the remainder.

```
             7. 3
Example:  √54.61 21
           49
      143 | 561
            429
            13221
```

9. Double the first two digits of the quotient to obtain a new trial divisor and write this number to the left of the remainder.

```
             7. 3
Example:  √54.61 21
           49
      143 | 561
          | 429
      146 | 13221
```

10. Determine how many times the new trial divisor will divide into all but the last digit of the remainder and write this number in the quotient above the third group of digits and also to the right of the trial divisor.

```
             7. 3 9
Example:  √54.61 21
           49
      143 | 561
          | 429
     1469 | 13221
```

11. Multiply the trial divisor by the last digit of the quotient and subtract the product from the remainder.

```
             7. 3 9
Example:  √54.61 21
           49
      143 | 561
          | 429
     1469 | 13221
          | 13221
```

12. Prove the problem by multiplying 7.39 by itself.

RATIO AND PROPORTION

Ratio and proportion is a form of mathematics whereby many problems may be solved more quickly and also minimize the chances of error over the step-by-step method of arithmetic.

A RATIO can be defined as "the relationship or comparison of two like quantities, the quotient of the first number divided by the second."

If a destroyer has a top speed of 30 knots and a cargo ship has a top speed of 15 knots, then we can say that the destroyer can travel at a speed 2 times the top speed of the cargo ship or a ratio of 2 to 1.

The comparison of the speed of the DD to that of the AK was made by dividing one number into the other, in this case 15 knots into 30 knots. This comparsion, made by division, is called a ratio.

A ratio is normally written as a common fraction. The ratio of the DD (30 knots) to that of the AK (15 knots) would be written as $\frac{30 \text{ knots}}{15 \text{ knots}}$ or more correctly, 30 : 15. The symbol ":" denotes ratio.

Comparison by means of a ratio is limited to quantities of the same kind. For example, in order to express the ratio between 6 ft. and 3 yards., both quantities must be written in terms of the same unit. Thus, the proper forms of this ratio would be either 2 yds. : 3 yds. or 6 ft. : 9 ft. Mathematically, like terms cancel each other so the yd. or ft. would cancel each other out and the resulting ratio would read 2:3 or 6:9.

An INVERSE RATIO is the reciprocal of the original ratio. Therefore, the inverse ratio of 2:3 would be 3:2.

The scale of scale drawings is a practical application of ratio.

The scale of a drawing is the ratio between the length of any line on the drawing and the actual length of the full sized object.

If the scale of a drawing was 1:16, and a dimension on the full size object was 48", you would find the length of the line on the drawing by multiplying the actual length by 1/16. Thus, 1/16 x 48 = 3. Therefore, the line on the drawing would be 3" long.

Inversely, if the actual length of a full sized object was unknown, it could be determined by multiplying the scaled down size (3") by the determined ratio (1:16). Thus, 3 x 16 = 48. Therefore, the actual length of the line on the full sized object is 48".

If the scale of a drawing is inches to feet, (1" equals 2') then the ratio would be converted to inches, in this case 1:24.

Closely allied with the study of ratio is the subject of PROPORTION. The term, proportion, can be defined as "a relation of equality."

Mathematically, a proportion is nothing more than an equation of two ratios which are equal to each other. Proportion can be written in three different ways as in the following examples:

15:20::3:4

15:20 = 3:4

$\frac{15}{20} = \frac{3}{4}$

It is evident from the last example that a proportion is nothing more than an equation of common fractions.

The value of proportion is that if any three of the terms are given, the fourth or unknown term may be found by solving a simple problem of common fractions.

Certain names have been given to the terms of the two ratios that make up a proportion. In a proportion such as 15:20 :: 3:4, the first and the last terms (the outside terms) are called the EXTREMES. In this case, 15 and 4 would be the extremes. If the proportion is written as a fraction, then the numerator of the first fraction and the denominator of the second fraction are the extremes.

extreme $\frac{15}{20} = \frac{3}{4}$ extreme

The two remaining terms are called the MEANS.

A missing term is usually identified by an alphabetical letter such as the letter "X".

If a term is missing, it is an easy task to find the value of that missing term. Simply multiply the two known terms that are alike (extremes or means) and divide the product by the remaining term.

Example: 2:X :: 3:15
X = unknown value
2 X 15 ÷ 3 = 10
Therefore, X = 10 or
2:10 :: 3:15

Since the extremes (2 and 15) are alike (both are extremes), they must be multiplied. The product of this multiplication must then be divided by the one known means (3) which results in a quotient of 10. Therefore, the unknown means (X) equals 10 which is the value needed to complete the proportion.

If both of the means were known and only one extreme known, then you would multiply the two means and divide by the known extreme.

Example: K:30 :: 15:90
K = unknown value
30 x 15 ÷ 90 = 5 therefore,
K = 5 or
5:30 :: 15:90

It must be remembered that in order to have a true proportion, both ratios must reduce to an identical lowest term.

Example: $\frac{5}{30} = \frac{15}{90} = \frac{1}{6} = \frac{1}{6}$ or

$\frac{1}{6} = \frac{1}{6}$

One of the most common types of problems based on proportions involves triangles with proportional sides. Suppose that the corresponding sides of two triangles are known to be proportional as in figure 8-2. The side lengths of triangle "A" are 8", 9", and 11". The only known length of triangle "B" is 10" which corresponds to the 8" side of triangle "A". The lengths of side b and side c of triangle "B" are unknown but since both triangles are the same kind (corresponding), these lengths can be determined by forming proportions as follows:

8:10 :: 9:b or $\frac{8}{10} = \frac{9}{b}$

$\frac{9 \times 10}{8}$ = 11 1/4 thus b = 11 1/4"

Now we have two known sides to triangle "B". Therefore, we can form a proportion using either 8:10 or 9:11 1/4 in order to find the length of side c.

8:10 :: 11:c equals $\frac{10 \times 11}{8}$ = 13 3/4 thus

c = 13 3/4" or we can say that

9:11 1/4 :: 11:c equals $\frac{11\ 1/4 \times 11}{9}$ = 13 3/4

thus
c = 13 3/4"

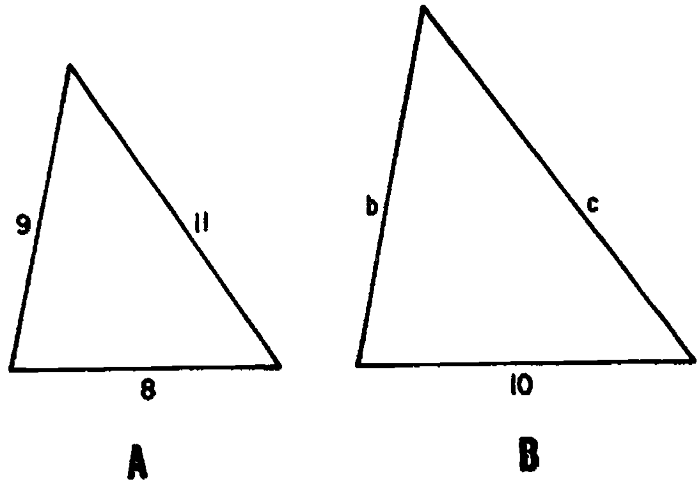


Figure 8-2.—Triangles with opposite sides proportional.

The following problem can also be solved by using proportion.

If a casting weighing 126 lbs. contains 12 lbs. of zinc, how much zinc would a 312 lb. casting of the same alloy contain?

#1 casting weight 126 / #2 casting weight 312 = 12 zinc weight #1 / W zinc weight #2

$\frac{312 \times 12}{126}$ = 29.71 therefore,
W = 29.71 lbs. or we could say that the casting weighing 312 lbs. contains 29.71 lbs. of zinc.

GEOMETRIC CONSTRUCTION

Patterns are geometric shapes which conform to a draftsman's plan (blueprint) plus any additions necessary for casting such draft, shrinkage allowances, and machine finish allowance.

As a Patternmaker, you will be constantly solving graphic problems (problems of geometric construction). You must learn to lay out clean, accurate lines to make the layout for the pattern and to outline the pattern itself in order to shape it to the desired configuration.

There are several geometric methods of solving many of the graphic problems you will encounter. Some are more accurate than others, however, you should know all of the different methods in order to choose the best way to solve a particular problem for a specific application.

Most graphic problems can be solved by trial and error or by measuring with a scale. Neither of these methods is accurate and must not be used in patternmaking. Therefore, because of its importance with respect to accuracy, only the geometric method of construction, as related to the basic rules and to other graphic solutions, is described in this manual.

In order to effectively study this area of information, you must have a pencil divider, 12" scale, flexible straight edge, 30° - 60° triangle, and a "T" square.

Definitions of some geometric terms used in the following information are listed below.

Angle—A figure formed by two non-parallel lines converging at a common point.
Apex—The highest point of a triangle.
Arc—A continuous portion of a circle or curve.
Bisect—Dividing into two equal parts.
Circumference—A continuous line enclosing the area of a circle, ellipse, or closed curve.
Curve—Any line deviating from perfectly straight that contains no straight angles.
Diameter—A straight line extending from a point on the circumference, passing through the center, to the opposite point on the circumference of a circle.
Hypotenuse—the side of a right triangle that is opposite the right angle.
Intersect—To meet and cross at a point.
Parallel—Extending in the same direction while maintaining an equal distance at all points.
Perpendicular—Being at right angles (90°) from a line or plane.
Plane—A perfectly flat or level surface having two dimensions.
Point—A narrowly localized place having no dimensions.
Polygon—Any figure having three or more sides of equal or unequal length enclosing 360°.
Radius—A straight line extending from the center of a circle to the circumference of that circle (1/2 diameter).
Tangent—A curved or straight line which touches but does not cross another curved or straight line at a point other than its ends.
Vertex—The point of intersection of two lines forming an angle.

TO BISECT A LINE:

1. Use your dividers and adjust them with a spread that is visually greater than one-half the length of the line.

2. Insert the point of the dividers at one end of the line, and draw an arc, as shown in view A of figure 8-3.

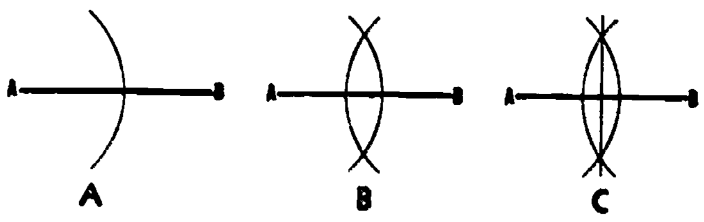
3. Insert the point at the other end of the line, and with the same adjustment, draw an arc from that end, intersecting the first arc (view B of fig. 8-3).

4. Draw a straight line connecting the two intersection points of the arcs to bisect the line (view C of fig. 8-3).

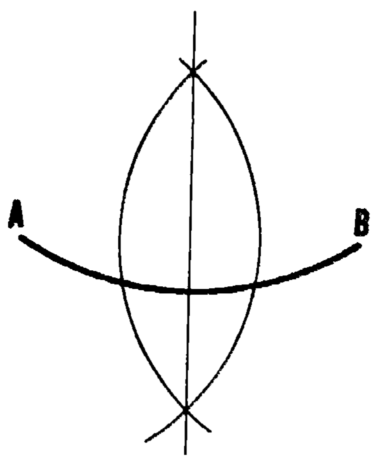
TO BISECT AN ARC, follow the same steps as were given for bisecting a line, using the ends of the arc as centers for the arcs which intersect. (See fig. 8-4.)

TO BISECT AN ANGLE:

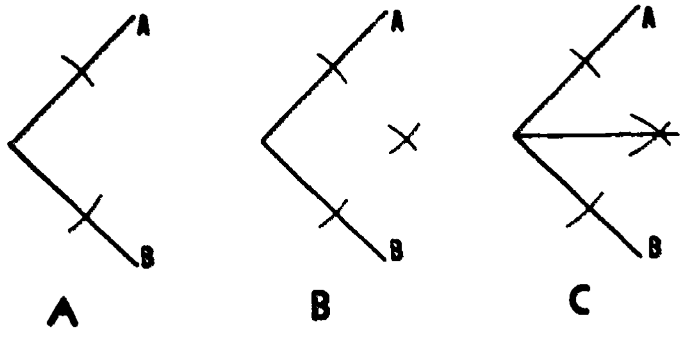
1. Use the point of the angle as the center for the point of the dividers, and draw arcs cutting the legs of the angle (view A of fig. 8-5).



23.224
Figure 8-3.—Bisecting a line.



23.225
Figure 8-4.—Bisecting an arc.



23.226

Figure 8-5.—Bisecting an angle.

2. Use the points where the arcs cut the legs as centers for arcs which intersect each other inside the angle, as shown in view B of figure 8-5.

3. Connect the intersection point of these arcs with the point of the angle to bisect the angle (view C of fig. 8-5).

WHEN COPYING OR TRANSFERRING AN ANGLE, there is a simple geometrical method of constructing angles which you should know. In figure 8-6, the angle AOB is to be copied on the baseline B'O'.

1. Use the dividers to measure the length of side AO by inserting the point at O and adjusting the leg to fall on A.

2. Draw an arc intersecting both legs of the angle. (See view A of fig. 8-6.)

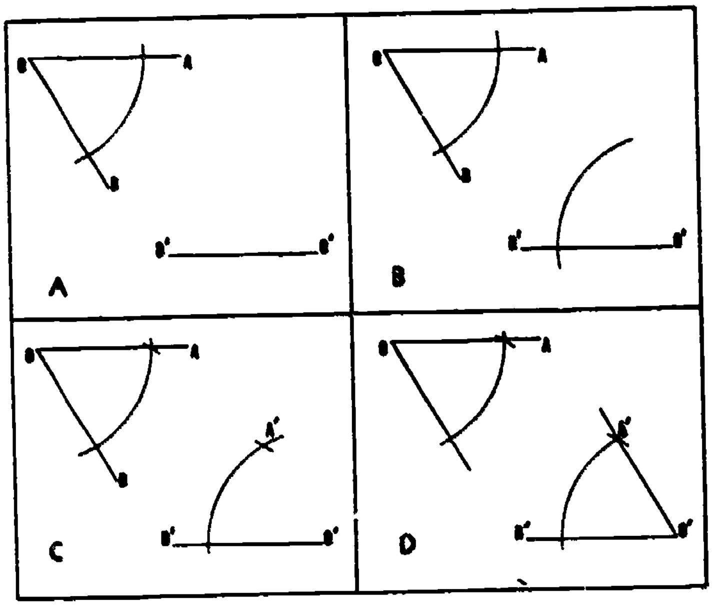
3. With the dividers adjusted to the same radius, place the point at O' and draw an arc, as shown in view B of figure 8-6.

4. Use the dividers to measure between the legs of the angle in the same way, and draw an arc from line O'B' using this measurement, as shown in view C of figure 8-6.

5. Connect the intersection point of the two arcs to point O' to draw leg A'O' of angle A'O'B' (view D of fig. 8-6).

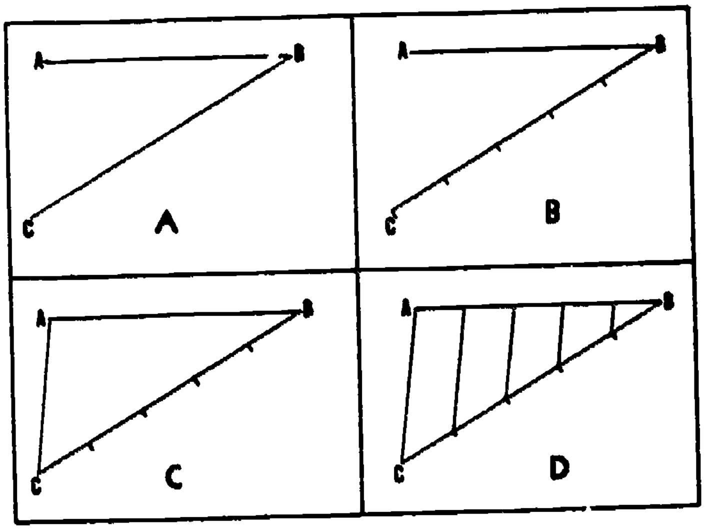
WHEN DIVIDING A LINE INTO EQUAL PARTS, a line may be divided into any number of equal parts. As an illustration of the geometrical method, line AB in figure 8-7 is divided into five equal parts:

1. First a line is drawn at an angle from one end of the line AB, as shown in view A of figure 8-7.



23.227

Figure 8-6.—Copying an angle.



23.228

Figure 8-7.—Dividing a line geometrically.

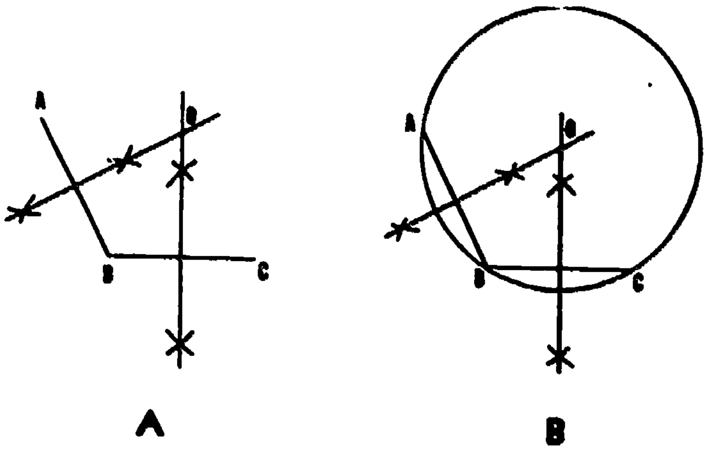
2. On this line, five equal points are stepped off with a divider or any other measuring device (view B of fig. 8-7).

3. A line is drawn from the last of the stepped-off points to the end of line AB. This line is shown as AC in view C of figure 8-7.

4. Now from each of the other stepped-off points, draw lines parallel with line AC. (See view D of fig. 8-7.)

WHEN DRAWING A CIRCLE OR AN ARC THROUGH THREE GIVEN POINTS, such as points A, B, and C in figure 8-8.

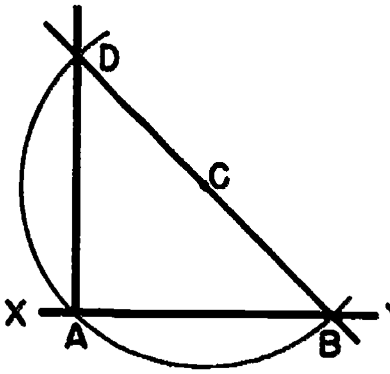
1. Draw lines between the points and bisect these lines, as shown in view A of figure 8-8.
2. The point where the bisecting lines intersect each other is the center, O, of the circle. Place the point of the dividers at this center, and adjust the dividers until the opposite leg falls on one of the three given points.
3. Draw the circle, as shown in view B of figure 8-8, and, if your layout work has been accurate, the arc of the circle will pass through all three points.



23.229
Figure 8-8.—Drawing a circle through three given points.

TO DRAW A PERPENDICULAR FROM THE END OF A LINE:

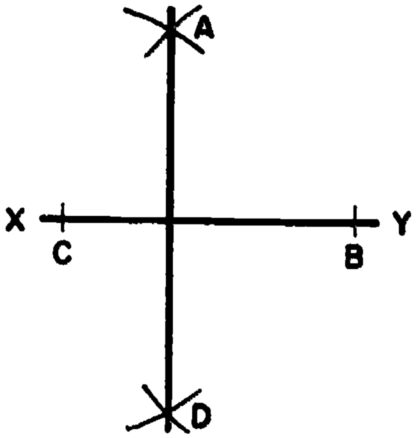
1. Establish any point such as C, shown in figure 8-9, above the baseline, AY.
2. With the dividers set at a radius of CA, draw an arc as illustrated. The point where the arc intersects line AT is point B.
3. Through B and C draw a line cutting the arc. Label this point D.
4. Then draw DA, which will beperpendicular to AY.



11.217
Figure 8-9.—Drawing a perpendicular from the end of the line.

TO DRAW A PERPENDICULAR TO A GIVEN LINE FROM A GIVEN POINT:

1. From a given point A above the given line, XY, as shown in figure 8-10, establish any two points on line XY, such as C and B. (It does not matter whether C and B are on opposite sides of A, or are both on the same side of A.)
2. With B as a center, and with a radius of BA, draw arcs above and below line XY.
3. With C as a center, and a radius of CA, draw arcs intersecting the arcs made in step 2.
4. Draw a line DA, through the intersecting arcs, the line DA will be perpendicular to line XY.



11.216
Figure 8-10.—Drawing a perpendicular to a given line from a given point.

BLENDING ARCS AND TANGENTS

Laying out circles, or arcs, and straight lines tangent to them is difficult because there is an element of optical illusion involved. It is easier to draw a straight line to a curved one than it is to draw a curved line to a straight one. Therefore, on pattern layouts, major circles or arcs are drawn first.

Even when a Patternmaker draws a straight line to a curve, an optical illusion may cause him to fail to blend the curve and the line perfectly.

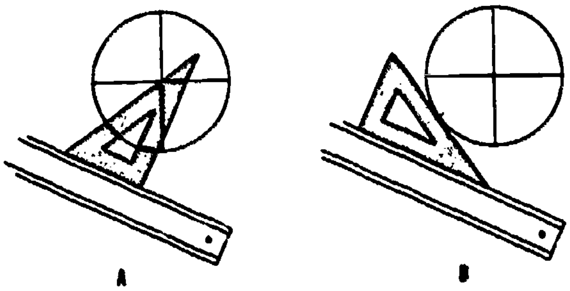
In this section, a few simple methods are discussed which will help you to blend lines and arcs.

TO USE THE DRAFTSMAN'S METHOD OF DRAWING A TANGENT TO A CIRCLE AT A GIVEN POINT:

1. Place a triangle against a straightedge as shown in view A of figure 8-11. The hypotenuse of the triangle should pass through the center of the circle and the point where the line is to be tangent to the circle.
2. Hold the straightedge firmly in place and turn the triangle over.
3. Then move the triangle until the hypotenuse passes through the point of tangency and draw the tangent, as shown in view B of figure 8-11.

WHEN DRAWING A LINE TO THE END OF AN ARC, you may find that when you draw an arc which terminates in a straight line, you have a natural tendency to overdraw the arc. To avoid this error:

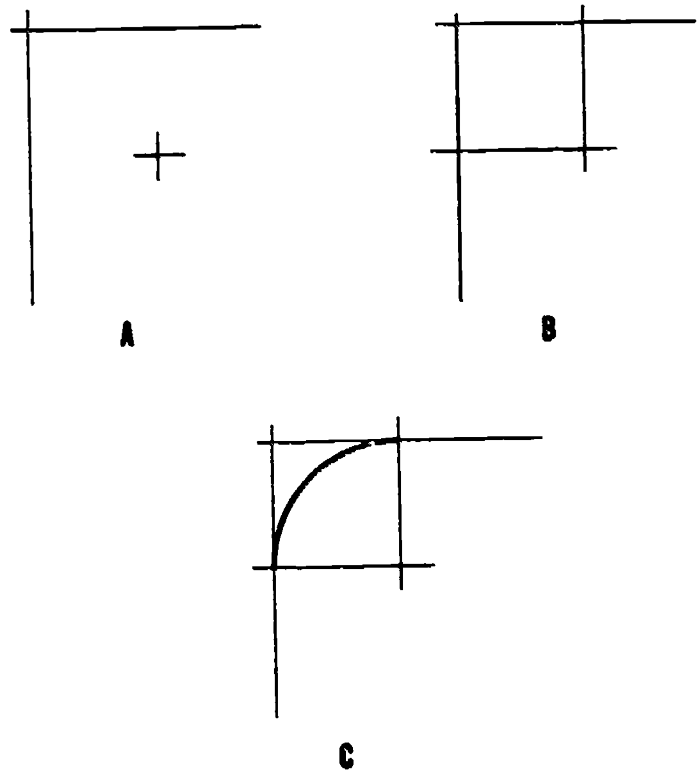
1. Draw a radius from the center of the arc, as shown in view A of figure 8-12 to the point of tangency. In view B of figure 8-12, a radius has been drawn to both points.
2. Watch this radius carefully as you draw the arc, and stop at the exact point at which the line of the arc touches the point of tangency. (See view C of figure 8-12.)



23.230
Figure 8-11.—Drawing a tangent to a circle at a given point.

In drawing a straight line to the end of an arc, there seems to be a natural tendency to run it inside its true position. In figure 8-13 the error at the left is no greater than the one at the right, but the line ending below the end of the arc looks as if it were the greater error.

WHEN DRAWING ARCS TANGENT TO TWO LINES (FILLETS AND ROUNDS), small arcs tangent to two lines defining an inside corner are called fillets, and must often be drawn after the straight lines have been drawn. Small arcs tangent to two lines defining an outside corner are called rounds.



23.231
Figure 8-12.—Precaution to avoid overdrawing an arc that ends in a straight line.

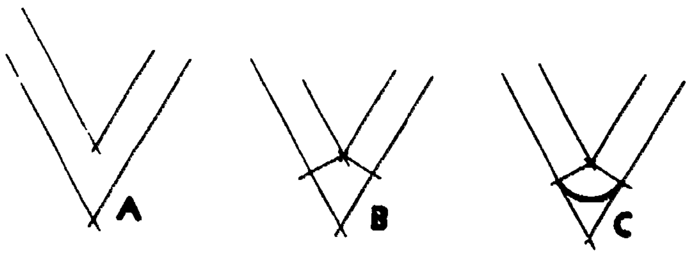
23.232
Figure 8-13.—Errors in drawing a line to the end of an arc.

When the lines form an angle that is not a right angle:

1. Draw lines that are parallel to the first two lines, inside the angle and at a distance of the given radius from them as shown in view A of figure 8-14. The intersection of these parallel lines will be the center, O, of the fillet's arc.
2. Establish the exact points of tangency, as shown in view B of figure 8-14, the center, O, perpendicular to the legs to the angle.
3. Now draw the fillet, using point O as the center of the circle. Start at one point of tangency and stop when the arc touches the other.

When the two lines form a right angle:

1. Adjust the dividers to the required radius.
2. Place the point of the dividers at the corner of the angle, and draw a short arc intersecting each straight line. (See view A of fig. 8-15.) Section points of the arcs and the lines are the points of tangency.
3. Use the intersection points as centers for the point of the dividers, and, with your dividers adjusted to the given radius, draw intersecting arcs inside the angle, as shown in view B of figure 8-15.
4. Use this point of intersection as the center, O, for the point when you draw the fillet, as shown in view C of figure 8-15.

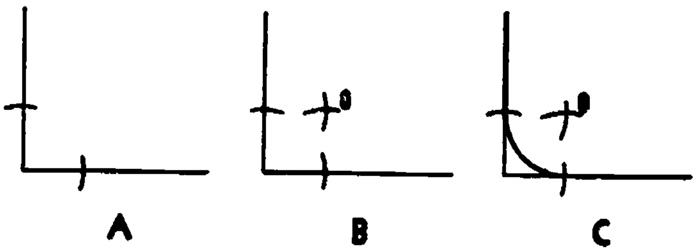


23.233
Figure 8-14.—Drawing a fillet or round to two straight lines.

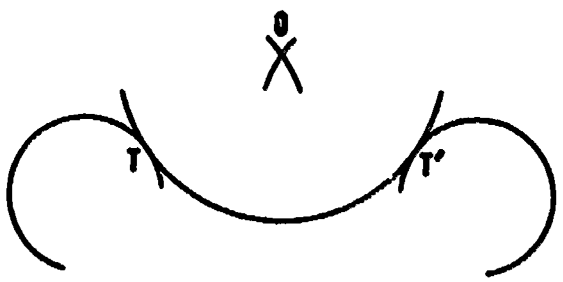
WHEN DRAWING LARGE ARCS TANGENT TO SMALLER ARCS, any of the methods of drawing fillets can be applied in laying out large circles or arcs tangent to other arcs. The trial and error method is illustrated in figure 8-16. The arc of a large circle is to be drawn tangent to two small circles or arcs. Points T and T' are estimated as the points of tangency and are used to find the intersecting arcs at point O. Point O is used as the center in drawing the arc from T to T'.

The trial and error method may also be used in passing a circle through three given points. In view A of figure 8-17, arcs with an equal radius have been drawn from each of the three points. You can see that they fail to have a common point of intersection and are, therefore, not at the proper center. Nevertheless, from this trial the Patternmaker is able to judge where the center will probably fall and to select a point, O, to use as the center in drawing his first trial arc. If this trial arc fails to pass through the three points perfectly, as shown in view B of figure 8-17, he moves the center as indicated. This time it is possible to judge the position of the center so accurately that the circle may be drawn through the points. (See view C of fig. 8-17.)

WHEN ESTABLISHING EXACT POINTS OF TANGENCY (Fig. 8-16), you will see that the arcs have been drawn with slightly excess lines. If you are working in pencil, you can first draw the arcs lightly, erase the excess lines,



23.234
Figure 8-15.—Drawing a fillet or round to a right angle.



23.235
Figure 8-16.—Trial and error method of drawing a large arc tangent to two smaller arcs.

and then darken or BRIGHTEN the remaining lines. If you are inking a drawing, it is wise to establish the exact points of tangency before you ink the arcs, since it is difficult to erase excess ink lines. This may be done by lightly drawing the radius from the center of the circle of the arc to the point of tangency. (See fig. 8-12.) In figure 8-18, the radii for several tangent arcs have been drawn to establish the exact points of tangency.

TO DRAW A REVERSE OR OGEE CURVE TANGENT TO TWO LINES, erect a perpendicular at point A and drop one at point B as shown in view A of fig. 8-19. Connect the points A and B with a line as shown in view B of figure 8-19. Assume a point C on this line through which the curve will pass. This point may be the midpoint of the line, if equal arcs are desired. Bisect AC and CB, as shown in view C of figure 8-19. The intersection of these lines with the perpendiculars from points A and B are the centers of the required arcs. Complete the curve as shown in view D of figure 8-19.

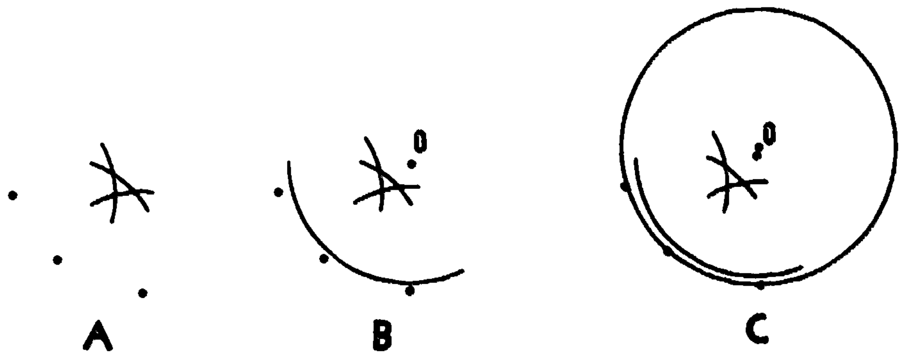
DRAWING PLANE FIGURES

A plane has only two dimensions. For all practical purposes, your layout is a plane. A drawing showing one side of a square box is a drawing of a plane figure, since a square is a plane figure.

This section gives methods of construction for a number of common plane figures.

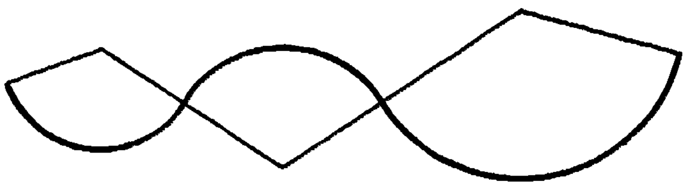
TO DRAW TRIANGLES WITH GIVEN SIDES, such as lines A, B, and C in view A of figure 8-20:

1. Draw one side in the desired position as the baseline.
2. Adjust the dividers to the length of a second side, and using one end of the baseline as a center for the point of the dividers, draw an arc.
3. Adjust the dividers to the length of the third side, and from the other end of the baseline, draw an arc, as shown in view B of figure 8-20.



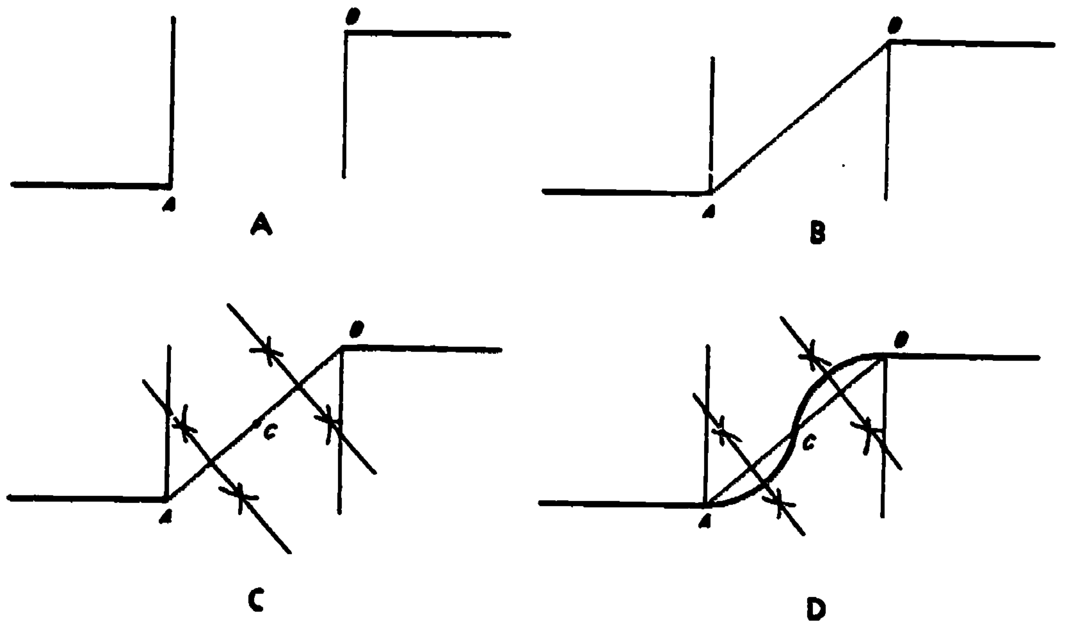
23.236

Figure 8-17.—Trial and error method of finding the center of a circle which passes through three given points.

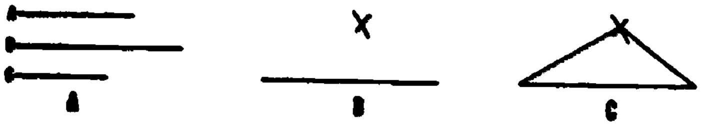


23.237

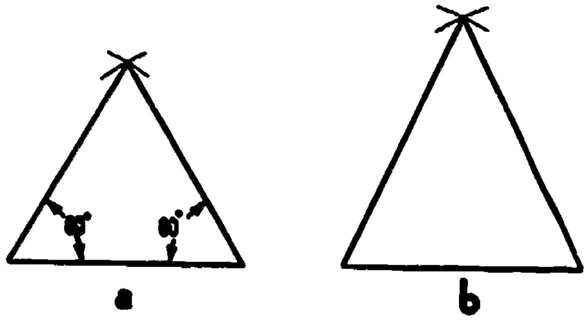
Figure 8-18.—Establishing the points of tangency for several tangent arcs.



23.238
Figure 8-19.—Reverse or ogee curve.



23.239
Figure 8-20.—Drawing a triangle with three given sides.



23.240
Figure 8-21.—Drawing triangular plane figures. A. An equilateral triangle. B. An isosceles triangle.

4. Connect the intersection point of these arcs to the ends of the baseline for the sides of the triangle. (See view C of fig. 8-20.)

WHEN DRAWING AN EQUILATERAL TRIANGLE which has three equal sides, draw one side and then use the length of that side as the radius when you draw intersecting arcs from each end of it. (See view A of fig. 8-21.)

TO DRAW AN ISOSCELES TRIANGLE which has two equal sides, locate the base, and draw intersecting arcs from each end of it using the length of one of the equal sides as the radius. (See view B of fig. 8-21.)

TO DRAW A RIGHT TRIANGLE—ONE WITH AN INCLUDED 90° ANGLE—see bisecting a line, figure 8-3; drawing a perpendicular from the end of a line, figure 8-9; or drawing a perpendicular to a given line from a given point, figure 8-10.

TO CONSTRUCT A REGULAR PENTAGON (FIVE SIDED FIGURE) WITHIN A CIRCLE:

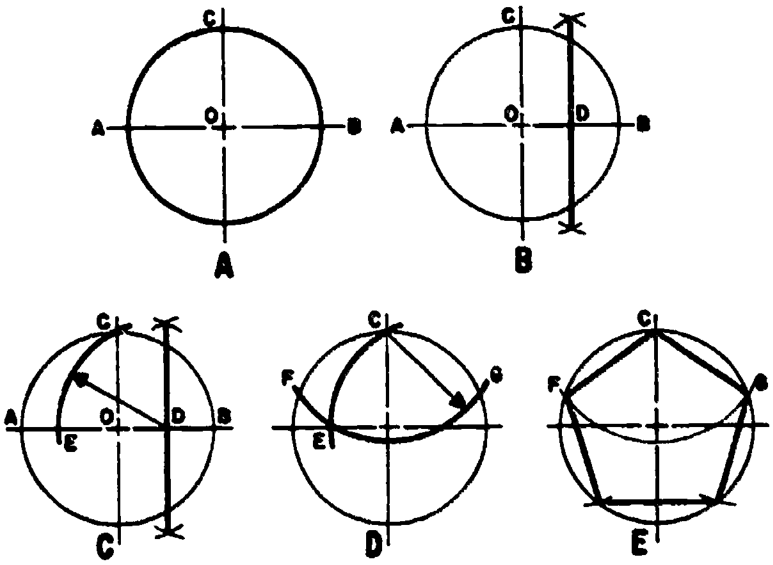
1. Draw the diameter of the circle, shown as AOB in view A of figure 8-22.

2. Bisect the radius OB of the circle, as shown in view B of figure 8-22.

3. With D as a center and a radius equal to DC, strike arc CE, as shown in view C of figure 8-22.

4. With C as a center, strike the arc FG passing through the point E, as shown in view D of figure 8-22.

5. Distance CF or CG is equal to the length of one side of the pentagon. The other sides are stepped off with the dividers, as shown in view E of figure 8-22.



23.241
Figure 8-22.—Drawing a regular pentagon in a circle.

Hexagonal forms (six sided) of the bolt head and nut are common figures in mechanical drawings. There are several ways of DRAWING A REGULAR HEXAGON. If you are given the distance between two opposite sides of a hexagon, called the SHORT DISTANCE or DISTANCE ACROSS FLATS:

1. Draw a horizontal line and a vertical line, each as long as this given distance and intersecting at right angles to each other, as shown in view A of figure 8-23.

2. With these lines as diameters and their intersection as the center for the point of the dividers, draw a circle, as shown in view B of figure 8-23.

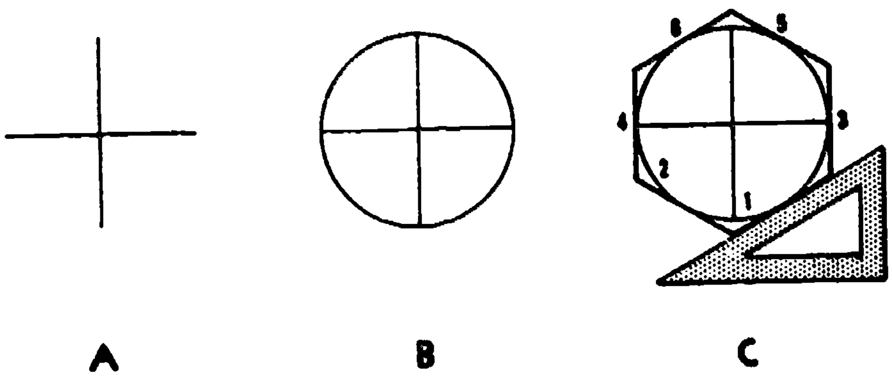
3. Using the 30°—60° triangle resting on a T-square or straightedge base, draw lines tangent to the circle in the order shown in view C of figure 8-23.

If you are given the distance between opposite corners of a hexagon, called the DISTANCE ACROSS CORNERS or the LONG DIAMETER:

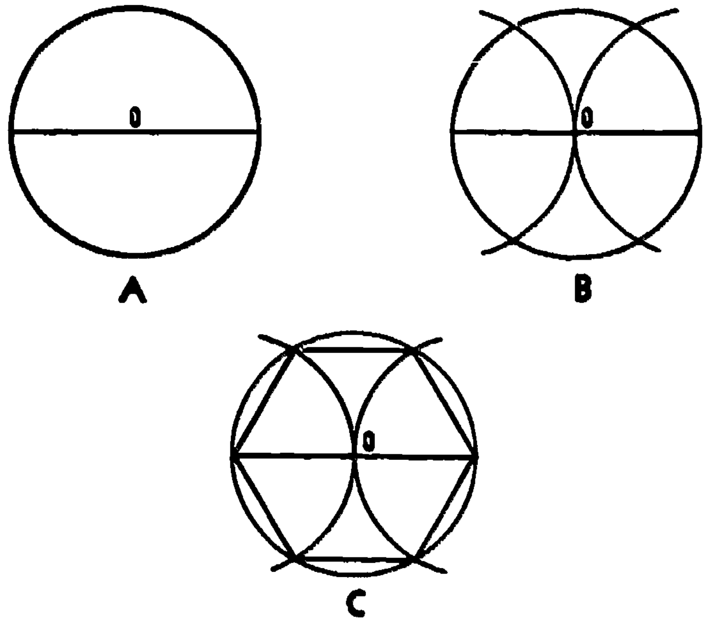
1. Draw a circle with this distance as the diameter. (See view A of fig. 8-24.)

2. Using the same radius as you used to draw the circle, draw arcs with the ends of the diameter as centers, as shown in view B of figure 8-24.

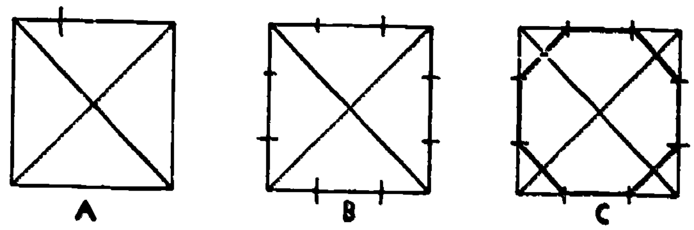
3. Connect the points where the arcs intersect the circle with those where the diameter touches the circle as shown in view C of figure 8-24.



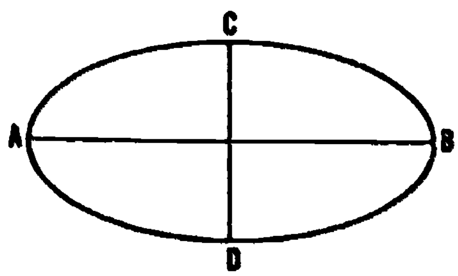
23.242
Figure 8-23.—Drawing a regular hexagon when the distance across flats is given.



23.243
Figure 8-24.—Drawing a regular hexagon when the distance across corners is given.



23.244
Figure 8-25.—Drawing a regular octagon when the distance between sides is given.



23.245
Figure 8-26.—An ellipse with major axis AB, and minor axis CD.

WHEN DRAWING A REGULAR OCTAGON (8 SIDED FIGURE), if you are given the distance between opposite sides of an octagon:

1. Use this as the side dimension in drawing a square, as shown in view A of figure 8-25.

2. Draw the diagonals of the square.

3. Adjust the dividers to a radius equal to one-half the length of a diagonal.

4. Place the point of the dividers on each corner and draw arcs intersecting the sides of the square, as shown in view B of figure 8-25.

5. Connect the points of intersection, forming a regular octagon. (See view C of fig. 8-25.)

One of the most difficult figures to draw is the ELLIPSE. There are a number of ways of drawing it. Generally you will be given the length of the major and minor axes of the ellipse. (See fig. 8-26.)

An ellipse which is not absolutely accurate but which gives a good visual effect may be drawn, using the compass, as follows:

1. Draw the major and minor axes.

2. Draw a line connecting one end of the major axis and one end of the minor axis. (See view A of fig. 8-27.)

3. Using a radius equal to half the major axis and with C as the center, lay off OE on OB. (See view B of fig. 8-27.)

4. Using a radius equal to EB, lay off CF on CB. (See view C of fig. 8-27.)

5. Bisect line FB as shown in figure 25D. Extend the bisecting line to intersect AB at X and CD at Y.

6. Using a radius equal to XB, lay off AX', and using a radius equal to DY, lay off CY'. (See view D of fig. 8-27.)

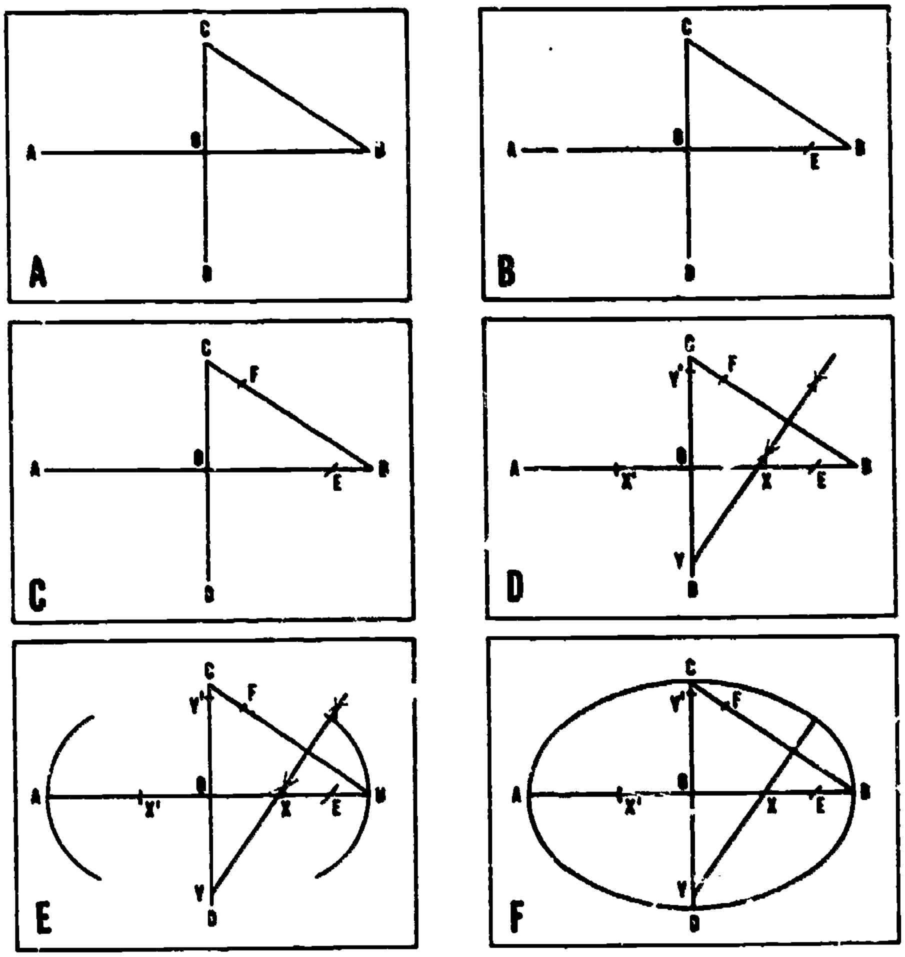
7. Using the radii XB and X'A, draw the end arcs as shown in view E of figure 8-27.

8. Using the radii YC and Y'D draw the side arcs, as shown in view F of figure 8-27.

The easiest method of drawing a LARGE ELLIPSE is the pin-and-string method. To use this method:

1. Draw the major and minor axes.

2. Set the dividers to one-half the length of the major axis, and, using one end of the minor axis as a center, draw arcs intersecting the major axis. Points F and F' are called the foci of the ellipse. (See view A of fig. 8-28.)



23.246

Figure 8-27.—Drawing an ellipse.

3. Drive pins at the foci and at one end of the minor axis, and tie a cord around the three pins, as shown in view B of figure 8-28.

4. Remove the pin at the end of the minor axis, and place a pencil or pen inside the loop. Keeping the string taut, draw the line of the ellipse, as shown in view C of figure 8-28.

You may have trouble keeping the line smooth when you reach the major axis and must shift your string over the heads of the pins. It is better to remove the pencil or pen from the drawing surface, shift the string to the other side of the pins, and then replace the drawing point carefully so that there is no break in the line. It is not necessary to shift if you use a continuous string, passing around the pins, rather than tied to them.

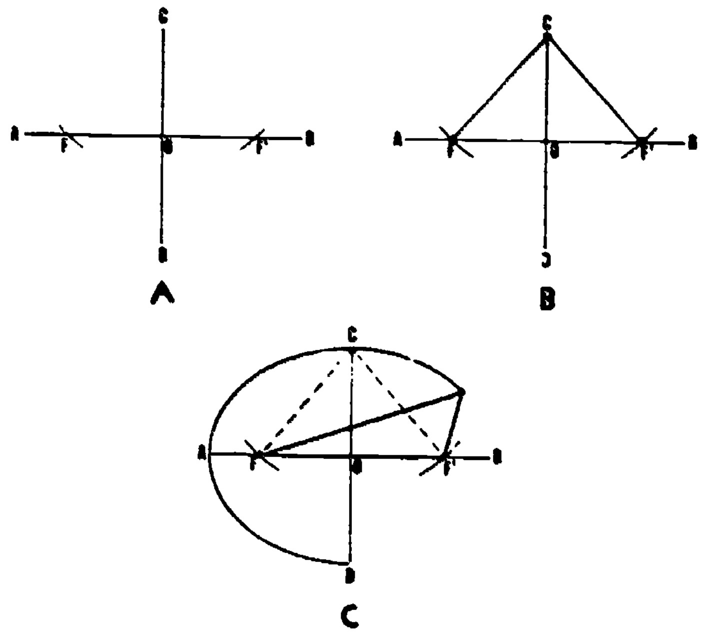
An ellipse may also be drawn by the trammel method. On the straight edge of a strip of paper, cardboard, or plastic, mark half the distance of the major axis, AO in view A of figure 8-29. Then mark half the distance of the minor axis, CO. Draw the major and minor axes on the drawing sheet. Move the straight edge, keeping point A on the minor axis and point C on the major axis and, using point O as the guide, draw the line of the ellipse, as shown in view B of figure 8-29.

The concentric-circle method of drawing an ellipse is the most accurate of the methods discussed in this section, provided you can handle your instruments with accuracy. It involves carefully plotting the ellipse.

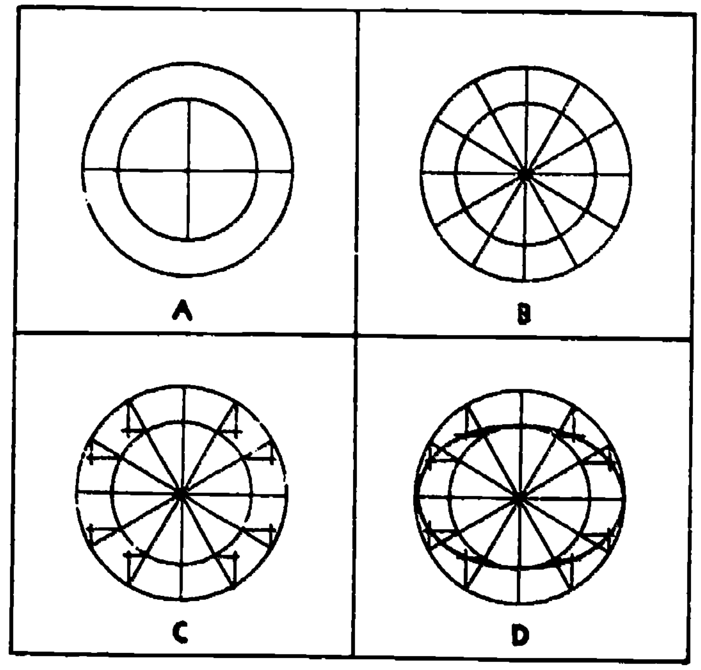
1. Draw the major and minor axes.

2. With the intersection as a center, draw a circle that has the major axis as a diameter. (See view A of fig. 8-30.)

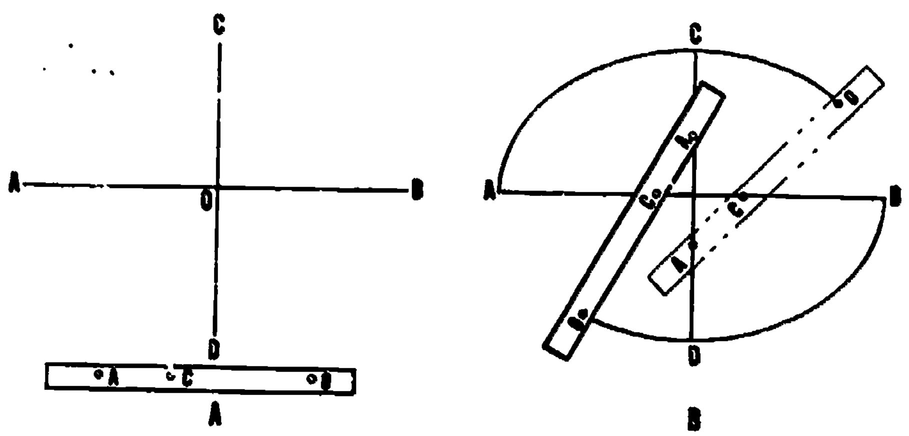
3. Draw a number of radial or slant lines through the center to the arc of the larger circle. (See view B of fig. 8-30.)



23.247
Figure 8-28.—Drawing an ellipse, using the pin-and-string method.



23.249
Figure 8-30.—Drawing an ellipse, using the two-circle method.



23.248
Figure 8-29.—Drawing an ellipse, using the trammel method.

4. Wherever these lines cut the smaller circle, draw short horizontal lines outward from the arc of that circle.

5. Wherever the radial lines touch the larger circle, draw short vertical lines to intersect the short horizontal lines. (See view C of fig. 8-30.) The points where these short horizontal and vertical lines intersect define the ellipse.

6. Use the French curve and draw the ellipse from these plotted points. (See view D of fig. 8-30.)

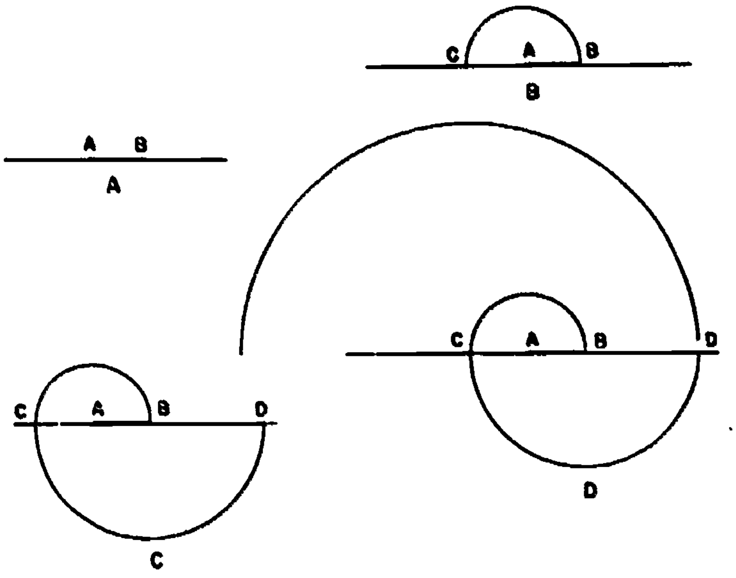
DRAWING SPIRALS AND INVOLUTES

A spiral or involute is a constantly changing curve winding, coiling, or circling around a center point receding or approaching its own center. For all practical purposes, the main spring in your watch is a spiral. This section gives methods of construction for the more common spirals.

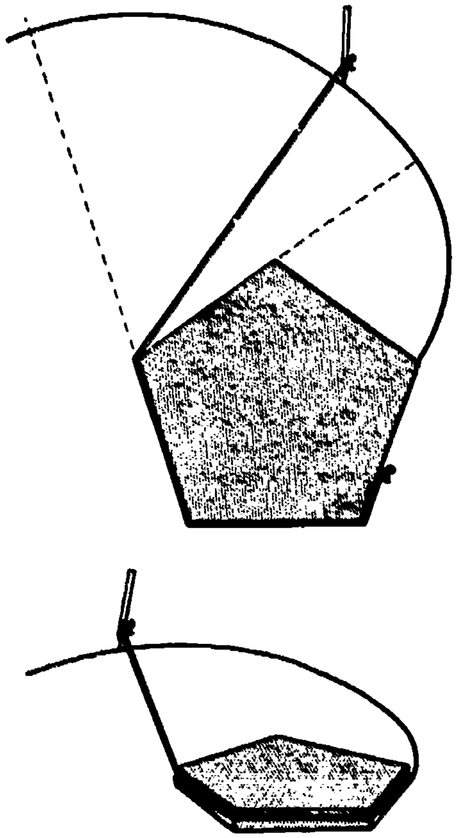
An involute is the curve that might be traced by a point on a cord that is being unwound from a line, a triangle, a square or another polygon, or a circle. Figure 8-31 illustrates the pin-and-string method of drawing the involute of a pentagon.

To draw an INVOLUTE OF A LINE, extend the line AB as shown in view A of figure 8-32. Using the length AB as a radius and A as a center, draw a semicircle, as shown in view B of figure 8-32. Then, using BC as the radius and B as the center, draw a second semicircle continuing the curve, as shown in view C of figure 8-32. Then, with CD as the radius and C as the center, draw the next arc, as shown in view D of figure 8-32. Proceed in the same manner until the curve is the desired size.

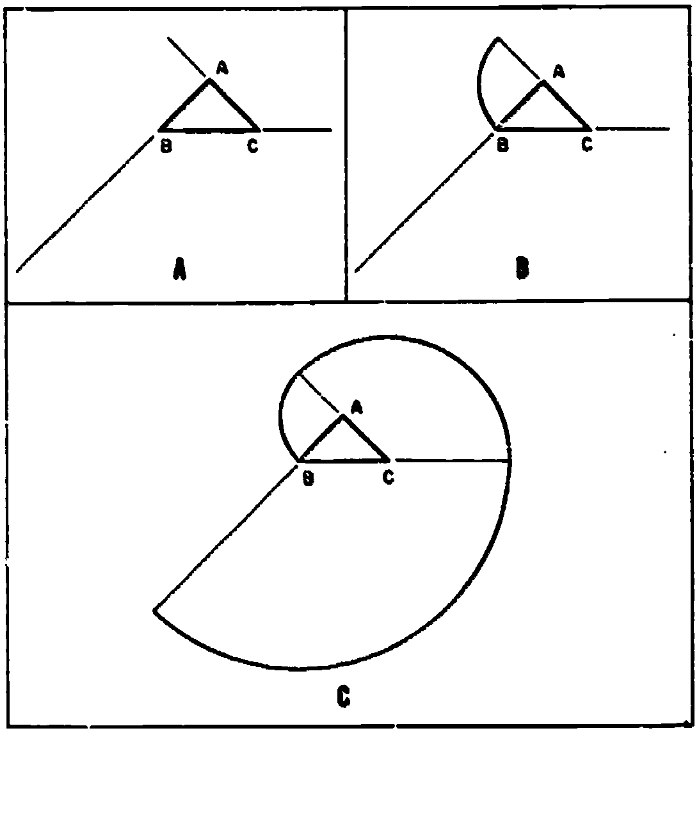
WHEN DRAWING THE INVOLUTE OF A TRIANGLE, extend the sides as shown in view A of figure 8-33. Using one side AB as radius, and A as the center, draw an arc from B to the extension of side AC, as shown in view B of



23.251
Figure 8-32.—Method of drawing the involute of a line.



23.250
Figure 8-31.—Pin-and-string method of drawing an involute of a pentagon.



23.252
Figure 8-33.—Method of drawing the involute of a triangle.

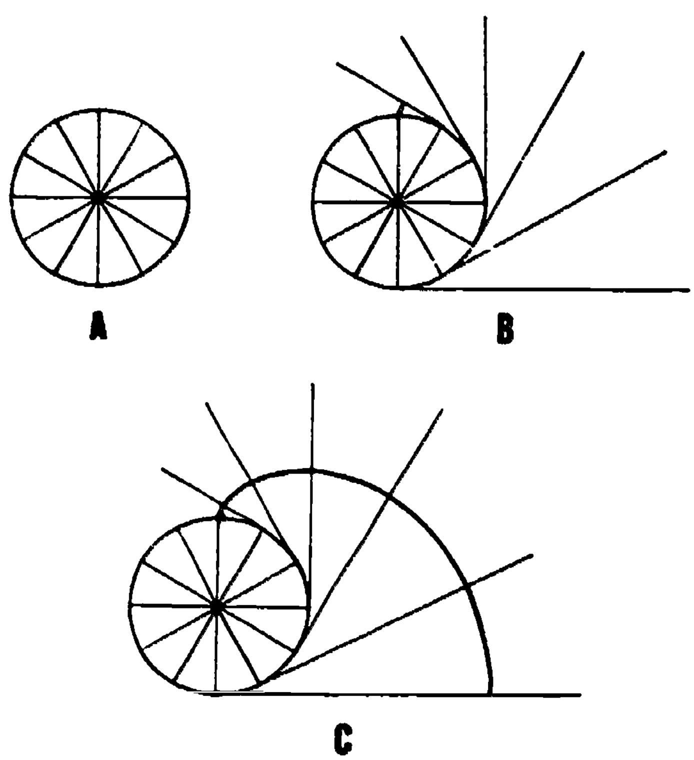
figure 8-33. Using a radius the length of AC plus its extension, and with C as the center, draw an arc to the extension of side BC. With BC plus its extension as the radius and B as the center, draw the arc to the extension of side AB, as shown in view C of figure 8-33. Continue in this manner until the figure is the desired size.

TO DRAW THE INVOLUTE OF A CIRCLE, consider the circle as a polygon with a great number of sides. Divide the circumference of the circle into a number of equal parts. Then draw tangents from each division, as shown in view A of figure 8-34. With the rectified distance of a division as a radius, draw an arc from one division to intersect the tangent of the next division, as shown in view B of figure 8-34. With the intersection point on this tangent to the point of tangency as a radius, draw an arc to intersect the next tangent. (See view C of figure 8-34.) Continue until the figure is of the required size.

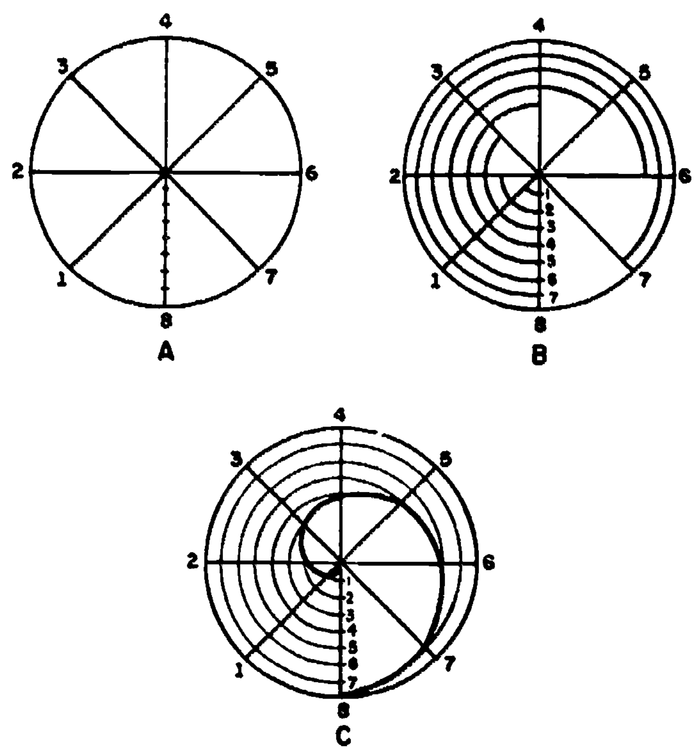
WHEN DRAWING A SPIRAL OF ARCHIMEDES, the spiral is generated by a point moving around a fixed point, its distance increasing uniformly with the angle. To draw a spiral which makes one turn in a given circle, divide the circle into a number of equal parts and number these parts in succession. (See view A of fig. 8-35.) Then divide the radius of the circle into the same number of parts and number them from the center outward, as shown in view A of figure 8-35. Using the center of the circle as a center, draw from each of the numbered divisions an arc which intersects the corresponding numbered division on the radius, as shown in view B of figure 8-35. These intersections are the points of the curve, as shown in view C of figure 8-35.

WHEN DRAWING THE HELIX, consider the helix as a curve in space which is generated by a point moving uniformly along a straight line which revolves around an axis. If the line moves parallel to the axis, it will generate a cylindrical helix. If it moves at an angle to the axis, it will generate a conical helix. The LEAD of a helix is the distance parallel with the axis which the point advances along the line in one revolution.

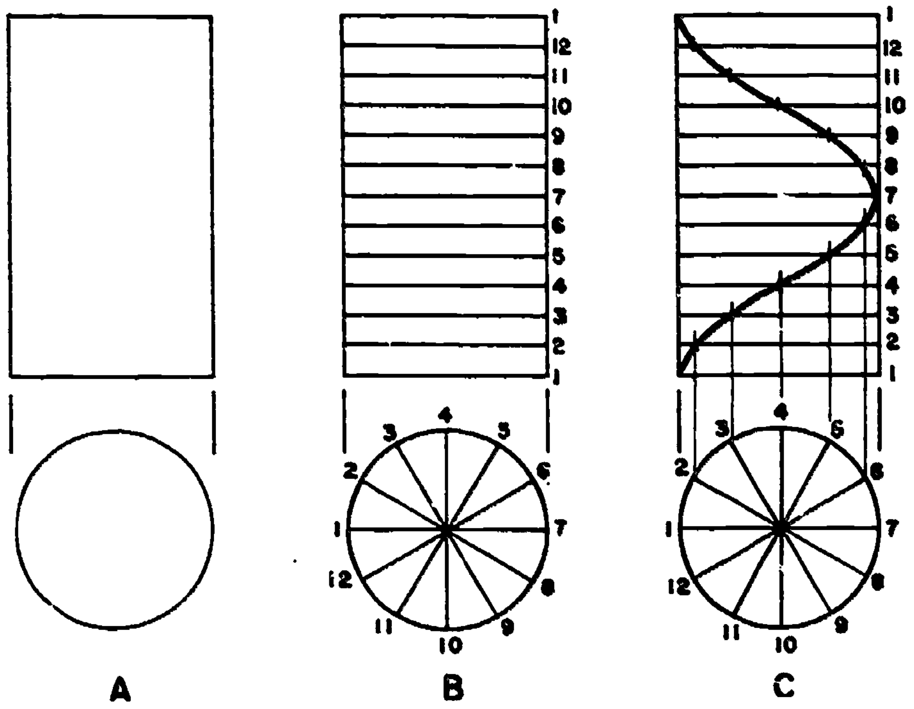
To draw a helix, draw two views of the cylinder, as shown in view A of figure 8-36.



23.253
Figure 8-34.—Method of drawing the involute of a circle.



23.254
Figure 8-35.—Method of drawing a spiral of Archimedes.



23.255

Figure 8-36.—Method of drawing a helix.

Divide the lead into an equal number of parts and the diameter into the same number of parts, as shown in view B of figure 8-36. The intersection of the lines from these points, as shown in view C of figure 8-36, are the points of cylindrical helix.

DETERMINING AREAS AND VOLUMES

As a Patternmaker, you must be able to calculate the amount of material needed to manufacture the pattern and determine the weight of the pattern in order to calculate the approximate weight of the casting. In order to do this, you must possess a knowledge of geometry and be able to determine areas and volumes of geometric shapes and figures.

Area is defined as the extent of a surface bounded by two dimensions such as length and width. The unit of measure denoting area is "square" such as square inches, square feet, square yards, etc.

Volume can be defined as the extent of an object bounded by three dimensions such as length, width, and height. The unit of measure denoting volume is "cubic" such as cubic inches, cubic feet, etc.

In order to find the area (A) of the rectangle shown in figure 8-37, you must multiply the length (L) by the width (W) or A = LW. Since L = 8 and W = 5, A = 40 square inches.

In order to find the volume (V) of the cube shown in figure 8-38, you must multiply length (L) times width (W) times height (H) or V = LWH. Since L = 8", W = 5", and H = 7", V = 280 cubic inches.

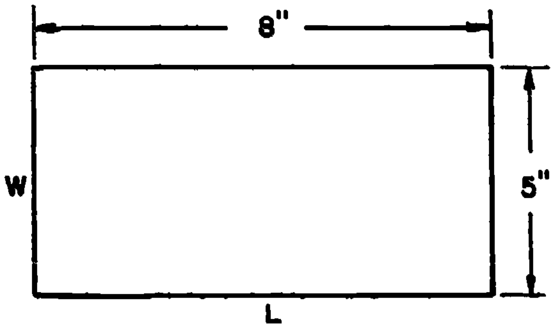
Many of the geometric figures you will be concerned with are illustrated in figure 8-39. Along with the figures are the formula and example problems for calculating area and volume for that particular figure.

When values are enclosed in parentheses ( ), brackets [ ] , braces { }, or lined over by the vinculum ⟶, they are said to be GROUPED.

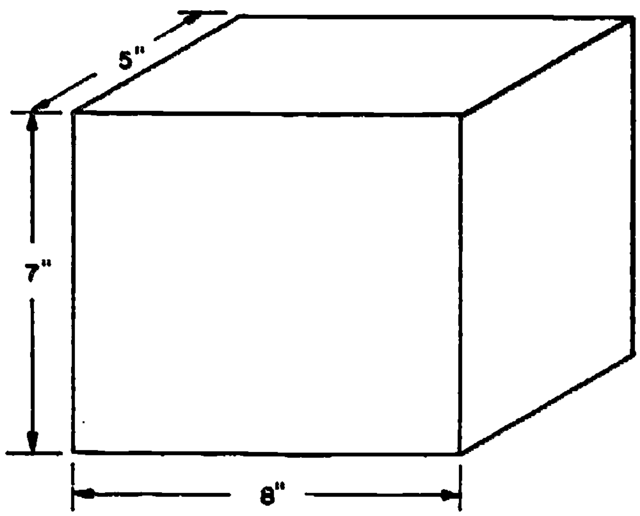
Some equations may contain a group within a group such as in the formula for finding the area of a trapezium where,

$$\text{Area} = 1/2\ [a(e + d) + bd + ce]$$

In this formula, you have parentheses and brackets. The order of precedent concerning



68.221
Figure 8-37.— Two dimensional view.



68.222
Figure 8-38.— Three dimensional view.

these grouping symbols is; parentheses can be enclosed in braces and braces can be enclosed in brackets. However, the reverse is not true. In other words, the values enclosed by parentheses must be considered before considering the values within the brackets etc. In order to explain further, let's find the area of a trapezium using the formula and values shown in figure 8-39.

$$\text{Area} = [1/2 \quad a(e + d) + bd + ce]$$

$$\text{Area} = [1/2 \quad 10\,(8 + 6) + 3 \times 6 + 5 \times 8]$$

$$\text{Area} = [1/2 \quad 10\,(14) + 3 \times 6 + 5 \times 8]$$

$$\text{Area} = [1/2 \quad 140 + 3 \times 6 + 5 \times 8]$$

$$\text{Area} = [1/2 \quad 140 + 18 + 40]$$

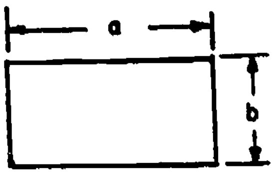
$$\text{Area} = [1/2 \quad 198]$$

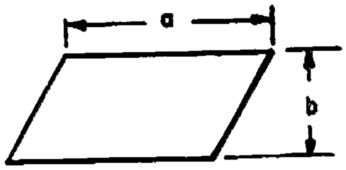
$$\text{Area} = [99]$$

The first step, after putting numerical value to the letter symbols, is to add "e + d" as they are enclosed within parentheses. The next step is to consider the process dictated by the preceding value which in this case is "a". Since there is no symbol between "a" and the parentheses, it is understood that "a" must be multiplied by the sum of "e + d" which results in a product of 140. Next, you must multiply "b + d" and "c + e" which results in sums of 18 and 40, respectively. When these are added to 140, you have a value of 198 which must now be multiplied by 1/2 resulting in a product of 99. Therefore, since all values are in inches, the Area = 99 square inches.

Rectangle and Parallelogram

Area = ab





Triangle

Area = ½ cd.

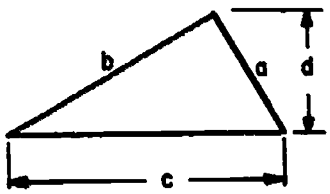
Area = $\sqrt{s\,(s-a)\,(s-b)\,(s-c)}$ when

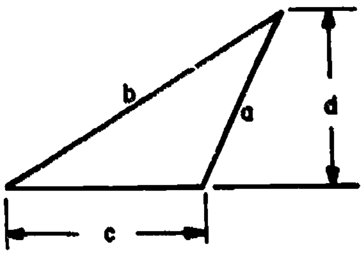
$s = \frac{1}{2}(a + b + c)$

Example: a = 3″. b = 4″. c = 5″

$s = \frac{3'' + 4'' + 5''}{2} = 6''$

Area = $\sqrt{6\,(6-3)\,(6-4)\,(6-5)}$ = 6 sq. in.



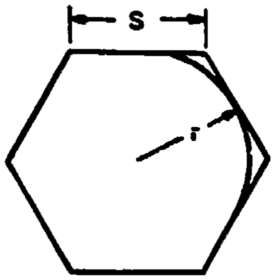


Regular Polygons

n = Number of sides. s = Length of one side. r = Inside radius

Area = ½ nsr

Number of Sides	Area
5	1.72047 s^2 = 3.63273 r^2
6	2.59809 s^2 = 3.46408 r^2
7	3.63395 s^2 = 3.37099 r^2
8	4.82847 s^2 = 3.31368 r^2
9	6.18181 s^2 = 3.27574 r^2
10	7.69416 s^2 = 3.24922 r^2
11	9.36570 s^2 = 3.22987 r^2
12	11.19616 s^2 = 3.21539 r^2

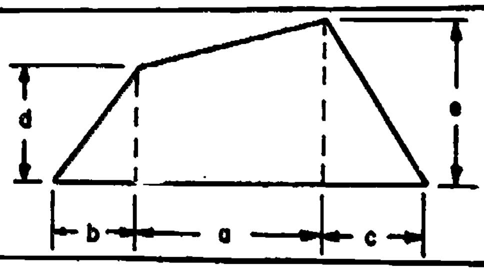


Trapezium

Area = ½ [a (e + d) + bd + ce]

Example: a = 10″. b = 3″. c = 5″. d = 6″. e = 8″

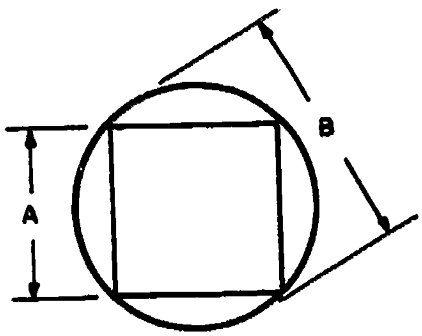
Area = ½ [10 (8 + 6) + (3 × 6) + (5 × 8)] = 99 sq. in.



Square

The diagonal of a square = A × 1.414

The side of a square inscribed in a given circle is: B × .707.



68.223.1

Figure 8-39.—Areas and volumes for calculating weights of castings.

Circle

θ (the Greek letter Theta) = angle included between radii

π (pi) = 3.1416, D = Diameter, R = Radius, C = Chord.

h = Height of Arc, L = Length of Arc.

Circumference = $\pi D = 2\pi R = 2\sqrt{\pi \times \text{Area}}$

Diameter = $2R$ = Circumference $\div \pi = 2\sqrt{\frac{\text{Area}}{\pi}}$

Radius = $\frac{1}{2}D$ = Circumference $\div 2\pi = \sqrt{\frac{\text{Area}}{\pi}}$

Radius = $\dfrac{\left(\frac{C}{2}\right)^2 + h^2}{2h}$

Area = $\frac{1}{4}\pi D^2 = 0.7854\ D^2 = \pi R^2$

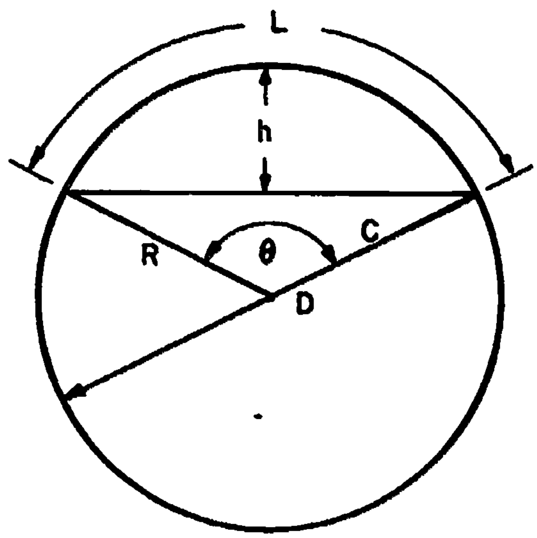
Chord = $2\sqrt{h\ (D-h)} = 2R \times \text{sine } \frac{1}{2}\theta$

Height of Arc, $h = R - \sqrt{R^2 - \left(\frac{C}{2}\right)^2}$

Length of Arc, $L = \frac{\theta}{360} \times 2\pi R = 0.0174533\ R\theta$

$\frac{1}{2}\theta$ (in degrees) = $28.6479\frac{L}{R}$

Sine $\frac{1}{2}\theta = \frac{C}{2} \div R$



Sector of a Circle

Area = $\frac{1}{2}$ LR

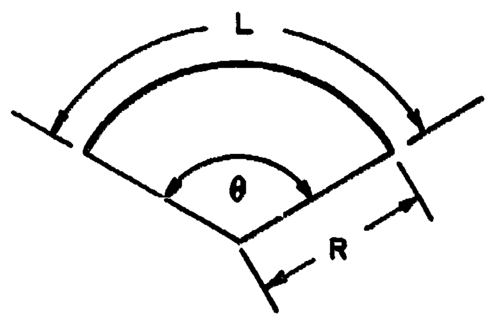
Example. L = 10.472″, R = 5″

Area = $\frac{10.472}{2} \times 5$ = 26.180 sq. in.

or Area = $\pi R^2 \times \frac{\theta}{360} = 0.0087266\ R^2\theta$

Example: R = 5″, θ = 120°

Area = $3.1416 \times 5^2 \times \frac{120}{360}$ = 26.180 sq. in.



Segment of a Circle

Area = $\pi R^2 \times \frac{\theta}{360} - \frac{C\ (R-h)}{2}$

Example: R = 5″, θ = 120°, C = 8.66″, h = 2.5″

Area = $3.1416 \times 5^2 \times \frac{120}{360} - \frac{8.66\ (5-2.5)}{2}$ = 15.355 sq. in.

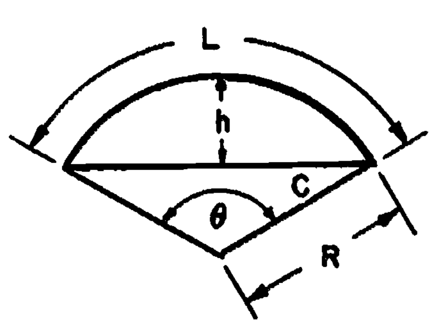
Length of arc L = $0.0174533\ R\theta$

Area = $\frac{1}{2}\left[LR - C\ (R-h)\right]$

Example: R = 5″, C = 8.66″, h = 2.5″, θ = 120°

L = $0.0174533 \times 5 \times 120$ = 10.472″

Area = $\frac{1}{2}\left[(10.472 \times 5) - 8.66\ (5-2.5)\right]$ = 15.355 sq. in.



68.223.2

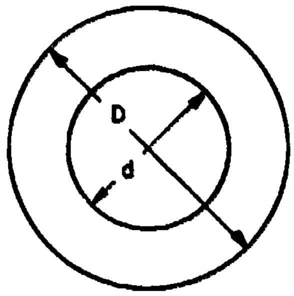
Figure 8-39.—Areas and volumes for calculating weights of castings—Continued.

Circular Ring

Area = $0.7854\,(D^2 - d^2)$, or $0.7854\,(D - d)(D + d)$

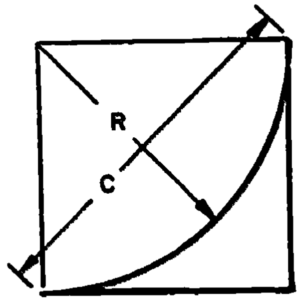
Example: $D = 10''$, $d = 3''$

Area = $0.7854\,(10^2 - 3^2) = 71.4714$ sq. in.



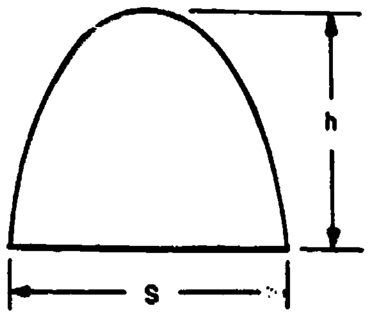
Spandrel

Area = $0.2146\,R^2 = 0.1073\,C^2$
Example: $R = 3$
Area = $0.2146 \times 3^2 = 1.9314$



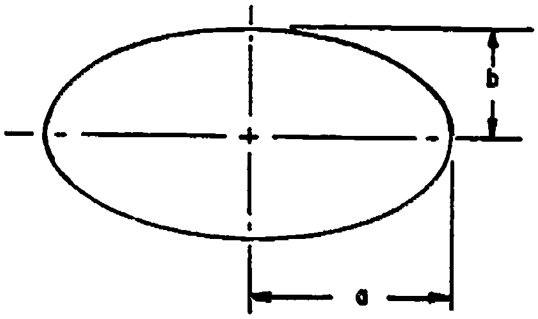
Parabolic Segment

Area = $\frac{2}{3}\,sh$
Example: $s = 3$, $h = 4$
Area = $\frac{2}{3} \times 3 \times 4 = 8$



Ellipse

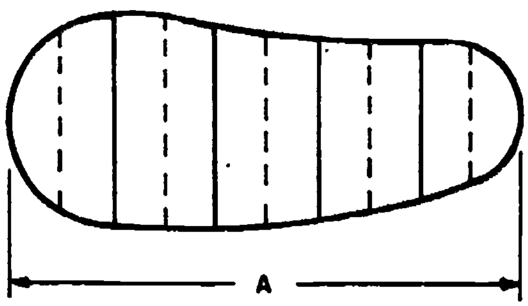
Area = $\pi ab = 3.1416\,ab$
Example: $a = 3$, $b = 4$
Area = $3.1416 \times 3 \times 4 = 37.6992$



Irregular Figures

Area may be found as follows:
Divide the figure into equal spaces as showp by the lines in the figure.

(1) Add lengths of dotted lines.
(2) Divide sum by number of spaces.
(3) Multiply result by "A."

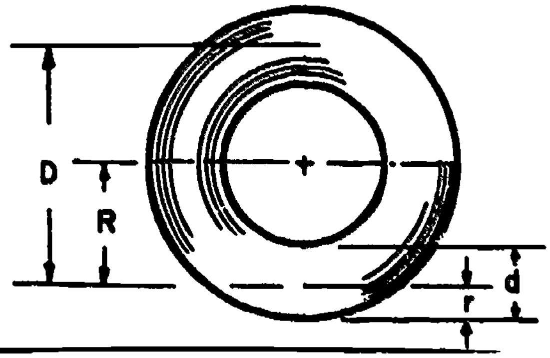


68.223.3

Figure 8-39.—Areas and volumes for calculating weights of castings—Continued.

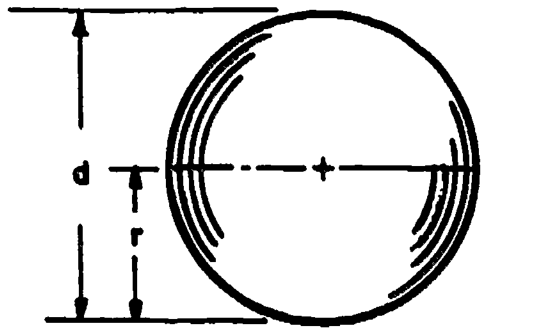
Ring of Circular Cross Section

Area of Surface $= 4\pi^2 Rr = 39.4784\ Rr$
Area of Surface $= \pi^2 Dd = 9.8696\ Dd$
Volume $= 2\pi^2 Rr^2 = 19.7392\ Rr^2$
Volume $= \frac{1}{4}\pi^2 Dd^2 = 2.4674\ Dd^2$



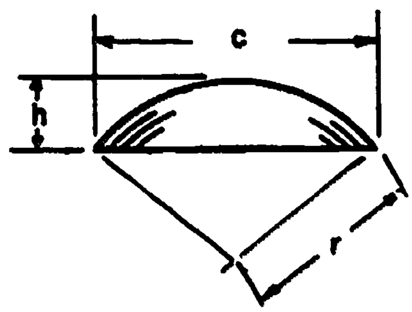
Sphere

Surface $= 4\pi r^2 = 12.5664\ r^2 = \pi d^2$
Volume $= \frac{4}{3}\pi r^3 = 4.1888\ r^3$
Volume $= \frac{1}{6}\pi d^3 = 0.5236\ d^3$



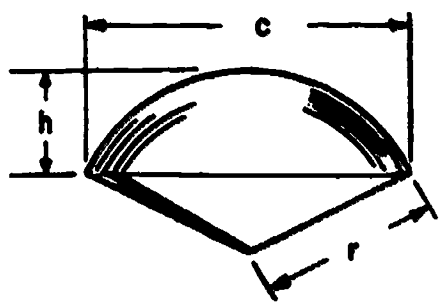
Segment of a Sphere

Spherical Surface $= 2\pi rh = \frac{1}{4}\pi(c^2 + 4h^2) = 0.7854\ (c^2 + 4h^2)$
Total Surface $= \frac{1}{4}\pi(c^2 + 8rh) = 0.7854\ (c^2 + 8rh)$
Volume $= \frac{1}{3}\pi h^2(3r - h) = 1.0472\ h^2\ (3r - h)$
or
Volume $= \frac{1}{24}\pi h(3c^2 + 4h^2) = 0.1309\ h\ (3c^2 + 4h^2)$



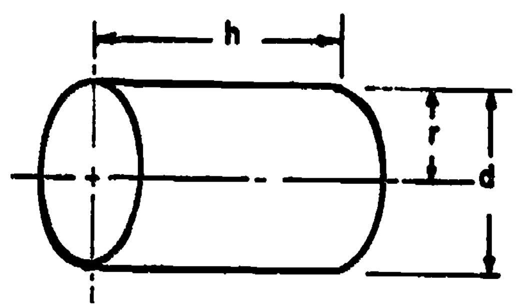
Sector of a Sphere

Total Surface $= \frac{1}{2}\pi r(4h + c) = 1.5708\ r\ (4h + c)$
Volume $= \frac{2}{3}\pi r^2 h = 2.0944\ r^2 h$



Cylinder

Cylindrical Surface $= \pi dh = 2\pi rh = 6.2832\ rh$
Total Surface $= 2\pi r(r + h) = 6.2832\ (r + h)$
Volume $= \pi r^2 h = \frac{1}{4}\pi d^2 h = 0.7854\ d^2 h$

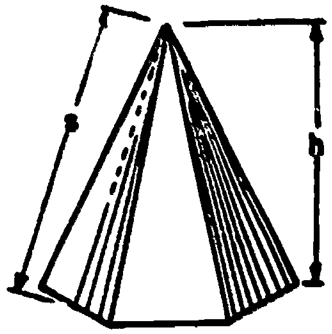


68.223.4

Figure 8-39.—Areas and volumes for calculating weights of castings—Continued.

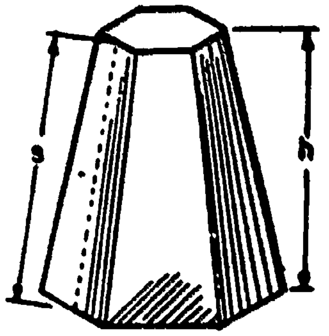
Pyramid

A = area of base
P = perimeter of base
Lateral Area = $\frac{1}{2}$ Ps
Volume = $\frac{1}{3}$ Ah



Frustum of a Pyramid

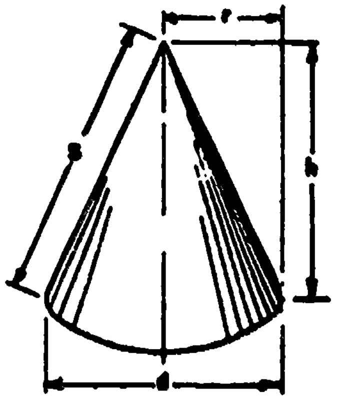
A = area of base
a = area of top
m = area of midsection
P = perimeter of base
p = perimeter of top
Lateral Area = $\frac{1}{2}s(P + p)$
Volume = $\frac{1}{3}h(a + A + \sqrt{aA})$
Volume = $\frac{1}{6}h(A + a + 4m)$



Cone

Conical Area = $\pi rs = \pi r\sqrt{r^2 + h^2}$

Volume = $\frac{1}{3}\pi r^2 h = 1.0472\, r^2 h = 0.2618\, d^2 h$



Frustum of a Cone

A = area of base
a = area of top
m = area of midsection
$R = D \div 2;\ r = d \div 2$
Area of Conical Surface = $\frac{1}{2}\pi s(D + d) = 1.5708\, s(D + d)$
Volume = $\frac{1}{3}h(R^2 + Rr + r^2) = 1.0472\, h(R^2 + Rr + r^2)$
Volume = $\frac{1}{12}h(D^2 + Dd + d^2) = 0.2618\, h(D^2 + Dd + d^2)$
Volume = $\frac{1}{3}h(a + A + \sqrt{aA}) = \frac{1}{6}h(a + A + 4m)$

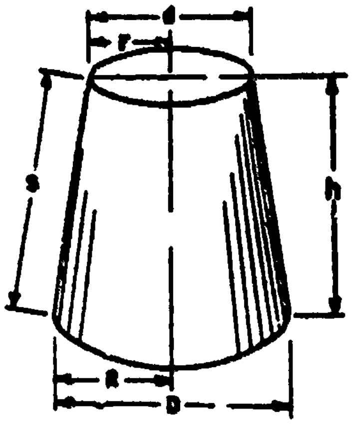


Figure 8-39.—Areas and volumes for calculating weights of castings—Continued. 68.223.5

CALCULATIONS OF CASTING WEIGHTS

There are two methods used to CALCULATE the APPROXIMATE weights of castings; volume method and weight method.

To determine the weight of a specific casting using the volume method, you must break down the pattern design into simple geometric sections or shapes and calculate the volume of each shape in cubic inches. If the pattern is cored, you must also determine the volume contained in the cores and subtract this figure from the total volume of the pattern.

After you have determined the total volume of the pattern minus the core volume, you must multiply by the weight of the specific casting material. The weights for most casting materials are shown in Table 8-1.

To explain further, let's say that a certain cored pattern is to be cast in brass and has a volume of 530 cubic inches and cores containing 215 cubic inches. Look at Table 8-1 and you will find that brass weighs .310 lbs. per cubic inch. Therefore, the approximate weight of this casting is 97.65 lbs.

casting weight = .310 (530 - 215)
= .310 (315)
= 96.75 lbs.

To use the weight method for calculating the approximate weight of a casting, you must determine the weight of the pattern. If you are fortunate enough to have a scale, you can simply weigh the pattern and the cores. In order to obtain the core weight, you must weigh the actual sand core, not the core box.

Next, you must multiply the pattern weight by the appropriate factor from Table 8-2. These factors are nothing more than ratios between certain pattern materials to certain casting materials.

The next step is to multiply the core weight by the appropriate factor from Table 8-2 and then subtract this product from the pattern weight.

Problem: A certain cored, white pine, pattern for a cast iron casting weighs 12.8 lbs. and has cores weighing a total of 3.8 lbs. What is the approximate weight of the casting?

Casting weight = 12.6 x 16 - 3.8 x 4
= 207.6 - 15.2
= 192.4 lbs.

Table 8-1.—Casting Material Weights

Material	Weight in pounds per cubic inch
Aluminum	.089
Bismuth	.353
Brass	.310
Bronze	.310
Aluminum Bronze	.295
Manganese Bronze	.308
Cast Iron	.260
Cast Iron, Wrought	.280
Copper	.324
Lead	.409
Monel	.345
Magnesium	.066
Steel	.281
Tin	.263
Low Melting Point Alloy	.350
Zinc	.254
Plaster of Paris	.0894

68.215

Table 8-2.—Factors

Pattern Material	Casting Material: Cast Steel	Cast Iron	Bronze	Copper	Zinc	Aluminum
Pine	17.0	16.0	19.0	19.6	15.0	5.7
Redwood	17.0	16.0	19.0	19.6	15.0	5.7
Mahogany	13.0	12.0	14.0	14.7	11.5	4.5
Cherry	11.5	10.5	12.5	13.0	10.0	3.8
Poplar	15.0	14.0	17.0	17.5	13.0	5.0
Walnut	11.5	10.5	12.5	13.0	10.0	3.8
Cedar	19.0	18.0	21.0	21.5	17.0	6.3
Plaster of Paris	3.2	2.85	3.2	3.44	2.7	1.1
Aluminum	3.2	2.85	3.2	3.44	2.7	1.0

68.216

If a scale is not available, you must determine the pattern weight mathematically by finding the total volume of the pattern minus the total volume of the cores and then multiplying this figure by the weight of the specific pattern material. Table 8-3 shows the weights of some pattern materials per cubic foot.

After you have determined the pattern weight, you proceed as before by multiplying by the appropriate factor from Table 8-2. To explain further, let's say that you have determined that a certain cored redwood pattern for a cast iron part has a volume of 180 cubic inches and 72 cubic inches of core. Table 8-3 shows that redwood weighs 28 lbs. per cubic foot. Since the pattern is measured in cubic inches, you must determine the weight of redwood per cubic inch by dividing 1728 (number of cubic inches contained in 1 cubic foot) into the weight of redwood per cubic foot (28).

Example: $\frac{28}{1728} = .0162$

Therefore, redwood weighs .0162 lbs. per cubic inch.

Table 8-3.—Pattern Material Weights

PATTERN MATERIAL	WEIGHT PER CUBIC FOOT
WHITE OR SUGAR PINE	23.8
SPANISH MAHOGANY	53
HONDURAS MAHOGANY	36
POPLAR	39
DOUGLAS FIR	31.8
CEDAR	23.2
CALIFORNIA SPRUCE	25
CHERRY	42
MAPLE	49
REDWOOD	28
RED OAK	44
WHITE OAK	47
PLASTER OF PARIS	12.87

68.217

Where pattern volume (P) = 180 cubic inches, core volume (C) = 72, the weight of redwood per cubic foot (R) = 28, and the factor for cast iron (F) = 16, the formula for finding the casting weight (W) could look like this:

$$W = F\left[\frac{R}{1728}\ (P - C)\right]$$

$$W = 16\left[\frac{28}{1728}\ (180 - 72)\right]$$

$$W = 16\left[\frac{28}{1728}\ (108)\right]$$

$$W = 16\left[.0162\ \ (108)\right]$$

$$W = 16\left[1.7496\right]$$

$$W = 27.9936 \text{ lbs.}$$

PRINCIPLES OF SURFACE DEVELOPMENT

In the Navy, the principles of surface development are used for many types of repair work. For example, they are used in sheet metal work such as heating, ventilating and air-conditioning systems; in shipfitter work such as structural components on boat or ship parts; and in patternmaking such as joining curved surfaces together.

As a PM3 or PM2, you must have a knowledge of pattern joinery to choose the best type of development for any particular job. Therefore, the principles of surface development are necessary to transpose any shape from a flat plane to a three-dimensional object in order to cut the pattern components without error or waste. These principles will be discussed in this section and their application as applied to patternmaking will be discussed in the chapter on flanged fittings.

A surface has two dimensions—length and width. It is bounded by lines which are either straight or curved. The surface itself may be PLANE, PLANE-CURVED as peripheral surface of a cylinder, WARPED as the surface of a screw thread, or DOUBLE-CURVED as the surface of a sphere. A plane surface is flat. A plane-curved surface can be unrolled and laid out flat. This is called DEVELOPING the surface. A warped surface or a double-curved surface cannot be developed except approximately.

In figure 8-40, a number of three-dimensional figures are illustrated. Try to form a mental picture of what would happen if the surfaces of these figures were unfolded or unrolled and laid out in a flat plane. The polyhedrons, of course, would be merely a system of connected squares, triangles, or other polygons. A cylinder with parallel ends would unroll into a parallelogram. A cone would unroll into a section of a circle. However, warped surfaces could not be made to lie flat, and double-curved surfaces present a similar problem.

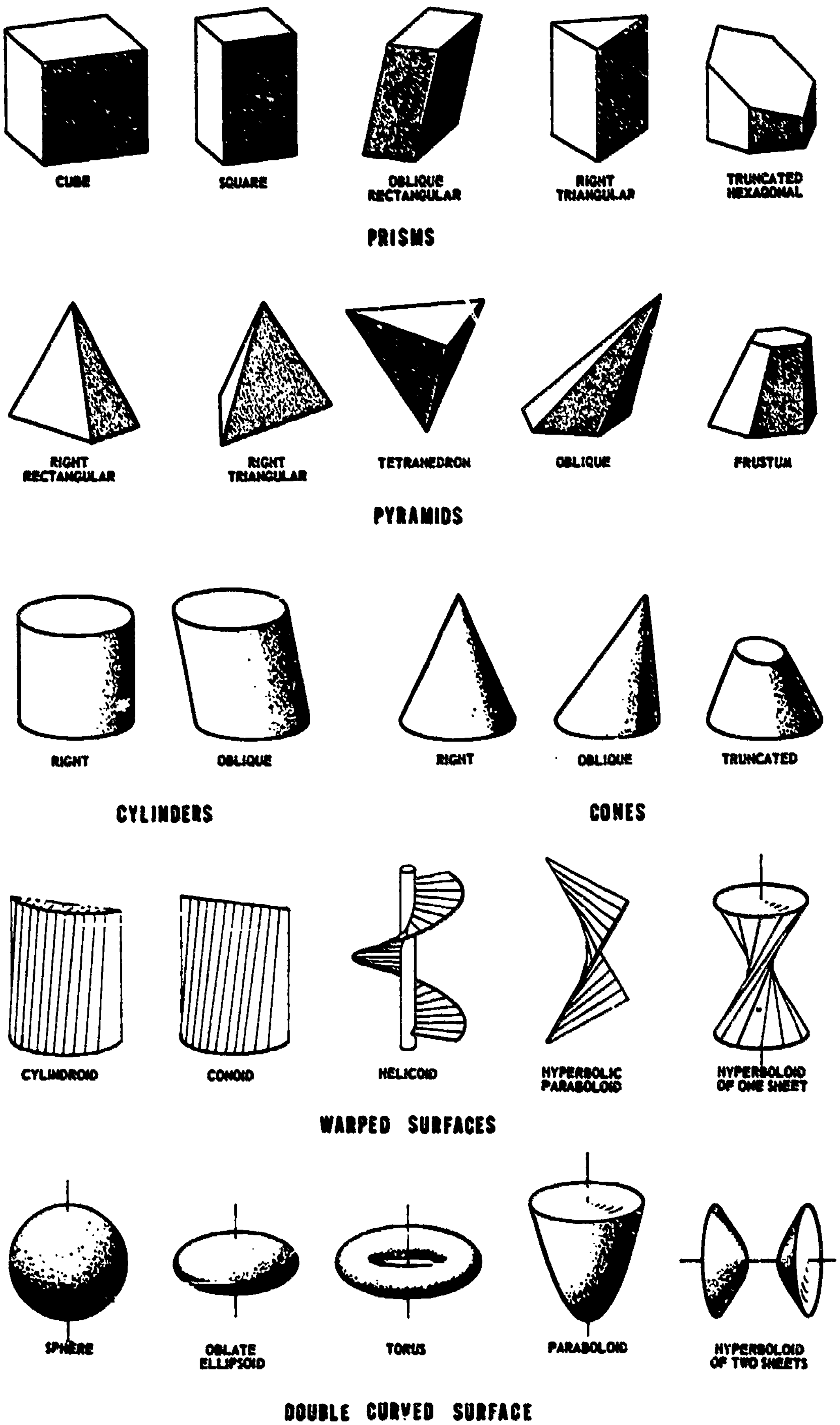
The three principal methods of developing the surface of three-dimensional objects are called PARALLEL DEVELOPMENT, RADIAL DEVELOPMENT, and TRIANGULATION. Parallel development is used for surfaces such as those of prisms or cylinders. (See view A of fig. 8-41.) Radial development is used for surfaces such as those of cones and pyramids, which may be said to be generated by a line of which one end remains fixed while the other end rotates about it. (See view B of fig. 8-41.) Triangulation is used for surfaces which do not lend themselves to either of the other two methods, to approximate the development of warped surfaces. (See view C of fig. 8-41.)

Double-curved surfaces, such as the surface of a sphere, may be developed approximately by several methods which you will probably never have occasion to use in the Navy but which are interesting in that the identical methods are applied in various map projections. A sphere may be cut into horizontal sections, or zones, which may be considered and developed as frustums of cones, as shown in view A of figure 8-42.

A sphere may also be cut into equal meridian sections, called lunes, and these developed as if they were sections of cylinders. (See view B of fig. 8-42.)

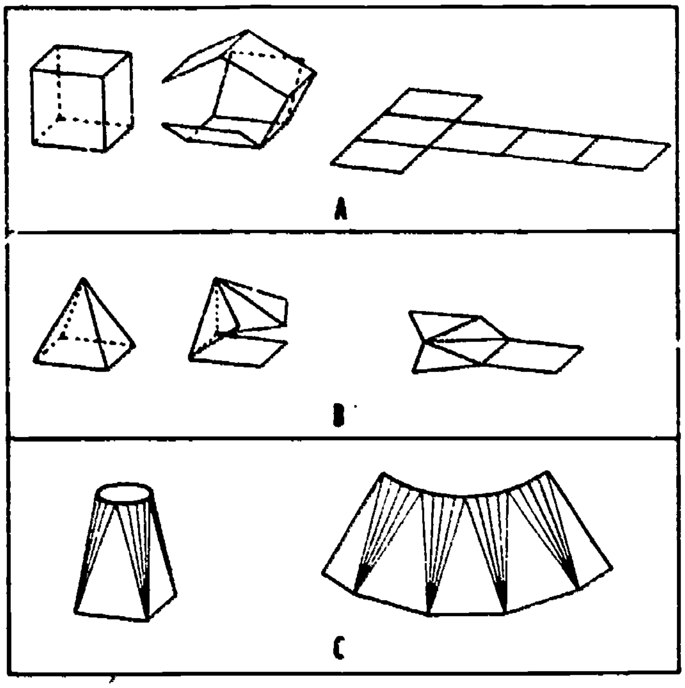
PARALLEL DEVELOPMENT

The surfaces of prisms and cylinders are made up of parallel elements or of elements

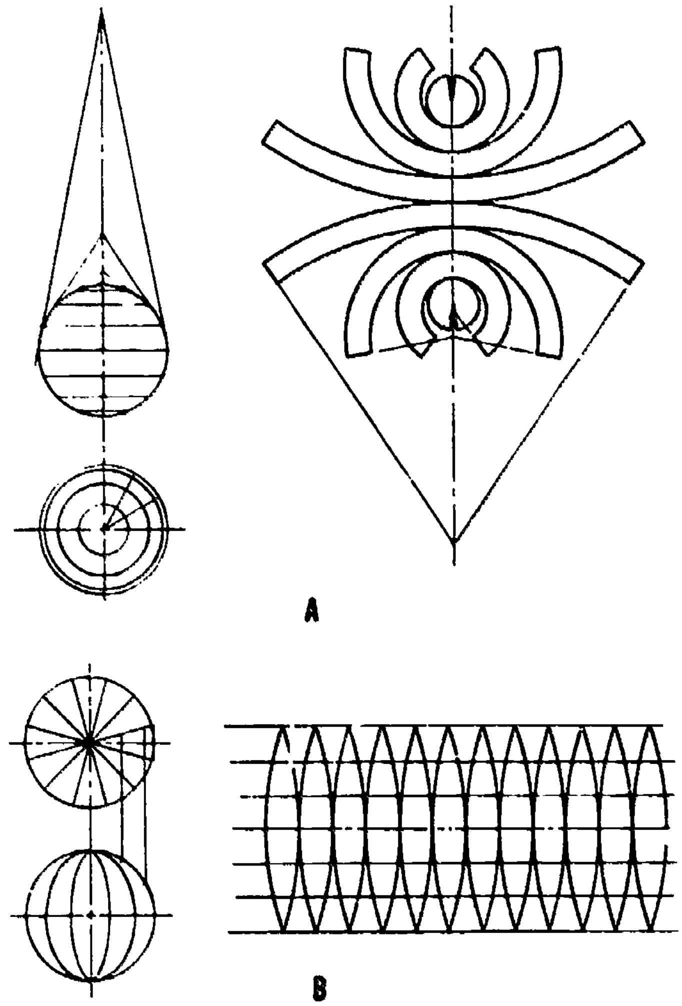


65.50(68)

Figure 8-40.—Three-dimensional shapes.



11.212:249(65)
Figure 8-41.—Surface development: A. Parallel development. B. Radial development. C. Development by triangulation.



68.75
Figure 8-42.—Development of double-curved surfaces.

that can be treated as parallel elements. For example, in figure 8-43, the steps in developing a rectangular prism are illustrated.

1. In order to determine the length of all the edges of the prism, draw the front and top views in orthographic projection. (See view A of fig. 8-43.)

2. Draw the development to one side of the front view so that the dimensions of vertical elements on that view can be projected to the development as shown in view B of figure 8-43.

3. Transfer the dimensions of other elements from the top view. (See view C of fig. 8-43.) Notice that all bend lines are marked with crosses near their ends to distinguish them from outlines.

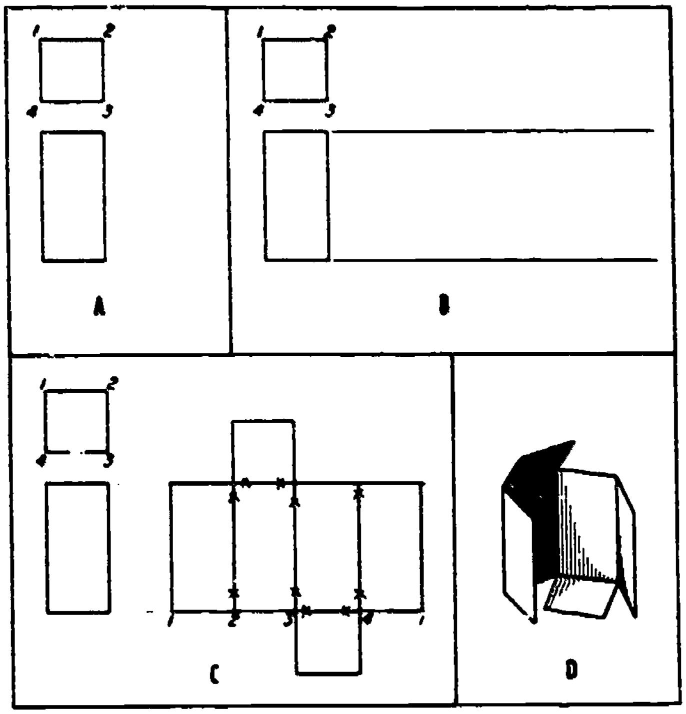
4. To check the drawing, measure the lines of edges which are to be joined as illustrated in the pictorial drawing in view D of figure 8-43. Such edges must correspond exactly.

In figure 8-44, the steps in the development of a truncated hexagonal prism are illustrated.

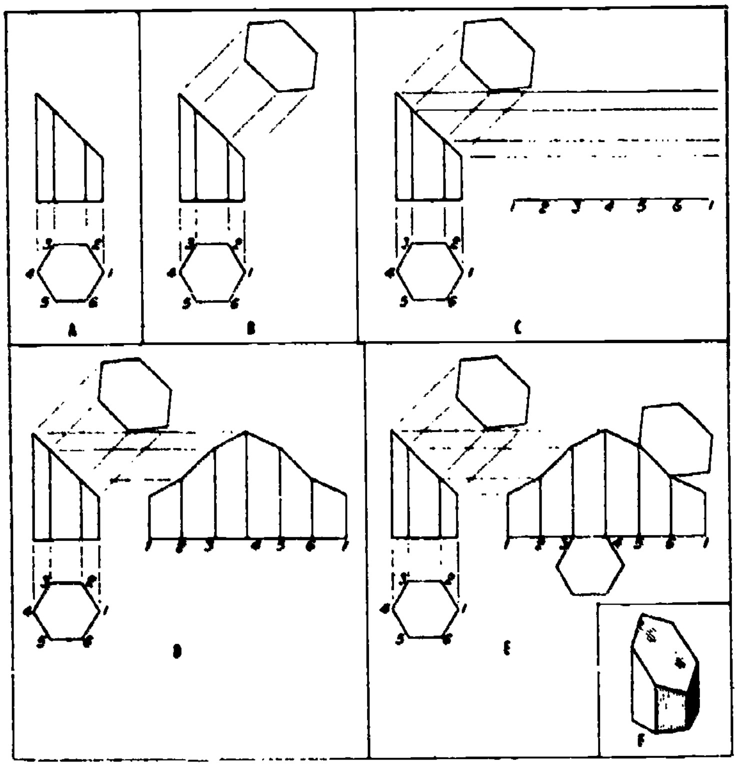
1. Draw a front view and a bottom view of the prism in orthographic projection. (See view A of fig. 8-44.)

2. Since the true shape of the slanting plane and the length of the lines of its edges are not shown in these views, draw an auxiliary view as shown in view B of figure 8-44. Note that it is not necessary to draw the entire prism in the auxiliary view, since only the dimensions of the plane surface are required.

3. Project the lines of the front view horizontally as the first step in constructing the development. (See view C of fig. 8-44.)



11.212(65)C
Figure 8-43.—Parallel development of a rectangular prism.



68.76
Figure 8-44.—Development of a truncated hexagonal prism.

4. Number the points of intersection of planes on the bottom view, and mark off line segments of the same length on the baseline of the development.

5. Erect vertical lines from these numbered points to intersect the lines projected from the front view of the prism. (See view D of fig. 8-44.) These intersections mark the corners of the prism.

6. Connect the intersection points with straight lines.

7. Draw the bottom of the prism attached to one of the sides at the baseline. Draw the slanting plane at the top of the prism, as it is shown in the auxiliary view, attached to one of the sides. (See view E of fig. 8-44.)

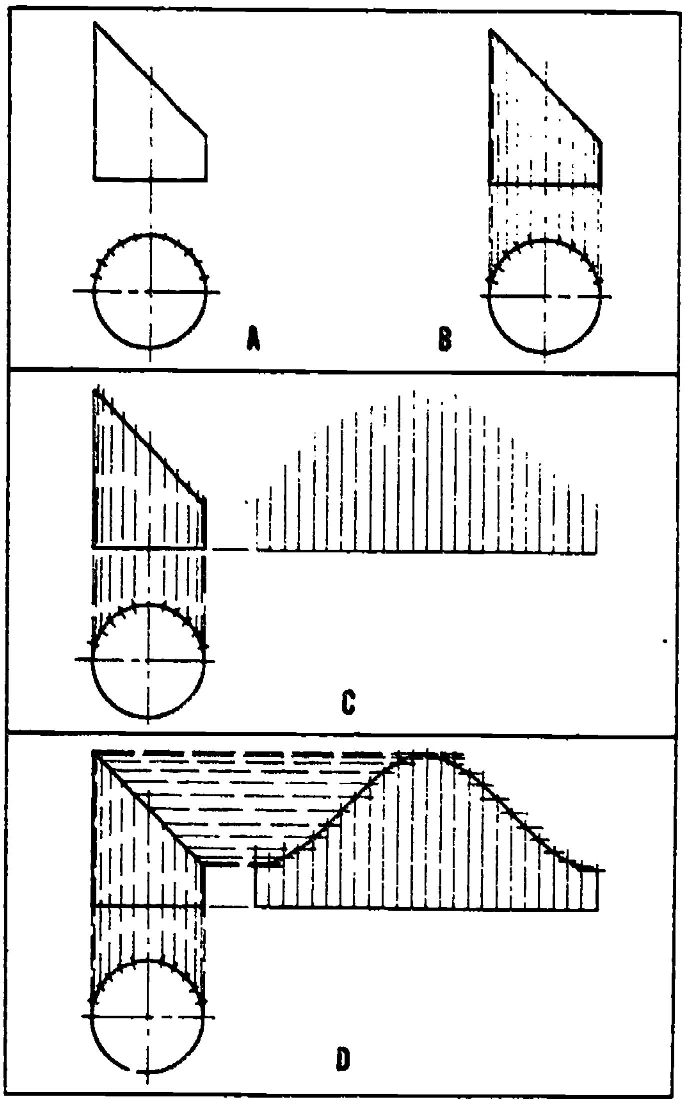
8. Check all measurements of edges to be joined as shown in the pictorial drawing in view F of figure 8-44, in order to be sure that they will coincide exactly.

The development of a truncated cylinder, illustrated in figure 8-45, is made with a very similar procedure. The cylinder is considered to be a prism with an infinite number of sides. In developing a cylinder, the number of sides must necessarily be limited, but the greater the number of sides, the more accurate the development is likely to be.

1. To develop one-half of a two-piece elbow, first draw a front and bottom view of that piece in orthographic projection. (See view A of fig. 8-45.) Since the elbow does not require an end piece, it is not necessary to draw an auxiliary view showing the true shape of the ellipse formed by the cutting plane at the top of the cylinder.

2. Divide half the circumference of the circle into a number of equal parts. The parts should be small enough so that, when a straight line is drawn between division points, it will approximate the length of the arc. Project lines from these points to the front view, as shown in view B of figure 8-45. The resulting parallel lines on the front view are called ELEMENTS.

3. Lay off the baseline, called the STRETCH-OUT LINE, of the development. The length of this line may be calculated as π times the diameter of the cylinder (3.1416 X D).



11.239(65)B

Figure 8-45.—Development of a truncated cylinder.

4. Divide the stretchout line into twice the number of equal parts as the number on the half circle of the orthographic view. (See view C of fig. 8-45.)

5. Erect perpendiculars at each point, as shown in view C of figure 8-45.

6. Using a T-square, project the lengths of the elements on the front view to the development. (See view D of fig. 8-45.)

7. Using a french curve, join the resulting points of intersection in a smooth curve.

When the two pieces of the elbow are identical, it is only necessary to make one pattern.

When a four-piece elbow is to be drawn, the same steps are followed to produce as many developments as may be required. The orthographic view may be drawn of the whole elbow and the developments drawn beside each separate piece, as illustrated in figure 8-46. Here only one end and one middle development are drawn, since the other two pieces are identical with these.

When two pieces, such as two cylinders or a cylinder and a prism, intersect, it is necessary to determine the exact points of intersection in order to make developments (for the pieces) that will fit together without gaps or unnecessary overlaps. These intersections are determined by carefully drawing the elements intersecting on orthographic views and then projecting or transferring these intersection points to the developments. In figure 8-47, for example, the steps in making developments for a T-joint are illustrated. The T-joint shown consists of two cylinders with equal diameters, which intersect at right angles.

1. Draw a front view and a side view of the T-joint. A bottom view representing the open end of the other cylinder might also be drawn. However, since this cylinder is perfectly round, a semicircle may be drawn attached to the front view, and the division points for the elements located on it. (See view A of fig. 8-47.)

2. Draw equally spaced divisions to locate the elements and project these division points to both cylinders. The points where the elements of one cylinder intersect those of the other define the intersection of the two cylinders. (See view B of fig. 8-47.)

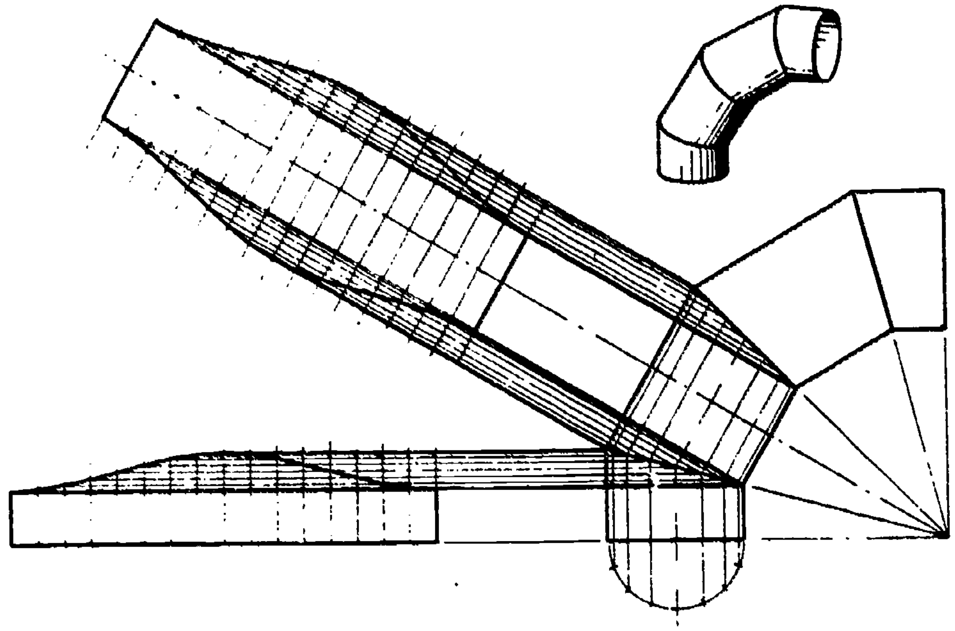
3. Draw the surface pattern of the projecting pipe at one side of the orthographic view so that the length of each element can be projected from the front view, as shown in view C of figure 8-47.

4. Draw the surfaces pattern of the cross pipe below the front view, projecting lines down from the branch pipe to locate the opening for it, as shown in view D of figure 8-47.

When the T-joint is made of two cylindrical pipes of unequal diameter, the procedure differs slightly.

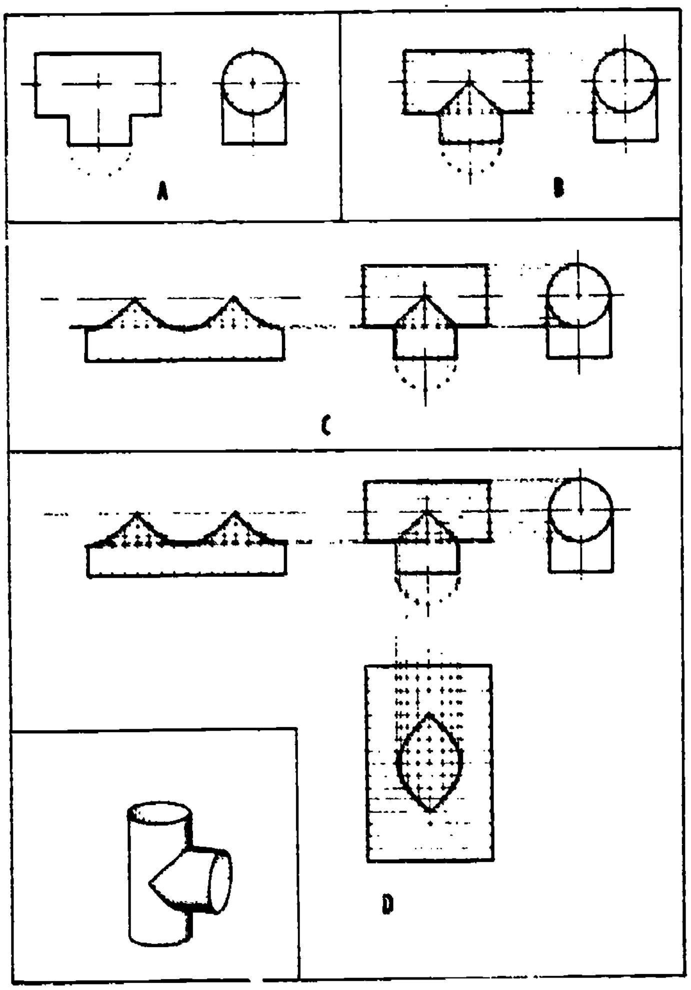
1. Draw the orthographic views.

2. Divide the smaller diameter branch pipe into equal parts, and draw the elements on this pipe in both views, as shown in view A of figure 8-48. The length of each element is shown in the side view.



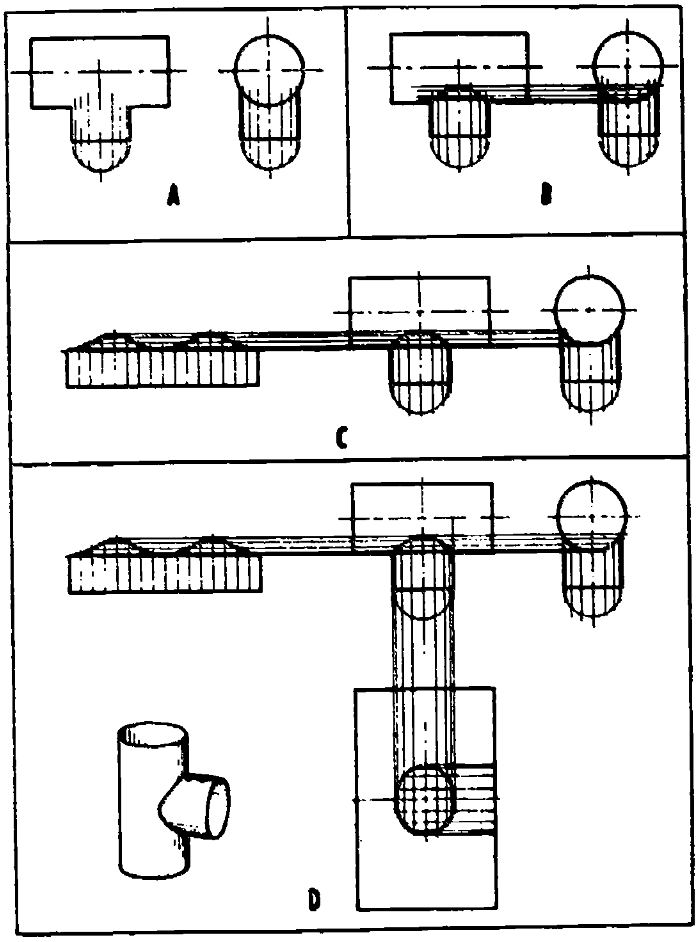
68.77

Figure 8-46.—Developments for a four-piece elbow.



68.78

Figure 8-47.—Development of a T-joint composed of cylinders of equal diameters.



68.79

Figure 8-48.—Development of a T-joint with two cylindrical pipes of unequal diameters.

3. Project lines from the upper end of each element in the side view to the front view, as shown in view B of figure 8-48. The intersections of these lines with the vertical lines drawn on the branch pipe define the intersection of the two pipes.

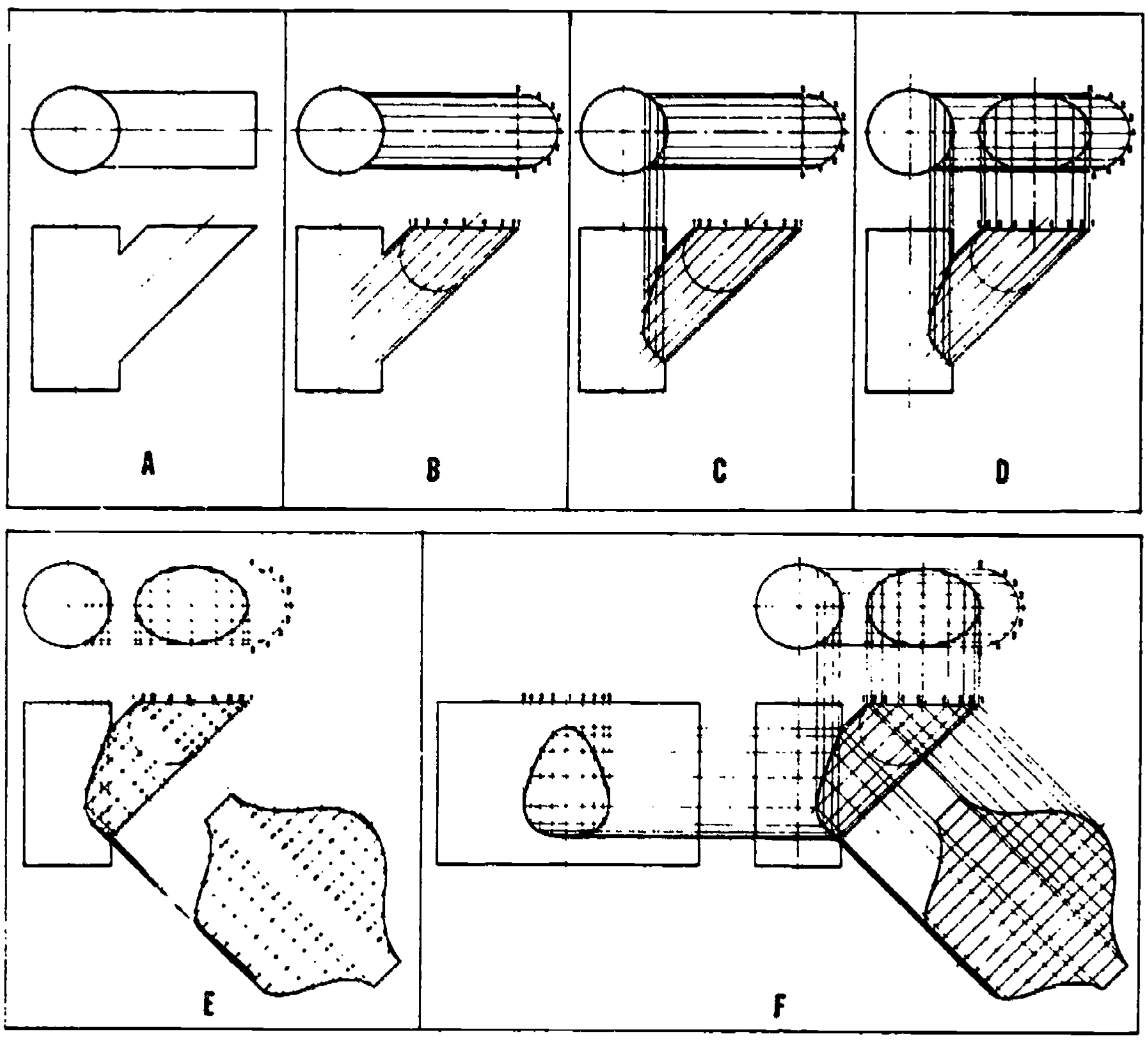
4. Draw the line of intersection on the front view.

5. Draw the surface pattern of the branch pipe to the left, continuing the projection lines to locate the ends of elements. (See view C of fig. 8-48.)

6. Draw the surface pattern of the larger diameter main pipe beneath the front view, projecting lines down from the branch pipe to locate the opening for it, as shown in view D of figure 8-48.

Figure 8-49 illustrates the steps in drawing a round pipe joint made up of two cylindrical pipes of unequal diameters which intersect at an angle other than 90 degrees.

1. Draw the front and top orthographic views. The ellipse formed by the top of the branch pipe may be omitted at this point and drawn later. (See view A of fig. 8-49.)
2. Draw the elements on the branch pipe in both views. (See view B of fig. 8-49.)
3. Project lines down from the left end of each element in the top view to the corresponding element in the front view, and draw the line of intersection. (See view C of fig. 8-49.)



68.80
Figure 8-49.—Development of a round pipe joint made of two cylindrical pipes of unequal diameters, intersecting at an angle other than 90 degrees.

4. Draw the ellipse formed by the end of the branch pipe in the top view, by projecting lines up from the upper end of each element in the front view to the corresponding element in the top view. (See view D of fig. 8-49.)

5. Draw the pattern of the branch pipe to the right and perpendicular to the pipe as it appears in the front view, as shown in view E of figure 8-49.

6. Draw the pattern for the main pipe to the left, with lines projecting from the intersection of the two pipes on the orthographic view to locate the opening for the branch pipe. (See view F of fig. 8-49.)

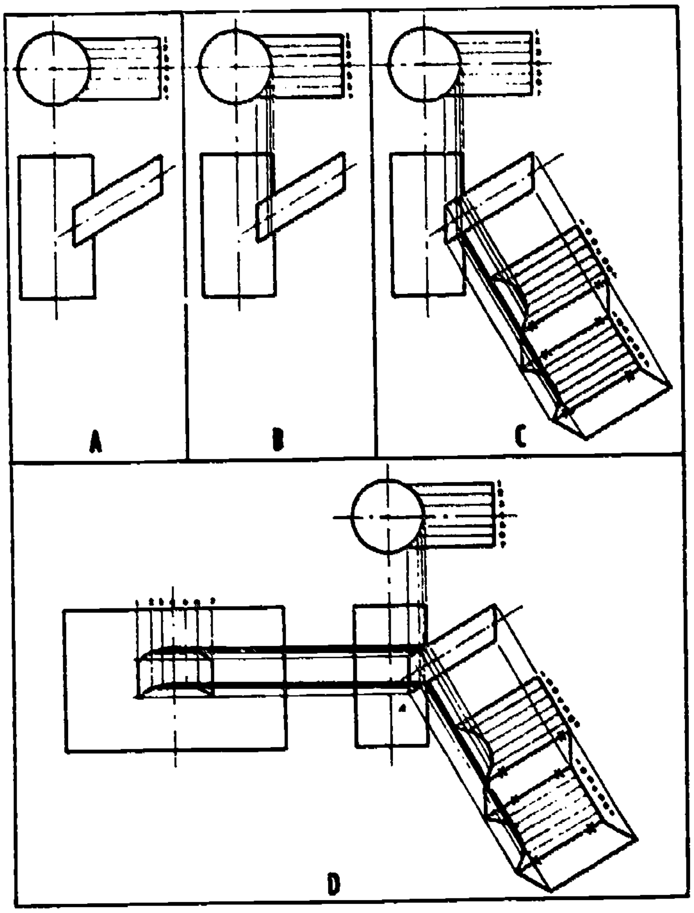
When a pipe joint consists of a rectangular pipe intersecting a round pipe at an angle other than 90 degrees, the procedure is similar.

1. Draw the orthographic views, as shown in view A of figure 8-50, dividing the upper surface of the rectangular pipe in the top view by equally spaced elements.

2. The points of intersection of these lines with the circle are then projected down to the upper and lower surfaces of the branch pipe in the front view. (See view B of figure 8-50.)

3. Develop the surface pattern of the rectangular pipe perpendicular to it in the front view, as shown in view C of figure 8-50.

4. Draw the surface pattern of the round pipe, with the opening for the rectangular pipe, to the side of the front view, as shown in view D of figure 8-50.



68.81

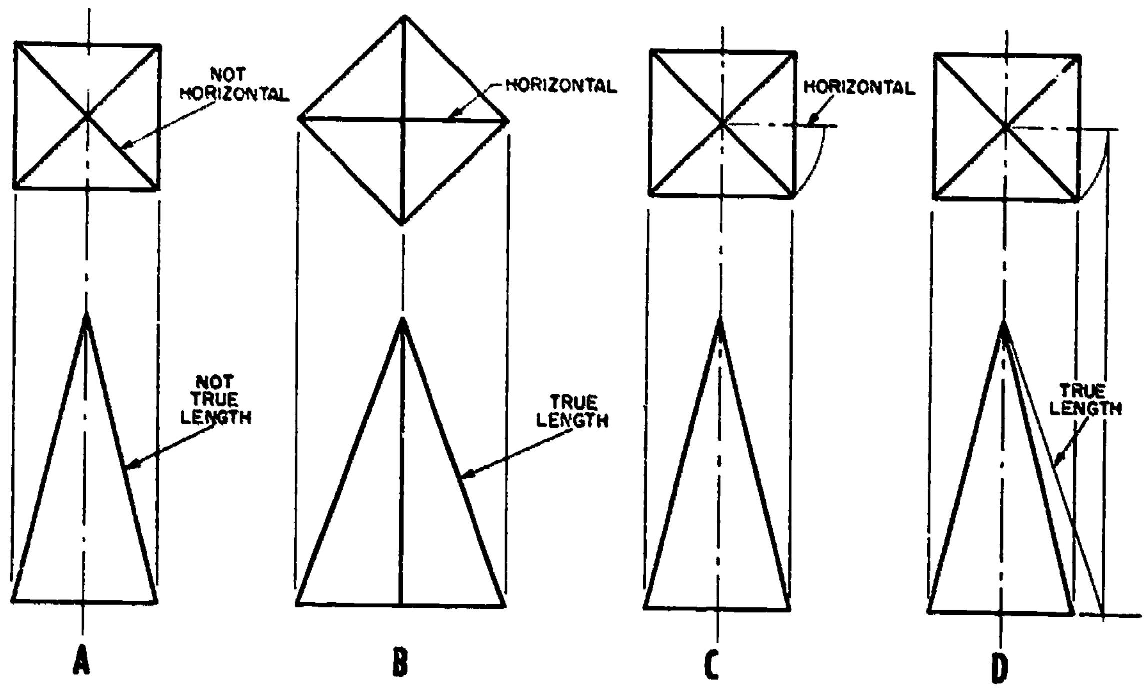
Figure 8-50.—Development of a pipe joint in which a rectangular pipe intersects a round pipe at an angle other than 90 degrees.

RADIAL DEVELOPMENT

The sides of a pyramid and the elements of a cone meet at a point called the vertex of apex. These same lines meet at a point in the development of a pyramid or cone and are said to radiate from this point. Consequently, the method of developing pyramids or cones is called radial development. (See fig. 8-51.)

In radial development, the same general procedures are followed as those used in parallel development, except that since the slanting lines of pyramids and cones do not always appear in their true lengths on the orthographic views, as shown in view A of figure 8-51, certain other procedures must be followed in order to determine these true lengths. To find the true lengths of these edges, the pyramid may be rotated so that some of the edges appear in their true lengths in the views, as shown in view B of figure 8-51. In this case, the lines which appear as horizontal lines in the top view are shown in outline and in their true length in the front view. IN OTHER WORDS, WHEN A LINE APPEARS AS HORIZONTAL OR AS A POINT IN THE TOP VIEW, THE CORRESPONDING LINE IN THE FRONT VIEW IS ITS TRUE LENGTH. CONVERSELY, WHEN A LINE APPEARS AS HORIZONTAL IN THE FRONT VIEW, THE CORRESPONDING LINE IN THE TOP VIEW IS ITS TRUE LENGTH.

Usually, instead of rotating the whole pyramid, the line of the edge itself may be simply rotated into the horizontal on a conventional orthographic view. For example, in view C of figure 8-51, the line of an edge from apex to base as it appears in the top view is used as the radius for an arc to the horizontal. The point of intersection of the arc with the horizontal is projected to the front view and a true-length



68.82
Figure 8-51.—Methods of finding the true length of a line in radial development.

line for that edge drawn, as shown in view D of figure 8-51.

The steps for developing a truncated pyramid are illustrated in figure 8-52. This is a transition piece for connecting a large square pipe with a smaller one. Normally the square ends would be terminated in square collars which would also be developed.

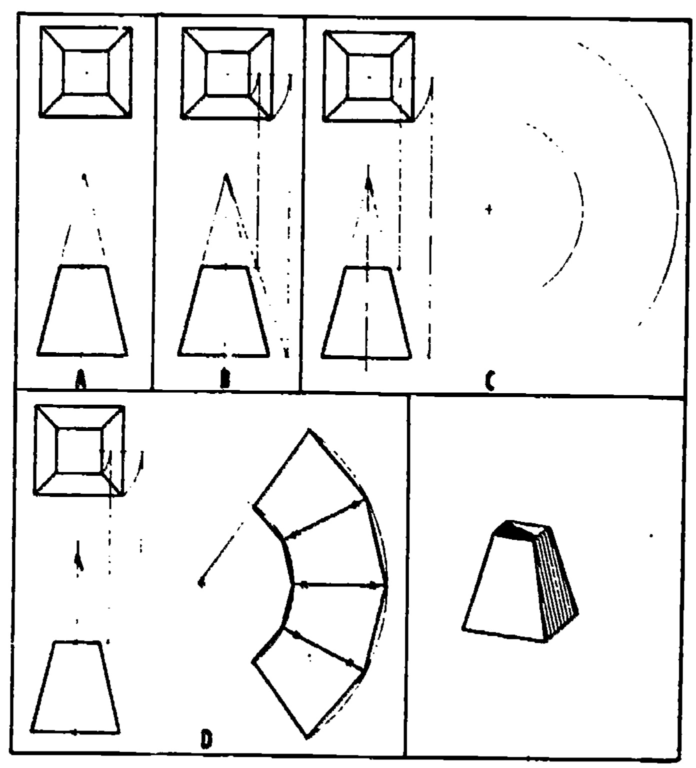
1. Draw the orthographic views, completing the lines of the sides to the apex. (See view A of fig. 8-52.)

2. Rotate the line of one edge in the top view to the horizontal and project it to the front view. (See view B of fig. 8-52.)

3. Draw an arc with a radius equal to the length of this true-length line plus its extension to the apex of the pyramid, and a second arc defining the upper limit of the true-length line, as shown in view C of figure 8-52.

4. Step off lengths along these arcs equal to the sides of the pyramid. (See view D of fig. 8-52.)

5. Connect these points successively with each other and also connect them by light lines with the vertex, as shown in view D of figure 8-52.



11.239(65)C
Figure 8-52.—Development of a truncated pyramid.

To develop a truncated pentagonal pyramid like that shown in figure 8-53, the same general steps are followed. However, since one lateral edge appears in its true length in the front view, the limits of the other edges may be projected onto the line of this edge in order to determine the true lengths. The length of each edge is then measured, and this measurement transferred to the development.

Figure 8-54 shows the development of an offset transition piece. It is called OFFSET because the center of one end is not in line with that of the other end. The three parts consist of an upper section and a lower section, which are truncated rectangular prisms, and a third section, which is a truncated oblique pyramid.

1. Draw the orthographic views, extending the lines of the sides of the pyramid to its apex in both views. (See view A of fig. 8-54.)

2. Rotate the lines of the sides to the horizontal in the top view, project the points thus located to the front view, and draw the true-length lines. (See view B of fig. 8-54.)

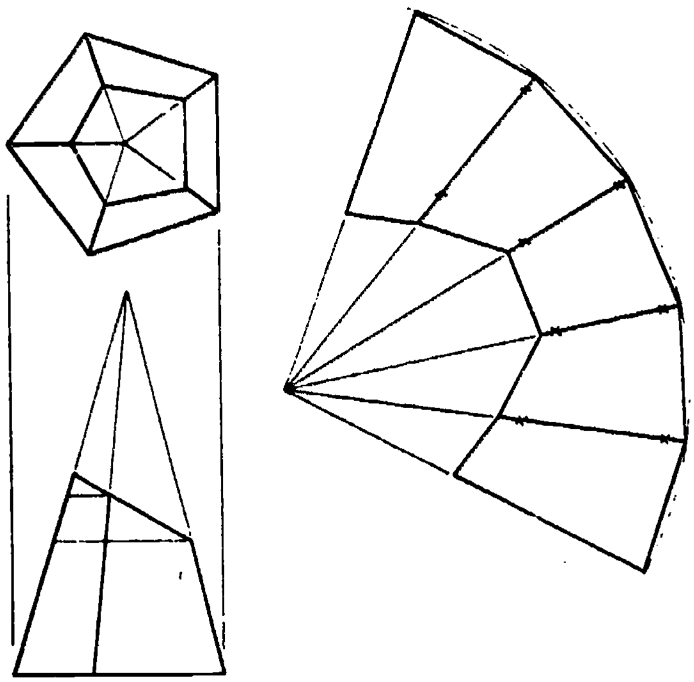
3. At one side of the views, develop the surface pattern of the oblique square pyramid. Construct one triangle at a time, taking the length of the three sides of each triangle from the views. (See view C of fig. 8-54.) Draw the upper edges to complete the pattern.

4. Draw the surface patterns of the upper and lower prisms, as shown in view D of figure 8-54.

The development of a cone is similar. It is considered to be a pyramid with an infinite number of sides. In actual practice, of course, the number of sides must be limited. Elements representing these sides are drawn on the orthographic views and projected to the development. The steps in developing a truncated right cone are illustrated in figure 8-55.

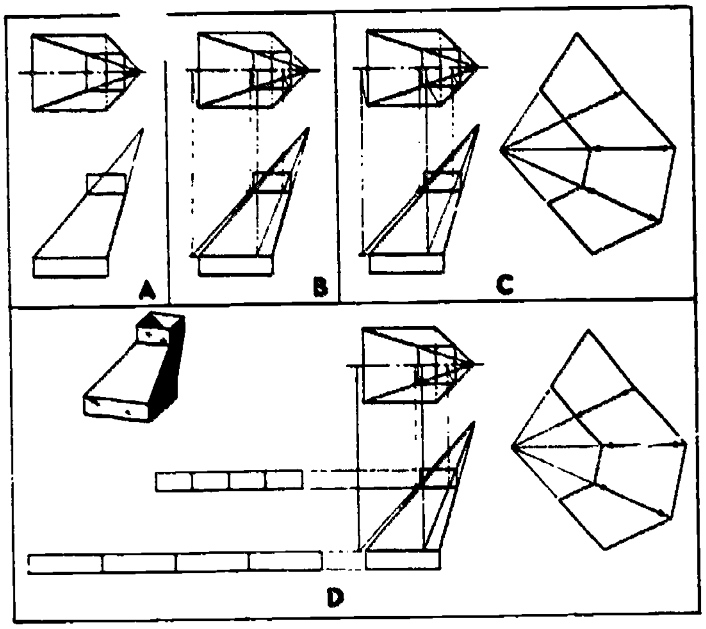
The right cone has a centerline which is perpendicular to its base. Thus the elements on a right cone are all the same length. The true length of these elements is shown by those which fall to the extreme right and left in the front view, since these elements are horizontal lines in the top view. The cone in figure 8-55 is cut by a slanting plane. Therefore, the termination points of the elements between the two outside elements must be projected to one of the outside lines in order for their true length to be determined.

1. Draw the orthographic views, including either a side view, as shown in view A of figure



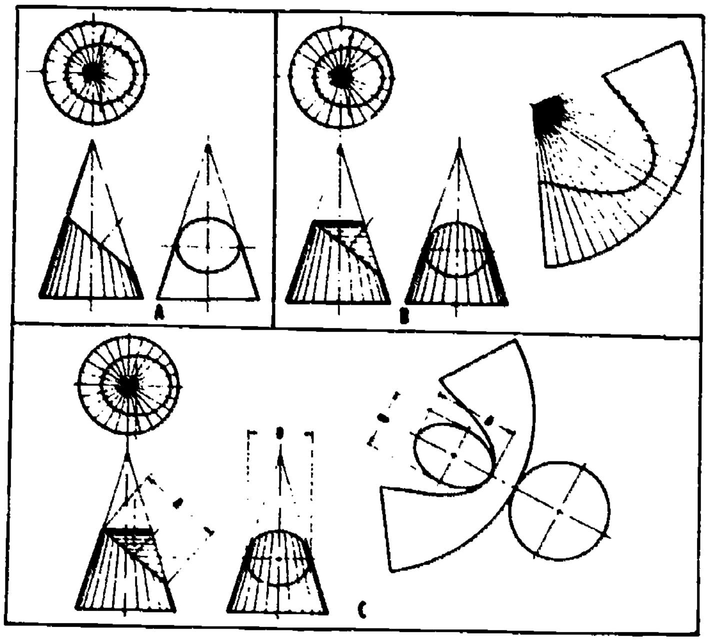
68.83

Figure 8-53.—Development of a truncated pentagonal pyramid with the upper corners cut by a slanting plane.



68.84

Figure 8-54.—Development of an offset transition piece.



68.85
Figure 8-55.—Development of a truncated right cone.

8-55, or an auxiliary view of the ellipse which is formed by the slanting plane. Note that the center of the ellipse must be determined since it does not fall on the centerline of the cone. This center point is projected to the side view and defines the length of the minor axis of the ellipse. The length of the major axis is defined by the length of the slanting line in the front view.

2. Develop the surface pattern of the cone, using the length from the apex to the base as a radius for drawing the arc. Step off on this line the equally spaced divisions of the base. Then measure each element individually and transfer this measurement to the development. The ends of each of these elements define the curve of the upper edge of the peripheral surface. (See view B of fig. 8-55.)

3. Draw the circle of the surface of the base and the ellipse of the top surface attached to the peripheral surface as shown in view C of figure 8-55.

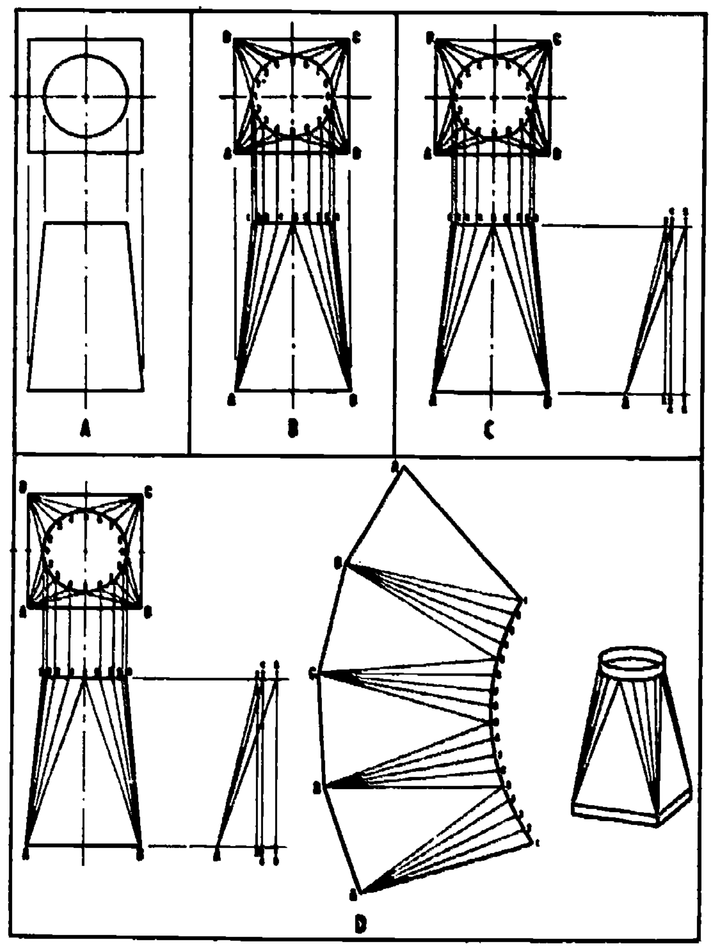
TRIANGULATION DEVELOPMENT

Triangulation is slower and more difficult than parallel line or radial development, but it is more practical for many types of figures. Also it is the only method by which the developments of warped surfaces may be approximated. In development by triangulation, the piece is divided into a series of triangles as in radial development. However, there is no one single apex for the triangles. The problem, therefore, becomes one of finding the true lengths of the varying oblique lines. This is usually done by drawing a TRUE-LENGTH DIAGRAM.

Figure 8-56 illustrates the steps in the triangulation of a warped transition piece joining a large square pipe and a smaller round pipe.

1. Draw the top and front orthographic views. (See view A of fig. 8-56.)

2. Divide the circle in the top view into a number of equal spaces and connect the division points with the corners of the square, as shown in view B of figure 8-56.

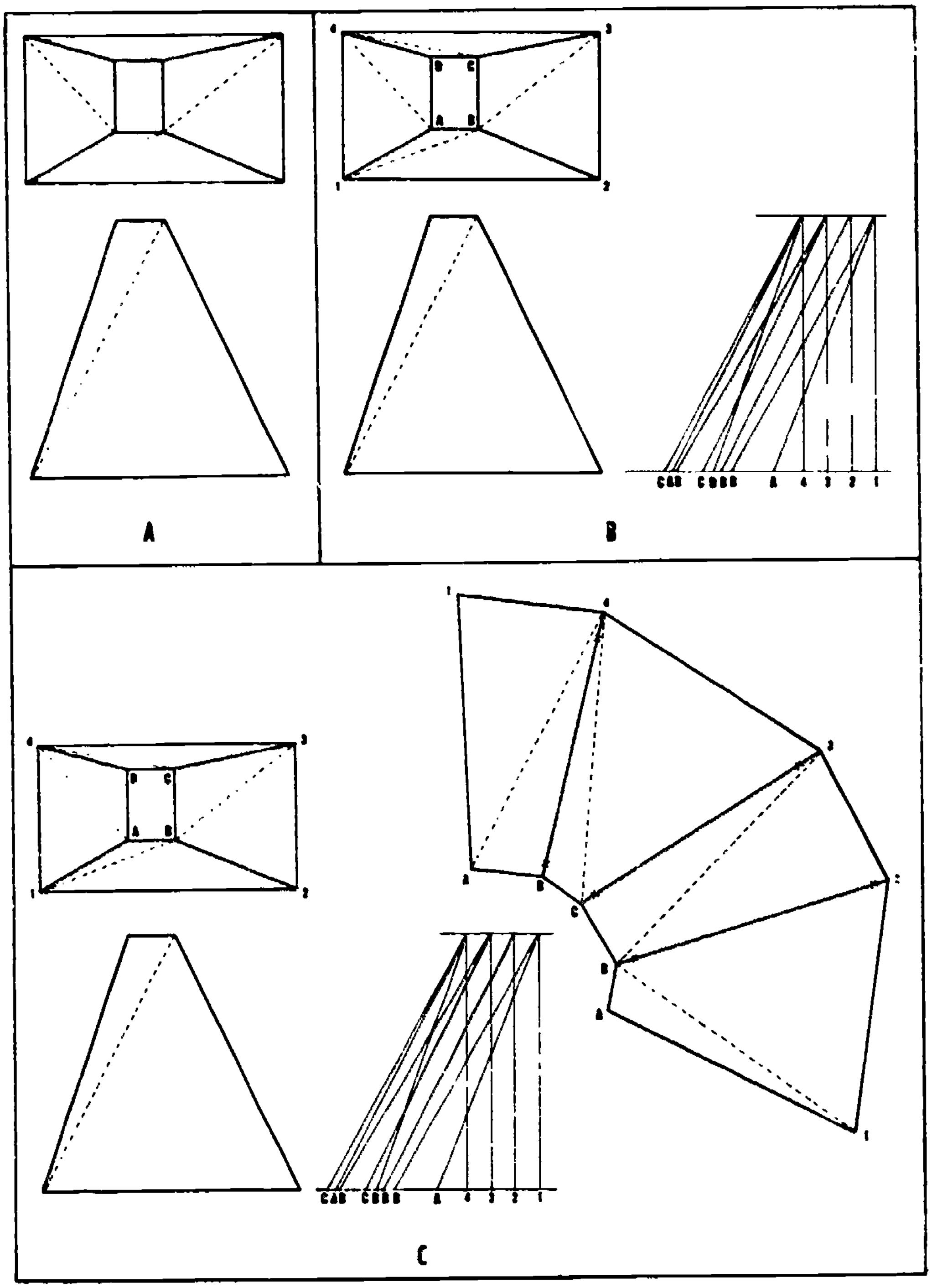


11.249(65)C
Figure 8-56.—Development by triangulation of a transition piece.

3. Transfer the division points to the front view, and draw the elements. Some of the triangles are slightly curved, but they may be considered as flat.

4. Now the true length of each of these elements may be found by drawing a right triangle with a base equal to the length of an element of the top view and with an altitude equal to the altitude of the corresponding element on the front view. The hypotenuse of the triangle is the true length of the element. In view C of figure 8-56, the true-length diagram consists of only three right triangles. Since the piece is symmetrical, a number of the elements are the same length.

5. Draw the surface pattern, constructing one triangle at a time. (See view D of fig. 8-56.)



68.86

Figure 8-57.—Development of a rectangular transition piece which is not a true pyramid.

Figure 8-57 shows the steps in developing a rectangular transition piece which is not a true pyramid because the extended lateral edges would not meet at a common vertex. This may best be developed by drawing diagonals which split the sides into two triangles. These diagonals are usually drawn as dotted lines to differentiate them from other elements. Then the true length of each element is found, and the surface pattern developed by constructing each triangle in turn. To find the true-length lines, a true-length diagram is drawn.

1. Draw the orthographic views with the bend lines and the diagonals. (See view A of fig. 8-57.)

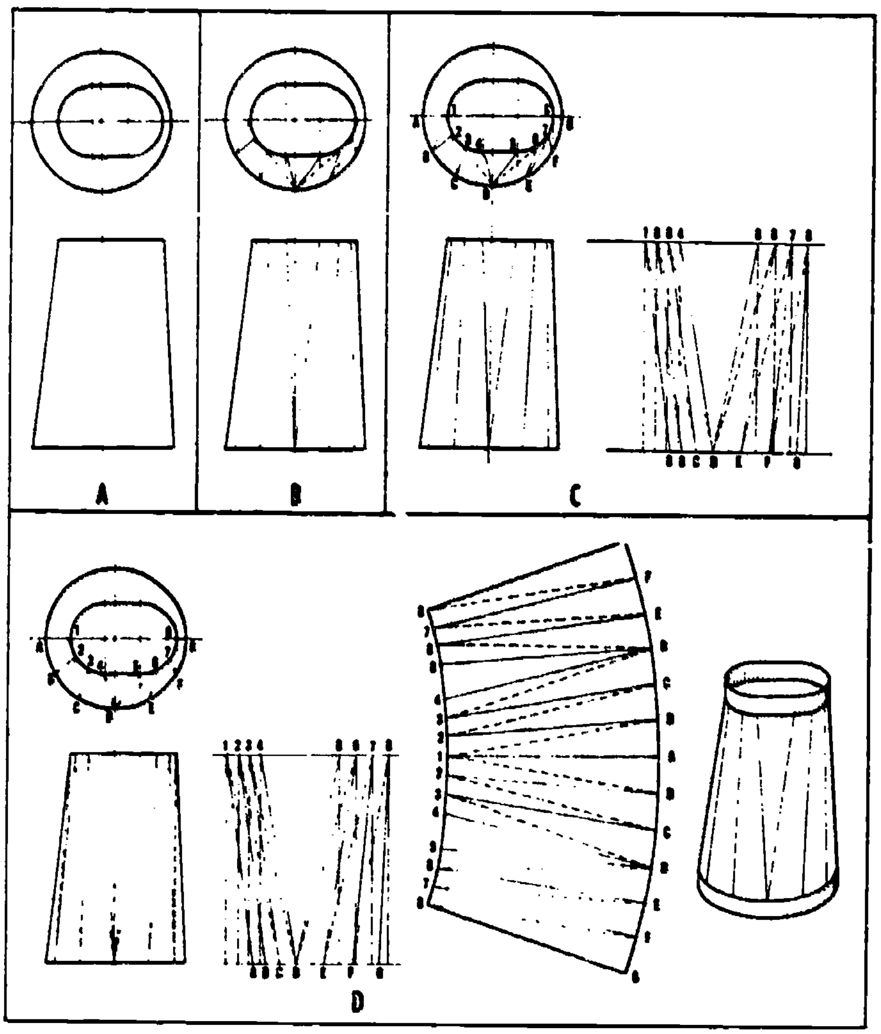
2. Draw a true-length diagram of these elements. (See view B of fig. 8-57.)

3. Draw the surface pattern by constructing one triangle at a time. (See view C of fig. 8-57.)

The fitting in figure 8-58 has a warped surface. Its base is round and its top is oblong. The method for development consists of dividing the surface into quadrilaterals of approximately the same size, and then drawing a diagonal across each of these to produce two triangles. When the true lengths of these elements have been found, the surface pattern may be drawn, triangle by triangle.

1. Draw the top and front orthographic views. (See view A of fig. 8-58.)

2. Divide the circle of the base into a number of equal spaces and the arcs at the ends of



68.87

Figure 8-58.—Development of a warped transition piece.

the oblong into half as many. Since the transition piece is symmetrical on a central axis, this may be done on only half of the top view. Connect these division points as shown in view B of figure 8-58. Use dotted lines for the diagonals to differentiate them.

3. Project the division points to the front view, and draw the elements there.

4. Draw the true-length diagram for the elements. (See view C of fig. 8-58.)

5. Draw an approximation of the surface pattern of the warped surface by constructing one triangle after another. (See view D of fig. 8-58.)

METRIC SYSTEM

The Metric System is an extremely accurate universal system of weights and measures based on a unit called a METER and expressed in the decimal scale. In other words, it is a system based on units of ten making it a very uncomplicated system to work with.

The names of metric denominations are formed by prefixing to the name of the primary unit of measure such as MICROmeter, MILLImeter, etc.

Table 8-4 explains the Metric System by showing nomenclature and giving the English measure equivalents.

Tables 8-4, 8-5, 8-6, 8-7, 8-8, and 8-9 are on the following pages.

Table 8-4. —Metric System and English Conversion

Metric System and English Conversion

Micro, a millionth	= $\frac{1}{1,000,000}$
Milli, a thousandth	= $\frac{1}{1000}$
Centi, a hundredth	= $\frac{1}{100}$
Deci, a tenth	= $\frac{1}{10}$
Deca, ten	= 10
Hecto, one hundred	= 100
Kilo, one thousand	= 1000
Myria, ten thousand	= 10,000
Mega, one million	= 1,000,000

Principal Units of Metric System

The meter for lengths
The square meter for surfaces
The cubic meter for large volumes
The liter for small volumes
The gram for weights

Measures of Length

10 millimeters (mm.)	= 1 centimeter (cm.)
10 centimeters	= 1 decimeter (dm.)
10 decimeters	= 1 meter (m.)
10 meters	= 1 decameter (Dm.)
10 decameters	= 1 hectometer (Hm.)
10 hectometers	= 1 kilometer (Km.)
10 kilometers	= 1 myriameter

A meter is used in ordinary measurements; the centimeter or millimeter in calculating very small distances; and the kilometer for long distances.

Square Measure—Measures of Surface

100 square millimeters ($mm.^2$)	= 1 square centimeter ($cm.^2$)
100 square centimeters	= 1 square decimeter ($dm.^2$)
100 square decimeters	= 1 square meter ($m.^2$)
100 centiares, or square meters	= 1 are (a.)
100 ares	= 1 hectare (ha.)

The square meter is used for ordinary surfaces; the are, a square, each of whose sides is 10 meters, is the unit of land measure.

Cubic Measure—Measures of Volume

1000 cubic millimeters ($mm.^3$)	= 1 cubic centimeter ($cm.^3$ or cc.)
1000 cubic centimeters	= 1 cubic decimeter ($dm.^3$)
1000 cubic decimeters	= 1 cubic meter ($m.^3$)

The term stere is used to designate the cubic meter in measuring wood and timber. A tenth of a stere is a decistere, and ten steres are a decastere.

Liquid and Dry Measures—Measures of Capacity

10 milliliters (ml.)	= 1 centiliter (cl.)
10 centiliters	= 1 deciliter (dl.)
10 deciliters	= 1 liter (l.)
10 liters	= 1 decaliter (Dl.)
10 decaliters	= 1 hectoliter (Hl.)
10 hectoliters	= 1 kiloliter (Kl.)

The liter, which is a cube each of whose edges is $\frac{1}{10}$ of a meter in length, is the principal unit of measures of capacity. The hectoliter is the unit that is used in measuring large quantities of grain, fruits, roots, and liquids.

Measures of Weight

10 milligrams (mg.)	= 1 centigram (cg.)
10 centigrams	= 1 decigram (dg.)
10 decigrams	= 1 gram (g.)
10 grams	= 1 decagram (Dg.)
10 decagrams	= 1 hectogram (Hg.)
10 hectograms	= 1 kilogram (Kg.)
1000 kilograms	= 1 (metric) ton (T.)

68.224.1

Table 8-4.—Metric System and English Conversion—Continued

The gram, which is the primary unit of weights, is the weight of one cubic centimeter of pure distilled water at a temperature of 39.2° F., the kilogram is the weight of 1 liter of water; the ton is the weight of 1 cubic meter of water. The gram is used in weighing gold, jewels, and small quantities of things. The kilogram, commonly called kilo for brevity, is used by grocers; the ton is used for weighing heavy articles.

Measures of Pressure

1 Pound per square inch	=	144 pounds per square foot 0.068 atmosphere 2.042 inches of mercury at 62° F. 27.7 inches of water at 62° F. 2.31 feet of water at 62° F.
1 Atmosphere	=	30 inches of mercury at 62° F. 14.7 pounds per square inch 2116.3 pounds per square foot 33.95 feet of water at 62° F.
1 Foot of water at 62° F.	=	62.355 pounds per square foot 0.433 pound per square inch
1 Inch of mercury at 62° F.		1.132 foot of water 13.58 inches of water 0.491 pound per square inch

Metric and English Conversion Table

Measures of Length

1 millimeter	=	0.03937 inch
1 centimeter	=	0.3937 inch
1 meter	=	39.37 inches 3.2808 feet 1.0936 yards
1 kilometer	=	0.6214 mile
1 inch	=	25.4 millimeters 2.54 centimeters
1 foot	=	304.8 millimeters 0.3048 meter
1 yard	=	0.9144 meter
1 mile	=	1.609 kilometer

Square Measure–Measures of Surface

1 square millimeter	=	0.00155 square inch
1 square centimeter	=	0.155 square inch
1 square meter	=	10.764 square feet 1.196 square yard
1 are	=	0.0247 acre 1076.4 square feet
1 hectare	=	2.471 acres 107,640 square feet
1 square kilometer	=	0.3861 square mile 247.1 acres
1 square inch	=	6.452 square centimeters 645.2 square millimeters
1 square foot	=	0.0929 square meter 9.290 square centimeters
1 square yard	=	0.836 square meter
1 acre	=	0.4047 hectare 40.47 ares
1 square mile	=	2.5899 square kilometers

Cubic Measure–Measures of Volume and Capacity

1 cubic centimeter	=	0.061 cubic inch
1 cubic decimeter	=	61.023 cubic inches 0.0353 cubic foot

68.224.2

Table 8-4.—Metric System and English Conversion—Continued

1 cubic meter	=	35.314 cubic feet 1.308 cubic yards 264.2 U. S. gallons
1 liter	=	1 cubic decimeter 61.023 cubic inches 0.0353 cubic foot 1.0567 U. S. quarts 0.2642 U. S. gallons 2.202 lbs. of water at 62° F.
1 cubic inch	=	16.383 cubic centimeters
1 cubic foot	=	0.02832 cubic meter 28.317 cubic decimeters 28.317 liters
1 cubic yard	=	0.7645 cubic meter
1 gallon U. S.	=	3.785 liters
1 gallon British	=	4.543 liters

Measures of Weight

1 gram	=	0.03216 ounce troy 0.03527 ounce avoirdupois 15.432 grains
1 kilogram	=	2.2046 pounds avoirdupois 35.274 ounces avoirdupois
1 metric ton	=	0.9842 ton of 2,240 pounds 19.68 hundredweight 2204.6 pounds 1.1023 tons of 2,000 pounds
1 grain	=	0.0648 gram
1 ounce troy	=	31.103 grams
1 ounce avoirdupois	=	28.35 grams
1 pound	=	0.4536 kilogram 453.6 grams
1 ton of 2240 pounds	=	1.016 metric tons 1016 kilograms

Inches and Equivalents in Millim

Inches	MM	Inches	MM	Inches	MM
1/64	.397	45/64	17.859	26	660.4
1/32	.794	23/32	18.256	27	685.8
3/64	1.191	47/64	18.653	28	711.2
1/16	1.588	3/4	19.050	29	637.6
5/64	1.984	49/64	19.447	30	762.0
3/32	2.381	25/32	19.844	31	787.4
7/64	2.778	51/64	20.241	32	812.8
1/8	3.175	13/16	20.638	33	838.2
9/64	3.572	53/64	21.034	34	863.6
5/32	3.969	27/32	21.431	35	889.0
11/64	4.366	55/64	21.828	36	914.4
3/16	4.763	7/8	22.225	37	939.8
13/64	5.159	57/64	22.622	38	965.2
7/32	5.556	29/32	23.019	39	990.6
15/64	5.953	59/64	23.416	40	1016.0
1/4	6.350	15/16	23.813	41	1041.4
17/64	6.747	61/64	24.209	42	1066.8
9/32	7.144	31/32	24.606	43	1092.2
19/64	7.540	63/64	25.003	44	1117.6
5/16	7.938	1	25.400	45	1143.0
21/64	8.334	2	50.8	46	1168.4
11/32	8.731	3	76.2	47	1193.8
23/64	9.128	4	101.6	48	1219.2
3/8	9.525	5	127.0	49	1244.6
25/64	9.922	6	152.4	50	1270.0
13/32	10.319	7	177.8	51	1295.4
27/64	10.716	8	203.2	52	1320.8
7/16	11.113	9	228.6	53	1346.2
29/64	11.509	10	254.0	54	1371.6
15/32	11.906	11	279.4	55	1397.0
31/64	12.303	12	304.8	56	1422.4
1/2	12.700	13	330.2	57	1447.8
33/64	13.097	14	355.6	58	1473.2
17/32	13.494	15	381.0	59	1498.6
35/64	13.891	16	406.4	60	1524.0
9/16	14.288	17	431.8	61	1549.4
37/64	14.684	18	457.2	62	1574.8
19/32	15.081	19	482.6	63	1600.2
39/64	15.478	20	508.0	64	1625.6
5/8	15.875	21	533.4	65	1651.0
41/64	16.272	22	558.8	66	1676.4
21/32	16.669	23	584.2	67	1701.8
43/64	17.066	24	609.6	68	1727.2
11/16	17.463	25	635.0	69	1752.6

68.224.3

Table 8-4.—Metric System and English Conversion—Continued

Inches and Equivalents in Millimeters—*Continued*

Inches	MM	Inches	MM	Inches	MM
70	1778.0	114	2895.6	158	4013.2
71	1803.4	115	2921.0	159	4038.6
72	1828.8	116	2946.4	160	4064.0
73	1854.2	117	2971.8	161	4089.4
74	1879.6	118	2997.2	162	4114.8
75	1905.0	119	3022.6	163	4140.2
76	1930.4	120	3048.0	164	4165.6
77	1955.8	121	3073.4	165	4191.0
78	1981.2	122	3098.8	166	4216.4
79	2006.6	123	3124.2	167	4241.8
80	2032.0	124	3149.6	168	4267.2
81	2057.4	125	3175.0	169	4292.6
82	2082.8	126	3200.4	170	4318.0
83	2108.2	127	3225.8	171	4343.4
84	2133.6	128	3251.2	172	4368.8
85	2159.0	129	3276.6	173	4394.2
86	2184.4	130	3302.0	174	4419.6
87	2209.8	131	3327.4	175	4445.0
88	2235.2	132	3352.8	176	4470.4
89	2260.6	133	3378.2	177	4495.8
90	2286.0	134	3403.6	178	4521.2
91	2311.4	135	3429.0	179	4546.6
92	2336.8	136	3454.4	180	4572.0
93	2362.2	137	3479.8	181	4597.4
94	2387.6	138	3505.2	182	4622.8
95	2413.0	139	3530.6	183	4648.2
96	2438.4	140	3556.0	184	4673.6
97	2463.8	141	3581.4	185	4699.0
98	2489.2	142	3606.8	186	4724.4
99	2514.6	143	3632.2	187	4749.8
100	2540.0	144	3657.6	188	4775.2
101	2565.4	145	3683.0	189	4800.6
102	2590.8	146	3708.4	190	4826.0
103	2616.2	147	3733.8	191	4851.4
104	2641.6	148	3759.2	192	4876.8
105	2667.0	149	3784.6	193	4902.2
106	2692.4	150	3810.0	194	4927.6
107	2717.8	151	3835.4	195	4953.0
108	2743.2	152	3860.8	196	4978.4
109	2768.6	153	3886.2	197	5003.8
110	2794.0	154	3911.6	198	5029.2
111	2819.4	155	3937.0	199	5054.6
112	2844.8	156	3962.4	200	5080.0
113	2870.2	157	3987.8		

Millimeters and Equivalents in Inches

MM	Inches	MM	Inches	MM	Inches
1/100	.0004	45/100	.0177	89/100	.0350
2/100	.0008	46/100	.0181	90/100	.0354
3/100	.0012	47/100	.0185	91/100	.0358
4/100	.0016	48/100	.0189	92/100	.0362
5/100	.0020	49/100	.0193	93/100	.0366
6/100	.0024	50/100	.0197	94/100	.0370
7/100	.0028	51/100	.0201	95/100	.0374
8/100	.0031	52/100	.0205	96/100	.0378
9/100	.0035	53/100	.0209	97/100	.0382
10/100	.0039	54/100	.0213	98/100	.0386
11/100	.0043	55/100	.0217	99/100	.0390
12/100	.0017	56/100	.0221	1	.0394
13/100	.0051	57/100	.0224	2	.0787
14/100	.0055	58/100	.0228	3	.1181
15/100	.0059	59/100	.0232	4	.1575
16/100	.0063	60/100	.0236	5	.1969
17/100	.0067	61/100	.0240	6	.2362
18/100	.0071	62/100	.0244	7	.2756
19/100	.0075	63/100	.0248	8	.3150
20/100	.0079	64/100	.0252	9	.3543
21/100	.0083	65/100	.0256	10	.3937
22/100	.0087	66/100	.0260	11	.4331
23/100	.0091	67/100	.0264	12	.4724
24/100	.0094	68/100	.0268	13	.5118
25/100	.0098	69/100	.0272	14	.5512
26/100	.0102	70/100	.0276	15	.5906
27/100	.0106	71/100	.0280	16	.6299
28/100	.0110	72/100	.0284	17	.6693
29/100	.0114	73/100	.0287	18	.7087
30/100	.0118	74/100	.0291	19	.7480
31/100	.0122	75/100	.0295	20	.7874
32/100	.0126	76/100	.0299	21	.8268
33/100	.0130	77/100	.0303	22	.8661
34/100	.0134	78/100	.0307	23	.9055
35/100	.0138	79/100	.0311	24	.9449
36/100	.0142	80/100	.0315	25	.9843
37/100	.0146	81/100	.0319	26	1.0236
38/100	.0150	82/100	.0323	27	1.0630
39/100	.0154	83/100	.0327	28	1.1024
40/100	.0158	84/100	.0331	29	1.1417
41/100	.0161	85/100	.0335	30	1.1811
42/100	.0165	86/100	.0339	31	1.2205
43/100	.0169	87/100	.0343	32	1.2598
44/100	.0173	88/100	.0347	33	1.2992

69.224.4

Table 6-4.—Metric System and English Conversion—Continued

Millimeters and Equivalents in Inches—*Continued*

MM	Inches	MM	Inches	MM	Inches
34	1.3386	78	3.0709	122	4.8031
35	1.3780	79	3.1102	123	4.8425
36	1.4173	80	3.1496	124	4.8819
37	1.4567	81	3.1890	125	4.9213
38	1.4961	82	3.2283	126	4.9606
39	1.5354	83	3.2677	127	5.0000
40	1.5748	84	3.3071	128	5.0394
41	1.6142	85	3.3465	129	5.0787
42	1.6535	86	3.3858	130	5.1181
43	1.6929	87	3.4252	131	5.1575
44	1.7323	88	3.4646	132	5.1968
45	1.7717	89	3.5039	133	5.2362
46	1.8110	90	3.5433	134	5.2756
47	1.8504	91	3.5827	135	5.3150
48	1.8898	92	3.6220	136	5.3543
49	1.9291	93	3.6614	137	5.3937
50	1.9685	94	3.7008	138	5.4331
51	2.0079	95	3.7402	139	5.4724
52	2.0472	96	3.7795	140	5.5118
53	2.0866	97	3.8189	141	5.5512
54	2.1260	98	3.8583	142	5.5905
55	2.1654	99	3.8976	143	5.6299
56	2.2047	100	3.9370	144	5.6693
57	2.2441	101	3.9764	145	5.7087
58	2.2835	102	4.0157	146	5.7480
59	2.3228	103	4.0551	147	5.7874
60	2.3622	104	4.0945	148	5.8268
61	2.4016	105	4.1339	149	5.8661
62	2.4409	106	4.1732	150	5.9055
63	2.4803	107	4.2126	151	5.9449
64	2.5197	108	4.2520	152	5.9842
65	2.5591	109	4.2913	153	6.0236
66	2.5984	110	4.3307	154	6.0630
67	2.6378	111	4.3701	155	6.1024
68	2.6772	112	4.4094	156	6.1417
69	2.7165	113	4.4488	157	6.1811
70	2.7559	114	4.4882	158	6.2205
71	2.7953	115	4.5276	159	6.2598
72	2.8346	116	4.5669	160	6.2992
73	2.8740	117	4.6063	161	6.3386
74	2.9134	118	4.6457	162	6.3779
75	2.9528	119	4.6850	163	6.4173
76	2.9921	120	4.7244	164	6.4567
77	3.0315	121	4.7638	165	6.4961

Millimeters and Equivalents in Inches—*Concluded*

MM	Inches	MM	Inches	MM	Inches
166	6.5354	211	8.3071	256	10.079
167	6.5748	212	8.3464	257	10.118
168	6.6142	213	8.3858	258	10.157
169	6.6535	214	8.4252	259	10.197
170	6.6929	215	8.4646	260	10.236
171	6.7323	216	8.5039	261	10.276
172	6.7716	217	8.5433	262	10.315
173	6.8110	218	8.5827	263	10.354
174	6.8504	219	8.6220	264	10.394
175	6.8898	220	8.6614	265	10.433
176	6.9291	221	8.7008	266	10.472
177	6.9685	222	8.7401	267	10.512
178	7.0079	223	8.7795	268	10.551
179	7.0472	224	8.8189	269	10.591
180	7.0866	225	8.8583	270	10.630
181	7.1260	226	8.8976	271	10.669
182	7.1653	227	8.9370	272	10.709
183	7.2047	228	8.9764	273	10.748
184	7.2441	229	9.0157	274	10.787
185	7.2835	230	9.0551	275	10.827
186	7.3228	231	9.0945	276	10.866
187	7.3622	232	9.1338	277	10.905
188	7.4016	233	9.1732	278	10.945
189	7.4409	234	9.2126	279	10.984
190	7.4803	235	9.2520	280	11.024
191	7.5197	236	9.2913	281	11.063
192	7.5590	237	9.3307	282	11.102
193	7.5984	238	9.3701	283	11.142
194	7.6378	239	9.4094	284	11.181
195	7.6772	240	9.4488	285	11.220
196	7.7165	241	9.4882	286	11.260
197	7.7559	242	9.5275	287	11.299
198	7.7953	243	9.5669	288	11.339
199	7.8346	244	9.6063	289	11.378
200	7.8740	245	9.6457	290	11.417
201	7.9134	246	9.6850	291	11.457
202	7.9527	247	9.7244	292	11.496
203	7.9921	248	9.7638	293	11.535
204	8.0315	249	9.8031	294	11.575
205	8.0709	250	9.8425	295	11.614
206	8.1102	251	9.8819	296	11.654
207	8.1496	252	9.9212	297	11.693
208	8.1890	253	9.9606	298	11.732
209	8.2283	254	10.000	299	11.772
210	8.2677	255	10.039		

68.224.5

Table 8-4.—Metric System and English Conversion—Continued

Useful Factors, English Measures

Inches	×	0.08333	= feet
"	×	0.02778	= yards
"	×	0.00001578	= miles
Square inches	×	0.00695	= square feet
" "	×	0.0007716	= square yards
Cubic inches	×	0.00058	= cubic feet
" "	×	0.0000214	= cubic yards
" "	×	0.004329	= U. S. gallons
Feet	×	0.3334	= yards
"	×	0.00019	= miles
Square feet	×	144.0	= square inches
" "	×	0.1112	= square yards
Cubic feet	×	1,728	= cubic inches
" "	×	0.03704	= cubic yards
" "	×	7.48	= U. S. gallons
Yards	×	36	= inches
"	×	3	= feet
"	×	0.0005681	= miles
Square yards	×	1,296	= square inches
" "	×	9	= square feet
Cubic yards	×	46,656	= cubic inches
" "	×	27	= cubic feet
Miles	×	63,360	= inches
"	×	5,280	= feet
"	×	1,760	= yards
Avoirdupois ounces	×	0.0625	= pounds
" "	×	0.00003125	= tons
" pounds	×	16	= ounces
" "	×	.001	= hundredweight
" "	×	.0005	= tons
" "	×	27.681	= cubic inches of water at 39.2° F
" tons	×	32,000	= ounces
" "	×	2,000	= pounds
Watts	×	0.00134	= horse power
Horse power	×	746	= watts

Weight of round iron per foot = square of diameter in quarter inches ÷ 6.
Weight of flat iron per foot = width × thickness × 3⅓.
Weight of flat plates per square foot = 5 pounds for each ⅛ inch thickness.

Useful Factors, Metric Measures

Millimeters × 0.03937	= inches
Millimeters ÷ 25.4	= inches
Centimeters × 0.3937	= inches
Centimeters ÷ 2.54	= inches
Meters × 39.37	= inches
Meters × 3.281	= feet
Meters × 1.094	= yards
Kilometers × 0.621	= miles
Kilometers ÷ 1.6093	= miles
Kilometers × 3280.7	= feet
Square millimeters × 0.0155	= square inches
Square millimeters ÷ 645.1	= square inches
Square centimeters × 0.155	= square inches
Square centimeters ÷ 6.451	= square inches
Square meters × 10.764	= square feet
Square kilometers × 247.1	= acres
Hectares × 2.471	= acres
Cubic centimeters ÷ 16.385	= cubic inches
Cubic centimeters ÷ 3.69	= fluid drachms, U. S. Pharmacopœia
Cubic centimeters ÷ 29.57	= fluid ounce U. S. Pharmacopœia
Cubic meters × 35.315	= cubic feet
Cubic meters × 1.038	= cubic yards
Cubic meters × 264.2	= gallons, United States
Liters × 61.022	= cubic inches
Liters × 33.84	= fluid ounces
Liters × 0.2642	= gallons, United States
Liters ÷ 3.78	= gallons, United States
Liters ÷ 28.316	= cubic feet
Hectoliters × 3.531	= cubic feet
Hectoliters × 2.84	= bushels, United States
Hectoliters × 0.131	= cubic yards
Hectoliters × 26.42	= gallons, United States
Grams × 15.432	= grains
Grams (water) ÷ 29.57	= fluid ounces
Grams ÷ 28.35	= ounces, avoirdupois
Kilograms × 2.2046	= pounds
Kilograms × 35.3	= ounces, avoirdupois
Kilograms ÷ 1102.3	= tons, 2000 pounds

68.224.6

Table 8-5.—Mathematical Symbols

SYMBOL	NAME OR MEANING	
+	Addition or positive value	
-	Subtraction or negative value	
±	Positive or negative value	
·	Multiplication dot (Centered; not to be mistaken for decimal point.)	
x	Multiplication symbol	
( )	Parentheses	Grouping symbols
[ ]	Brackets	Grouping symbols
{ }	Braces	Grouping symbols
——	Vinculum (overscore)	Grouping symbols
%	Percent	
÷	Division symbol	
:	Ratio symbol	
::	Proportion symbol	
=	Equality symbol	
≠	"Not equal" symbol	
<	Less than	
≤	Less than or equal to	
>	Greater than	
≥	Greater than or equal to	
∝	"Varies directly as" or "is proportional to" (Not to be mistaken for Greek alpha (α).)	
$\sqrt{\ }$	Square root symbol	
$\sqrt{\overline{\quad}}$	Square root symbol with vinculum. Vinculum is made long enough to cover all factors of the number whose square root is to be taken.	
$\sqrt[n]{\ }$	Radical symbol. Letter n represents a number indicating which root is to be taken.	
i or j	Imaginary unit; operator j for electronics; represents $\sqrt{-1}$.	
∞	Infinity symbol	
. . .	Ellipsis. Used in series of numbers in which successive numbers are predictable by their conformance to a pattern; meaning is approximated by "etc."	
$\log_a N$	Logarithm of N to the base a.	
log N	Logarithm of N to the base 10. (understood)	
ln N	Natural or Napierian logarithm of N. Base of the natural or Napierian logarithm system.	
$\lvert X \rvert$	Absolute value of X.	
π	Pi. The ratio of the circumference of any circle to its diameter. Approximate numerical value is 22/7.	
	Therefore	
∠ or ∢	Angle	

68.218

Table 8-6.—Table of Decimal Equivalents of Fractions of an Inch

1/64----	0.0156	17/64---	0.2656	33/64---	0.5156	49/64---	0.7656
1/32----	.0313	9/32----	.2813	17/32---	.5313	25/32---	.7813
3/64----	.0469	19/64---	.2969	35/64---	.5469	51/64---	.7969
1/16----	.0625	5/16----	.3125	9/16----	.5625	13/16---	.8125
5/64----	.0781	21/64---	.3281	37/64---	.5781	53/64---	.8281
3/32----	.0938	11/32---	.3438	19/32---	.5938	27/32---	.8438
7/64----	.1094	23/64---	.3594	39/64---	.6094	55/64---	.8594
1/8-----	.125	3/8-----	.375	5/8-----	.625	7/8-----	.875
9/64----	.1406	25/64---	.3906	41/64---	.6406	57/64---	.8906
5/32----	.1563	13/32---	.4063	21/32---	.6563	29/32---	.9063
11/64---	.1719	27/64---	.4219	43/64---	.6719	59/64---	.9219
3/16----	.1875	7/16----	.4375	11/16---	.6875	15/16---	.9375
13/64---	.2031	29/64---	.4531	45/64---	.7031	61/64---	.9531
7/32----	.2188	15/32---	.4688	23/32---	.7188	31/32---	.9688
15/64---	.2344	31/64---	.4844	47/64---	.7344	63/64---	.9844
1/4-----	.25	1/2-----	.5	3/4-----	.75	1-------	1.0

142.1

Table 8-7.—Weights and Measures

Weights and Measures

Distance

12 inches	= 1 foot (ft)
3 feet	= 1 yard (yd)
5-1/2 yards	= 1 rod (rd)
16-1/2 feet	= 1 rod
1,760 yards	= 1 statute mile (mi)
5,280 feet	= 1 statute mile

Additional measures of length occasionally used

1000 mils = 1 inch; 3 inches = 1 palm; 4 inches = 1 hand
9 inches = 1 span; 2½ feet = 1 military space
5½ yards or 16½ feet = 1 rod; 2 yards = 1 fathom;
a cable length = 120 fathoms = 720 feet;
1 inch = 0.0001157 cable length = 0.013889 fathom = 0.111111 span.

Old Land or Surveyors' Measure*

7.92 inches = 1 link (l.)
100 links, or 66 feet, or 4 rods = 1 chain (ch.)
10 chains or 220 yards = 1 furlong
8 furlongs or 80 chains = 1 mile (mi.)

* Sometimes called Gunter's Chain.

Nautical Measure

6080.26 feet or 1.15156 statute miles = 1 nautical mile or knot†
3 nautical miles = 1 league
60 nautical miles, or 69.169 statute miles = 1 degree at the equator
360 degrees = circumference of the earth at the equator

† The value varies according to different measures of the earth's diameter.

Square Measures—Measures of Surface

144 square inches (sq. in.)	= 1 square foot (sq. ft.)
9 square feet	= 1 square yard (sq. yd.)
30¼ square yards or 272¼ square feet	= 1 square rod (sq. rd.)
160 square rods or 43,560 square feet	= 1 acre (A.)
640 acres	= 1 square mile (sq. mi.)

Surveyors' Measure

16 square rods	= 1 square chain (sq. ch.)
10 square chains	= 1 acre (A.)
640 acres	= 1 square mile (sq. mi.)
1 square mile	= 1 section (sec.)
36 sections	= 1 township (tp.)

Solid or Cubic Measure—Measures of Volume

1728 cubic inches (cu. in.)	= 1 cubic foot (cu. ft.)
27 cubic feet	= 1 cubic yard (cu. yd.)

The following measures are also used for wood and masonry.

1 cord of wood = a pile, 4 × 4 × 8 feet = 128 cubic feet
1 perch of masonry = 16½ × 1½ × 1 foot = 24¾ cubic feet

Shipping Measure

Register Ton—For register tonnage or for measuring entire internal capacity of a ship or vessel:

100 cubic feet = 1 register ton

Shipping Ton—For the measurement of cargo.

40 cubic feet = 1 United States shipping ton = 32.143 U. S. bushels
42 cubic feet = 1 British shipping ton = 32.719 imperial bushels.

68.225.1

Table 8-7.—Weights and Measures—Continued

Carpenter's Rule—To find the weight a vessel will carry multiply the length of keel by the breadth at main beam by the depth of the hold in feet and divide by 95 (the cubic feet allowed for a ton). The result will be the tonnage.

Dry Measure

2 cups = 1 pint (pt)

2 pints = 1 quart (qt)

4 quarts = 1 gallon (gal)

8 quarts = 1 peck (pk)

4 pecks = 1 bushel (bu)

Counting Units

12 units	= 1 dozen (doz)
12 dozens	= 1 gross
144 units	= 1 gross
24 sheets	= 1 quire
480 sheets	= 1 ream

Equivalents

1 cubic foot of water weighs 62.5 pounds (approx) = 1,000 ounces
1 gallon of water weighs 8-1/3 pounds (approx)
1 cubic foot = 7.48 gallons
1 inch = 2.54 centimeters
1 foot = 30.4801 centimeters
1 meter = 39.37 inches
1 liter = 1.05668 quarts (liquid) = 0.90808 quart (dry)
1 nautical mile = 6,080 feet (approx)
1 fathom = 6 feet
1 shot of chain = 15 fathoms

Liquid Measure

3 teaspoons (tsp) = 1 tablespoon (tbsp)
16 tablespoons = 1 cup
2 cups = 1 pint
16 fluid ounces (oz) = 1 pint

4 gills (gi.)	= 1 pint (pt.)
2 pints	= 1 quart (qt.)
4 quarts	= 1 gallon (gal.) {U.S. 231 cubic inches; British 277.274 cubic inches}
1 cubic foot	= 7.48 U.S. gallons

Old Liquid Measure

31½ gallons	= 1 barrel (bbl.)
42 gallons	= 1 tierce
2 barrels or 63 gallons	= 1 hogshead (hhd.)
84 gallons or 2 tierces	= 1 puncheon
2 hogsheads or 4 barrels or 126 gallons	= 1 pipe or butt
2 pipes or 3 puncheons	= 1 tun

Apothecaries' Fluid Measure

60 minims = 1 fluid drachm; 8 drachms = 1 fluid ounce

1 U. S. fluid ounce = 8 drachms = 1.805 cubic inch = $\frac{1}{128}$ U. S. gallon. The fluid ounce in Great Britian is 1.732 cubic inches.

Measures of Weight

Avoirdupois or Commercial Weight

16 drachms or 437.5 grains	= 1 ounce (oz.)
16 ounces or 7000 grains	= 1 pound (lb.)
2000 pounds	= 1 net or short ton
2240 pounds	= 1 gross or long ton
2204.6 pounds	= 1 metric ton

Measures of weight occasionally used in collecting duties on foreign goods at U. S. custom houses and in freighting coal are:

1 hundredweight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundredweight); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal = 100 pounds.

68.225.2

Table 8-7.—Weights and Measures—Continued

Troy Weight*

24 grains	= 1 pennyweight (pwt.)
20 pennyweight	= 1 ounce (oz.)
12 ounces or 5760 grains	= 1 pound (lb.)

A carat of the jewelers, for precious stones = 3.2 grains in the United States. The International carat = 3.168 grains or 200 milligrams. In avoirdupois, apothecaries' and troy weights, the grain is the same, 1 pound troy = 0.82286 pound avoirdupois.

* Used for weighing gold, silver, jewels, etc.

Apothecaries' Weight†

20 grains (gr.)	= 1 scruple (℈)
3 scruples	= 1 drachm (ʒ)
8 drachms	= 1 ounce (℥)
12 ounces	= 1 pound troy (lb.)

† This table is used in compounding medicines and prescriptions.

Measures of Time

one millionth of a second	= 1 microsecond (μsec.)
one thousandth of a second	= 1 millisecond (msec.)
1/3600 hour	= 1 second (sec.)
60 seconds (sec.)	= 1 minute (min.)
60 minutes	= 1 hour (hr.)
24 hours	= 1 day (da.)
7 days	= 1 week (wk.)
365 days	= 1 solar year (yr.)
366 days	= 1 leap-year (every four years)
100 years	= 1 century

By the Gregorian calender every year whose number is divisible by 4 is a leap year except that the centesimal years (each 100 years: 1800, 1900, 2000, etc.) are leap-years only when the number of the year is divisible by 400.

Water Conversion Factors

U. S. gallons	×	8.33	= pounds
U. S. gallons	×	0.13368	= cubic feet
U. S. gallons	×	231	= cubic inches
U. S. gallons	×	0.83	= English gallons
U. S. gallons	×	3.78	= liters
English gallons (Imperial)	×	10	= pounds
English gallons (Imperial)	×	0.16	= cubic feet
English gallons (Imperial)	×	277.274	= cubic inches
English gallons (Imperial)	×	1.2	= U. S. gallons
English gallons (Imperial)	×	4.537	= liters
Cubic inches of water (39.1°)	×	0.036024	= pounds
Cubic inches of water (39.1°)	×	0.004329	= U. S. gallons
Cubic inches of water (39.1°)	×	0.003607	= English gallons
Cubic inches of water (39.1°)	×	0.576384	= ounces
Cubic feet (of water) (39.1°)	×	62.425	= pounds
Cubic feet (of water) (39.1°)	×	7.48	= U. S. gallons
Cubic feet (of water) (39.1°)	×	6.232	= English gallons
Cubic feet (of water) (39.1°)	×	0.028	= tons
Pounds of water	×	27.72	= cubic inches
Pounds of water	×	0.01602	= cubic feet
Pounds of water	×	0.12	= U. S. gallons
Pounds of water	×	0.10	= English gallons

Miscellaneous Tables

Numbers

12 units	= 1 dozen
12 dozen	= 1 gross
12 gross	= 1 great gross
20 units	= 1 score

Circular and Angular Measures

60 seconds (″)	= 1 minute (′)
60 minutes	= 1 degree (°)
90 degrees	= 1 quadrant
360 degrees	= 1 circumference

68.225.3

Table 8-8.—Rectangular Capacities

RECTANGULAR TANKS

Capacity in U. S. Gallons Per Foot of Depth

Widths, Feet	Length of Tank—in Feet						
	2	2½	3	3½	4	4½	5
2	29.92	37.40	44.88	52.36	59.84	67.32	74.81
2½	—	46.75	56.10	65.45	74.81	84.16	93.51
3	—	—	67.32	78.55	89.77	101.0	112.2
3½	—	—	—	91.64	104.7	117.8	130.9
4	—	—	—	—	119.7	134.6	149.6
4½	—	—	—	—	—	151.5	168.3
5	—	—	—	—	—	—	187.0
	5½	6	6½	7	7½	8	8½
2	82.29	89.77	97.25	104.7	112.2	119.7	127.2
2½	102.9	112.2	121.6	130.9	140.3	149.6	159.0
3	123.4	134.6	145.9	157.1	168.3	179.5	190.8
3½	144.0	157.1	170.2	183.3	196.4	209.5	222.5
4	164.6	179.5	194.5	209.5	224.4	239.4	254.3
4½	185.1	202.0	218.8	235.6	252.5	269.3	286.1
5	205.7	224.4	243.1	261.8	280.5	299.2	317.9
5½	226.3	246.9	267.4	288.0	308.6	329.1	349.7
6	—	269.3	291.7	314.2	336.6	359.1	381.5
6½	—	—	316.1	340.4	364.7	389.0	413.3
7	—	—	—	366.5	392.7	418.9	445.1
7½	—	—	—	—	420.8	448.8	476.9
8	—	—	—	—	—	478.8	508.7
8½	—	—	—	—	—	—	540.5
	9	9½	10	10½	11	11½	12
2	134.6	142.1	149.6	157.1	164.6	172.1	179.5
2½	168.3	177.7	187.0	196.4	205.7	215.1	224.4
3	202.0	213.2	224.4	235.6	246.9	258.1	269.3
3½	235.6	248.7	261.8	274.9	288.0	301.1	314.2
4	269.3	284.3	299.2	314.2	329.1	344.1	359.1
4½	303.0	319.3	336.6	353.5	370.3	387.1	403.9
5	336.6	355.3	374.0	392.7	411.4	430.1	448.8
5½	370.3	390.9	411.4	432.0	452.6	473.1	493.7
6	403.9	426.4	448.8	471.3	493.7	516.2	538.6
6½	437.6	461.9	486.2	510.5	534.9	559.2	583.5
7	471.3	497.5	523.6	549.8	576.0	602.2	628.4
7½	504.9	533.0	561.0	589.1	617.1	645.2	673.2
8	538.6	568.[illegible]	598.4	628.4	658.3	688.2	718.1
8½	572.3	604.1	635.8	667.6	699.4	731.2	763.0
9	605.9	639.6	673.2	706.9	740.6	774.2	807.9
9½	—	675.1	710.6	746.2	781.7	817.2	852.3
10	—	—	748.1	785.5	822.9	860.3	897.7
10½	—	—	—	824.7	864.0	903.3	942.5
11	—	—	—	—	905.1	946.3	987.4
11½	—	—	—	—	—	989.3	1032
12	—	—	—	—	—	—	1077

U. S. Gallon of water weighs 8.34523 Pounds Avoirdupois at 4° C.

68.226

Table 8-9.—Circular Capacities

CIRCULAR TANKS

Capacity in U. S. Gallons Per Foot of Depth

Diam., Ft. In.	Gallons	Diam., Ft. In.	Gallons	Diam., Ft. In.	Gallons
1	5.875	3 6	71.97	5 11	205.7
1 1	6.895	3 7	75.44	6	211.5
1 2	7.997	3 8	78.99	6 3	229.5
1 3	9.180	3 9	82.62	6 6	248.2
1 4	10.44	3 10	86.33	6 9	267.7
1 5	11.79	3 11	90.13	7	287.9
1 6	13.22	4	94.00	7 3	308.8
1 7	14.73	4 1	97.96	7 6	330.5
1 8	16.32	4 2	102.0	7 9	352.9
1 9	17.99	4 3	106.1	8	376.0
1 10	19.75	4 4	110.3	8 3	399.9
1 11	21.58	4 5	114.6	8 6	424.5
2	23.50	4 6	119.0	8 9	449.8
2 1	25.50	4 7	123.4	9	475.9
2 2	27.58	4 8	127.9	9 3	502.7
2 3	29.74	4 9	132.6	9 6	530.2
2 4	31.99	4 10	137.3	9 9	558.5
2 5	34.31	4 11	142.0	10	587.5
2 6	36.72	5	146.9	10 3	617.3
2 7	39.21	5 1	151.8	10 6	647.7
2 8	41.78	5 2	156.8	10 9	679.0
2 9	44.43	5 3	161.9	11	710.9
2 10	47.16	5 4	167.1	11 3	743.6
2 11	49.98	5 5	172.4	11 6	777.0
3	52.88	5 6	177.7	11 9	811.1
3 1	55.86	5 7	183.2	12	846.0
3 2	58.92	5 8	188.7	12 3	881.6
3 3	62.06	5 9	194.2	12 6	918.0
3 4	65.28	5 10	199.9	12 9	955.1
3 5	68.58				

U. S. Gallon of water weighs 8.34523 Pounds Avoirdupois at 4° C.

68.227

CHAPTER 9

BLUEPRINTS AND LAYOUTS

When you became a striker for Patternmaker you probably spent your first day in the shop just looking around. You watched the men in the shop do the many varied jobs. Did you notice that all of the men in the shop who were laying out work were doing so from some sort of plan? This plan may have been a sketch, a drawing, a blueprint or a layout. In order for you to lay out work, you will have to be able to read these plans, and as you advance you will be expected to make sketches and drawings.

The Rate Training Manual, Blueprint Reading and Sketching, NAVPERS 10077-C, chapters 1, 2, 3, and 6 will give you information on fundamentals that you must master before proceeding with this chapter.

This chapter deals primarily with blueprints and layouts as used by the Patternmaker and also contains additional information regarding visualization, freehand sketching, and making a layout from a casting.

The following terms are defined from the Patternmaker's point of view:

A SKETCH is a rough outline of an object from which a pattern is to be constructed, given dimensions and details of the job to be done. Such information as angles to be used, and type of material required are included in the sketch.

A DRAWING is similar to a sketch, but it is made with mechanical drawing instruments and it is drawn to scale.

A BLUEPRINT is a duplicate of a drawing or sketch. Usually, only accurate drawings are blueprinted. These blueprints are furnished by the manufacturers of the machinery installed aboard your ship, and also by the bureaus concerned with the building and maintenance of the ship on which you are serving.

A LAYOUT is generally a duplicate of a sketch, drawing, or blueprint which includes object lines and centerlines but omits hidden lines, dimension lines, and notes. The term "layout" is also used to describe an orthographic plan (to be used as a pattern) developed from dimensional data rather than a sketch, drawing, or blueprint. A layout is made full-size and is as accurate as possible. In patternmaking, a layout is a full-sized drawing of a pattern made with the appropriate shrinkage rule and showing pattern construction and core arrangement.

PURPOSE AND USE OF BLUEPRINTS

The design engineer is constantly working on plans for new machines or plans to improve existing machines. Much of his work is accomplished through mathematics and mechanical drafting. Mathematics is used to calculate the strength of the parts and to determine their dimensions. Mechanical drafting is the means by which the shape, dimensions, kinds of material, finish, and all other details of the parts were recorded.

It would be almost impossible for the design engineer, using words alone, to convey his ideas, thoughts, calculations, and dimensions to the many users of blueprints in the construction of a new machine. However, through mechanical drafting, it is possible to record in the form of drawings (blueprints), every item of information necessary for the construction of the machine. Mechanical drafting, then, is really a special language and is defined as follows: "A language which uses lines, symbols, dimensions, and notations to accurately describe the form, size, kind of material, finish, and construction of an object."

BLUEPRINTS, also called prints, make it possible for you to understand what is wanted. In a comparatively little space, they give a great deal of information in a universal language that everyone may recognize. Even a foreigner who does not understand English may read and work from your blueprints, and you may do the same with his prints.

VISUALIZATION OF BLUEPRINTS

As a PM3 or PM2, you must have the ability to interpret blueprints correctly and to visualize the size and shape of an object in all its proportions and in its fine details. You must be able to see beyond the blueprint and to visualize a pattern which very often will not look even remotely like what you see on the blueprint.

The act of forming a mental image of an object described on a flat plane (orthographic projection) into a three-dimensional shape, is called VISUALIZATION. In other words, visualization is the act of recognizing the shape of a three-dimensional object when all you have to go by is a flat drawing.

Some people find it easy to visualize three-dimensional objects from flat drawings; other people find it difficult. The ability to visualize can be greatly developed by continued practice. Before you can even practice visualization, you must of course be able to read and write the language of the trade — that is, blueprints and drawings. Then, through constant practice, you can develop a creative imagination that will enable you to visualize three-dimensional shapes from flat drawings.

TYPES OF BLUEPRINTS

As a Patternmaker, you are a member of a team working to achieve a common goal (a sound, usable casting) through the use of drawings and blueprints. For example, on board a repair ship or tender a drawing may go to the Patternmaker (PM) whose job it is to make patterns of a part in wood, metal, plaster, or plastic. These patterns are used by the Molder (ML) in making molds for rough castings. These castings must be finished in the machine shop by the Machinery Repairman (MR). Sometimes a drawing may go directly to the Hull Maintenance Technician (HT) who will forge the part in the blacksmith shop, or weld or braze a series of castings together to make the final product.

Of the many types of blueprints you will use aboard ship, the simplest one is the PLAN VIEW. This is a blueprint which shows the position, location, and use of the various parts of the ship. You will use plan views to find your duty and battle stations, the sickbay, the barber shop, and other parts of the ship.

In addition to plan views you will find aboard ship other blueprints called ASSEMBLY PRINTS, UNIT or SUB-ASSEMBLY PRINTS, and DETAIL PRINTS. These prints show various kinds of machinery and mechanical equipment.

ASSEMBLY PRINTS show the various parts of the mechanism, how the parts fit together, and their relation to each other.

Individual mechanisms, such as motors and pumps, will be shown on UNIT or SUB-ASSEMBLY PRINTS. These show location, shape, size, and relationships of the parts of the sub-assembly unit.

Assembly and sub-assembly prints are used to learn operation and maintenance of machines and equipment.

The Patternmaker and the Machinery Repairman will be most interested in the DETAIL PRINTS. These prints will give you all the information you need to make a new part. They show size, shape, kind of material, and method of finishing. You will find them indispensable in your work.

Occasionally, the Patternmaker may work from an orthographic drawing or blueprint called a PATTERNMAKER'S BLUEPRINT or a CASTING DRAWING. A blueprint of this type is made as a single drawing of the unmachined casting. A Patternmaker's blueprint shows several things that an ordinary detail blueprint does not show; for example, a Patternmaker's blueprint shows allowances for machining, core prints, draft, location of dowels, parting line of the pattern, radii, and fillets as cast, shrink rule to be used, pattern material, and material from which the casting is to be made. Similar drawings or blueprints may also be made for the core boxes.

Blueprint Colors

Blueprints are exact copies of mechanical or other types of drawings. A MECHANICAL DRAWING is one made with instruments such as compasses, rules, and dividers. Blueprints, or prints, as they are often called, are made from these drawings in much the same way that photographs are made from negatives.

The negative for the blueprint is known as a TRACING. It is made by placing a sheet of translucent tracing paper or cloth over the drawing. Everything on the drawing is traced on the tracing paper or cloth with black waterproof ink or a special black pencil. After the tracing is completed, it is checked, and the original drawing is filed for future use. Some drawings are made directly on the tracing material in pencil and then traced with ink or with the special black pencil.

Next, the tracing is covered with a sheet of sensitized light-green blueprint paper and placed in the blueprinting machine, with the tracing toward the source of light. The sensitized side of the blueprint paper must also be toward the source of light which penetrates the tracing at all parts not covered by lines and causes a chemical action on the blueprint paper. There is no chemical action under the lines of the tracing because the black lines block off the light.

After proper exposure, the sensitized paper is removed and washed in a developing solution and then in clear water. The exposed portions of the sensitized paper turn a deep blue during the washing. The lines are white.

Any number of prints can be made from one tracing if it is handled carefully. When a large number of prints are required, they are made in a blueprinting machine, but the same principle is involved.

Blueprints aren't always blue. All kinds of reproduced drawings are commonly referred to as blueprints or prints. They may be white, brown, black, gray, or other colors. The differences lie in the kinds of papers used and in the development processes.

BLACK-AND-WHITE PRINTS have black lines on white background.

AMMONIA PRINTS, or OZALIDS, have black, maroon, purple, or blue lines on white background.

VAN DYKES have white lines on dark brown background.

NEGATIVE PHOTOSTATS have white lines on dark gray background.

Regardless of the color, you will have to become expert in reading the prints and in visualizing their object. This skill is a MUST if you are to succeed as a Patternmaker.

Care of Blueprints

Blueprints are not just scraps of paper. They are valuable permanent records and can be used again and again if you take care of them. Here are a few simple rules for getting the best results from them:

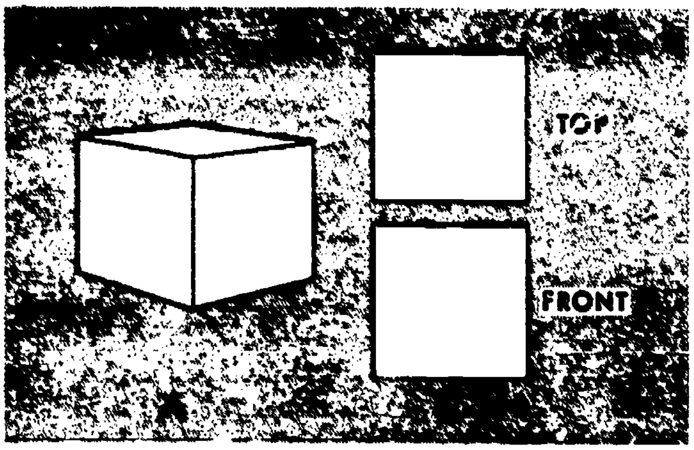
1. Keep them out of strong sunlight—they might fade.
2. Do not allow them to get wet or grease-smudged.
3. Do not make pencil or crayon notations on a print without proper authority. If you should get instructions to mark a blueprint, use a pencil with colored lead which can be easily seen against the background. Ordinary (black lead) pencil marks are hard to see on a colored background. Yellow is generally a good color to use on blueprints.
4. Never measure distance on a blueprint. If you cannot find a dimension on one view, look at another view. If you still can't find it, ask someone who knows. Why not measure? Because the original mechanical drawings might not have been drawn exactly to scale, or the print may have shrunk or stretched.
5. Keep your blueprints stowed in their proper place so that they can be readily located the next time you want to refer to them.

READING A BLUEPRINT

Reading a blueprint is the act of recognizing and applying the principles of ORTHOGRAPHIC PROJECTION to interpret the shape of an object from orthographic views. Orthographic projection is a method of describing the shape of an object by two or more views on planes which are perpendicular to each other. An orthographic projection is so arranged that each view shows the object from one direction, while a combination of two or more views show the complete object.

It is easy to draw a single two-dimensional view of one side of a cube. Since you know that each side is square, a single square drawn to scale will describe any side. Now, in order to show that the object is a cube instead of a plane figure, you will have to draw at least two sides of it. The indicated relation of these two sides to each other on the drawing is what is meant by orthographic projection. In other words, orthographic projection is the means for showing the relationship of all sides of an object. (See fig. 9-1.)

"Third-angle orthographic projection is the standard for mechanical drawings." To understand what this means, imagine that you have a cubical box made of transparent material.



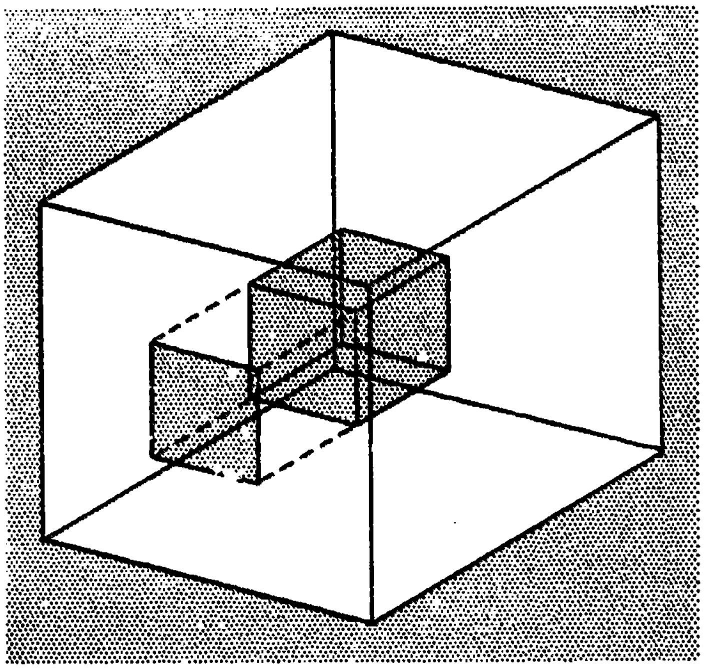
65.19(68)
Figure 9-1.—A. Perspective drawing of a cube. B. Two sides of the cube in orthographic projection.

Now imagine that a cube is suspended in the center of this transparent box. If you draw dashed lines from the corners of the cube toward one side of the box as shown in figure 9-2, you will see that each corner forms a point on the surface of the box. If these points are connected by straight lines, you will have a square exactly the same as the square face of the cube.

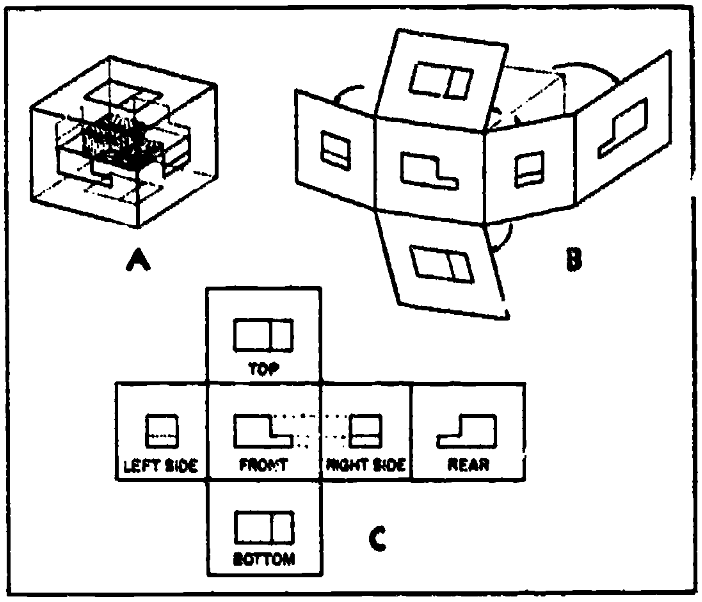
If you do this to all six sides of a solid cube, you will have projected images of its sides on the transparent box, as shown in part A of figure 9-3. Now, if you cut the transparent box apart and partially unfold it, it will appear as shown in part B of figure 9-3. Completely unfolded and laid flat as if it were a drawing, it will appear as shown in part C of figure 9-3. This is third-angle projection.

Notice that dashed lines drawn from the corners of one view in part C of figure 9-3 project to the corners of an adjacent view. Since it is impractical for a draftsman to use a transparent box in projecting the image of an object, he uses this method instead. The lines used to carry over the dimensions from view to view are called CONSTRUCTION LINES.

The arrangement of the views in figure 9-3 is the usual one. However, the rear view may be shown as if it were hinged to the left profile plane or to the top or bottom planes, as well as to the right profile plane. Even if you draw only two or three views of an object, arrange them in the relation in which they appear in figure 9-3.



68.65
Figure 9-2.—Projection of one side of a cube.



65.14
Figure 9-3.—Third-angle orthographic projection.

Take a Patternmaker's look at the blueprint of a hinge for a piece of fire control equipment. (See figs. 9-4 and 9-5.) It is typical of the kind of repair jobs you will very likely get aboard a repair ship or tender. As you look at this or any other print, try to get all the possible answers to these questions:

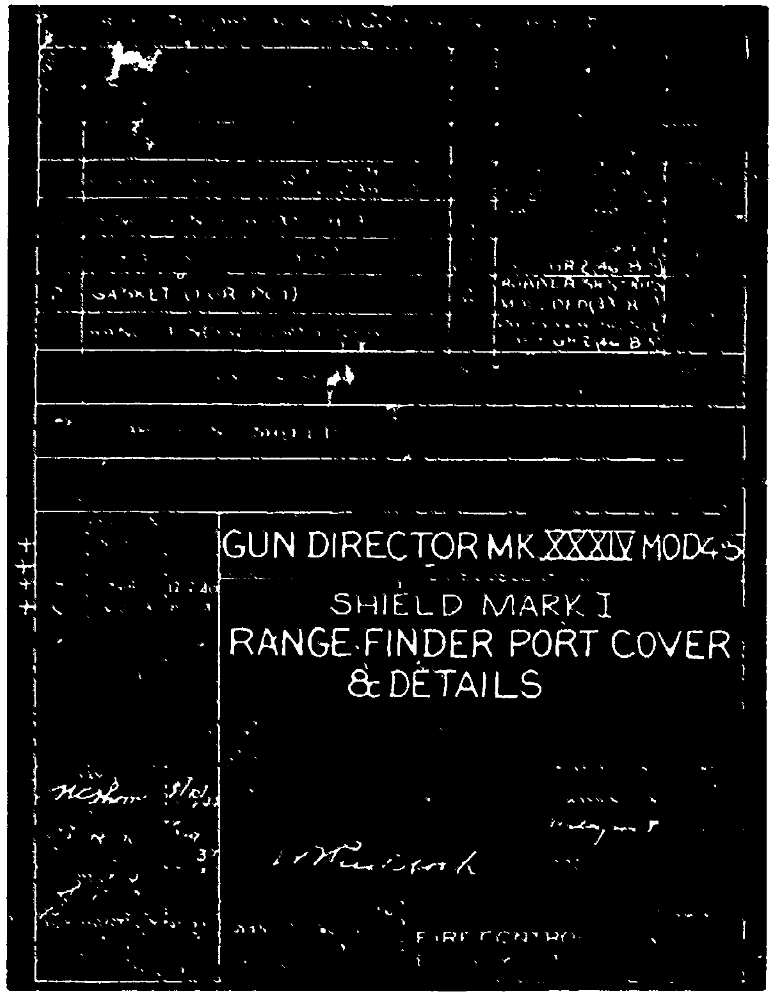
1. What is the size, form, and nature of the object and what is its relation to the other parts?
2. What pattern construction will produce the best casting?

Look at the title block of the blueprint first. It will give you, in most cases, much information about the job you are working on. Figure 9-4 shows the title block of the blueprint that includes the drawing of the hinge. The hinge, as indicated by the title block, is used for the rangefinder port cover and cover shaft of a gun director. It is to be made of phosphor bronze, grade 2 (46-P-5), and is a moving part. The scale of the drawing is full-size (1/1) and half-size (1/2) and that knowledge is of value in visualizing the object.

While looking at the title block, notice also its "revisions" column. Be especially on the alert for any blueprint changes that have been made in the field, even if they have not been marked in the title block.

Be sure to determine from the title block WHAT METAL is to be used for the casting. Many patterns and castings have been made incorrectly when this basic point has been overlooked. Metals do not contract alike and each pattern must be made with a specific metal in mind. Bronze alloys, for example, will shrink and contract about 5/32 or 3/16 inch per foot. The proper shrink rule for the specific bronze alloy must be used or all measurements of the hinge layout will be wrong.

Figure 9-5 is a reproduction of the blueprint of the hinge. These two views give you the shape and size of the finished casting of the hinge. Study the views carefully, and as long as necessary, in order to establish or visualize the shape and proportions. Train yourself in picking out the major characteristics or features of each view. Try to pick out the basic design of the object and temporarily eliminate subordinate parts, such as strengthening ribs, from your analysis. By following the outline or visible lines particularly, and by studying the two views of this drawing, you should be able to come up



45.159(68)

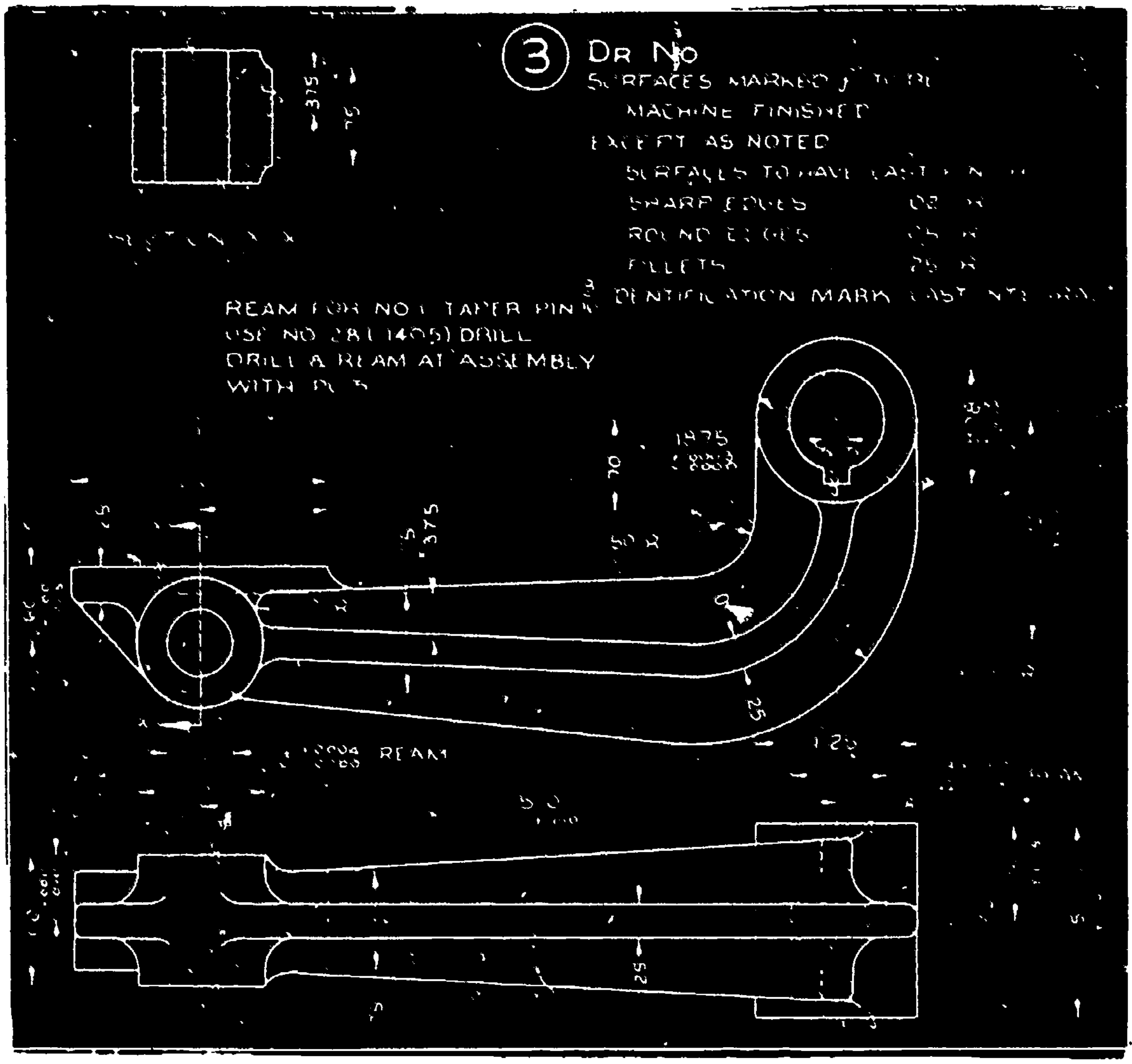
Figure 9-4.—Title block.

with a mental picture of the hinge. Observe the dimensions closely in order to get the correct starting and ending point of each measurement. Study the sectional view to better understand the left end of the hinge.

Read all the notes that you find on a print. Most of the instructions will be for the Machinery Repairman so that he may machine the casting to the desired finish and dimensions. You will have to provide some added finish allowance for all surfaces that are to be machined later by him. Be sure you understand the machine finish symbol and any other symbols on the print. A machine finished surface is designated in several ways on a blueprint; by the older symbol f, or the newer symbol V, or by specifying the tolerance under the dimensions in question, such as

.75"

(±.005")



23.27(68)A

Figure 9-5. — Blueprint of a hinge.

The finish marks used on a blueprint show what surfaces are to be machined or they may indicate the varying degrees of exactness, the character, or quality of the finish. The common practice is to place a letter f so that its cross-line intersects the line on the drawing requiring finish, followed by a number or symbol selected to represent different degrees of finish or smoothness. When these numbers or symbols are used, the finish is represented by a code placed directly on the blueprint. The code used in one blueprint will be applicable to that blueprint only. On another blueprint, the same numbers or symbols may have a different meaning. Table 9-1 gives typical examples of the finish designations used on Navy blueprints, followed by a recommended allowance for each type of finish.

In some cases, words are used to indicate finish. The following definitions should be used:

Term	Meaning
"Cored" —	The hole is left as cast.
"Cast Finish" —	Surfaces indicated are left as cast.
"Tool Finish" —	Machine finish is required.
"Bore or Bored" —	Machine finish is required.
"Turned" —	Machine finish is required.
"Hone or Honed" —	Machine finish is required.

Table 9-1.—Finish Designations on Navy Blueprints

Preferred Symbols	Meaning	Finish Allowance (inches)	Alternate Symbols			
F_1	Rough Tool Finish	1/8	V_1	Fr.	FIN.	TF.
F_2	Fine Tool Finish	1/8	V_2	F.	Fs.	SF.
F_3	Grind Finish	1/8	V_3	Fg.	Gr.	
F_4	Polish	1/16	V_4	Bf.	Buff	
F_5	Drill	1/8	V_5	Dr.		
F_6	Ream	1/8	V_6	Rm.		
F_7	File Finish	1/32	V_7	ff.	Ff.	
F_8	Scrape	1/64	V_8	scr.		
F_9	Spot Face	1/32	V_9			
Finish All Over				F.A.O.		f.a.o.

68.187

If a part is to be machined all over, a note, such as, "Finish All Over," "F.A.O." or "f.a.o." may be used and the finish numbers and symbols may be omitted.

After you have completed these steps, have analyzed the print as much as necessary, and know the shape and size of the object, you are then ready to study the print further and reach a decision on the pattern construction. You must consider what type of pattern is the most practicable to build and also the easiest to mold, and to finish. This is perhaps the most difficult as well as the most important phase of your job as Patternmaker.

According to figure 9-5, there are no pressure-tight chambers, channels, pockets, or voids. Thus, coring presents no problems. Another factor in determining the pattern construction is the number, size, and purpose of the subordinate parts of the basic casting. The hinge does not have any loose pieces and the strengthening rib may be considered as an integral part of the casting. If you select the parted pattern type of construction, you will have to determine where the parting line is to be located. Where the parts of the pattern separate is an important factor in the determination of the molding position and arrangement of the pattern. In many cases, talking it over with the Molder will help in making the best decision.

FREEHAND SKETCHES

Once in a while you will receive a hand-drawn sketch to use as the basis of a pattern layout. There are two major differences between a sketch and a blueprint of a finished drawing: (1) a finished drawing (of which the blueprint is merely a copy) is made with drawing instruments, while a sketch is usually drawn freehand; (2) the views on a finished drawing or print are drawn to scale while the dimensions on a sketch may or may not be drawn to scale.

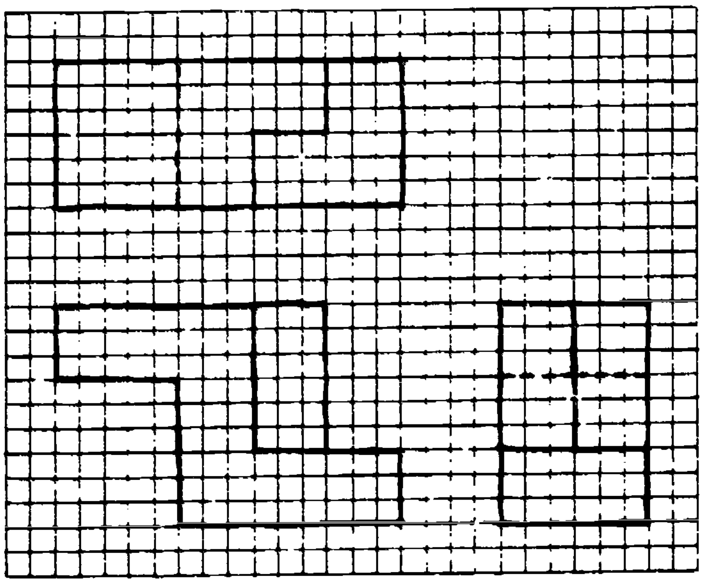
It is important to remember these differences when you are working with a sketch.

To make a freehand sketch, you need paper, pencil, and eraser. A 2H pencil may be used or a common No. 2 pencil. Cross-section paper like that used in making graphs or charts is helpful. You can assign a value to a square, so that it is easier to draw your sketch to rough scale. (See fig. 9-6.)

To make a working sketch directly from a machine part, you will need special instruments to measure the part. The drafting scales are too delicate to use on machinery. If the measuring edge of the drafting scale is nicked, any measurements taken from it when you are drawing may be inaccurate.

In measuring parts of machines, a steel machinist's rule is useful. For cabinet work, use a carpenter's rule. CALIPERS are invaluable for making accurate measurements of machinery or tools. The curved legs of the outside calipers make is possible to reach places where the rule cannot be used. Inside calipers are adapted to measuring the width of holes or gaps.

Calipers can be used for taking measurements which are accurate to within 1/64 of an inch. It takes some practice, however, to develop the right "feel" required for taking measurements this accurate. When measurements of a cylindrical piece are taken with outside calipers, the calipers should just touch the piece but be free to slide over it under their own weight. When you measure holes with inside calipers, be sure the measurement is taken in a plane exactly perpendicular to the axis of the hole.



68.67

Figure 9-6. — Working sketch on cross-section paper.

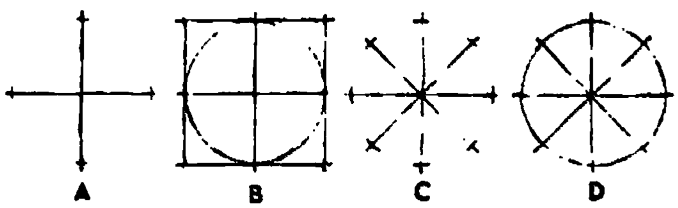
TECHNIQUE OF SKETCHING

In freehand pencil sketching, draw lines with a series of short strokes, instead of trying to draw each line with one stroke. Using short strokes, you can better control the direction of your line and the pressure of your pencil on the paper.

In sketching lines, swing your hand in the direction your line should go and back again a couple of times before you touch your pencil to the paper. In this way, you get the feel of the line. In sketching long lines, place a dot where you want the line to begin and one where you want it to end. Then use these dots to guide your eye and your hand as you draw the line.

Keep your freehand sketch neat. To do this, sketch your lines lightly first. Lines which are not essential to the drawing can be sketched so lightly that it is not necessary to erase them. Essential lines can be darkened by running the pencil over them with more pressure after they have been drawn lightly first.

Perfectly round circles are one of the most difficult things to draw freehand. Figure 9-7 shows methods of drawing circles and curves using straight lines as construction lines. First draw two straight lines crossing each other at right angles, as in part A of figure 9-7. The point where they cross will serve as the center of the circle. The four lines radiating from this center will serve as the radii of the circle.



65.41

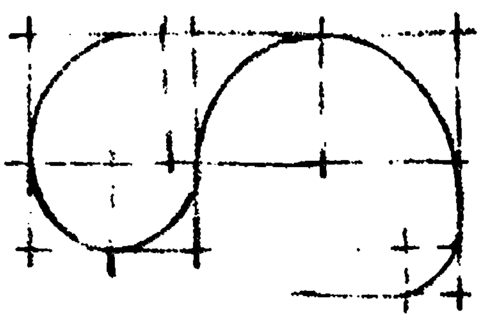
Figure 9-7. — Sketching circles.

You can use a piece of marked scrap paper to measure an equal distance on each radius from the center. Sketch a square, with the center of each side passing through the mark defining a radius. (See part B of fig. 9-7.) Now sketch in your circle, using the angles of the square as a guide for each arc.

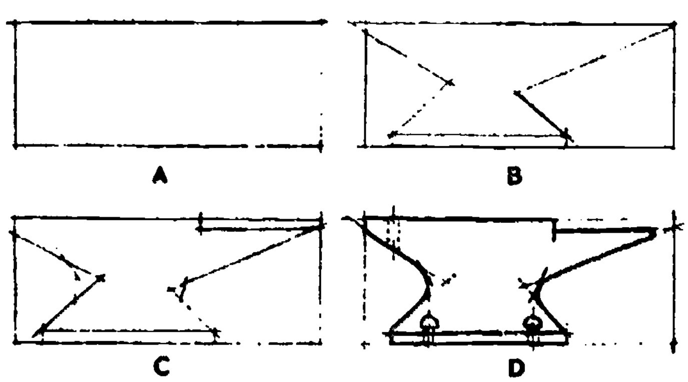
In parts C and D of figure 9-7, four lines, instead of two, are sketched crossing each other. The radii are measured as in constructing the other circle, but the square is not added before the circle is drawn.

Figure 9-8 shows a convenient way of sketching arcs, tangent arcs, and curves by blocking them in with straight lines.

When you are drawing a part, such as that shown in figure 9-9, don't start at one corner and draw it detail by detail and expect it to come out with the various elements in correct proportion. It is better to block in the overall shape of the object first. (See part A of fig. 9-9.) Then draw light guidelines at the correct angle for the various outlines of the object. (See parts B and C of fig. 9-9.) Finish the sketch, by first making an outline of the object, and then drawing in the details, as shown in part D of figure 9-9.



65.42
Figure 9-8.—Sketching curves.



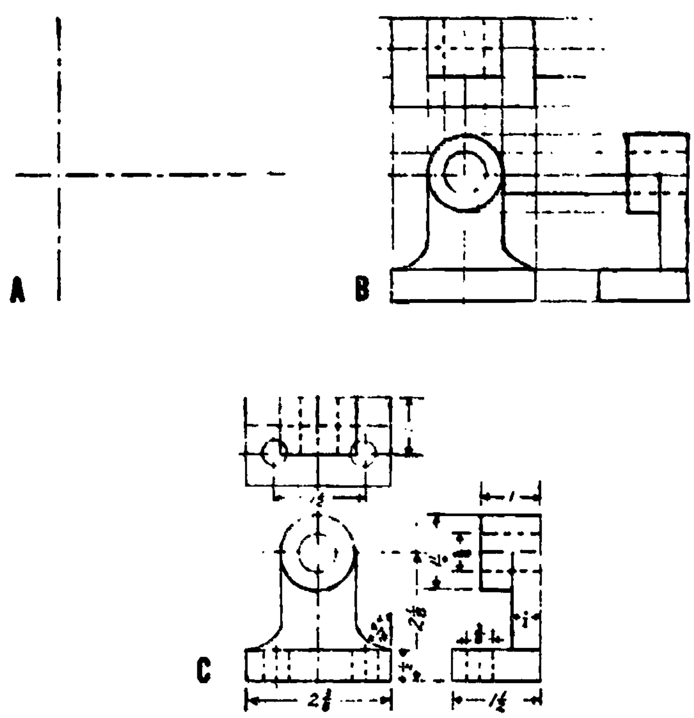
65.44
Figure 9-9.—The use of construction lines in sketching an object.

ORDER OF WORKING
A FREEHAND SKETCH

If you are assigned to make a working sketch from a machine part or a model, first choose a clean sheet of paper, either plain or ruled. Estimate the size the sketch should be, and select the views which will give the best picture of the object. Then draw the orthographic projections of these views, leaving adequate space between them for dimensions.

When you draw the views:

1. Sketch in centerlines, as shown in part A of figure 9-10.
2. Block in the views.
3. Sketch in the outlines, aligning them as in part B of figure 9-10.
4. Draw the details on the surface of the views.
5. Darken the lines of the finished drawing.



65.44.0
Figure 9-10.—Progress of a working sketch.

6. Use an artgum or a kneaded eraser to erase the construction lines which are no longer needed.
7. Draw all necessary extension and dimension lines.
8. Letter in the dimensions. (See part C of fig. 9-10.)

MAKING PATTERN LAYOUTS

You will remember that a blueprint is a copy of a drawing made to scale with the conventional drawing instruments. You, as a Patternmaker, must redraw the part to be cast to full-scale, using an appropriate shrink rule. For maximum precision use a bench knife to scribe the lines of the required views on a pattern layout board. Be sure to consider the specific molding requirements such as shrinkages, finishes, parting cores, core prints, and loose pieces, if applicable. Dimensions and blueprint notes are not usually shown on a pattern layout. Only those full-scale views that are necessary to the construction of the pattern are shown on the pattern layout. You will find that drawing the layout helps you to visualize the size and shape of the casting and also helps you to outline a definite plan for beginning your pattern construction. The layout enables you to project centerlines and construction lines directly onto the partially constructed pattern during various stages of construction. The layout also helps you to make appropriate templates and to check the completed pattern and core box (if required) for accuracy.

Most Patternmakers consider a layout as the stepping stone from the blueprint to the pattern. When they have finished the layout, they use it to make the pattern, thus considerably reducing the number of times that it is necessary to refer to the blueprint.

In making a pattern layout, you should use a dry board. If possible it should be of white pine. The board should also be a little larger than the actual size of the drawing. Smooth the face of the board and square one edge for use as a working edge from which you will make most of your basic measurements. DO NOT sand the surface of the layout board because the abrasive particles of the sandpaper will become imbedded in the layout board and will cause the layout tools to become dull.

Check the surface with a straightedge for wind and warp. For jobs requiring a layout board wider than 10 inches, reinforce the board with battens to prevent warping. If the layout board is not properly prepared, your pattern layout will not have the required accuracy.

LAYOUTS FROM BLUEPRINTS

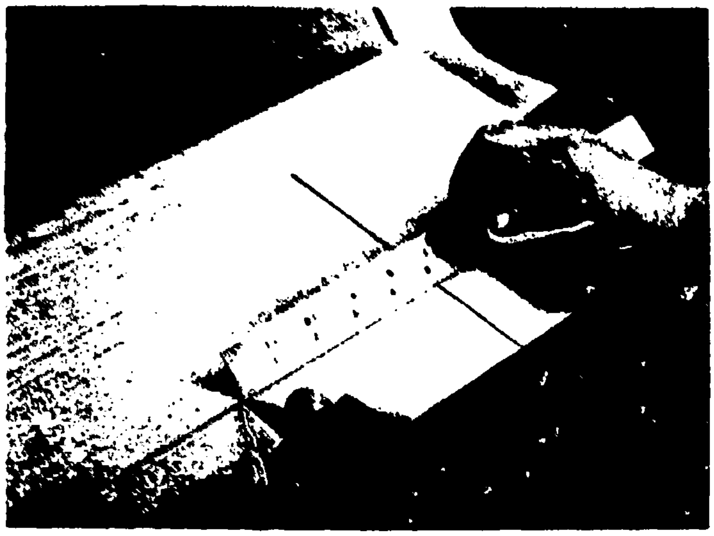
In making a layout of a pattern from a blueprint, you will usually find that all the dimensions you need are indicated on the print. The men who design and draw blueprints are fully aware of the importance of all the necessary dimensions being shown in prints. There will be very few times when you will have to figure it out for yourself.

Referring to figure 9-5, you are now ready to scribe the horizontal centerline of the lower boss on the layout. This is the basic reference line from which other measurements are to be made and must, therefore, be scribed with great precision. Hold the marking or panel gage flush against the working edge of the board and scribe this horizontal centerline in the direction of the grain of the wood. Allow adequate space on the board for the required views to be drawn. With the aid of a combination square, scribe the vertical centerline at right angles to the horizontal centerline. Be sure that the bench knife is especially sharp to avoid tearing the wood fibers as you scribe across the grain of the wood. After scribing these basic reference lines, blacken them with a wedge-pointed or chisel-pointed lead pencil.

Select the proper shrink rule for bronze. To avoid any mistakes, stow away all other rules except the one you are using for the layout. Use the shrink rule to locate the left vertical centerline as shown in figure 9-11.

Notice that the measurement is 5 inches to the left of the right centerline. These two centerlines will be used to obtain the center points of the bosses, the cylindrically shaped projections, which are the outstanding features of the hinge pattern. Cut the lines deeply and sharply and fill them in with a black pencil. As a trick of the trade in measuring, it should be mentioned that some Patternmakers DO NOT use the first or last inch graduation markings on the shrink rule as shown in figure 9-11. It is believed that wear on the ends of a shrink rule may result in an inaccurate measurement. This is more or less a matter of individual preference. Whenever this is done extreme care should be taken to ensure that proper lengths are measured from the starting, reference point on the rule.

Continuing the layout: Scribe the 1-inch diameter boss on the left and the 1 1/4-inch diameter boss on the right, using a pair of dividers. The right boss is 1 7/10 inches above the left boss. This is illustrated in figure 9-12. (Note: When transferring a decimal measurement from the blueprint to the layout, check the table of decimal equivalents for the nearest fractional measurement in 1/64 above the decimal measurements. In other words, 7/10 inch is approximately 0.703125 inches on the table of decimal equivalents, or 45/64 inches.) The next step is to locate the point for scribing the curved portion of the right end of the pattern. This point is 7/10 inch from the horizontal centerline of the right boss. It is also 1 1/8 inches left of the vertical centerline (1 inch from the outside of the rib plus 1/8 inch from the center of the rib). Locate this point with a combination square and a panel gage as shown in figure 9-13.



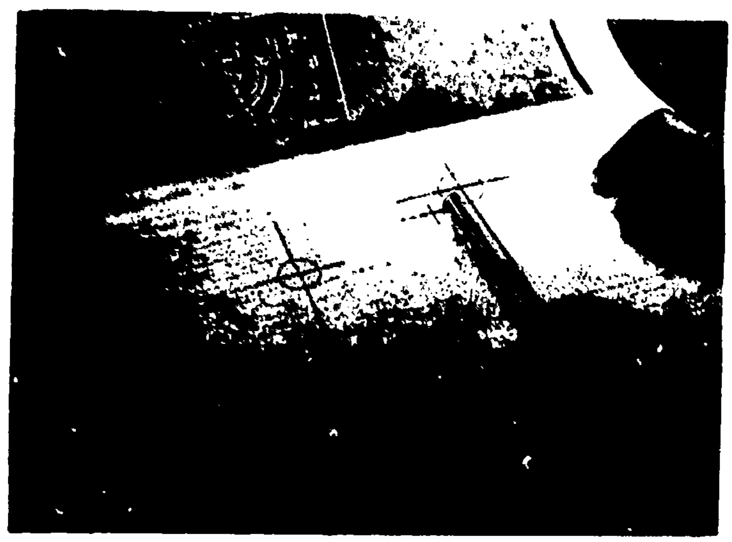
68.68
Figure 9-11.—Locating the left centerline.

Set a divider at 1/2 inch, 1 inch, 1 1/4 inches, and 1 3/4 inches and scribe the outline and rib curves in this sequence. Now scribe vertical lines tangent between these curves and the boss. This completes the outline of the right end of the pattern as shown in figure 9-14.

Doublecheck your work as you make each measurement because it is very difficult to locate mistakes if you wait until the entire layout is completed before checking your measurements. Blacken the knife lines as you proceed with the layout so that the form and shape of the pattern will stand out prominently.

Scribe a top outline line tangent to the curve previously scribed on the right end to a point 3/8 inch above the center point of the left boss. Scribe a bottom outline line in t same way to a point 3/8 inch below the cent oint. The outlines of the rib are scribed f points 1/8 inch above and below the cente oint of the left boss and tangent to the rib rves previously scribed.

68.69
Figure 9-12.—Scribing bosses.



68.70
Figure 9-13.—Locating the point for scribing the curved portion of the right end of the pattern.

Next, scribe the outline of the left end of the pattern. The 2-inch flat surface is scribed at a point 6/10 inch above the boss center. The round edges are scribed at radii of 1/20 inch except for the point where the blueprint indicates a 1/10-inch radius. Figure 9-15 shows the completed outline of the left end of the pattern.

Using the blueprint dimensions and the vertical lines of the top view, scribe the side view of the hinge on the layout. This is shown in the bottom view of figure 9-16.

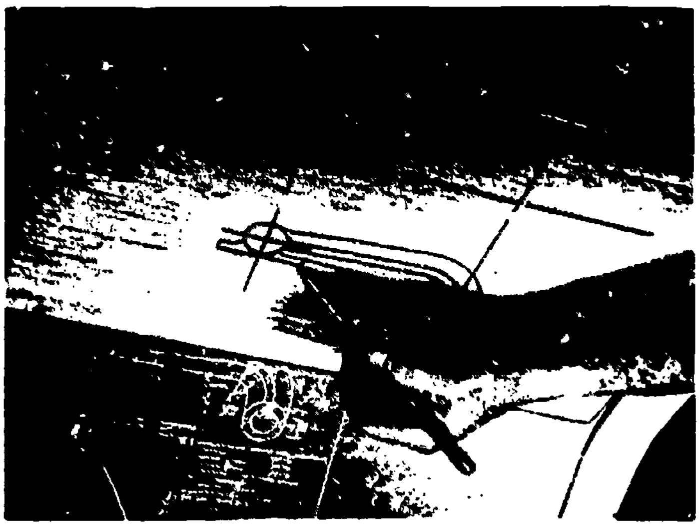
23.27(68)B
Figure 9-14.—Completing the outline of the right end of the pattern.

So far the layout has been mostly a reproduction of the blueprint made with a shrink rule. But now you must consider what additional features the layout and pattern must have to aid in the making of the mold. Two features, the parting line and the machine finish allowance, are needed in the layout of the hinge. As there are no holes to be cast in the hinge, cores are not used in this case.

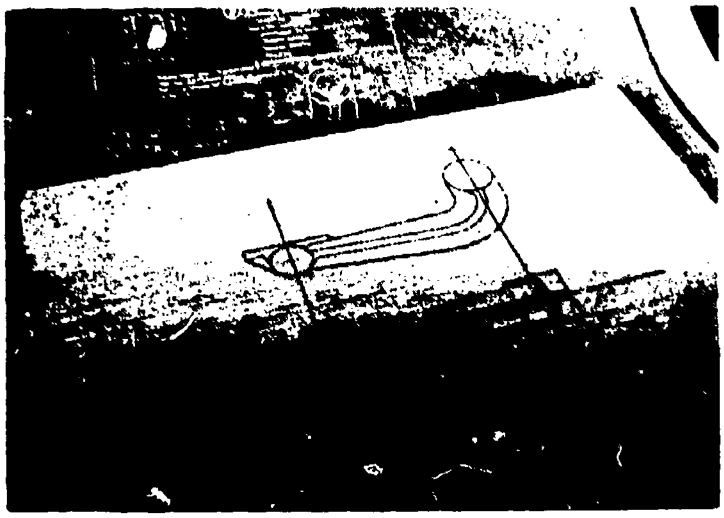
In laying out a pattern, you must also consider the easiest and quickest method of removing the pattern from the sand so that production will not be delayed.

There are no set rules for establishing parting lines as they are determined primarily by the nature of the casting to be made. For our sample layout then, it has been decided that the best plan is to split the hinge pattern with the parting line coming in the middle. A heavy line with two arrows pointing inward at each end ( ) is used to represent the parting line on the layout as shown in figure 9-17.

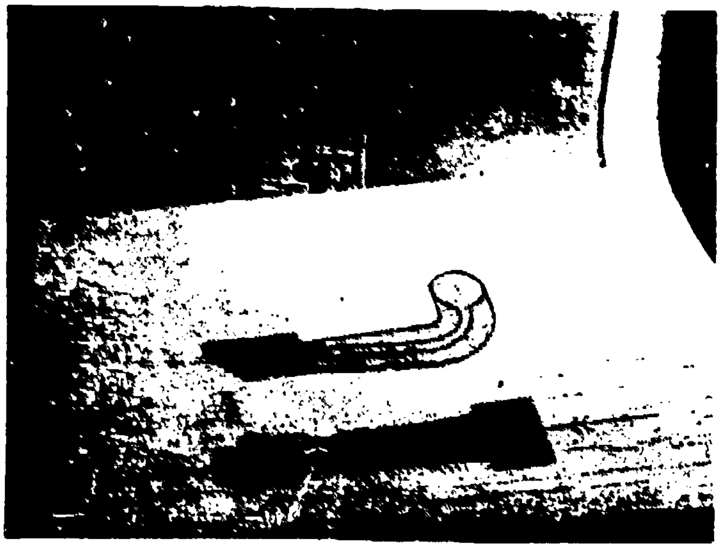
Now indicate on the layout where additional thickness must be added to the blueprint dimensions wherever the metal is to be machined later. This machine finish allowance is indicated by darkening or coloring the required allowance as shown in figure 9-17. The amount of allowance that is added varies for the different metals. In average cases, 3/16 inch to 1/4 inch is allowed for steel castings. For most



23.27(68)C
Figure 9-15.—Completing the outline of the left end of the pattern.



23.27(68)D
Figure 9-16.—Layout of the side view completed.



23.27(68)E
Figure 9-17.—Parting line established and finishes added.

cast iron castings, 1/8-inch finish allowance is sufficient. For brass, bronze, and aluminum alloys, 1/16-inch finish allowance is generally satisfactory. It is a good practice to check with the machine shop and find out how much allowance for finishing they want on their castings.

Whenever possible, design the pattern so that the machine finish surfaces will be cast in the drag. If some machine finish surfaces are to be cast in the cope, provide an extra allowance so that the casting can be machined to a greater depth to remove any sand or impurities that may have floated to the top of the casting.

Shellac the completed layout to keep the layout clean. As an extra precaution, the entire layout, including the edges of the layout board, should be shellacked to prevent warpage. Before getting started on the actual construction of the pattern, you must check the completed layout against the blueprint. Check all measurements, finish marks, and blueprint notes to make sure that the layout is an accurate representation of the pattern to be built. In some pattern shops, the PM1 or PMC will make the final inspection of the layout. Very often the PMC will use the layout as a training aid to instruct you and other pattern shop personnel in various construction techniques. After you have completed the construction of the pattern, the PM1 or PMC will make a final inspection of the pattern, the layout, and the blueprint, for accuracy. After the castings are made, the layout and the pattern are usually stowed in the pattern storage area for future reference, if storage space is available.

One note of caution must be mentioned concerning the construction of a pattern from a layout. As a general rule, draft is NOT shown on the layout and you must remember to include it all the time you are building the pattern. The exact amount of draft allowance depends upon the specific job and is often decided upon in conference with the Molder. Sufficient draft must be provided to facilitate the withdrawal of the pattern from the mold. On small, straight patterns the usual draft allowance is 1/8 inch per foot. On a pattern 3 inches deep, you will use approximately a 1/32-inch draft allowance.

LAYOUTS FROM CASTINGS

Thus far you have been given the procedure for making a pattern from a blueprint. Very often you will be required to make a pattern from a worn or broken casting without the aid of a blueprint. In scribing this layout, you must first obtain (by checking the casting) the centerlines or basic construction lines which will form the basis of the layout. The centerlines may be found very accurately by placing the sample casting on a surface plate. You then measure them from the surface plate to the center of the bosses, outlets, or holes by means of standard rules, squares, gages, or calipers. It is always best to work from a casting's machined surface if one is available. After the centerlines have been established by this method, you proceed to scribe the outline of the casting and to add the necessary details. Remember that the proper shrink rule must be used when transferring the standard rule measurements from the casting to the layout.

The following procedure is presented as a guide for drawing a layout from a casting:

1. First, find out from what part of the major assembly the worn casting was removed. Be sure you understand the purpose and function of the assembly.
2. Inspect the part and the rest of the unit closely to identify the surfaces which require machining. In some cases it may be necessary to build up or restore the dimensions of the worn surfaces.

3. Apply the standard metal tests such as the spark, chip, or file tests, in order to identify the kind of metal used in the worn part.

4. Make a working sketch of the casting by transferring all measurements from the worn part, using the standard measuring instruments such as calipers, scale, trammel, dividers, etc.

5. From the sketch make a layout, using the proper shrink rule.

6. Locate the core prints and add the proper machine finish allowance.

7. Doublecheck the layout carefully against the sample casting before proceeding with the construction of the pattern.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 10.

BACK DRAFT—An undesirable application of draft on a surface of a pattern. The draft slopes in the wrong direction, preventing the proper withdrawal of the pattern from the mold.

CHILL—A metal object placed in the wall of a mold, causing the metal to solidify more rapidly at that point.

COLLAPSIBLE PATTERN—A pattern so constructed as to permit its removal from the mold in sections.

DRAWBACK—Portion of a mold supported upon an iron plate which is so arranged that it may be drawn back for the removal of the pattern, and then reseated at the proper time in its relationship with the remainder of the mold.

GREEN SAND CORE—A body of sand usually formed directly from a pattern in making the mold. A core that is rot baked.

MASTER PATTERN—A pattern embodying a special additional contraction allowance and used for making castings that are to be used as patterns in production work.

MATCHED PARTING—Forming of a projection upon the parting surface of the cope half of a pattern and a corresponding depression in the surface of the drag.

MATCH PLATE—Wood or metal plate to which a pattern is attached at its parting line.

MEDIUM GRADE PATTERN—A pattern used only occasionally which may therefore be of a cheaper nature than a standard pattern.

PATTERN MEMBERS—The component parts that go toward making up a pattern.

PATTERN RECORD CARD—A filing card giving a description, location in storage, and the movement of a pattern.

SPLIT PATTERN—A pattern that is parted for convenience in molding. A parted pattern.

STANDARD PATTERN—A pattern in daily use or used as frequent intervals and therefore of first quality workmanship and material.

TEMPORARY PATTERN—A pattern used to produce only one or two castings and therefore made as cheaply as possible.

CHAPTER 10

PATTERN EQUIPMENT

The Patternmaker is responsible for providing the foundry with practical and economical pattern equipment to suit the quality and quantity of all castings. Accurate, well constructed patterns, made of suitable materials, designed to conform to foundry requirements will not only speed up production, but will eliminate many of the more common casting difficulties; thus resulting in the production of sound, usable service castings.

A PATTERN is defined as a full-size model — made of a suitable material with provisions included for molding, coring, and machining — from which a refractory mold is made. A pattern is the basis for all foundry practices.

Further study of the definition of a pattern will provide the following information:

The term FULL-SIZE MODEL is used to distinguish the pattern from a scale or sub-size object used to convey an idea.

The term SUITABLE MATERIAL is used to distinguish the material from which a pattern is constructed to provide the maximum wear for the number of castings to be produced.

The term PROVISIONS FOR MOLDING AND CORING includes such items as: (1) proper shrinkage allowance to compensate for the contraction in the solidification of molten metal, (2) proper draft on pattern surfaces that is necessary for the withdrawal of the pattern from the mold, and (3) the provision of ample projections or core prints of sufficient bearing surface and size and shape to form impressions in the mold cavity to support and locate the cores necessary to form the interior or exterior of a casting.

The term PROVISIONS FOR MACHINING includes the extra stock and machining lugs necessary for machine setup allowed on the pattern to permit machining the casting to accurate dimensions or a smooth finish.

CLASSIFICATION OF PATTERN EQUIPMENT

Pattern equipment is a general term used in the trade to refer to the great variety of types of patterns that are required in cast metal production. Although several different materials, such as wood, metal, plaster, and plastics are used to construct pattern equipment, the equipment itself may be classified for convenience as follows: loose patterns, single patterns, gated patterns, match plates or matchboards, cope and drag patterns, and special equipment (follow boards, skeletons, part patterns, and sweeps). Remember that this is an arbitrary classification for convenience. Other books may present other methods of classification that may be just as good. Cores may be required in any of these types of patterns to form an internal cavity in the mold.

Under the broad classification of loose patterns are the one-piece patterns and the one-piece built-up patterns. A one-piece pattern is a solid pattern but is not necessarily made from one piece of wood. A one-piece built-up pattern is a pattern that is not necessarily made from one piece of wood; it can be a series of pieces formed to make a certain shape, but the pattern will be in one piece.

TYPES AND KINDS OF PATTERNS

Although the number of castings required from a pattern will somewhat determine the TYPE of pattern to be manufactured, the KIND of pattern will specify the construction and molding procedures.

The type of pattern used is to facilitate a certain molding problem and is not related to the number of pieces or form of joinery that enter into the construction of the pattern. The kind of pattern is related to the grade and future use. Whether patterns are temporary, medium, or standard grades, the best materials and workmanship should go into their manufacture. A TEMPORARY GRADE PATTERN is a pattern used to produce only one or two castings and therefore made as cheaply as possible. A MEDIUM GRADE PATTERN is a pattern used occasionally which may be made cheaper than a standard grade pattern. A STANDARD GRADE PATTERN is a pattern in daily use or used at frequent intervals and requiring only minimum repairs.

In designing pattern equipment, remember that the pattern is only a means to an end. Patterns are used as tools by the Molder to make molds, which in turn are used to produce castings. Thus you must consider mold design before you begin building a pattern.

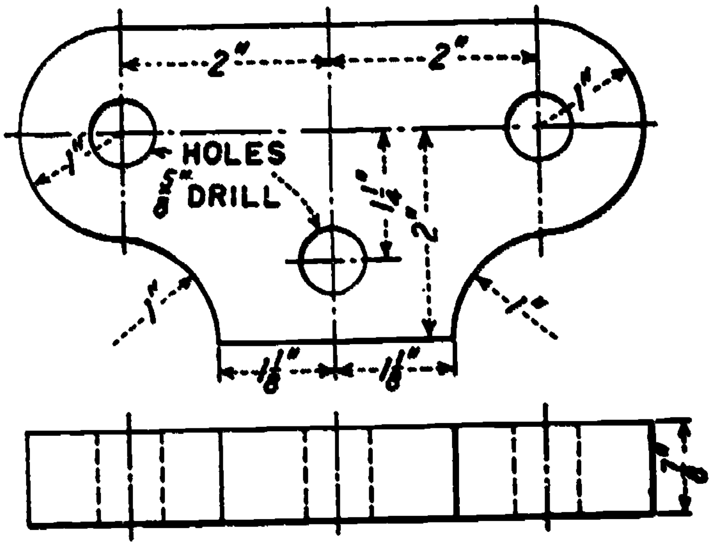
Since a given casting can usually be produced with any of several types of pattern equipment, you should be familiar with the general characteristics of each type, and the circumstances in which one type of equipment rather than another offers the greatest advantage. The type of pattern equipment and the construction procedures selected depend partly on the complexity and shape of the casting required and partly on the number of castings to be produced. Another important consideration is the cost of material and labor per casting.

In the mass production of castings, every attempt is made to design the pattern so as to reduce molding costs. Sometimes it may be more economical to spend a little more on the pattern equipment, if by doing so, it will reduce the cost per casting. When only one or two castings are required and when speed of production is the important factor, as in most work aboard repair ships or tenders, the Patternmakers and Molders will usually use job shop rather than production shop procedures. Because of all these factors, the proper design of pattern equipment and close cooperation between the Patternmaker and the Molder are essential to the production of sound castings as quickly as possible and at minimum cost. One of the basic decisions made by the Patternmaker and the Molder is to determine the best type of pattern for the foundry molding.

The following sections discuss the relative advantages and disadvantages of each type of pattern equipment.

Loose Patterns

The SINGLE LOOSE PATTERN is of greatest use when only a few castings are to be made. For very elementary projects, the Patternmaker may decide to use a loose pattern of the solid or one-piece type shown in figure 10-1. This is a relatively cheap and simple pattern to build because it has no partings. However, the cost of molding and the risk of a casting failure are increased since the pattern must be molded as a unit. The major molding difficulty is lifting off the top of the flask without rapping the pattern and without having the cope sand stick or drop out. To avoid this difficulty and to simplify the molding process, the Patternmaker probably will make a parted (split) pattern. (See fig. 10-2.) A parted pattern has separable cope and drag halves which are parted horizontally through the centerline. The methods used by the Molder in ramming the sand around parted parts of a pattern are discussed in another section of this training manual.



68.61

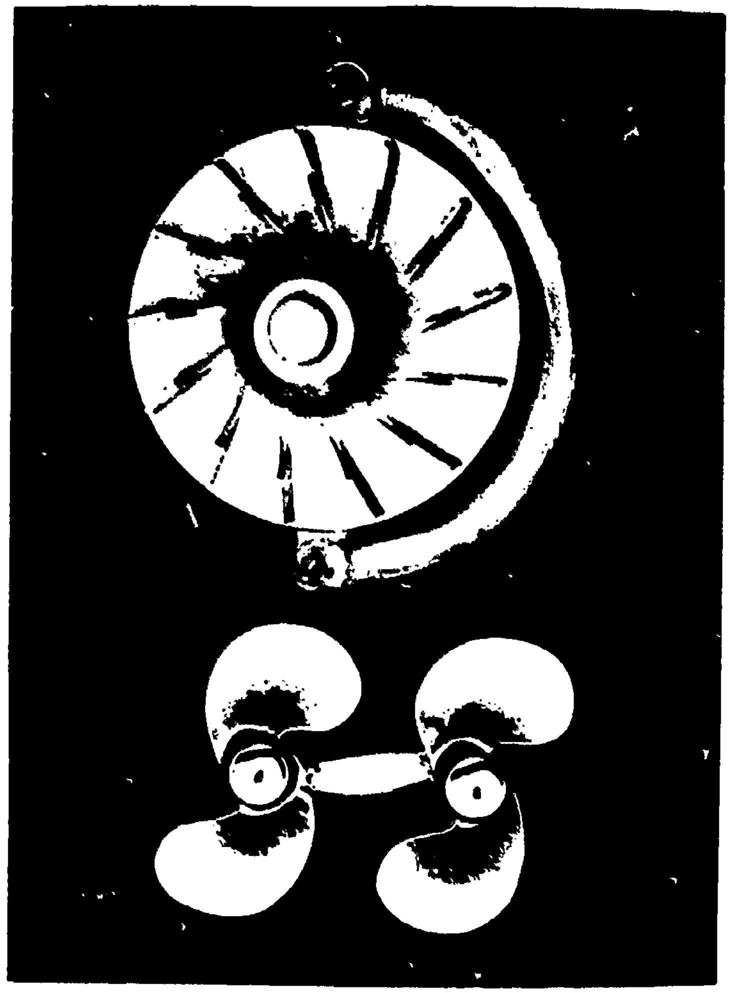
Figure 10-1.—A solid pattern.

23.67.1

Figure 10-2.—A parted pattern: A. Cope side. B. Drag side.

From the Molder's point of view a single loose pattern, whether it be of solid or parted construction, is time consuming to work since it requires the maximum number of hand molding operations. Often the time required to cut gates and risers by hand equals the time required to make the mold itself. But a more important consideration is the potential this type of pattern has for the production of uniformly sound castings. Frequently, when a number of castings are made from a single loose pattern, the quality of the castings produced varies because tne size and shape of gates and risers provided differ from mold to mold. This difficulty is most apparent when the Molder's skill is not sufficiently well developed to exactly duplicate the desired gating system from one mold to the next. Another fault inherent in loose wooden patterns is that they warp easily and are subject to damage in handling, in spite of the precautions usually taken by the Patternmaker in constructing the pattern.

The GATED PATTERN represents a step in the direction of quality control. It may be a single or a multiple loose pattern as shown in figure 10-3. A gated pattern reduces the overall molding time and, in the case of multiple parts produced in one mold, the permanently attached gates serve to hold the several parts in their proper relationship to each other within the flask. More important, though, is the fact that this type of equipment cuts down the number of hand operations, eliminates the possibility of variation in the size of the gates, and thus increases the probability that castings of uniform quality will be produced from the pattern equipment. Although the Patternmaker in this case forms the gates and risers as well as the pattern, this does not relieve the Molder of his responsibility for their design. In other words, when using gated patterns, the design and construction of gates and risers requires close cooperation between the Patternmaker and the Molder. Gated patterns, especially those made of wood, must be carefully handled since the relatively small gates are fragile. Like loose ungated patterns, gated patterns are subject to warpage. Nevertheless, gated patterns represent an economical improvement over ungated patterns when a small number of simple castings is required.



18.13X

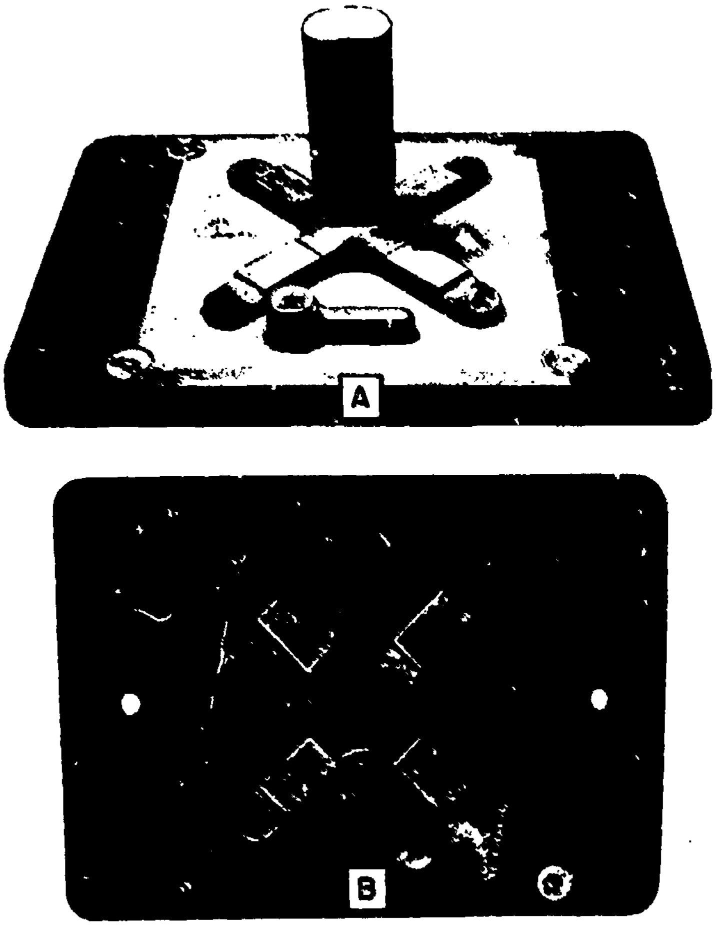
Figure 10-3.—Gated patterns.

Mounted Patterns

MATCHBOARD or MATCH PLATE equipment is indispensable where a fairly large number of small castings is to be made. Even though the number to be produced on a single job order is not unusually large (say 50 to 100), a matchboard may be used if the part is one that is likely to be called for repeatedly. A typical matchboard is illustrated in figure 10-4.

Master or universal match plates made of wood, aluminum, magnesium, or steel may be purchased to fit any standard flask. Normally, though, the Patternmaker makes the board of plywood or by gluing strips of wood together so that warping is prevented. Matchboards are made with flask pin holes or flask slides which exactly fit the particular size flask to be used.

The patterns for the individual castings usually are made up as single parted patterns and mounted on the board with brads or wood screws. The complete gating system usually is mounted securely on the matchboard also,



18.14
Figure 10-4.—Matchboard: A. Cope side. B. Drag side.

as shown in figure 10-4. Great care must be taken so that all the patterns mounted on the board will be exactly alike, and that cope and drag halves are in perfect alignment. To prevent wear during use, metal strips are usually attached at wear points on the board.

Although the possible advantages of molding with matchboards are fully realized only in the production foundry, the Navy foundryman can also benefit through their use in the production of small castings in bench molds. Assuming that the matchboard equipment is properly made, its use increases the Molder's efficiency by eliminating nearly all hand molding operations, produces castings of uniform quality, and increases yield by reducing the amount of scrap in the form of rejected castings. Mounted pattern equipment has a greater service life since it is more resistant to rough handling and warpage.

COPE and DRAG PATTERN equipment is in many respects similar to a match plate. The principle difference is that the drag portion of the pattern is mounted on one plate, while the cope portion is mounted on another. (See fig. 10-5.) Cope and drag equipment is usually used for patterns that are too large to be conveniently mounted on matchboards. Both types of equipment produce a dimensionally accurate mold with a minimum of hand molding operations. A further advantage of cope and drap equipment in production work is that two Molders can work separately on the job—one molds copes, while the other molds drags. In the job foundry, cope and drag pattern equipment is seldom used because the volume of

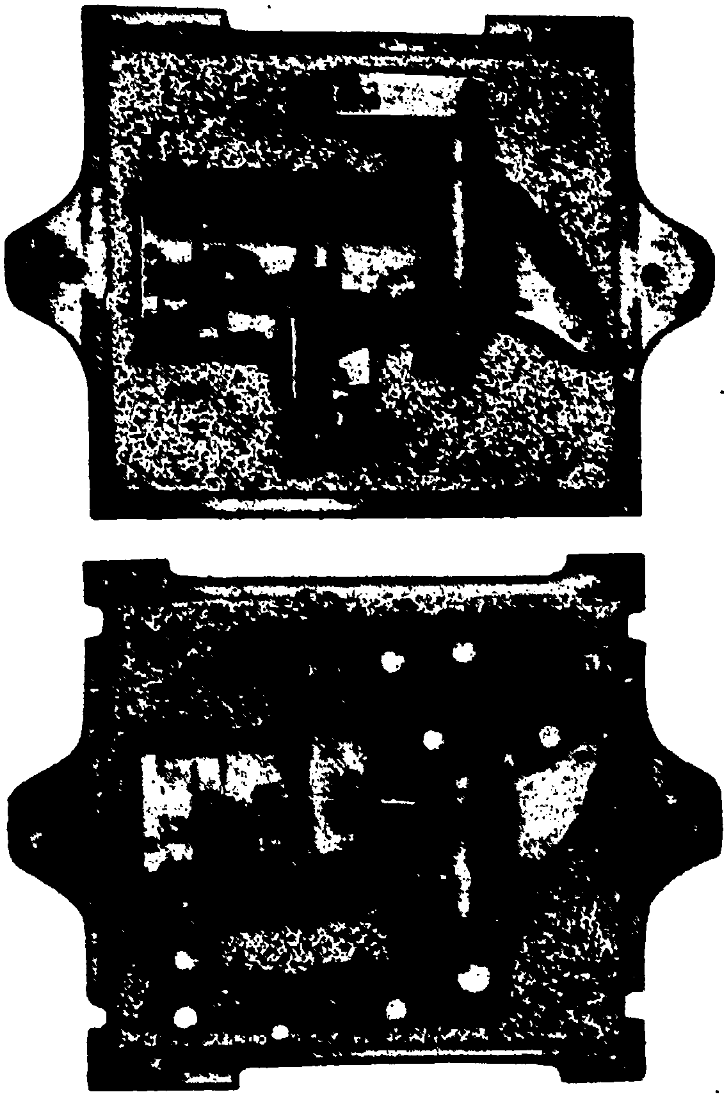


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Figure 10-5.—Cope and drag pattern equipment.

production is not sufficient to justify the cost of the pattern equipment.

Master Patterns

A master pattern is the name given to a pattern having a double contraction or shrinkage allowance. The castings made from the master pattern are used by the Patternmaker in making duplicate patterns that will have only a single contraction or shrinkage allowance for the particular metal required of the final casting. An allowance is made not only for the shrinkage of the metal pattern, but also, a second allowance is added for the shrinkage of the casting produced from the metal pattern. For example, a master pattern constructed for an aluminum pattern to be used in producing bronze castings has the shrinkage allowance for aluminum (5/32 inch per foot) plus the shrinkage allowance for bronze (3/16 inch per foot) or a total shrinkage allowance of 11/32 inch per foot. If the final casting is to be machine-finished, further allowances must be made for finishing the metal pattern and final casting. The actual metal pattern is made in the foundry by the Molder the same as any other casting of similar complexity would be made.

The different types of material that can be used in the construction of master patterns are numerous. These types include wood, plaster, aluminum, brass, bronze, sheet lead and white metal. As comparatively few castings are made from a master pattern, the cost of the materials is held to a minimum so that the pattern can be made as economically as possible. Therefore, for the general purposes of lower cost and of speed in the manufacture of a master pattern, pine is the most logical material to use.

Special Pattern Equipment

Special pattern equipment is a catch-all category including follow boards, ram-up blocks, sand matches, sweeps, and skeletons. Of these, the most frequently useful device is the follow board. It has two main applications: to aid in the molding of irregular parting patterns, and to mold with patterns that would be too fragile if the pattern were parted to form the parting line. A typical follow board is illustrated in figure 10-6. The device shown is essentially a special mold board into which a recess has been cut to fit the parting line of the pattern for which it is designed. Its use is the same as that of a regular mold board. The special name stems from the fact that the board is made for a particular pattern and FOLLOWS that pattern around during the drag's rollover. Patterns having an irregular parting line often may be molded with greater ease and accuracy with a follow board constructed so that its surface matches the pattern's irregular parting plane. (See fig. 10-7.)

RAM-UP BLOCKS are special devices which support and prevent thin-shelled patterns from springing or breaking during the ramming operation. The block usually is made of wood, but may be made of plaster. In either case, the block must accurately fit the portion of the pattern that it is to support. For the symmetrical pattern shown in cross section in figure 10-8, a wood block would be turned on a lathe. The Patternmaker may make the ram-up block as a loose auxiliary part or he may fasten it to the mold board, depending upon the preference of the Molder who is going to make the mold.

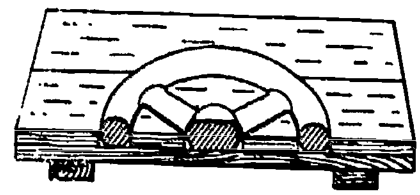

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Figure 10-6.—Follow board.

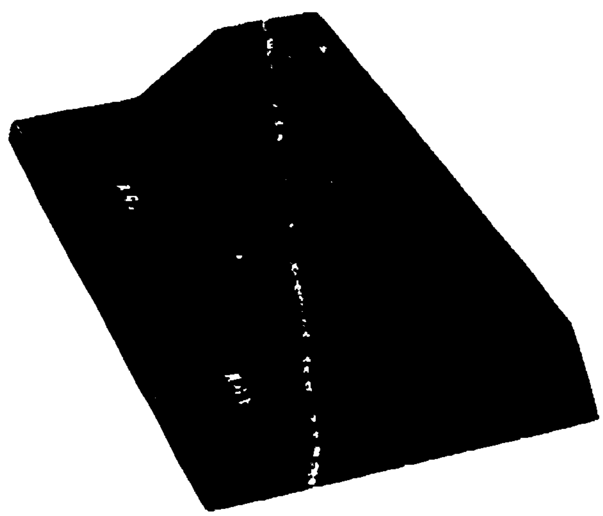

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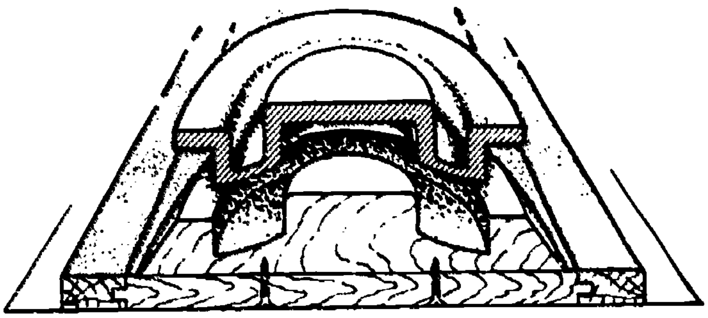
Figure 10-7.—Using a follow board to obtain an irregular parting line.



18.17X

Figure 10-8.—Ram-up block.

Although the ram-up block shown in figure 10-8 is intended to serve as a pattern protecting and supporting device, to prevent springing or breaking the pattern, it also functions as a follow board. Sometimes it is difficult to distinguish between a match plate, ram-up block, and a follow board. In making a distinction where a device serves more than one purpose, classify it according to its PRINCIPAL FUNCTION.

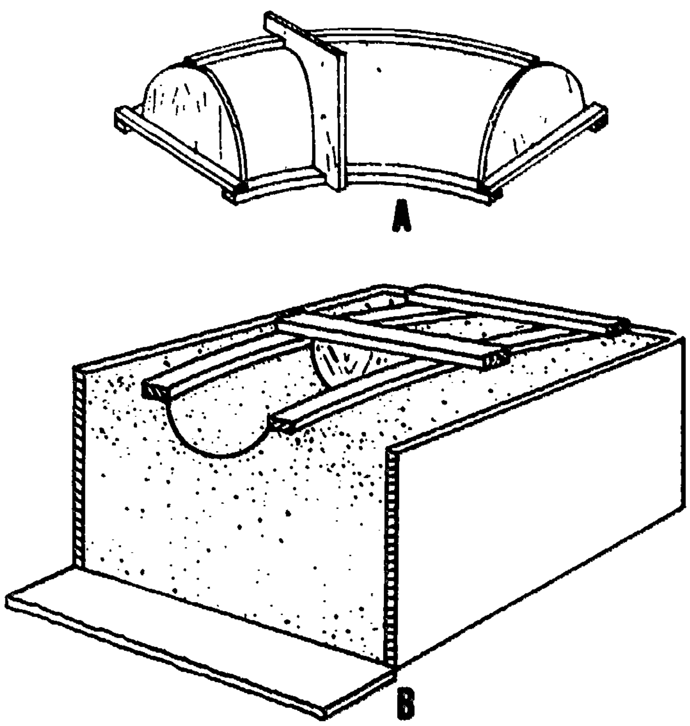


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Figure 10-9.—Skeletons and sweeps.

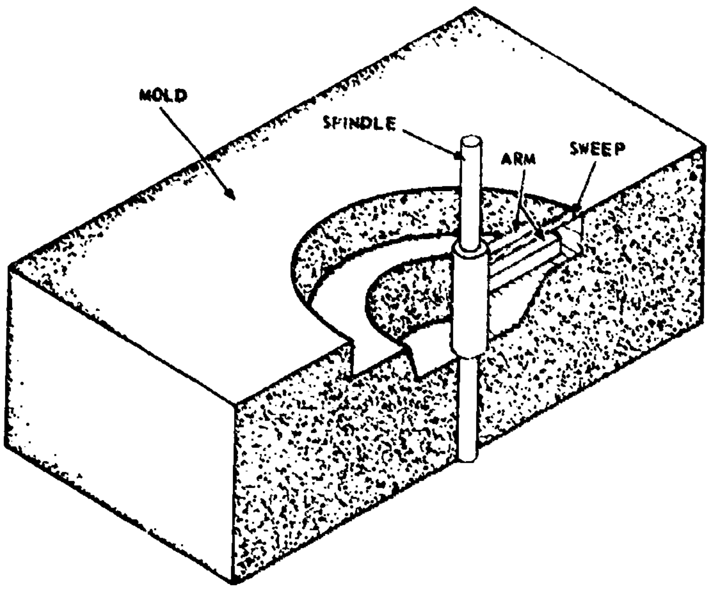
SKELETON PATTERNS are wooden frames designed to help the Molder make the mold. They are especially useful in the production of very large hollow or shell-like castings, such as large pipes, elbows, or housings. Usually, the Patternmaker provides the Molder with sweeps or strickles with edges cut to the cross-sectional shape of the casting to be made. The skeleton technique can also be used in making cores. Figure 10-9 illustrates the skeleton construction of a core box and the accompanying sweep made by the Patternmaker. The Molder does the rest of the work by hand.

Almost any reasonable shape and metal thickness can be swept with the proper templates and sweeps. However, the sweep technique is an economical procedure only when one or two castings having a relatively simple shape are required. When the shape is complex, sweeping is impractical. If more than a few castings are required, even a simple shape can be produced more efficiently with a pattern. The technique is employed so infrequently in modern foundry practice that it is practically a lost art. In job shops such as those aboard repair ships and advanced bases, the use of sweeps and skeletons may be advantageous for certain classes of large but symmetrically shaped castings where repeat orders are unlikely. Here their advantage is twofold: the time and expense of patternmaking is negligible, and the problem of storing a bulky pattern is eliminated. To construct a satisfactory mold with sweeps and skeletons is a real challenge to the Molder's skill.

If the casting desired is symmetrical about a central axis, the Patternmaker will mount the sweep on an upright spindle. The Molder then centers the upright spindle in a bed of packed sand and forms the mold cavity by rotating the sweep through the bed of sand until the desired mold shape is formed. See figure 10-10.

This method of forming circular molds is especially useful in making gear blanks, handwheels, pulleys, pump and impeller housings.

The PART PATTERN is another type of pattern equipment that is also applicable to circular work. A part pattern is actually only a portion of a pattern that is constructed so that the Molder can form the complete mold in stages, moving the part pattern from section to section in the mold. Marine propeller patterns are most often made as part patterns. The Patternmaker will usually build only one blade and the hub or one blade and the corresponding section of hub as the entire pattern. Appropriate jigs or vertical spindles are necessary to hold the part



68.62
Figure 10-10. — Forming a mold with spindle and sweep.

pattern in perfect alignment during the molding procedures.

The Molder mounts the hub of the propeller pattern on a vertical spindle in the center of a bed of sand in a large flask. He then rams the mold for the single blade and rotates the pattern about the spindle to get the pattern in the correct position for molding the second blade of the propeller. If a four-bladed propeller is required, the Molder will rotate the pattern 90° about the spindle. If a three-bladed propeller is required, he will rotate the pattern 120° about the spindle. Thus, using a part pattern of a single blade and hub and appropriate fixtures or jigs, the Molder may cast a propeller wheel with the required number of blades.

PART CORES are used in the same manner as part patterns, especially where long cores of the same cross section are required. Part cores are especially useful in making cores for long lengths of pipe. Instead of making one very long core box, the Patternmaker will make a shortened core box. The Molder then rams up a sufficient number of the short cores and places them end to end to give the required length. While you are pasting the part cores together, be sure to keep them in perfect alignment by using a jig, arbor, or fixture.

In building skeleton patterns, sweeps, strickles, and part patterns, the Patternmaker must work with very close precision because any errors will be exaggerated in the molding procedures.

PATTERNS WITH LOOSE PIECES do not actually comprise a separate classification of types of pattern equipment. Loose pieces may or may not be used in conjunction with any of the types of pattern equipment mentioned thus far. They are brought in at this point because they are so closely related to pattern design and the solution of some of the specific molding problems under discussion.

Many patterns with flanges, bosses, pads, and the like, have projecting parts which form undercuts that prevent the withdrawal of the pattern from the sand without tearing up the mold. To simplify the Molder's job of withdrawing such a pattern from the mold, the Patternmaker will construct the patterns with loose pieces. A loose piece is defined as a part of a pattern attached to the main body of the pattern with a metal rod or skewer. The loose piece remains in the mold and is taken out after the main body of the pattern is removed. (See fig. 10-11.)

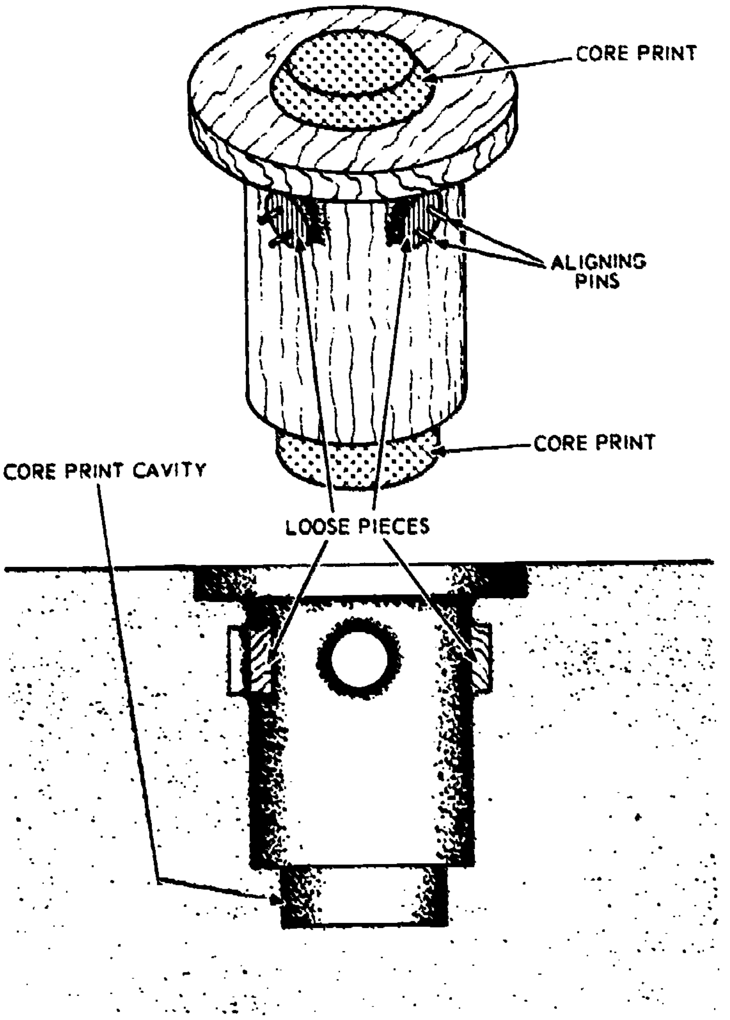
The Molder rams the pattern in the conventional way and removes the skewers. This frees the main body of the pattern from the loose pieces. He then withdraws the main body of the pattern leaving the loose pieces in the mold. Next, he reaches down into the mold, carefully draws the loose pieces from the side wall into the main mold cavity, and then lifts the loose pieces out of the cavity. It is good practice for the Molder immediately to replace the loose pieces on the pattern to make sure that all the loose pieces have been picked out of the mold before pouring the casting.

CORE BOXES

Although core boxes may be classified as special pattern equipment, they actually are part of the pattern made for a particular job. Therefore, core boxes should be treated as patterns. A description of cores and core boxes, their uses and methods of construction are presented in chapter 11 of this training manual.

PATTERN EQUIPMENT CONSIDERATIONS

The fundamental requirement of all patterns is that they must be so formed that the Molder can build up, with their use, molds of such shape



18.22(68)

Figure 10-11.—Pattern with loose pieces.

that the desired casting may be made with them. Therefore, the Patternmaker must have a knowledge of the various molding processes and methods in addition to the basic design rules, to create and construct patterns and core boxes so the Molder can use them to the best advantage. (See chapter 2 of this training manual.)

Guidelines for construction and checkpoints for determining the suitability of a pattern are:

1. Provide for the use of any loose pieces required on the pattern or core box.
2. Plan to have as much mold cavity in the drag as possible.
3. Use the proper shrink rule for the characteristics of the metal concerned.
4. Ensure that any necessary distortion allowance has been incorporated in the pattern.
5. Provide sufficient finish allowance for machining to the required overall dimensional tolerances.
6. Apply the proper draft in accordance with the size and shape of the pattern.
7. Ensure that the pattern has the proper strength and finish to withstand the abrasive action of foundry materials.

STRENGTH OF PATTERNS

The strength of any pattern is governed by the construction methods used. You should already know some methods of good pattern construction from practical instruction received on the job. Some of these methods of construction and pattern features that can be incorporated into a pattern to obtain maximum strength are:

1. Using the maximum thickness of lumber for the job.
2. Building small patterns from solid stock with carved fillets or leather fillets attached.
3. Using dado joints or lap joints whenever possible.
4. When practicable, making small fragile patterns out of metal.
5. Building up turned work with segments, then gluing and nailing where practicable.
6. On staved work, using the stile and rail method, bracing both laterally and longitudinally.
7. Spacing the distance between headers on staved work.
8. On turned flanges, inserting the flange material below the surface of the pattern to eliminate any feather edges.
9. Using wood dowels and screws whenever possible for reinforcing joints.
10. On large flat work, using stop-offs to eliminate any warping.
11. Using follow blocks, ram-up blocks, follow boards, and ram-up boards on fragile patterns.

ACCURACY OF PATTERNS

To produce a casting "true to the blueprint," it is necessary to make the pattern of such dimensions and shape as to allow for the natural shrinkage of the metal, the effects of mold restriction, and any other controlled phenomena.

Unless the Patternmaker knows the foundry process to be used in the production of castings, he should not design and construct a pattern with any closer tolerances than one-half the maximum shrinkage allowance required for the specific metal. Inasmuch as wood shrinks or swells due to the moisture absorption while the pattern is being constructed, it is almost impossible to hold dimensional tolerances any closer. Although metal patterns, plaster patterns, and plastic patterns can be held to a closer tolerance than wood patterns, do not apply closer tolerances than absolutely necessary.

PLANNING OF PATTERN EQUIPMENT

Pattern equipment, as a rule, is not an exact duplicate of the finished product, because the equipment is supplemented by special allowances necessary for the molding and machining processes. Therefore, the Patternmaker and the Molder should cooperate in order to obtain the most accurate means of producing a sound, usable casting.

In addition to the basic types and kinds of patterns previously discussed, the planning stage for pattern equipment should include consideration of the following:

1. Location and kind of parting line—straight or irregular.
2. Kinds of cores—green, dry, green-topped, or CO_2.
3. Location and size of core prints and/or chaplets.
4. Location and size of chills.
5. Projections requiring loose pieces.
6. Allowances for shrinkage, distortion, draft, machine finish, and machining lugs.
7. Type of material the pattern equipment is to be made of.
8. Metal or alloy to be cast.
9. Overall basic design rules that facilitate the production of a sound casting.

Pattern and Mold Partings

When referring to the parting of a mold or of a pattern, the plane separating the cope and drag is called the parting plane; when the parting is viewed as a line, it is called the parting line. There are two methods of parting a pattern: straight partings and curved (irregular) partings. With straight partings, which are the most common, the line of pattern separation lies in one plane. With an irregular parting pattern, the line of pattern separation is not a straight line, but cuts through two or more planes. Whenever possible, a straight parting should be used as it is simpler to handle in the molding process. If the irregular parting causes a deep pocket or recess, the pattern should be redesigned so that a molding method with a straight parting line requiring a core or a match plate can be used.

As a general rule, it is desirable to have all (or the greater portion) of the mold cavity in the drag for ease in molding. It is preferable to choose a parting which has a deep drag in order to reduce the weight of the mold. Reducing the weight of the cope is more important than reducing the weight of the drag because the cope requires more handling. It is also desirable to design the pattern so that the thickest sections of casting appear at the parting line in order that the casting can be fed most effectively.

In general, the line or plane selected for the pattern's parting will cut the pattern in such a manner that the parts separated are symmetrical (the parts correspond in size and shape). Pattern symmetry should not be the final consideration when deciding on the parting line. Before determining the pattern's parting, a decision must be made as to how the whole piece can be molded to produce a sound casting. Once this decision is made, choose the parting line which will give the best draw, and requires the least cores and loose pieces.

Cores

For detailed information concerning the classes and characteristics of cores, core prints, types of cores, core boxes and the various methods of construction, refer to chapter 11 of this training manual.

Chaplets

CHAPLETS are metal supports which are placed in the mold cavity to hold a core in place when normal molding methods are inadequate. The use of chaplets should be avoided whenever possible. When used, it is essential that they are absolutely clean. Since chaplets become a part of the casting itself—through the fusion of the surrounding molten metal in the mold cavity with the chaplet—their composition must be suitable for the metal from which the casting is poured. Soft steel chaplets are used in ferrous metal castings, and copper chaplets are used in brass and bronze castings.

In addition to having the proper composition—steel or copper—the size of the chaplet must be properly proportioned with the cross-sectional thickness of the part of the casting in which it is used. A chaplet made from the least amount of metal possible, but having sufficient strength to support the core, should be used. The use of oversized chaplets will result in poor fusion and may cause the casting to crack in those areas where the chaplet is located.

Chaplets of many types are available, but those shown in figure 10-12 are suitable for most applications. Prefabricated, double-ended, plain-stem chaplets are used with ferrous castings. Perforated chaplets, made by the Molder from rectangular strips of copper, are used with nonferrous castings.

Chills

CHILLS are metal devices used by the Molder to accelerate the solidification of metal in certain heavy sections of a casting. Two kinds of chills are used by the foundryman—external chills and internal chills. Typical examples of both types are shown in figure 10-13.

The face of an external chill has the same contour as that of the mold surface in which it is embedded. External chills may be cast to shape or they may be made from strip, bar, or rod stock. In any event, the metal from which the chill is made must have a higher melting temperature than that of the metal being cast. When external chills are used the following rules should be borne in mind:

1. Chill surfaces must be clean and accurately fitted to the casting area to be chilled.
2. The ends and sides of large, heavy, external chills should be tapered. Drastic cooling at the edge of chills will cause stresses to develop, which may result in cracks.

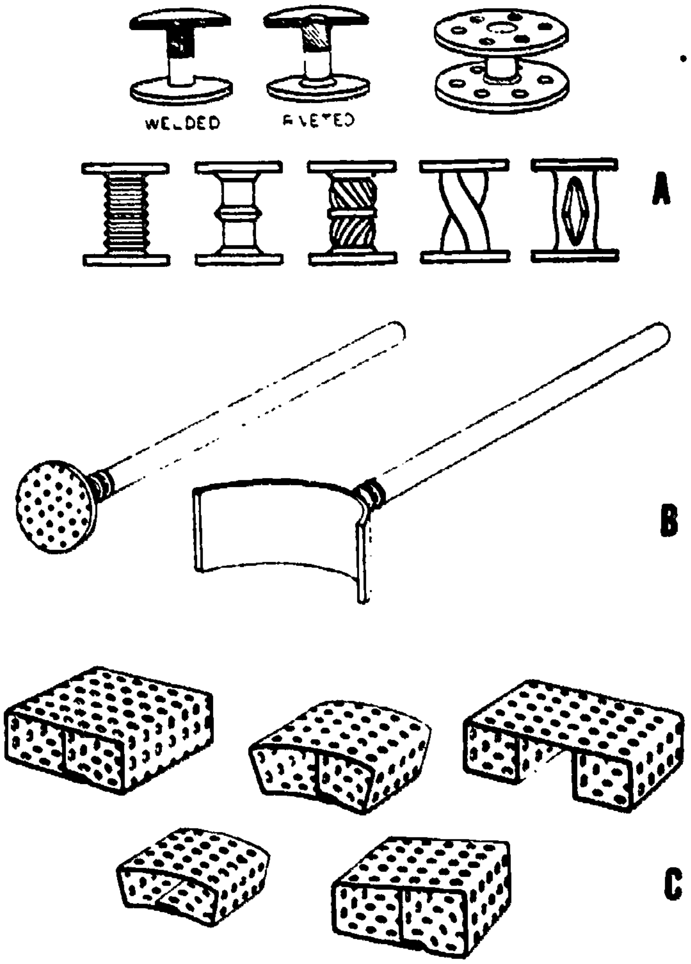


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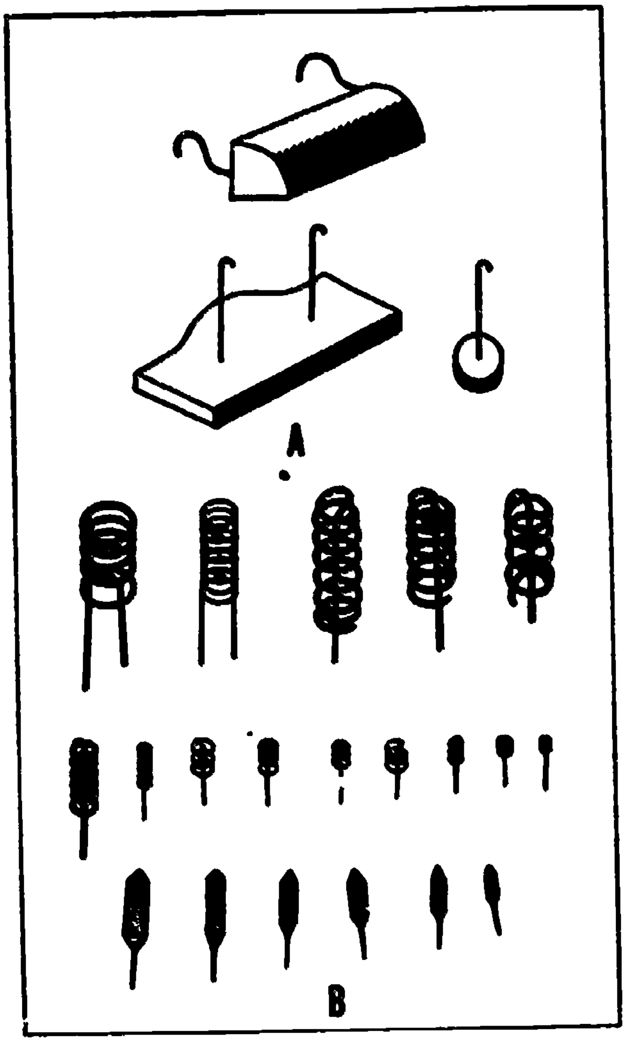
Figure 10-12.—Types of chaplets: A. Double-headed. B. Stem. C. Perforated.



23.18
Figure 10-13.—Chills: A. External. B. Internal.

3. External chills must have sufficient mass to prevent the metal in the casting from fusing to the chill. At the same time, however, they must not be so massive that their effect interferes with solidification in other parts of the casting.

Internal chills must have the same basic composition as the metal being cast, because they, like chaplets, become a part of the finished casting. For this reason, internal chills must be perfectly clean. Oxide, oil, or mold wash must be eliminated or harmful effects to the casting will result from the gases produced.

The size and shape of the chill is very important. Flat, solid chills should have a streamlined shape. A shape of this sort permits any gases that may be formed to rise easily to the casting surface. In regard to size, chills which are too small will not accomplish their purpose of inducing solidification. On the other hand, chills which are too large may cause cracking to occur in the casting.

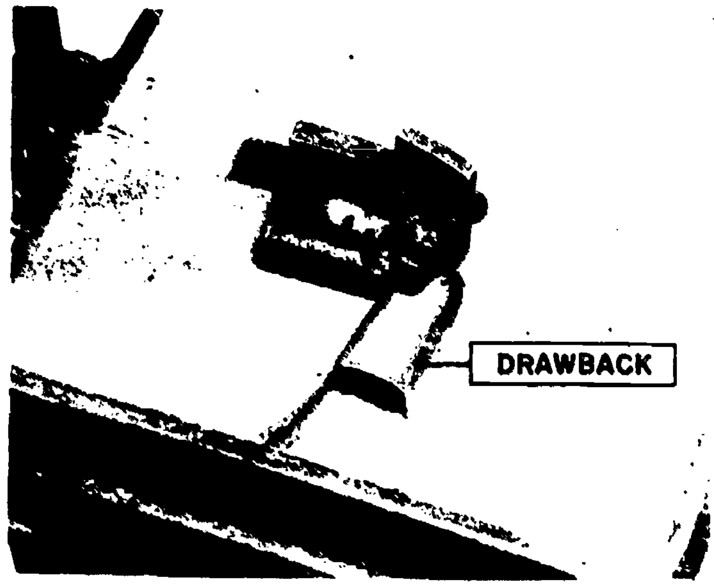
Properly locating chills, and thereby controlling the solidification of metal in a mold, requires considerable knowledge and experience. When the striker or ML3 must use chills, he should do so only under the close supervision of an ML1 or an MLC.

Loose Pieces

Many patterns are of such shapes that projecting elements (bosses, undercuts, and flanges) which are above or below the parting line form back draft to the line of withdrawal of the pattern from the mold. These projecting elements cannot be withdrawn at the same time as the main body of the pattern. This common problem can be solved through the use of loose pieces or drawbacks.

A loose piece is a pattern part that remains in the mold while the main body of the pattern is removed. The loose piece is carefully drawn from the mold wall into the main mold cavity, then lifted from the mold. (See fig. 10-11.) This is called "picking-in."

The function of the drawback is similar to that of a loose piece. Instead of being a pattern part, however, the drawback is a special kind of green sand core, rammed up into the mold on a supporting structure so that it may be drawn back and lifted away to clear an overhanging portion of the pattern, thus permitting pattern removal. (See fig. 10-14.) After the pattern has been removed, the drawback is relocated in the mold. The mold face contour of the drawback is formed by the pattern itself rather than by a core box.



18.22.1

Figure 10-14.—A drawback.

Pattern Allowances

Whatever the type and kind of pattern and the construction method employed, the pattern must embody certain allowances if it is to satisfactorily play its part in the finished product. For example, the pattern must provide shrinkage (contraction) allowance and distortion allowance during the casting's solidification; it must possess sufficient draft to enable the pattern to be withdrawn from the mold; it must allow for machine finishing; and it must provide machining lugs for machine setup in the machining process for the finished casting.

SHRINKAGE AND CONTRACTION.—As the metal "freezes" or changes from a liquid to a solid state, shrinkage and contraction take place. In common terminology, shrinkage and contraction describe the total volume change. Although shrinkage and contraction are part of the same process that accounts for the decrease in the size and volume of metal while it is cooling, many foundrymen (Patternmakers and Molders) now think of these two actions as two distinct processes.

Shrinkage is believed to be the loss brought about by the arrangement of the molecular structure of the metal as it passes from a liquid to a solid state. The Molder compensates for shrinkage through the provision of risers or heads which supply extra metal where it is needed to make up for the decrease in volume resulting from cooling from the liquid to the solid state.

Contraction is believed to occur immediately after shrinkage, as the metal cools to room temperature after solidification has taken place. The Patternmaker provides for dimensional contraction or the decrease in volume occurring in the solid state, by making the pattern slightly oversize with the appropriate shrinkage (contraction) rule for the particular metal to be cast. Shrinkages of metals have been determined by experimentation and converted into tables that are intended merely as guides, because each specific job may require minor deviations. The average shrinkages of metals that are common to Navy use are given in Table 10-1.

Table 10-1. — Average Metal Shrinkages

Material	Shrinkage per foot
Aluminum	5/32
Bismuth	5/32
Brass	3/16
Bronze	3/16
Aluminum Bronze	7/32
Manganese Bronze	7/32
Cast Iron	1/10 to 1/8
Cast Iron, Wrought	1/8
Copper	3/16
Lead	5/16
Monel	1/4
Magnesium	1/8 to 5/32
Steel	1/4
Tin	1/4
Low Melting Point Alloy	NIL
Zinc	5/16
Plaster of Paris	0 to 1/4

68.185

The amount of shrinkage varies with the casting design, type of metal, pouring temperature, mold method, mold material, and resistance of the mold to shrinkage. However, shrinkage does not occur uniformly in all directions. Therefore, the experience of the Patternmaker and Molder provides the basis of using any modified shrinkage tables.

DISTORTION. -- Uniform shrinkage may or may not follow a given shrink rule in all instances. Certain conditions affecting shrinkage must be considered when making the pattern, to ensure a sound, usable casting. Among these conditions is mold resistance which may be caused by tight ramming, hard cores, ribs, gates, risers, or other projections. Mold resistance will cause uneven shrinkage resulting in distortion of the casting. Therefore, distortion allowances must be made on the pattern to prevent twisting or warping of the casting due to internal stresses set up within the casting during solidification.

In examining the casting's basic design for areas where distortion may occur, the considerations to remember are: (1) contraction follows the lines of metal structure; (2) distortion results when contraction is unequal; and (3) distortion does not occur when the lines of contraction meet at a junction of members because neither member is affected by the other. Inasmuch as there may be shrinkage without distortion but not distortion without shrinkage; it can be said that distortion comes from unequal shrinkage.

Since the shrinkage allowances used in construction of the pattern are based on a vast amount of experimentation and experience, they should be used for the general run of jobs. However, it should be remembered that the shrinkage allowances assume normal unrestricted contractions. When the casting's design is such that normal shrinkage does not occur, or is partially restrained in a portion of the casting, it may be necessary to use a modified value (two or more shrinkage allowances based on the existing conditions) or to construct a modified pattern. The cause of abnormal contraction is usually mold resistance to the forces of contraction. If the mold or core cannot be changed or modified to permit normal contraction, all allowances will have to be made on the pattern.

Usually the dimensional accuracy of most castings is satisfactory when the pattern is made with shrink rule measurements. Occasionally, however, a pattern must be so constructed that it will compensate for any distortion resulting from uneven contraction which cannot be eliminated from the design. This technique is known as FAKING THE PATTERN.

When a pattern is to be constructed to compensate for distortion, it is necessary to break the design down into its component parts and analyse each basic design in terms of governing its contraction in the mold.

DRAFT. — The angle of slant (taper) tending away from the parting given to those surfaces of a pattern which would lie in the direction in which the pattern or its component parts are drawn from the sand is called DRAFT. Unless draft is provided on the vertical surfaces of the pattern, the pattern cannot be removed from the mold without excessive rapping, or damaging the mold wall.

In green sand molding, interior surfaces of patterns require more draft than exterior surfaces. So long as it does not distort the functional lines of the pattern, it is advisable to provide liberal draft. In any case, the draft on surfaces at right angles to the pattern face (parting line) should not be less than 1°. Usually, this allowance is added to the pattern. In those instances where a reduction in wall thickness is not objectionable or where an increase in dimensions at the face of the pattern is functionally objectionable, draft may be provided by subtracting the taper from the casting dimensions specified. Whether added or subtracted, the taper always runs away from the pattern face. If no surfaces are at right angles to the pattern face, draft is not necessary.

The amount of draft required of any pattern depends upon: (1) the length of the part that is to be withdrawn from the mold, (2) the direction of the grain in the wood, (3) the size and shape of the pattern, and (4) the intricacy of the work. Guidelines that have been proven by practical experience and that are recommended for use in the application of draft are:

1. Draft should be ample for a straight draw without severe rapping of the pattern.
2. Surfaces requiring draft will be determined by the molding position of the pattern.
3. The surface from which the draft starts is called the FACE (cope face or parting) of the pattern.
4. Draft enlarges the pattern towards the parting line.
5. Excess draft is added to holes or deep pockets to release the green sand with the least disturbance.
6. More draft is required for hand molding than for machine molding.
7. Draft on all interior surfaces should be greater than on exterior surfaces.
8. If draft is not sufficient, the pattern has to be severely rapped for withdrawal from the mold; rapping ruins patterns and core boxes.
9. Draft adds metal to the casting; the amount of draft should be made as small as possible and still enable the pattern to be withdrawn from the mold.
10. The average draft allowance is 1/8-inch per foot.
11. The surface of a pattern that lies vertical to the parting and parallel to the direction of the draw, and is to be coped out, is given excessive draft. Excessive draft is used to facilitate the lifting out of the projecting body of sand.

MACHINE FINISH AND TOOL CLEARANCE.— Two allowances in addition to those already mentioned are frequently required: machine finish and tool clearance allowance. The amount of allowance for machine finish depends upon the kind of finish specified for the casting as well as the mold location of the finish area. Whenever possible, surfaces to be machined are located in the drag. When this is impossible, it is necessary to provide an extra allowance to take care of any slag or dirt that may come to the surface of the casting in the cope. The usual machine finish allowances for castings of various sizes and of various metal compositions are indicated in table 10-2 and table 10-3.

Tool clearance is sometimes formed on a pattern to provide an opening for the tool to enter when finishing sections of the casting that are partially or entirely closed. Careful consideration should be given in providing tool clearance, so as not to weaken the casting.

From the standpoint of the Machinery Repairman the provision of adequate tool clearance is just as important as extra metal for machining. The Molder has little concern with this feature of a pattern except as it may relate to the location of gates and risers. At any rate, there must be sufficient space to start and finish the cut. Since the allowances necessary

Table 10-2. — Machine Finish Allowance Guide

Casting alloys	Pattern size	Bore, inch	Finish
Cast iron	Up to 12 in	1/8	3/32
	13 to 24 in	3/16	1/8
	25 to 42 in	1/4	3/16
	43 to 60 in	3/16	1/4
Cast steel	Up to 12 in	3/16	1/8
	13 to 24 in	1/4	3/16
	25 to 42 in	5/16	5/16
	43 to 60 in	3/8	3/8
Malleable iron	Up to 6 in	1/16	1/16
	6 to 9 in	3/32	1/16
	9 to 12 in	3/32	3/32
	12 to 24 in	5/32	1/8
	24 to 35 in	3/16	3/16
Brass, bronze, and aluminum alloy castings.	Up to 12 in	3/32	1/16
	13 to 24 in	3/16	1/8
	25 to 36 in	3/16	5/32

18.107(68B)AX

Table 10-3. — Machine Finish Allowance (Above The Average Shrinkage Allowance)

Drag (Inches)	Cope (Inches)	Tolerance expected, "as cast" (Inches)
1/8	5/32	± 1/16
5/32	3/16	± 3/32
3/16	1/4	± 1/8
1/4	5/16	± 5/32
5/16	7/16	± 3/16
3/8 to 1/2	5/8 to 3/4	± 1/4

18.107(68B)BX

here depend on the job at hand, they will have to be worked out in the planning conference.

ADDITION OF MACHINING LUGS.--When planning a pattern, consideration should be given to ways to facilitate the handling of castings during the machining processes. Provisions should be made to hold or to prevent distortion of the castings. A little extra work on the part of the Patternmaker (adding bosses, lugs, feet for leveling, or a bridge) will often save hours of machine shop time.

Generally, these provisions do not appear on the blueprint, but they do appear as projections on the pattern and become part of the casting. Their location, however, will depend on the facilities and requirements of the machine shop. As a PM3 or PM2 you should have a working knowledge of the various machine shop tools and the methods of mounting work for machining. In addition, you should consider not only the construction of the pattern and its mold but also the way the casting is to be machined. Therefore, for the best results, consult the Machinery Repairman when determining the size and location of the required projections.

Consideration should be given to the following provisions for holding or clamping a casting during the machine processes:

1. Adding bosses for holding a casting on a lathe when the casting cannot be conveniently held on a faceplate.
2. Adding crossmembers or a bridge on the ends of hollow cylinders to accommodate the lathe centers.
3. Adding feet for leveling or clamping.
4. Adding feet or flats to the inside of hollow castings if it is inconvenient to add them to the outside of the casting.
5. Make the projection length of contact on the main body of the casting as ample as possible.

Remember, adding projections to the pattern increases metal thickness (creating hot spots which will cause open grain in the structure of the metal) and results in a weak casting.

When adding machining lugs or other provisions for machining purposes, treat them as a part of the casting in addition to treating them as a boss or pad. (See the basic design rules, given in chapter 2 of this training manual.)

MAINTENANCE AND STORAGE OF PATTERN EQUIPMENT

Pattern equipment is a valuable part of the pattern shop and foundry and special provisions should be made for proper storage and maintenance upon completion of the finished castings. As a PM3 or PM2 you may be assigned the responsibility for the proper storage of pattern equipment and the preparation of a pattern record file. In addition, maintenance of patterns held in the pattern storeroom (responsibility of the pattern shop) is as important to the Patternmaker as making new patterns. For example, if a ship has a limited availability period, valuable time will be saved if the pattern is already constructed and held in storage or if a pattern on hand can (with minor alterations) be used to complete the job order.

The major problem in pattern storage is to provide conditions which will keep distortion of the pattern equipment to a minimum. The temperature and humidity of the storage area should be kept constant, preferably at normal room temperature (70°F). The pattern storeroom or storage area is divided into sections and each section is marked for a group (type, size or classification) of patterns. (See fig. 10-15.) Large patterns and core boxes, for convenience in handling, are placed as near to the storeroom deck as possible and are arranged in groups. Small patterns are stowed on shelves or racks made with built-up edges to keep the patterns from falling off. Matchboards and match plates are hung on racks according to size and shape. Special pattern equipment (matches, sweeps, etc.) may be placed in a separate section or may be placed with the pattern. Each section of the storeroom should be provided with ways of securing for sea to prevent damage to the patterns and equipment.

Naturally, space limitations aboard ship will govern the number of completed patterns that may be stored. Experience and up-to-date pattern record cards will aid you in deciding which of the patterns are used constantly or at frequent intervals.

Another advantage in maintaining pattern storage, which is often overlooked, is that the stored patterns are useful for training purposes. For this reason it is also advisable to keep certain temporary or infrequently used patterns on hand as samples to show how the pattern was made or how construction procedures may be improved.

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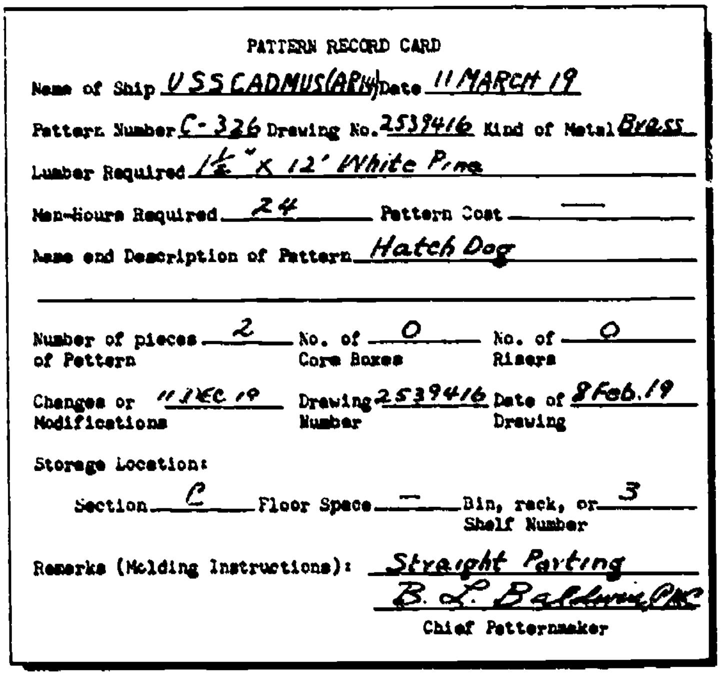
Figure 10-15. — Section of a typical pattern storeroom.

Because stored patterns have, in the past, produced sound castings, it may be assumed that the construction methods used were also satisfactory. However, DO NOT assume that the pattern is in as good condition as it was on the day it was made. Even under the best storage conditions wood patterns will become warped, checked, or damaged. Periodically check the stored patterns for general condition and return them to the pattern shop, if necessary, for minor repairs and refinishing.

Before placing a pattern in storage, prepare a PATTERN RECORD CARD for the locator file. One such form, which may be adapted, is shown in figure 10-16. Clean, refinish, and



PATTERN RECORD CARD

Name of Ship USS CADMUS(AR14) Date 11 MARCH 19

Pattern Number C-326 Drawing No. 2539416 Kind of Metal Brass

Lumber Required 1½" x 12' White Pine

Man-Hours Required 24 Pattern Cost —

Name and Description of Pattern Hatch Dog

Number of pieces of Pattern 2 No. of Core Boxes 0 No. of Risers 0

Changes or Modifications 11 DEC 19 Drawing Number 2539416 Date of Drawing 8 Feb. 19

Storage Location:

Section C Floor Space — Bin, rack, or Shelf Number 3

Remarks (Molding Instructions): Straight Parting

B. L. Baldwin PMC

Chief Patternmaker

23.3

Figure 10-16. — A pattern record card.

make minor repairs to the pattern. Tie together and tag all loose pieces, riser heads, and other molding aids, to avoid losing or mismatching the parts. Group the patterns according to type, size, or classification.

When a pattern is taken out of storage for reuse, inspect it thoroughly to make sure it is serviceable. Check the pattern against the blueprint if possible, to determine whether any revisions or changes (type of metal or additions) have been made since the pattern was last used. Check all fillets, loose pieces, riser heads, broken parts, and all other molding aids for proper alignment and condition. Repair if necessary. Clean and refinish the pattern. Finally, check with the supervisors of the pattern shop and foundry for any last minute changes or alterations prior to reissue.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 11.

BALANCED CORE — One with the seated portion of the core so proportioned that it will overbalance any tipping of that part of the core extending into the mold cavity.

BEDDING A CORE—Resting an irregular shaped core upon a bed of sand for drying.

BOOT JACK CORE—A type of core used in forming comparatively small openings occurring above or below the parting. The seat portion is so shaped that the core is easily dropped into place.

BREAKER CORE—Cores designed for the purpose of easy removal of risers from castings. Breaker cores are set in position over the contact area of the neck on an open riser, creating a small necking effect.

CAP CORE—A core superimposed upon a pattern to complete a portion of the mold cavity not given shape by the pattern.

COMBINATION CORE BOX—A core box that may be altered to form a core of another shape.

CORED CONSTRUCTION—Refers to a casting whose interior is formed by a dry sand core or cores.

CORE DRIER—A metal shell that conforms to the shape of the area of a core upon which the core rests while drying.

CORE FRAME—Frame of skeleton construction used in forming intermediate size cores.

CORE LOCK—Matched surfaces so formed upon contacting core bodies as to assure their correct registering or seating together.

CORE-MADE MOLD—A mold assembled from dry sand core bodies.

CORE MARKER—A core seat so shaped that the core will register or seat correctly when placed in the mold.

COVER CORE—A core set in place during the ramming of a mold to cover and complete a mold cavity formed by the withdrawal of a loose part of the pattern.

CRUSHING—The pushing out of shape or distortion of a core or mold when parts of the mold do not fit properly.

DROP OR TAIL CORE—The same as a boot jack core.

FALSE COPE—Temporary cope used only in the forming of the parting surface and therefore not a part of the finished mold.

FALSE SIDE—An intermediate loose panel supporting projections or depressions set against the inside of a core box or frame.

FLANGE—A stiffening member or the means of attachment to another object.

GATE CORE—Pre-formed cores made of a refractory material such as tile, ceramics, of dry sand that are placed in a mold to replace a cut or formed gating system.

INTERCASTING—The casting of interlinking members, such as an anchor chain.

KISS CORE—A core that contacts another core or is set against the side of a pattern to supply a portion of the mold cavity not furnished by the pattern.

LOOSE FLANGE—Flange member that may be drawn independently of the body of the pattern and is often used in combination with a cover core or slab core.

MARKING A CORE—Shaping the core print portion of a core and its seat so that the core cannot be misplaced within the mold.

OVERHANG—The extension at the parting line of the cope half of a core print beyond that of the drag in order to form clearance for the closing of the mold over the seated core in the drag. Also known as shingle.

RING CORE—Cores designed as green sand or dry sand cores used for shaping contours to the outside diameter of a casting. When a ring core is used, the mold usually requires a double rollover.

SECTIONAL CORE—A core made in two parts and pasted or wired together.

SLAB CORE—A plain flat core.

SPLASH CORE—Inserted refractory material placed in the pouring basin or at the bottom of the sprue to eliminate erosion caused by the sudden drop or rolling action of flowing metal.

STOCK CORES—Cores of standard diameters usually made on a core machine and kept in stock. They are cut to lengths as required.

STOPPING-OFF CORE—A core used in stopping off an unwanted part of a mold.

STOPPING-OFF PIECE—Specially prepared piece or section of a pattern used for stopping off an unwanted part of a mold or core box.

SUPERIMPOSED CORE—Same as cap core.

SUSPENDED CORE—A core having the core seat so formed that it may be suspended above the mold.

TALLY MARK—A symbol or combination of symbols indicating the correct location of a loose piece of a pattern or core box.

CHAPTER 11

CORES AND CORE BOXES

Many of the castings which are produced aboard ship are not composed of solid metal or alloy, but have voids or hollow areas, either internal or external. To prevent the metal poured for the casting from filling these void areas, sand cores of appropriate sizes and shapes are inserted at the necessary locations in the mold cavity, before the mold is poured.

The process of making these cores differs from the process of making a mold, in that the core sand is not rammed around a pattern. Instead, it is shaped to the casting requirements in a hollow pattern, or core box.

Most of the patterns you will be called on to build will not be as simple as the hinge job described in chapter 9 of this training manual. Some will be complicated by internal cavities which will require cores and core boxes. Before you continue with the procedure for constructing one of these more complicated patterns, you should be thoroughly familiar with the fundamentals of cores and core boxes.

This chapter is divided into two parts. The first part deals with the classes of cores, core characteristics, types of core prints, and types of cores. The second part describes core boxes and the various methods of construction.

CORES

What is a core? Cores may be defined as masses of sand that are placed in the mold, or left in the mold by the pattern, for the purpose of forming openings and various shaped cavities and contours in the casting. Cores may control the casting's interior and exterior contours or the flow of metal into the mold cavity. In addition, a core may make it possible to draw a portion of the pattern from the sand, which ordinarily would not be possible because of the shape of the pattern; or a core may be used to improve a particular surface due to the core's special characteristics.

CLASSES OF CORES

There are five classes of cores:

1. BAKED or DRY sand cores are made from special core sand mixtures.
2. GREEN SAND cores are made from regular molding sands and are formed in the mold by the pattern itself.
3. GREEN-TOPPED cores are combinations of green sand cores and baked cores; that is, part of the core is baked while the remainder is green sand. This type of core is especially useful in casting valve bodies.
4. CO_2 cores are made by mixing silica sand with sodium silicate (water glass); then hardening the mixture by gassing it with carbon dioxide (CO_2) for a few seconds. This type of core has many advantages. Among the most important are the following: (1) pasting of cores may be eliminated, making a one-piece core possible, (2) there is no danger of drop-outs, soft spots, or wet spots, (3) less draft is required for any loose piece, (4) there is a saving in baking or drying time, and (5) closer dimensional tolerances are possible.
5. SHELL cores are made from a resin-sand mixture and are formed on the inside of a hot, parted metal core box. Most shell cores are hollow and serve as vents for the removal of gasses; thereby making it possible to produce castings with a minimum of locked-in stresses. Using parted metal core boxes simplifies complicated coring since intricate cores can be made in one piece.

CHARACTERISTICS OF CORES

A core must not only possess the required shape, but it must also have the strength necessary to maintain its shape and dimensional accuracy after it is removed from the core box.

It must have strength to withstand handling during assembly, and enough refractoriness to withstand the heat of the molten metal. It must have sufficient permeability to vent off gases during the casting process. It must have collapsibility, to ensure easy removal from the casting upon cooling.

CATEGORIES OF CORES

The five categories of cores are baked sand, green sand, green-topped, CO_2, and shell cores. The type chiefly used aboard ship is the baked sand type. The following characteristics of any core are needed in all five types:

1. It should hold its shape before and during the baking or drying period.
2. It must be baked or dried rapidly, but thoroughly.
3. It should have hardness sufficient to resist the eroding action of the flowing molten metal.
4. It should produce as little gas as possible when it contacts the molten metal.
5. It should have sufficient permeability to permit easy escape of gases formed during pouring.
6. Its surface must be such as to prevent metal penetration.
7. It must have sufficient refractoriness to resist the heat of the metal at pouring temperature.
8. It must have sufficient hot strength to withstand the weight of the molten metal at its pouring temperature and during the beginning stages of solidification.
9. It must have collapsibility, but not to the degree as to cause cracks or hot tears in the casting.
10. It must retain its strength properties during storage and handling; and if the mold in which it is to be positioned must stand for a considerable time before the metal is poured, the core must not absorb more than a minimum of moisture.

TYPES OF CORES

Every patternmaking job presents specific problems that will constantly challenge your skill and ingenuity. Some of the most difficult phases of patternmaking are visualizing the interior shape of a casting, designing cores, and constructing the boxes needed to make the cores. As an aid in these phases of patternmaking, brief descriptions of the types of cores and their uses are given in the following sections. (To avoid confusion, the gating system—pouring basin, sprue, runner, in-gates and risers—that is necessary in producing a casting will not be shown.)

Stock or Standard Cores

Stock or standard cores are made in core boxes of standard lengths. These cores are kept in stock in the foundry for immediate use. Stock or standard cores are made in simple shapes, such as round, square, rectangular, and elliptical and may be used either horizontally or vertically. (See parts B and C of fig. 11-1.)

Stock cores are helpful when billets of a standard size are to be cast. Billet patterns are constructed in a set, such as a 2-inch outside diameter up to a 12-inch outside diameter with standard lengths of 6, 9, 12, 15, and 18 inches. The series (or set) of patterns are made in 1/2-inch diameter increments, while the core boxes are made in 1/4-inch diameter increments. Interchangeable cope and drag prints are used in conjunction with the set of billet patterns, making it possible to cast billets of the same outside diameter but of different inside diameters.

Balanced Cores

Balanced cores are cores with the core seat so proportioned that it will overbalance that part of the cores extending into the mold cavity. They are used on horizontal cores only. (See part D of fig. 11-1.)

View X in part D of figure 11-1 shows a cross section of a cylindrical casting containing a cavity that extends only part of the way into the body. If the cavity had extended clear through the casting, there would be no problem. A core print could be built on each end of the pattern to provide the seat for the core in the mold. However, since the cavity penetrates only part of the way into the body of the casting, there is a need for a balanced core print to seat the core properly. Notice that the core print is longer than the cavity in the casting. This balances the core in the mold and helps to resist the tendency of the pressure of the molten metal to float the core.

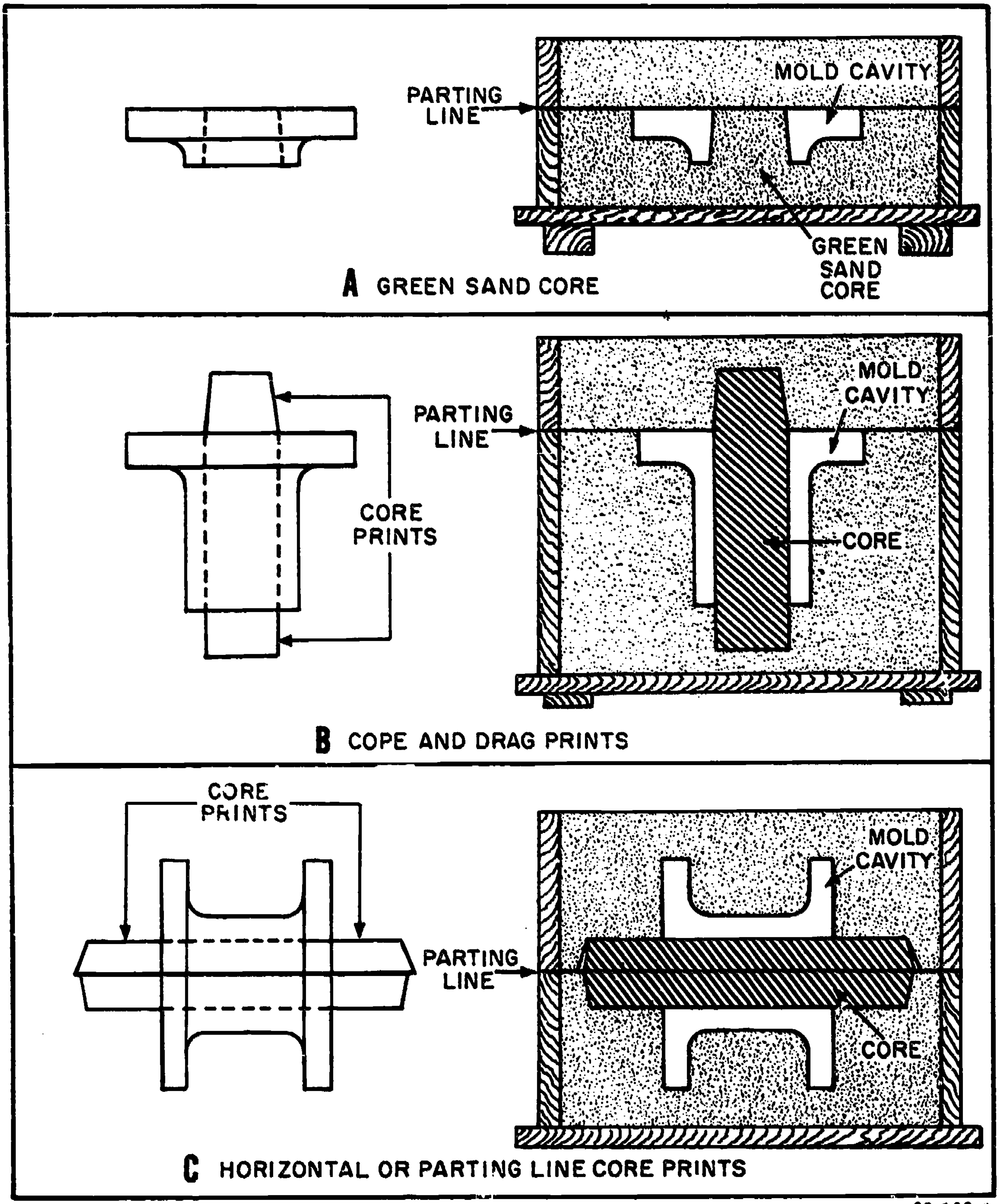


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Figure 11-1.—Types of core prints and simple applications.

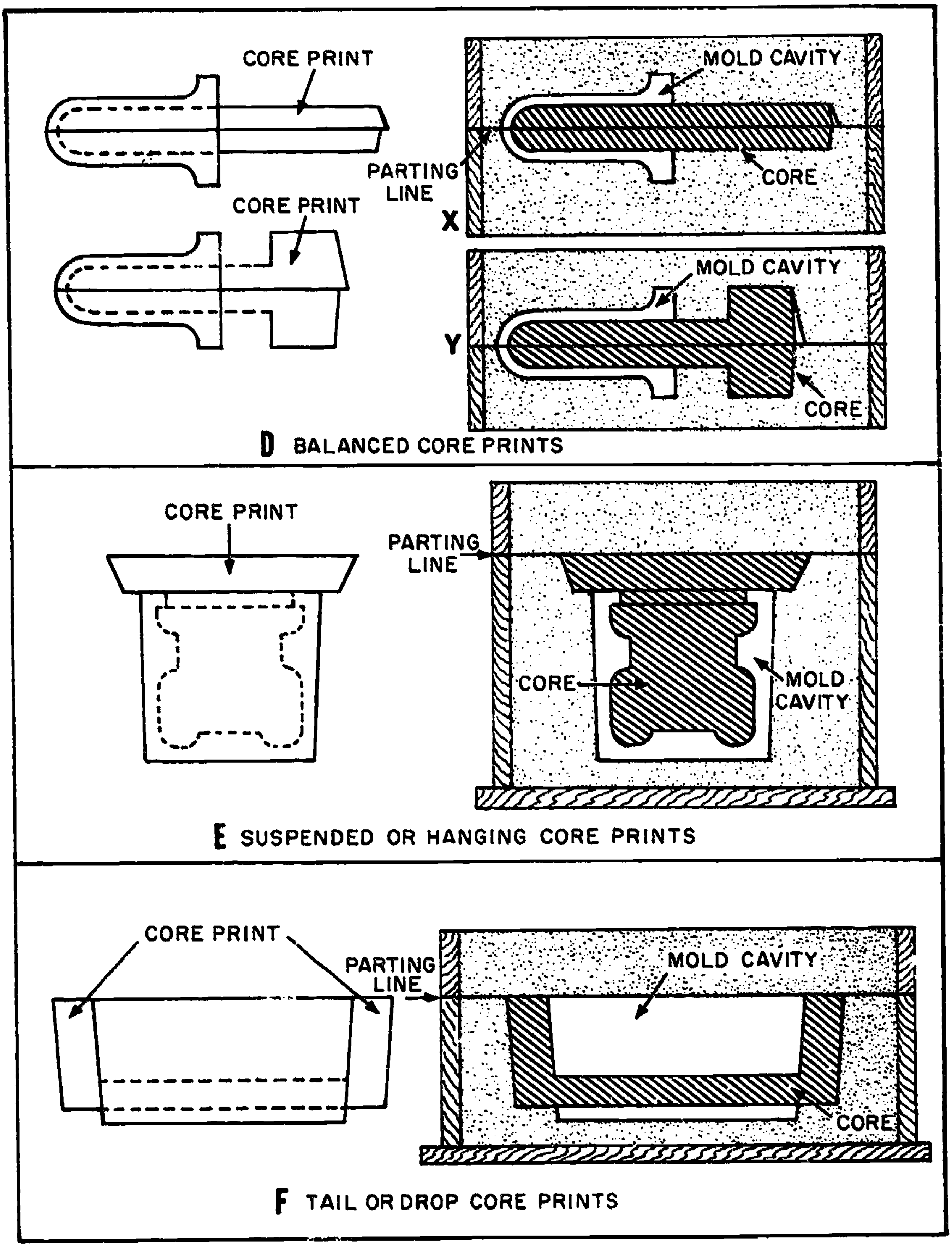

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Figure 11-1.—Types of core prints and simple applications—Continued.

View Y in part D of figure 11-1 illustrates the procedure for using a balanced core print of a flanged nature. The larger core print of the flanged type eliminates the extra length needed for balancing the extended portion of the core in the mold cavity. In addition, the flanged type balanced core print has a positive core locating feature. This feature is called WITNESSING or REGISTERING a core. The witness mark eliminates the possibility of placing the core in the mold in any other position than the correct one.

Slab Cores

Slab cores are plain flat cores (stock cores) used to cover an opening formed by the withdrawal of a loose piece of the pattern during the ramming-up process. They are made in stock boxes and used as requested by the Molder. Slab cores eliminate the use of an additional section of a flask.

A method of producing a four-flanged pipe connection using a slab core is illustrated in figure 11-2. Part A of figure 11-2 is an exploded isometric view of the pattern and loose flange; part B is an exploded orthographic side view of the pattern, the loose flange, and the slab core; parts C, D, and E illustrate steps in the production of this four-flanged pipe connection; and part F illustrates the finished casting. (Remember, the gating system is not shown in fig. 11-2.)

Since the procedure for this job differs from the usual methods of molding, a brief description is given in the following paragraphs.

The procedure for a four-flanged pipe connection has two important aspects: Ramming up the slab core upon removal of the loose flange, and the elimination of a cheek section of the mold. To insert the slab core requires a certain sequence of operations. The sequence and techniques involved are as follows:

1. Place the drag flask, joint down, on a molding board and position the drag half of the parted pattern in the flask. Ram the drag in the usual manner up to the top of the loose flange. (See part C of fig. 11-2.) Withdraw the loose flange from the partially completed drag and place the slab core over the flange opening core print. Ram up the remaining portion of the drag, place a bottom board on top of the drag, and roll the flask over.

2. Slick the parting surface of the drag, sprinkle parting sand (partine) over the parting and place the cope of the pattern and flask in position. Ram the cope in the usual manner. (See part D of fig. 11-2.)

3. Remove the cope section of the mold from the drag, and withdraw the cope pattern. Withdraw the drag pattern from the drag section of the mold. Check the mold interior carefully and repair damage as required.

4. Set the interior core in the mold cavity of the drag, taking extreme care in locating the core print of the "T" section into the hole in the slab core (see part E of fig. 11-2). Close and clamp the mold for pouring. The completed casting is illustrated in part F of figure 11-2.

Cover Cores

A cover core is a core set in place during the ramming of a mold, to cover and complete a mold cavity partly formed by the withdrawal of a loose part of the pattern. A cover core is used in the same manner as a slab core.

The term "cover core" as commonly used, refers to a cope or drag section of the mold which is made of oil-bonded sand in a core box instead of the usual practice of forming it in green sand in a flask. The underside of the cover core can be flat or contoured, depending on the conformation of the shape of the loose portion of the pattern. The core box is designed accordingly.

The cover core may be made in one or more sections depending on the shape and area to be covered. In certain types of large castings, use of sectional cover cores eliminates the use of large flasks and permits the cover cores to be made at the same time as the main mold, or prior to the preparation of the main mold.

A method of producing a four-flanged pipe connection using a cover core is illustrated in figure 11-3. Part A of this illustration is an exploded isometric view of the pattern and the loose core print for the cover core; part B is an exploded orthographic side view of the pattern and the loose core print for the cover core; parts C, D, and E illustrate the steps in the molding of a pattern with a cover core; and part F illustrates the finished casting. (Remember, the gating system is not shown in fig. 11-3.)

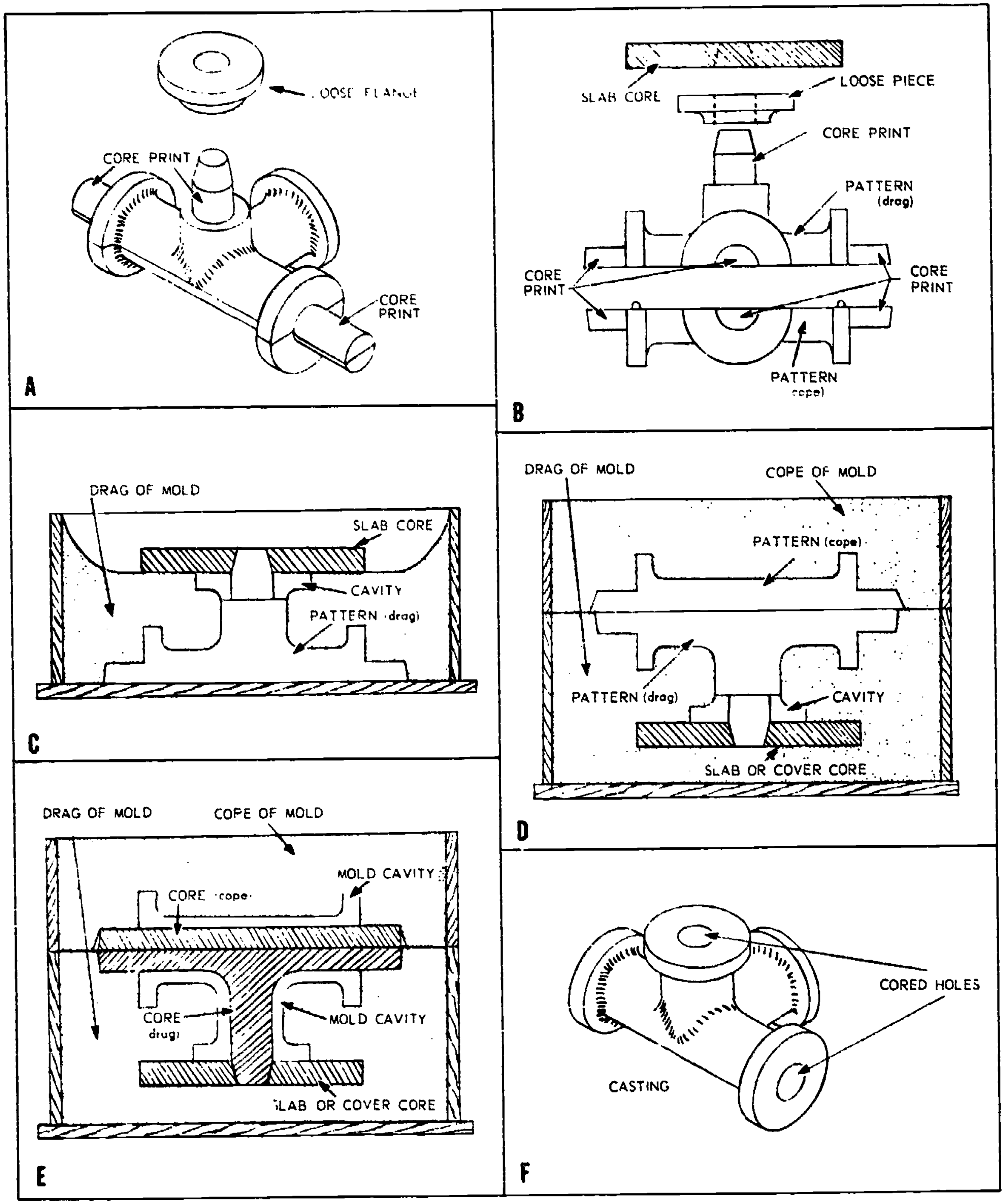

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Figure 11-2.—Application of a slab core.

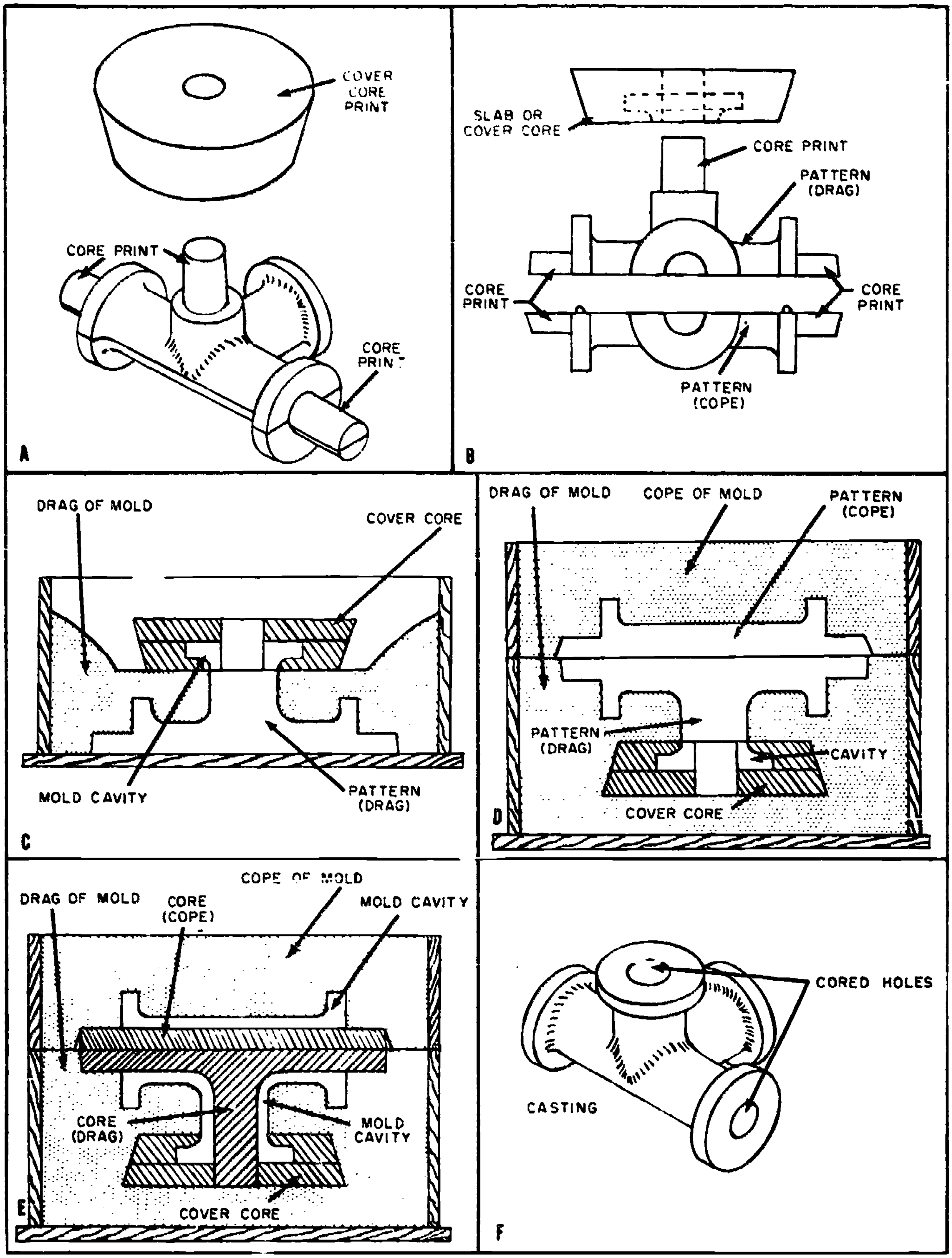

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Figure 11-3.—Variation of a slab core—a cover core.

Basically, the sequence of operations and techniques for molding a pattern with a cover core is the same as for a slab core. The main difference is that the loose piece on the pattern for the core print of the cover core takes not only that portion that locates the core print of the main body core, but also the full shape and size of the flange.

Suspended Cores

A suspended core is a core having the core seat so formed that it may be suspended above the mold cavity. (Part E of fig. 11-1 illustrates this principle of coring.)

The core print extends beyond the pattern body and forms a seat, which automatically locates, registers, and supports the suspended core. The core print of the suspended core is formed in the drag half of the mold at the parting line; therefore, when the core is set, it covers the entire mold cavity except for the gating system. The contact area between the parting surface of the cope and the top surface of the set core prevents the suspended core from floating during the pouring of the mold.

The bearing surface of the core print should be adequate to seat and carry the full weight of the core. Therefore, the thickness of the core should be sufficient to allow reinforcing rods to be inserted in the dry sand core. Five to ten degrees of taper (draft) on the core print are used for ease in core box construction and molding. Using over a ten-degree draft on the core print may cause a rocking motion of the set core when it is placed in the mold, thus giving the casting an uneven wall thickness. Therefore, to ensure a positive mold lock and an even wall thickness of the casting, it is recommended that a ten-degree draft should not be exceeded.

The molding position for a pattern using a suspended core will force any impurities in the molten metal to rise to the cope surface of the casting where ample finish allowance can be provided.

Superimposed or Cap Cores

A superimposed or cap core is a core or set of cores superimposed upon a pattern to complete a portion of the mold cavity not given shape by the body of the pattern. A part of the pattern is actually built in a core box, which requires the making of an oil-bonded core instead of the usual practice of forming the core in green sand. The oil-bonded core is used in the same manner as a slab core, cover core, or a ram-up core. The superimposed or cap core may be made in one or more sections depending upon the detail, shape, and area to be completed.

A method of producing a casting using a superimposed or cap core is illustrated in figure 11-4. Part A of figure 11-4 is an isometric view of the pattern; part B is an exploded orthographic view of the pattern and superimposed core; parts C, D, and E illustrate the steps in the molding of a pattern with a superimposed core; and part F illustrates the finished casting. (Remember, the gating system is not shown in fig. 11-4.)

Basically, the sequence of operations and techniques for molding a pattern with a superimposed core is the same as for one with a slab core or cover core. The main difference is that the shape of the cope side of the pattern requires a false cope, a sand match, a follow block, or a follow board to be constructed and used for support of the pattern during the ramming of the drag half of the mold. (See part C of fig. 11-4.)

Kiss Core

The term "kiss core" as commonly used means a core that contacts another core or is set against the side of a pattern to supply a portion of the mold cavity not furnished by the pattern. It may have no core prints and may depend on contact pressure to hold the core in place. It may be partially anchored with core prints and may depend on other parts of the core to kiss the mold for further support. It also may be anchored on one end with prints, with the other end of the core touching the mold or another core.

Some cores such as the kiss core shown in figure 11-5 do not require a core print for holding the core in position. They depend on contact pressure of the green sand. Cores for vertical holes are frequently held in position in this manner and may be used in places where

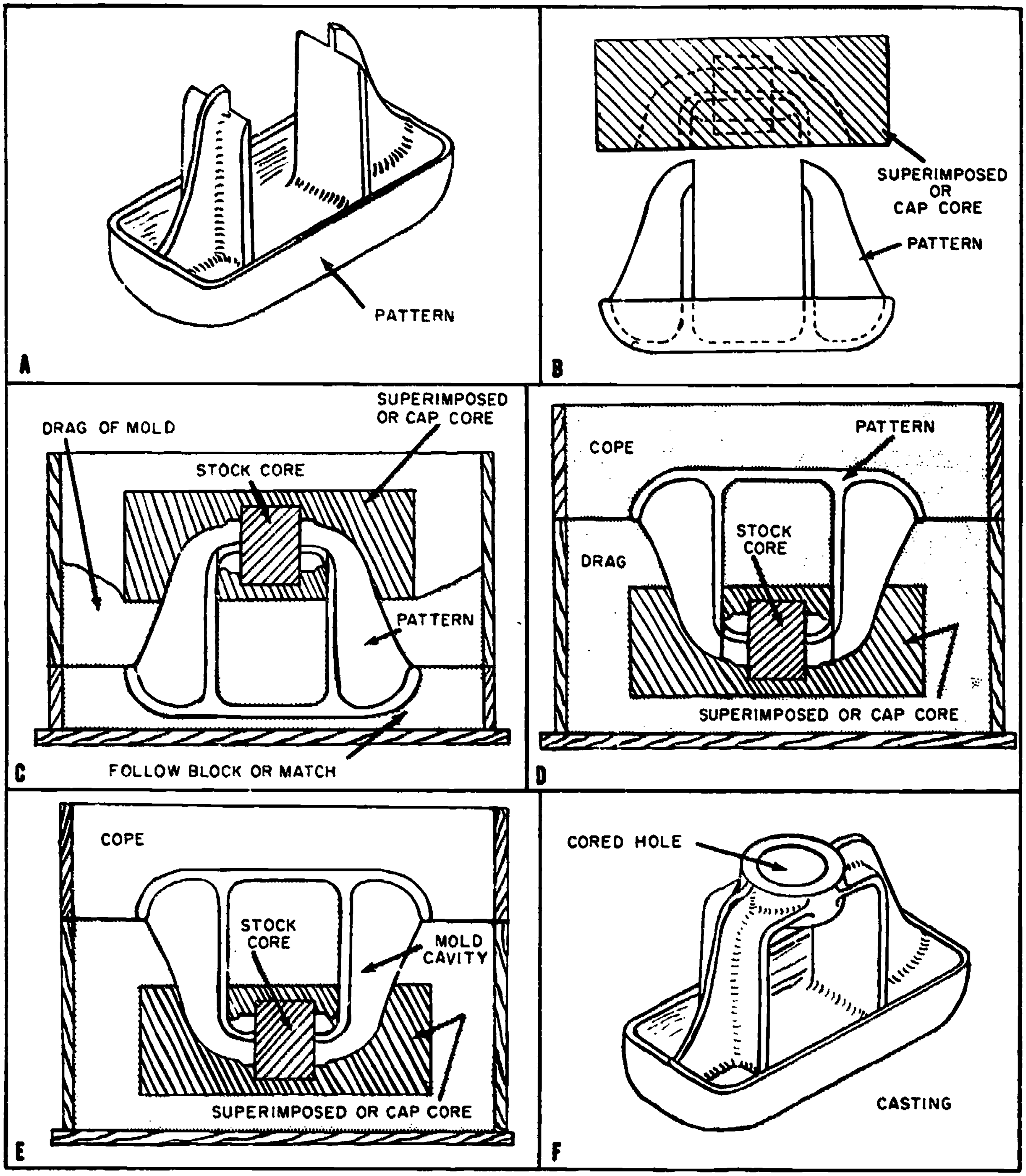

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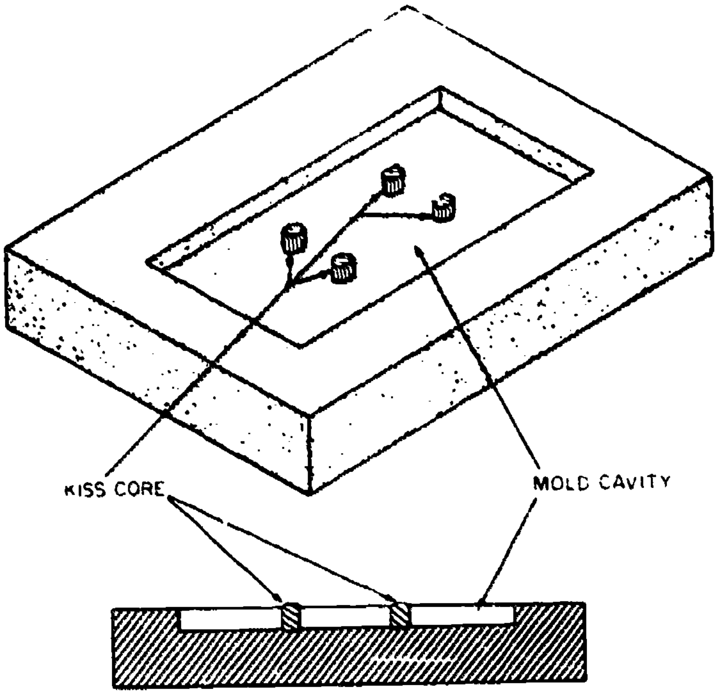
Figure 11-4.—Application of a superimposed or cap core.



18.55(68)A
Figure 11-5.—Kiss core application—no core prints.

dimensional accuracy is unimportant. The length of the core is 1/64 inch longer; therefore, the core projects slightly above the parting plane and is held in place by the contact pressure of the cope.

Castings such as the piston for a weight-loaded reducing valve shown in figure 11-6, require a different application of a kiss core. In the construction of the pattern for this piston, the inside diameter and the horizontal openings (ports) require core prints for support of the core. The vertical openings require a core that only goes through the casting wall and touches the green sand of the mold ("kissing thru").

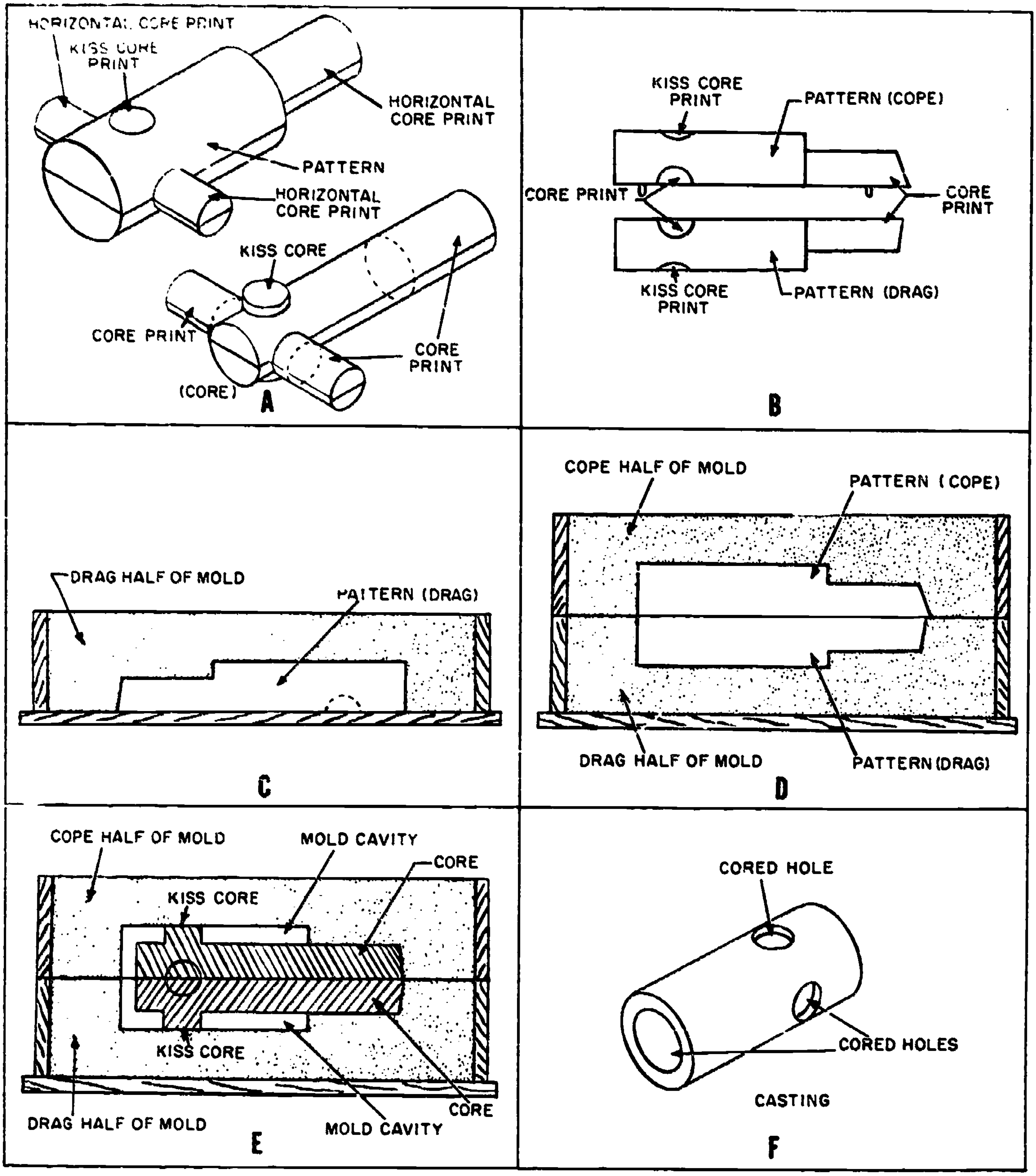
A method of producing a piston for a weight-loaded reducing valve using this application of a kiss core is illustrated in figure 11-6. Part A of this illustration is an isometric view of the pattern and core; part B is an exploded orthographic side view of the pattern parts C, D, E and illustrate the steps in the production of this piston, and part F illustrates the finished casting. (Remember, the gating system is not shown in fig. 11-6.)

Another application of the kiss core is for casting holes located at an angle to the withdrawal of the pattern from the mold. In this case, all the holes are made using the plug type impression, since it is impractical to draw the pattern from the sand with the core prints set at an angle. Holes are drilled in the pattern at the exact location and angle required. These holes are drilled 1/32 inch larger in diameter than shown on the blueprint. A plug is turned to the exact diameter of the holes shown on the blueprints, thus, creating a free-running fit between the plug and the hole. The plug should have a stop on one end and a taper on the other end for the core print. The pattern is rammed up in the usual manner. After the cope is lifted off the drag, the plug is pushed through each hole to the stop on the plug, causing each hole in the green sand of the drag to be the same depth. The pattern is withdrawn from the drag, then small cores known as STUB CORES are inserted in the angled holes formed by the core print section of the plug. The core print on the stub core matches the core print on the plug; since the cores are all the same length, they will be flush with the face of the mold. When the cope is reset on the drag, the pressure from the parting surface will hold the stub cores in place.

The method of producing a bracket having holes cast on an angle and for molding a pattern using a kiss core that has only a single vertical core print is illustrated in figure 11-7. Part A of this illustration is an isometric view of the pattern and turned plug; part B is an orthographic view of the pattern showing the bored holes; parts C, D, E, F, and G illustrate the steps in the production of this bracket; and part H illustrates the finished casting. (The gating system is not shown in fig. 11-7.)

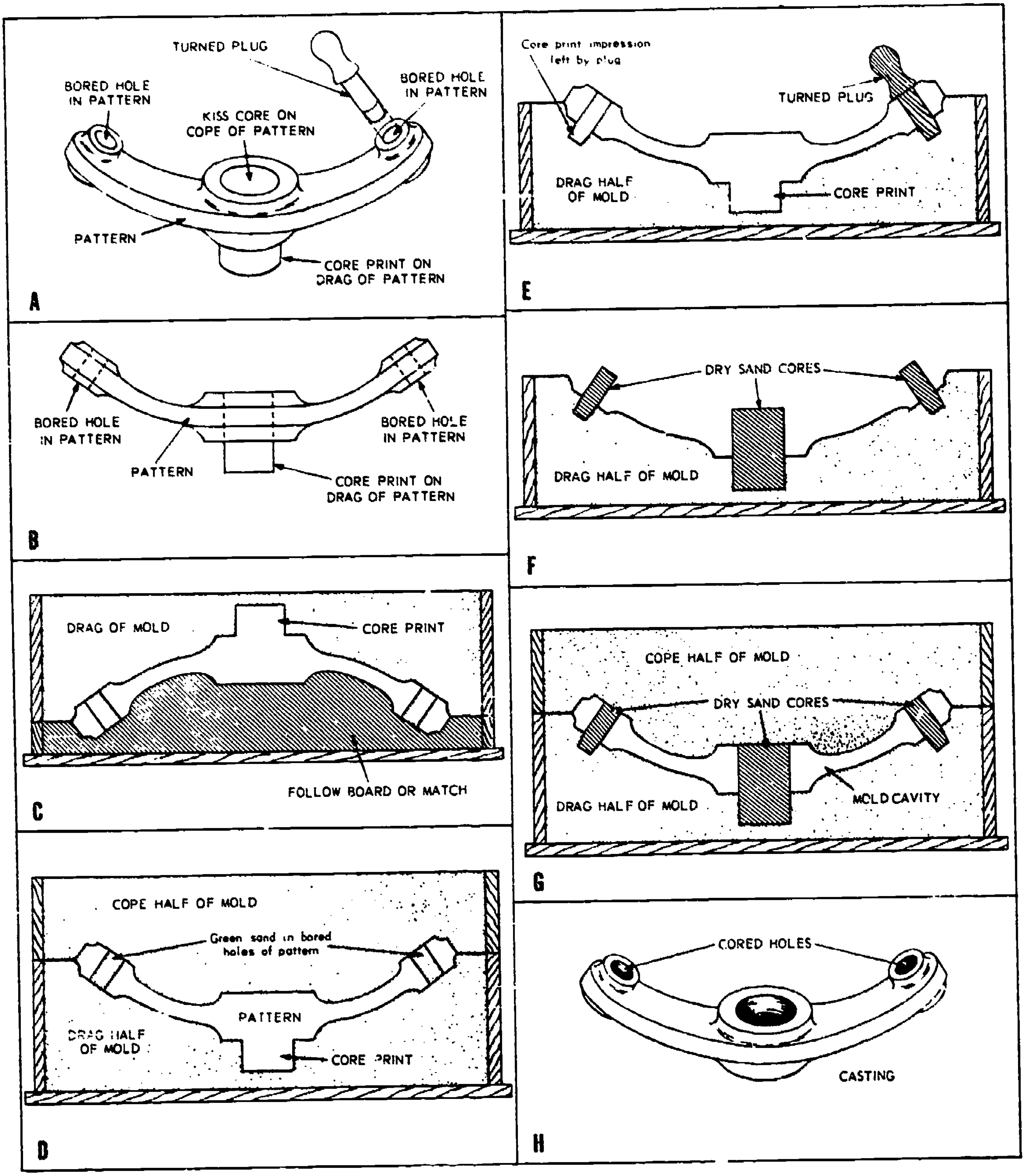
Ram-Up Cores

Ram-up cores are used to form portions of a casting that are difficult to make in green sand. They are incorporated in the mold during, rather than after, the mold is rammed. The ram-up core is positioned in the flask with the pattern and then remains in the mold after the pattern is withdrawn. The principle is illustrated in figure 11-8. When ram-up cores are used, the mold should be poured as soon after ramming as possible, otherwise, the ram-up core will absorb enough moisture to cause blows in the finished casting.



18.55(68)B

Figure 11-6.—Kiss core application—kissing through to green sand.



18.55(68)C

Figure 11-7.—Kiss core application—using one print and using plugged impressions.

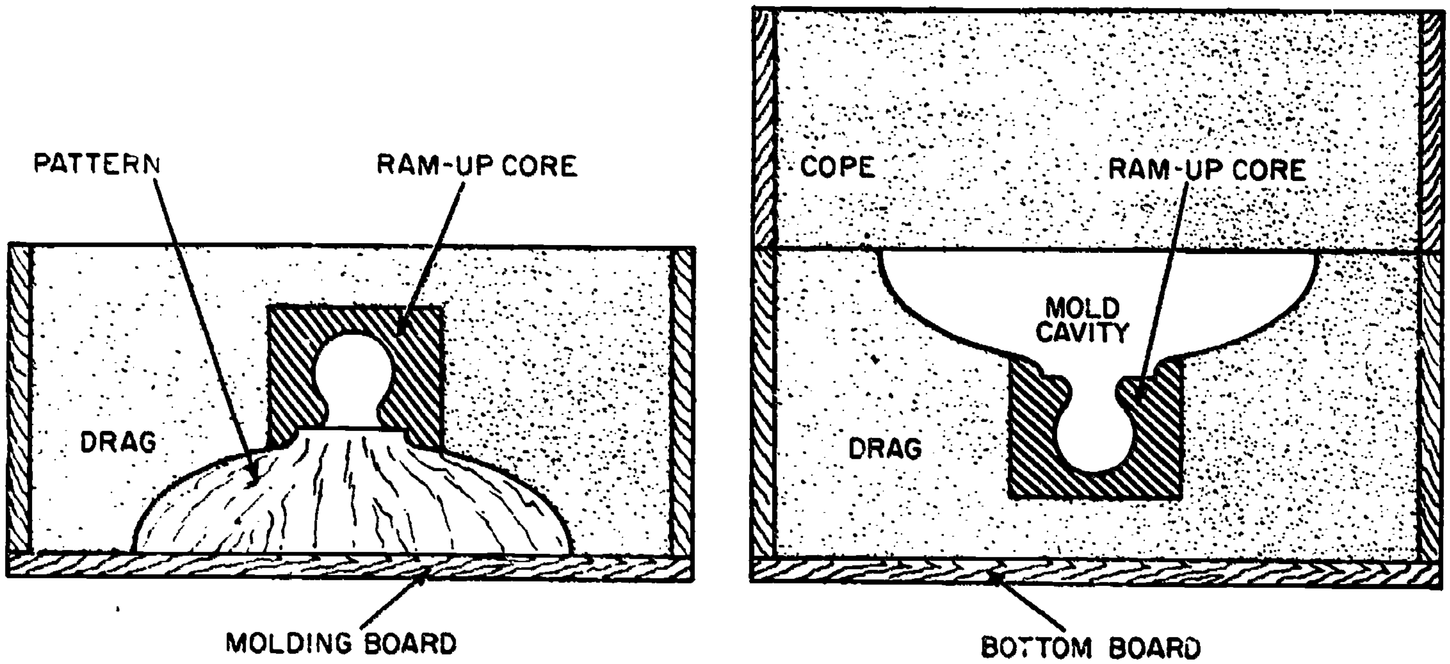


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Figure 11-8.—Ram-up core application.

Stop-Off or Drop Tail Cores

A stop-off core is a core used in forming comparatively small openings occurring above or below the parting of the mold. The seat portion is so shaped that the core is easily dropped in place. In addition, holes on top of or behind bosses and pads may be formed with stop-off cores.

Figure 11-9 illustrates how a core may be used as a stop-off. In the problem illustrated, the core also forms the slotted holes in the vertical leg of the casting. Thus, in this case, the core performs a dual purpose; that of a core forming a portion of the casting, and that of a stop-off to prevent metal from entering that part of the mold cavity formed by the core print. Other terms used for stop-off cores are: drop-tail, tell-tale, heel, wing or boot-jack cores.

Ring Cores

Often the type of pattern equipment used, and thus the molding procedure, depends upon the number of castings to be produced. For example, if a large number of castings like the pulley wheel shown in figure 11-10 is required, it would be worthwhile to make a core box and use a ring core to form the groove in the rim of the casting. A ring core is a core designed in green sand or dry sand and is used for shaping contours to the outside diameter of circular castings. It is often referred to as a mold when a double-rollover is required. On the other hand, if a limited number of these castings is required, the use of less elaborate pattern equipment may be in order.

A method for producing a grooved pulley wheel (requiring a ring core) with relatively simple pattern equipment is illustrated in figure 11-10. Parts A, B, C, D, E, F, and G illustrate the steps in the production of this wheel, and part H illustrates the finished casting. (Note that in fig. 11-10 the gating system has been included because the sprue leads directly to the nub of the wheel.)

Since the procedure differs considerably from the usual method of molding we will consider it in some detail. The pulley problem illustrated has two important aspects: making the green sand core and removing the pattern from the mold. To make the green sand core it is necessary to mold a false cheek; to remove

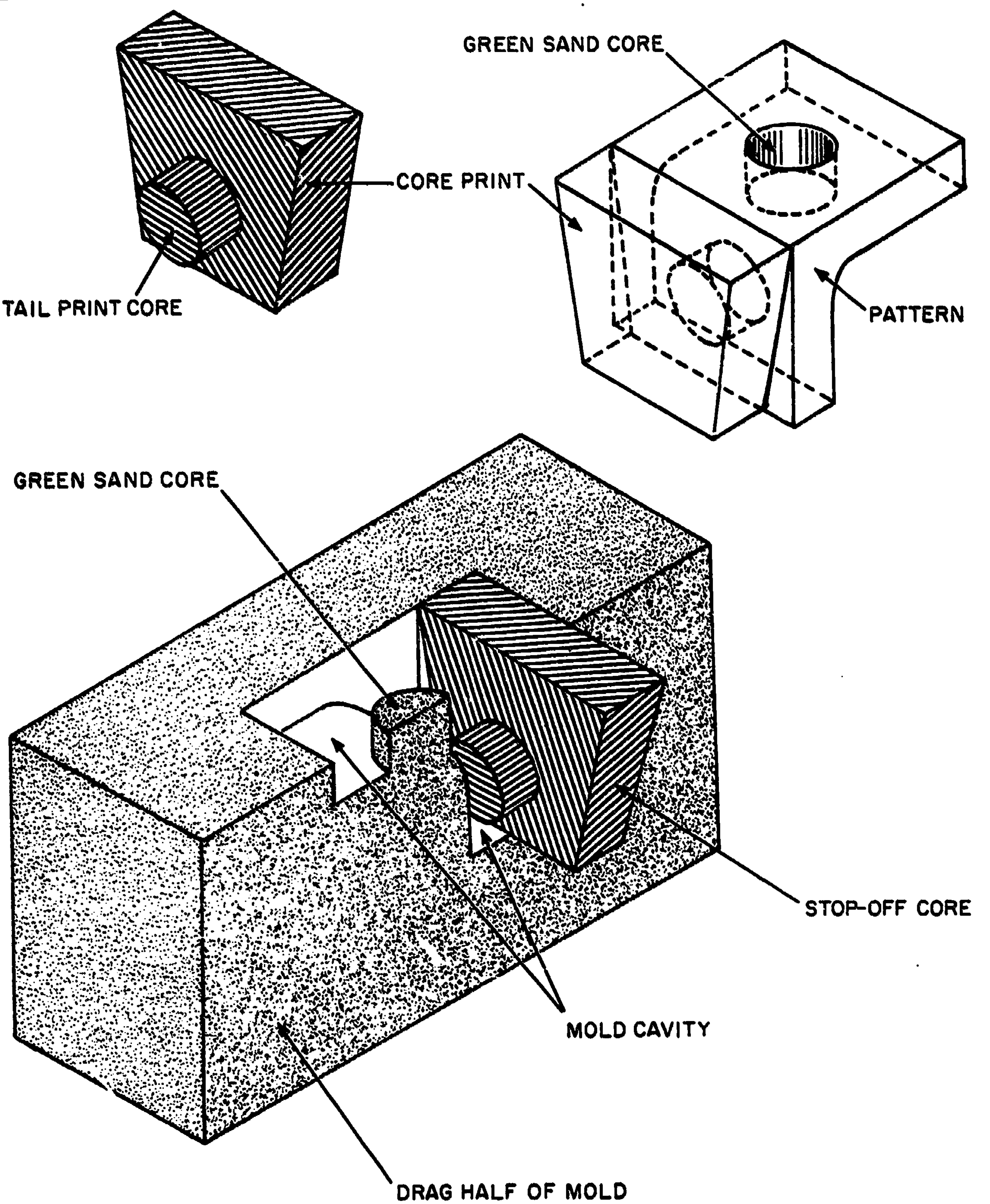

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Figure 11-9.—Stop-off or tail-print core application.

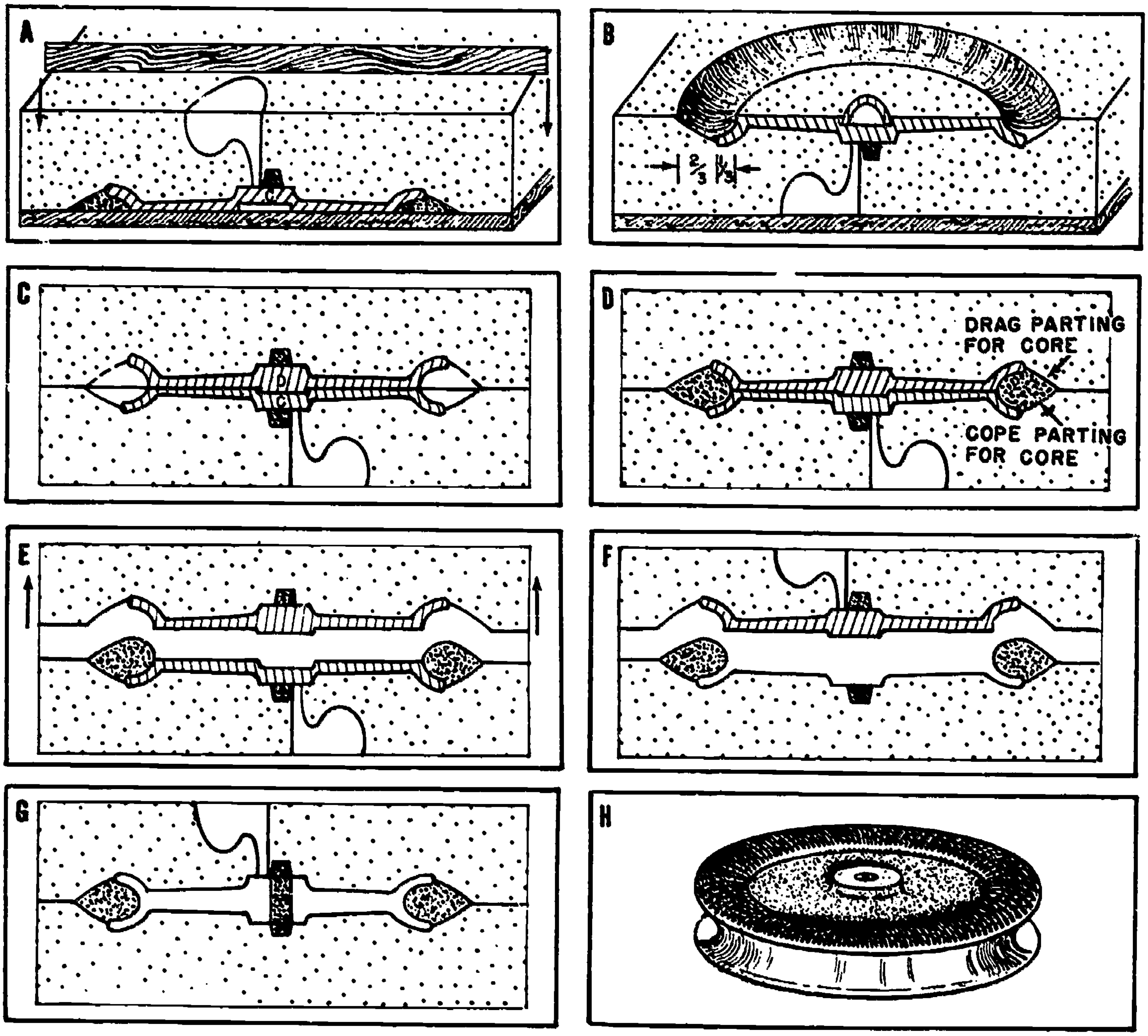

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Figure 11-10.—Ring core application.

the pattern from the mold requires a special sequence of operations. The sequence and techniques involved are as follows:

1. Place a cope flask, joint down, on a mold board and position the cope half of the parted pattern and a sprue pin in the flask. Ram the cope in the usual manner as shown in part A of figure 11-10. Place a bottom board on top of the cope and roll the flask over.

2. Next, cut the sand at the flask joint down about 30° to the tip of the groove all around the circumference of the pattern (see part B, fig. 11-10). Since the cut-down surface area will serve as a core print as well as a parting, its length must be sufficient to support the core after the pattern has been removed. Note that two-thirds of the space between the intersection of the cut-down parting line and the flask joint lines and the innermost point of the groove will be a core print. Adequate core prints are always important; in this problem they are crucial.

3. After cutting down the print-parting, slick the surface area, sprinkle parting sand (partine) over the parting and place the drag portion of the pattern and flask in position.

4. The next step is to mold the green sand core. Carefully tuck facing sand into the grooved portion of the pattern. Ram the core tightly and form a parting having the same angle on the drag side of the core as that previously formed in the cope (part D, fig. 11-10). Slick this surface area and blow out any loose sand. Apply parting sand to the entire mold joint area and ram the drag.

5. Now lift off the drag (part E, fig. 11-10). Note that the core remains in the cope. Next, rap and remove the pattern from the drag. Close the mold, place a bottom board on top of the drag, and roll the entire flask over.

6. Lift off the cope (part F, fig. 11-10), then rap and draw the cope half of the pattern. Check the mold interior carefully and repair damage if required. Set the vertical dry-sand hub core and close the mold for pouring (part G, fig. 11-10).

Setup Cores

A setup core is a simple core used to support a small core in the mold for extra bearing surface, if the small core is likely to be misaligned by sinking down in the mold. A setup core may also be designed to form a boss on the end of a casting or to form a seat for other cores. It may be designed to be used as a ram-up core.

The core print cavity is usually formed in the mold by a core print on the pattern. However, if a small print on a heavy core provides an inadequate support in the mold, it may be necessary to provide additional support for the small core. A brick may be rammed up in the mold under the core print to provide this extra support, or a special core may be designed to form the seat for the small core. Such a core, called a SETUP core, is placed under the small core print and used as a ram-up core.

A method of producing a casting using this technique is illustrated in figure 11-11. Part A of this illustration is an isometric view of the pattern, the main body core, and the setup core; parts B, C, and D illustrate steps in the production of this casting; and part E illustrates the finished casting. (The gating system is not shown in fig. 11-11.)

If a number of small core prints project from the end of a pattern or core assembly, a setup core may be designed to incorporate all of the core prints into one core. This setup core may be pasted to the main body core or core assembly and the complete core set into the mold as a complete unit.

If a small core print is used for a hole in a boss on the end of a casting, a setup core may be designed to combine the core print and the boss into one core.

The method of producing a casting requiring a setup core to include a boss on the end of a casting is illustrated in figure 11-12. Part A of this illustration is an isometric view of the pattern, the main body core, and the setup core; parts B, C, and D illustrate the steps in the production of this casting; and part E illustrates the finished casting. (The gating system is not shown in figure 11-12.)

Special Gating System Cores

The means whereby the molten metal is introduced into the mold, and a knowledge of what will happen when the molten metal follows a prescribed path as it enters the mold are

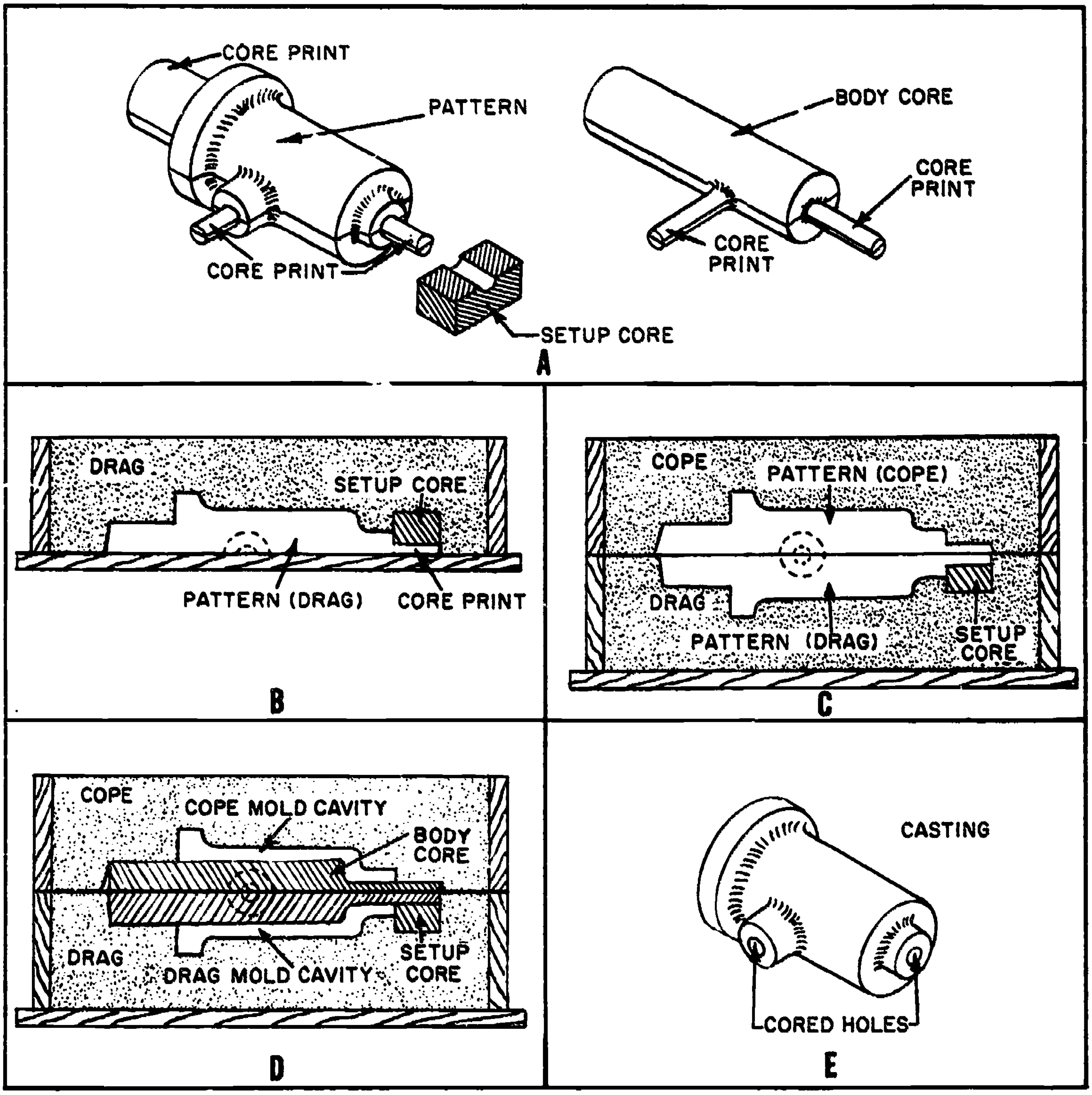

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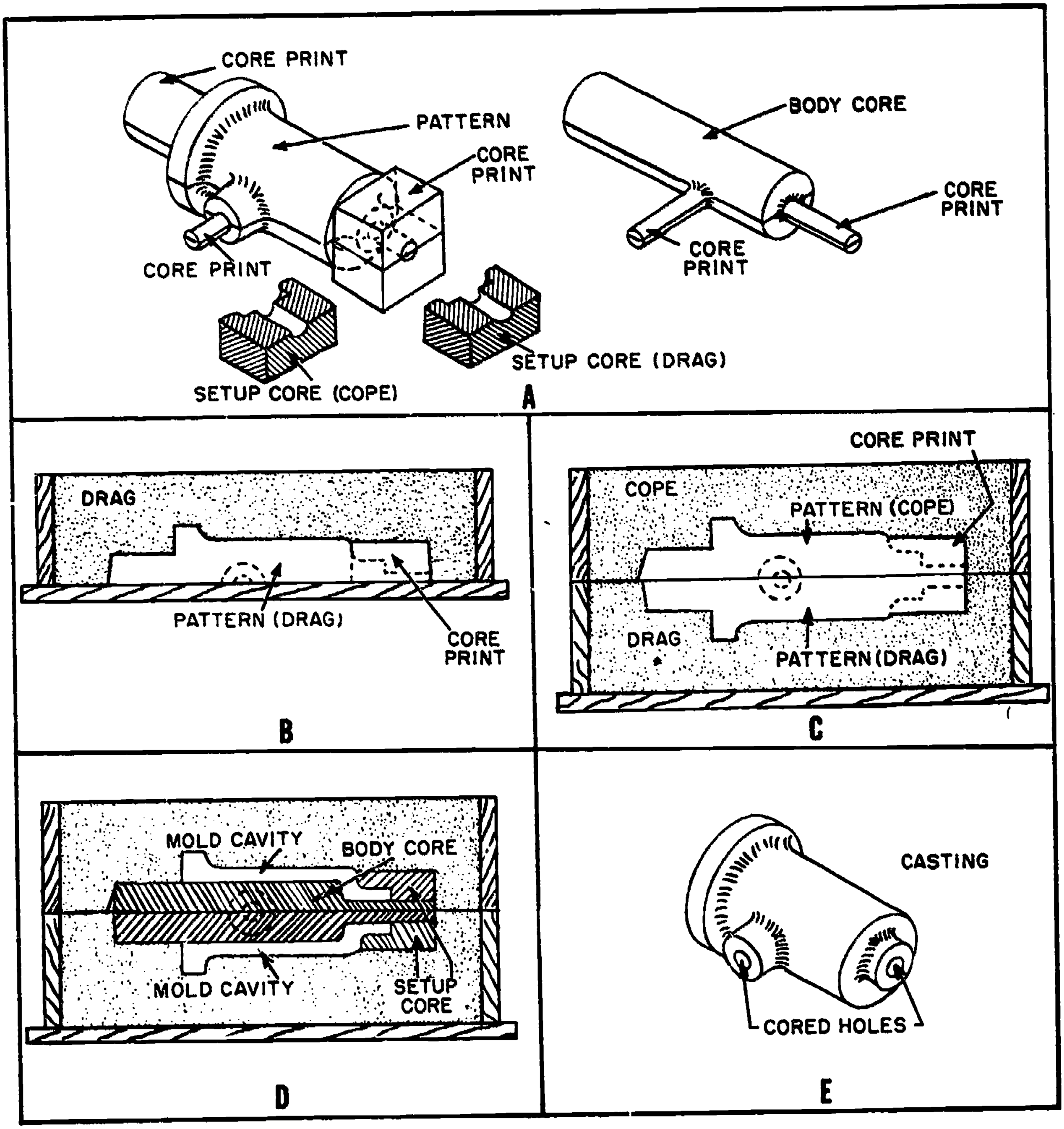
Figure 11-11.—Application of a setup core—as a simple core support.



68.114

Figure 11-12.—Application of a setup core—as an aid for exterior surfaces.

factors or primary importance in the production of a casting. A gating system plays an important part in dimensional casting control and must be designed to do the following:

1. Permit the complete filling of the mold cavity.
2. Introduce the molten metal into the mold with as little turbulence as possible to eliminate any gas pickup and to prevent mold erosion.
3. Regulate the rate of flow of metal into the mold cavity.

Special gating cores such as pouring basin cores, strainer cores, tile or gate cores, splash cores, and breaker cores may be used in conjunction with the general gating system in controlling the molten metal while it is being poured into the mold cavity. Applications of special gating cores are illustrated in figure 11-13 and are self-explanatory. Definitions of special gating system cores are:

1. POURING BASIN CORE—A core used for a cavity on the top of the cope into which metal is poured before it enters the sprue. (See part A of fig. 11-13.)
2. STRAINER CORE—A small perforated core in the sprue, runner, or gate to prevent entrance of slag and other extraneous material into the mold cavity. (See parts B and C of fig. 11-13.)
3. TILE OR GATE CORE—Preformed cores made of a refractory material such as tile, ceramic, or dry sand that are placed in a mold to replace a cut or formed (pattern) gating system. (See part D of fig. 11-13.)
4. SPLASH CORES—Inserted refractory material placed in the pouring basin or at the bottom of the sprue to eliminate erosion caused by the sudden drop or rolling action of flowing metal. (See part E of fig. 11-13.)
5. BREAKER CORE—Cores designed for the purpose of easy removal of risers from castings. Breaker cores are set in position over the contact area of the neck under an open riser, creating a necking effect. (See part F of fig. 11-13.) Other terms used for breaker cores are wafer cores and Washburn cores.

CORE PRINTS

When a core is placed in a mold, there must be some means provided to locate, hold, and anchor it in position. In order to do this, a projection is designed and added to the pattern. The projecting pieces, called CORE PRINTS, are attached to and become a permanent member of the pattern. The core prints make an impression in the sand, thus forming a seat into which the core is set and retained in its proper position. If it is possible for a core to be set in the mold UPSIDE-DOWN or WRONG-END-TO, locating marks called WITNESS MARKS (core markers or tell-tales) should be provided to prevent any possibility of wrongly placing the core within the mold.

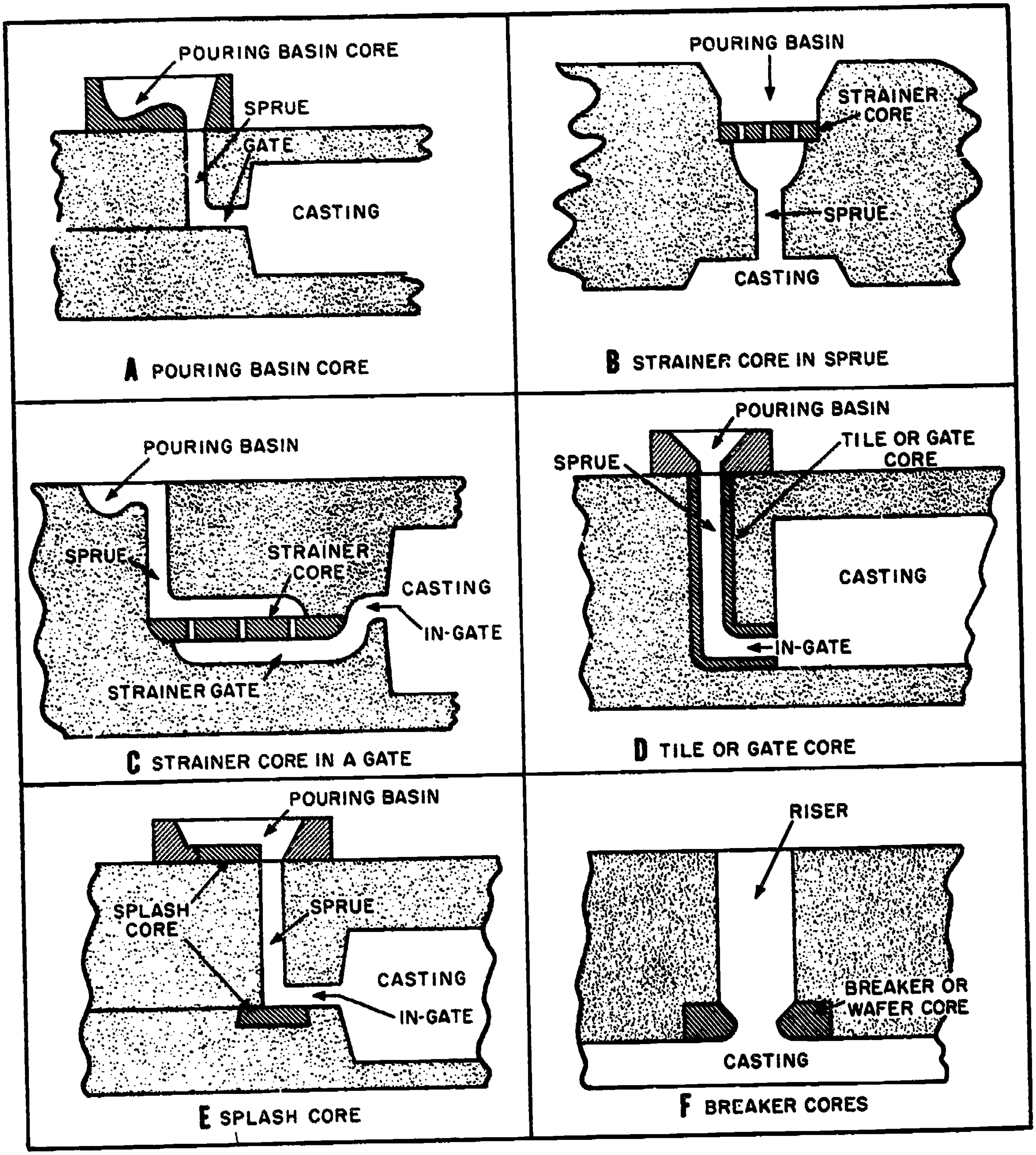
Although there are no fixed rules as to the length of core prints or how much taper (draft) they should have, good pattern practice requires that there should be sufficient bearing surface to support the weight of the core (depending on the type of mold in which the core is supported) and the pressure of the molten metal when being poured. Core print dimensions which have been successful in practical application are listed in the following chart and are intended ONLY as a guide.

CORE PRINT DIMENSIONS

Size of Core	Length of Core Print
Up to 1 1/2 inches in diameter	2-inch core print
From 2 to 5 inches	At least equal to the diameter of the core.
Above 5 inches in diameter	6 inch core print (minimum)

A few of the proven rules that may be applied to the various types of cores and core prints are:

1. Cores which have a diameter or width greater than their length may be molded in green sand.
2. When green sand cores prove impracticable, use dry sand cores.
3. Eliminate small cored holes because they can be costly.
4. All cope core prints should have a 5° to 10° taper (draft).
5. All drag core prints should have a 1° taper (draft).
6. All loose, round core prints should be doweled in the center only.



68.115

Figure 11-13.—Application of gating system cores.

7. All loose, rectangular core prints should be doweled with two dowels of different diameters to prevent misalignment and improper attachment.

8. The larger the core print, the better the accuracy in location and support in the mold.

9. When the length of a core is more than twice its diameter, the core should be supported at both ends.

10. Cores should not have diameters that are less than one-half the thickness of the wall they pierce.

11. If the core is round, the diameter should equal or exceed the metal thickness through which the core passes.

12. If the core is rectangular, the shortest distance across the flats should equal or exceed the metal thickness.

13. Secure the core at both ends if the metal thickness through which a vertical core is to pass equals two or more times the shortest distance across the flats.

14. Core prints should be of a sufficient size to permit easy escape of core gases.

15. The core print portion of a pattern, when practicable, should be so shaped or arranged as to simplify the making of the core box.

Although there are numerous types of cores and variations of them, core prints may be classified into five general types: (1) cope and drag prints, (2) horizontal or parting line prints, (3) balanced prints, (4) suspended or hanging prints, and (5) tail or drop prints (fig. 11-1).

COPE AND DRAG CORE PRINTS

When a core is set vertically in a mold, core prints are placed on the cope and drag of the pattern, thus giving the name COPE and DRAG prints (part B of fig. 11-1). The cope print is made with considerable taper (draft) as an aid in centering the core and to facilitate the closing of the mold, while the drag print has only a slight taper for ease in hand setting the core.

The length or height of cope and drag prints are in direct proportion to the diameter of the core. As the diameter of a vertical core increases, the length of the core print may be decreased due to the gained surface area of the core seat. Therefore, the larger the diameter of the core, the thinner or shorter the core print required for support of the core. Various ways of determining the dimensions of cope and drag prints may be used; one of the simplest is illustrated in figure 11-14. The length or height (C) of core prints up to 1 1/2 inches in diameter may be made equal to the diameter of the core (A). Cores above 1 1/2 inches in diameter need not be any longer than 1 1/2 inches.

HORIZONTAL OR PARTING LINE CORE PRINTS

Horizontal or parting line prints are used to form the core seats when the core is placed in a horizontal position. (See part C of fig. 11-1.) The core prints are usually the same in diameter as those of their respective cores. In addition, they should be long enough to give a solid bearing surface for the weight of the core plus the stress caused by the molten metal as it fills the mold; otherwise the molten metal will raise or displace the core, making the casting thinner on one side.

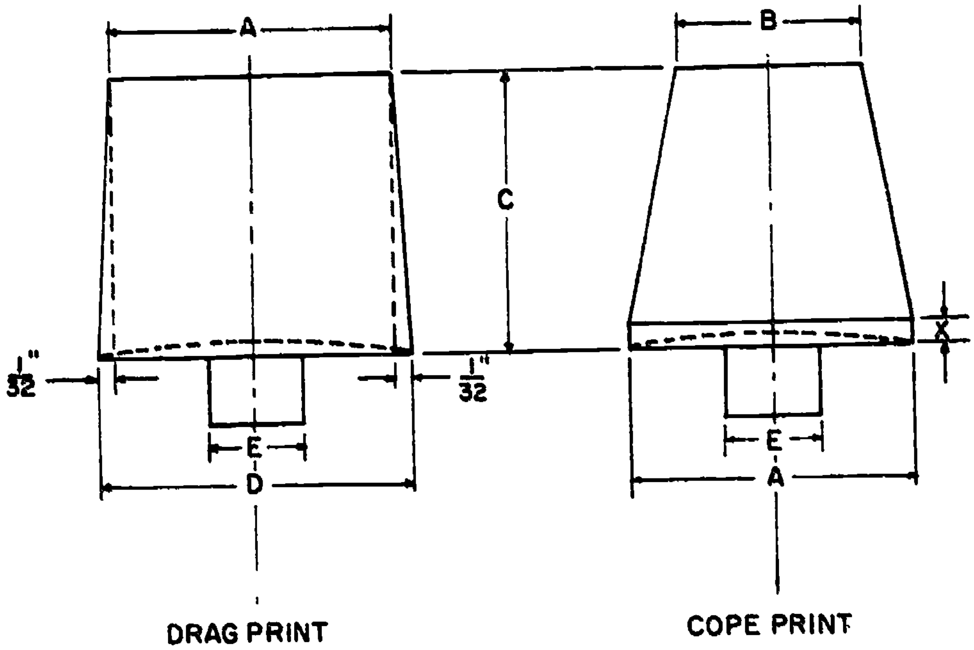
The following general rules for determining the length of horizontal core prints has proved satisfactory in practice: "For horizontal cores, the length of the c e prints should equal one-half the diameter of the core plus 1 inch." Remember that this is ONLY a general rule and any deviation must be considered in relation to the job requirements.

Referring to the preceding chart on Core Print Dimensions, note the core print lengths recommended for the various diameter cores. However, the length of small core prints having a diameter less than one inch may be considerably shorter than is listed; the core length may be from 3/4 to 1 inch in length, depending upon the weight of the core. Horizontal core prints should be longer than they would be normally, when the center section of the core is heavy and requires more support.

BALANCED CORE PRINTS

When a core is placed horizontally within a mold and receives its entire support from one end, the core print is so proportioned that it will outweigh or overbalance that portion of the core extending into the mold cavity. (See part D of fig. 11-1.)

Two methods may be employed to achieve this balance. The first method is to make the core print long enough to balance the weight of the unsupported end. The second method (recommended when an extra long core print is not practical) is to enlarge the core print by adding



Drag Print

A = Diameter of core
D = Diameter at base of print
= A + 1/32 + 1/32
C = Height of print
E = Diameter of dowel

Cope Print

A = Diameter of core
B = Diameter at top of print
= 2/3 of A
C = Height of print
E = Diameter of dowel
X = 1/8" (constant)

The dowel diameter may be determined as follows:

Diameter of Print "A"	Diameter of Dowel "E"
Up to 7/16" diameter	3/16"
7/16" to 5/8" diameter	1/4"
5/8" to 1"	3/8"
1" to 2"	1/2"
2" to 3"	3/4"
3" and above	1"

Example of determining the core print dimension using a 1" diameter vertical core.

Drag Print

A = 1" diameter
D = A + 1/16" = 1 1/16"
C = 1"
E = 3/8" diameter

Cope Print

A = 1" diameter
B = 2/3 of A = 5/8" diameter
C = 1"
E = 3/8" diameter
X = 1/8"

Example of determining the core print dimension using a 3" diameter vertical core.

Drag Print

A = 3" diameter
D = A + 1/16" = 3 1/16"
C = 1 1/2"
E = 3/4" diameter

Cope Print

A = 3" diameter
B = 2/3 of A = 2" diameter
C = 1 1/2'
E = 3/4" diameter
X = 1/8"

Figure 11-14.—Cope and drag print dimensions. 68.109

a flange or an offset section to give added weight to the supported end of the core. In addition, the flanged or offset section may be used as a witness mark to establish the exact depth of the core in the casting. When using balanced prints, consideration must be given to the length of the print. It would be impracticable to balance a core with a print several feet in length; instead chaplets (metal core supports) should be used to support the end of the core within the mold cavity.

SUSPENDED OR HANGING CORE PRINTS

A type of print called a SUSPENDED or HANGING core print derives its name from the fact that the core serves two purposes: (1) as a support for the hanging part of the main body of the core, and (2) as a complete cover for the mold. (See part E of fig. 11-1.) Therefore, suspended or hanging core prints are used when a cored casting is to be molded entirely in the drag. In addition, variations of this core print will eliminate the need for a three-part flask.

TAIL OR DROP CORE PRINTS

On special jobs where cored holes are required above or below the parting line, a TAIL or DROP print is used. (See part F of fig. 11-1.) The print is so shaped that the seat portion allows the core to be easily dropped in place. In addition, holes on top or behind bosses may be cored in this manner. The print portion of the core serves as a means of STOPPING-OFF the core seat and of locating the projecting core that forms the opening. Stopping-off or blocking-off the core seat may be done by filling in with a stock core after the projecting core has been set; or, after the projecting core has been set, by tamping molding sand into the core seat impression. In many cases, a single core print is sufficient when the projecting part is not too long; however, if the projecting part is long, the core should be supported at both ends.

CORE BOXES

The most common method of forming cores is to use a core box which is constructed of a suitable material, containing a cavity the shape of the desired core. This core box is rammed full of sand to form the core. After ramming, the core box is removed from the core, leaving the core on a core plate for support while the core is being baked.

The same allowances that are made on a pattern for draft, shrinkage, and finish are given to the core box. However, in many cases the core box is more complicated to construct than the pattern. The required number of core boxes is always furnished with the pattern and therefore becomes part of the pattern equipment for a particular job. All patterns and corresponding core boxes should be marked and/or numbered to prevent their loss while in use and during storage.

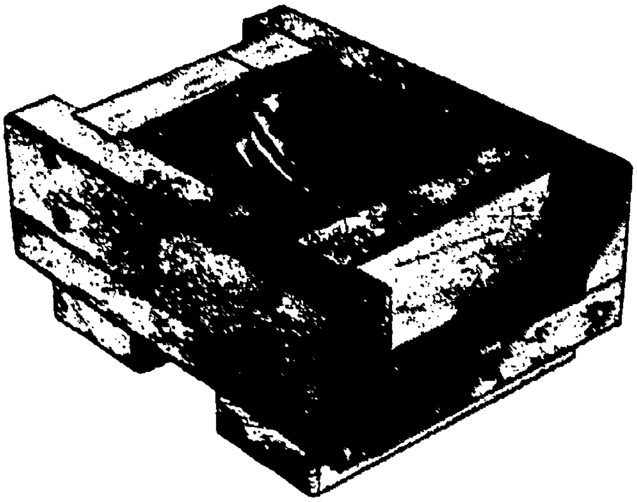
When the method of supporting and locating the core is determined, the next step is to determine the most practical method of forming the core. Core boxes must be constructed not only with regard to the size and shape of the core, but also with regard to the way in which the core can best be supported while drying. The shape or form of some cores is such that the core box may be made so that a whole core is formed; with other shapes it may be necessary to make a half core at a time. Many cores, depending on their shape, must be supported on green sand while drying. Intricate core work is sometimes supported upon special metal core driers.

TYPES OF CORE BOXES

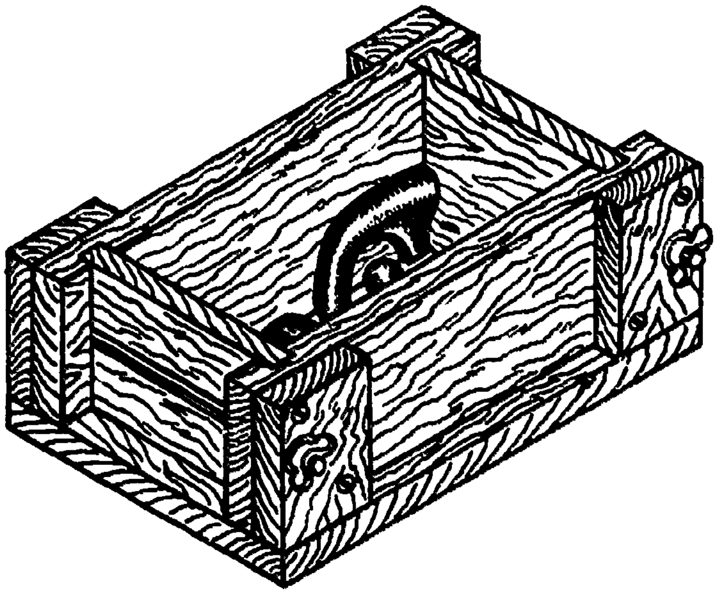
A few of the more common types of core boxes are described. Do not assume that these are the only types of core boxes.

1. The DUMP BOX is one which has four sides and a bottom and is open only on the face. It is made with butt or dado joints. Sand is rammed into the open face and the box is turned over onto a core plate. The core box is lifted off, leaving the core on the plate. If any loose pieces are used they will dump out with the core. Figure 11-15 shows one method of constructing a dump box.

2. A COLLAPSIBLE CORE BOX is similar to a dump box except that the four sides and bottom may be disassembled. After sand is rammed into the open face, the box is turned over onto the core plate. The collapsible box is used when back draft prevents the dumping of the core out of the box. Instead, the sides and bottom of the box are disassembled and pulled away from the core. (See fig. 11-16.)



68.116
Figure 11-15.—A dump box.



68.117
Figure 11-16.—Collapsible core box.

3. An OPEN END BOX is, as the name implies, open on the ends. The box is set up vertically so that one end is in contact with the core plate. Sand is rammed into the other open end at the top. The box is pulled away leaving the solid core standing on end. The open end box is usually made in parted halves as shown in figure 11-17.

4. A GANG BOX is usually an open end box used for making several cores at one time for mass production work. See figure 11-18.

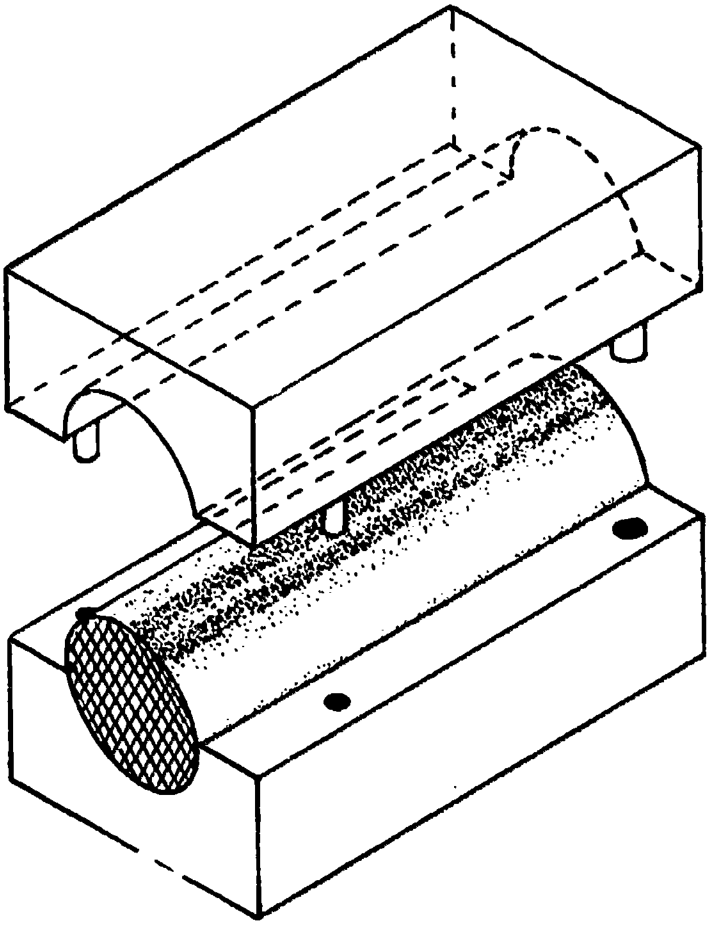


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Figure 11-17.—An open end box.

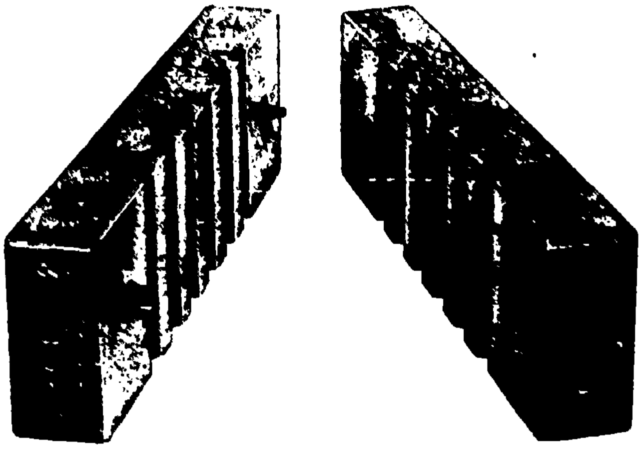

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Figure 11-18.—A gang box.

METHODS OF CONSTRUCTING CORE BOXES

Core boxes, like patterns, may be constructed in many different ways, depending upon the specific job requirements. Patternmakers and Molders in each shop will usually use different nomenclature for the various types of core boxes. However, all core boxes should be made strong enough to withstand the rough usage they will get in the foundry. The methods of construction which the Patternmaker will commonly use are described in the following sections.

Solid Construction

Solid construction as the name implies is a core box that is worked out of solid material. (See fig. 11-19.) Semicircular core boxes of 3 1/2 inches or less in diameter are usually made of solid construction. The greater portion of the waste is removed from the core cavity by a series of saw cuts (kerfs), and then finished by gouges or a core box plane.

Stepped-Up Construction

Stepped-up construction is so named because the stock, when fastened together, resembles steps. To save material, core boxes between 3 1/2 and 6 inches in diameter are stepped up as shown in part A of figure 11-20. For economy in jobs requiring only one casting, the core box may be stepped up as shown in part B of figure 11-20. Stepped-up construction is used also in the building of pipe and elbow patterns.

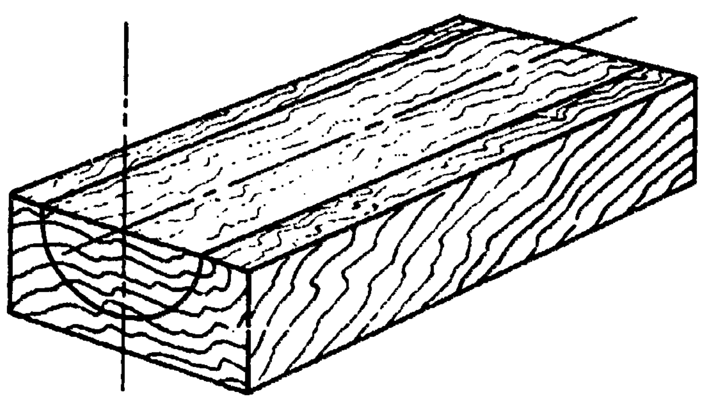

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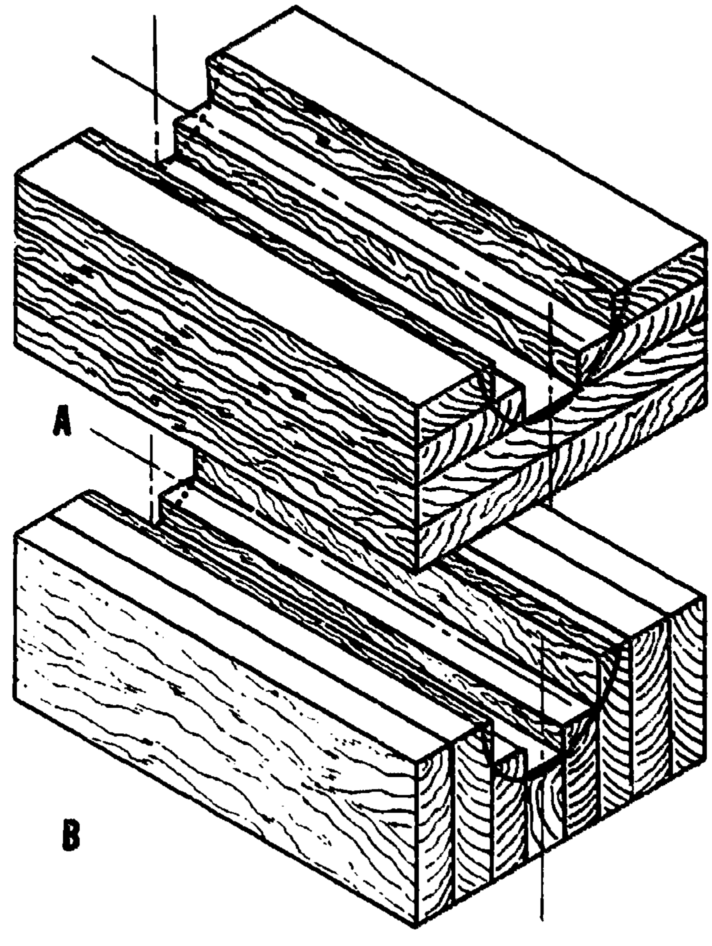
Figure 11-19.—Solid construction.



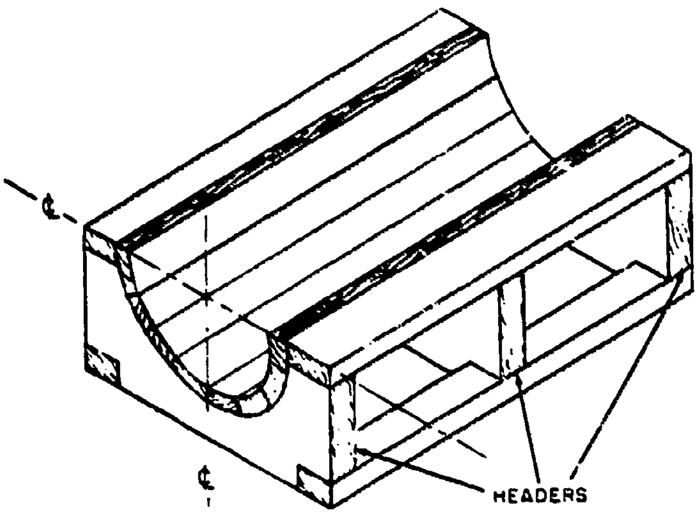
68.121
Figure 11-20.—Two versions of stepped-up construction.

Staved or Lagged-Up Construction

This method of construction is used for making cylindrical or conical-shaped cores exceeding 8 or 10 inches in diameter. Staved construction saves material, makes the core box stronger and lighter to handle, and is more likely to retain its dimensional form. Refer to figure 11-21.

Skeleton Construction

This method of construction is used for making extremely large cores for iron or steel castings where close precision is not essential. The core is shaped by the use of a sweep (strickle) as shown in figure 11-22.



68.122
Figure 11-21.—Staved construction.

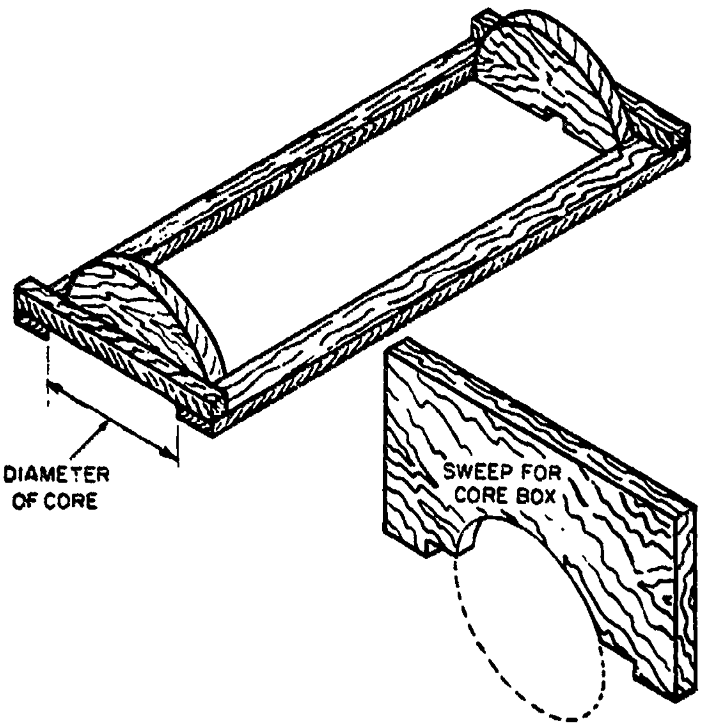


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Figure 11-22.—Skeleton construction.

Half-Box Construction

This method is used to make a core which is symmetrical about the longitudinal centerline. One half-box is constructed; each half core is made separately and the two halves are pasted together to form the completed core. Figure 11-23 illustrates a half-box and the half core.

Parted Construction

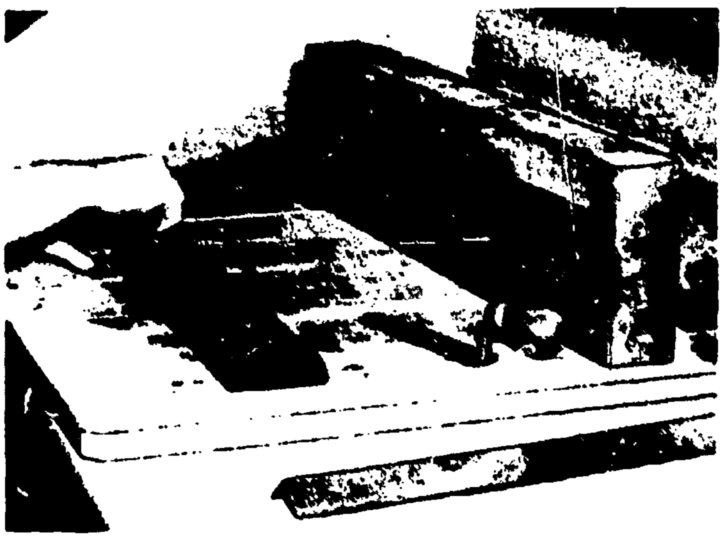
Parted (split) construction is used to simplify the making of a solid core in one operation. Figure 11-17 shows a parted type core box open at both ends. Figure 11-24 shows a three-piece parted type core box in which the bottom and parted halves may be pulled away from the core.

Framed Box Construction

This is one of the most common methods of core box construction. When quality work is required and when time permits, the framed box will be made with dado joints. In a job shop where speed is essential, butt joints will usually be used.

Combination Box Construction

This method enables you to make several different cores by the use of different change



68.124
Figure 11-23.—A half box.

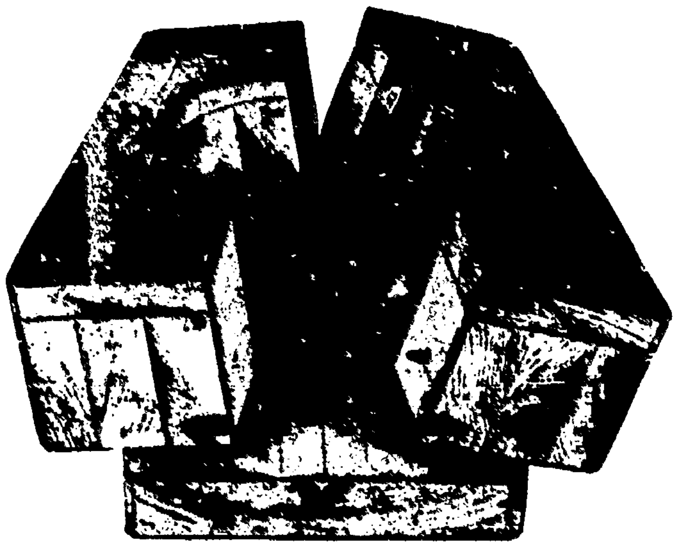


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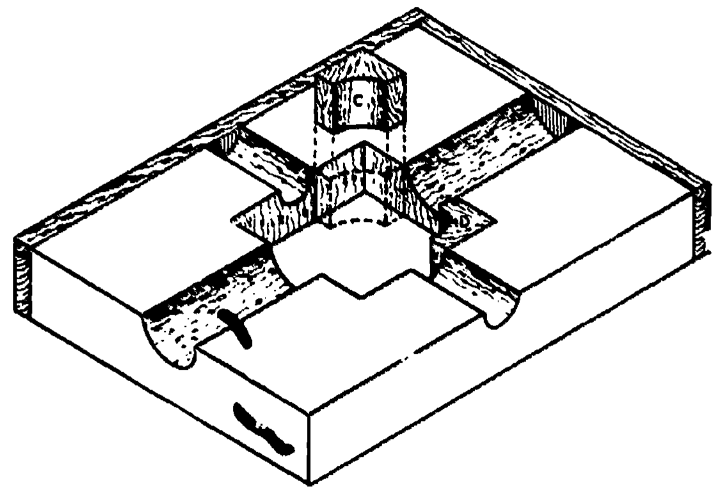
Figure 11-24.—Parted (split) construction.



68.126
Figure 11-25.—A combination core box.

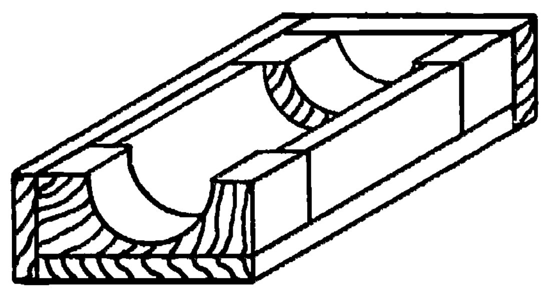
pieces within the core box. These change pieces are sometimes referred to as loose pieces. Figure 11-25 shows a typical combination core box with change pieces C and D. Note that the same half-box may be used to make a right and left core merely by alternating the change pieces.

Chambered Box Construction

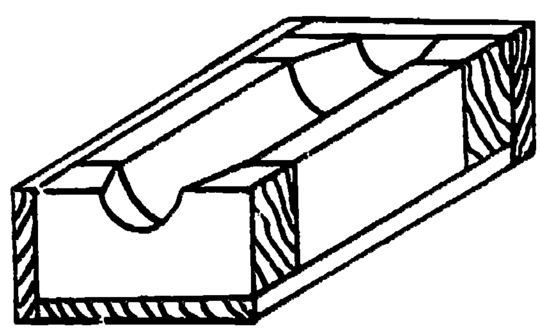
When a core box is built up in sections with the grain running lengthwise, the box is called **chambered** construction. The sections with cross-grain on the ends are glued and nailed to solid stock (tie-piece) which runs the full length of the box to tie all the sections together. (See fig. 11-26.) To give additional strength to the box, sides are added as tie-pieces. (One side piece and one end piece are not shown in fig. 11-26 as an aid in illustrating the construction features.)

Cone Box Construction

When a core box is constructed with cone shapes on the ends for core prints (as shown in fig. 11-27), the box is of cone construction. This type box is constructed much in the same manner as a box of chambered construction.



68.127
Figure 11-26.—Chambered construction.



68.128
Figure 11-27.—Cone construction.

Pinless Box Construction

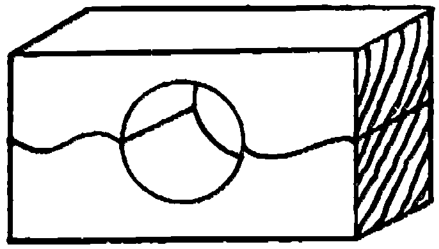
When only a few cores of a simple shape are required, a box of pinless construction is suitable. (See fig. 11-28.) Band saw an irregular line through the box. Put the box back together and the irregular cut line will become the centerline of the box. Lay out the core shape on the surface of the box and cut out the required shape.

Wing Box Construction

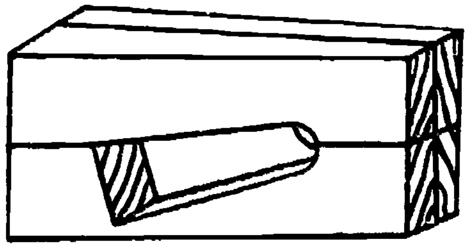
Wing construction core boxes are usually made up of two or more pieces of stock and may be parted along the center as shown in figure 11-29. Boxes of this type should have dowel pins for alignment. When being used, the box is filled at the top, then turned over; the box is pulled apart, leaving the core on the core plate.

Metal Faced Core Boxes

When a large number of cores are to be made from a permanent wooden core box, metal stripping or facing material is secured to the surface of the core box. The metal facing on the core box is to cover and protect the wood surface from the abrasive action of the core sand during the ramming of the core. This prevents excessive wear and prevents the core box from becoming worn and too shallow.



68.129
Figure 11-28.—Pinless construction.



68.130
Figure 11-29.—Wing construction.

INTERCASTING OF LINKED MEMBERS

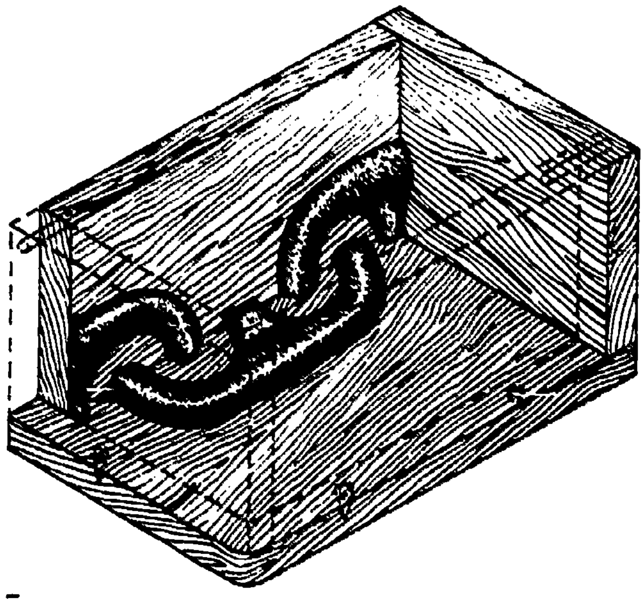
Intercasting of linked members is the process whereby two or more castings, such as links of a chain, or parts of a swivel or pelican hooks, are cast interlocked. Designing cast units having intercast members is challenging to the Patternmaker; and the principles used may be applied to other patternmaking problems.

CHAIN LINKS

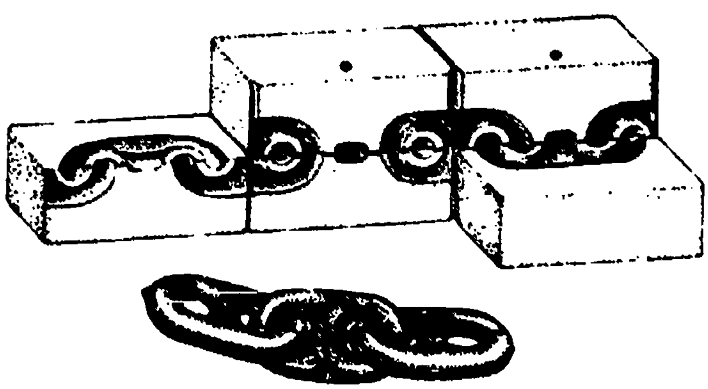
A cast unit, like a series of chain links in which considerable clearance exists between the intercast parts, is more a problem of designing a gating system than a problem in preventing fusion of the intercast parts. To accomplish this with great ease, the intercast links are made in a core made mold. The molding positions of the links are alternately flat and upright. The cope and the drag of the mold is parted horizontally and vertically along the centerlines of the link. By pasting the cores together with half of each link in the drag, the other half in the cope, each link will be completely surrounded by sand. The parting plane of the mold requires two different link pattern designs: one parting the link into four parts lengthwise along the centerlines, and the other parting the link into eight parts lengthwise, along the centerlines and through the centerline of the stud. (See fig. 11-30.) The core box is made with one-fourth of the link fastened to the bottom of the box and one-eighth of the link fastened on each end and mounted vertical to the baseline, with the half round section centered in the quarter link.

In this core box design, only one box is necessary to make any number of intercast links. Four cores, when pasted together, will make one complete link (fig. 11-31). Every four cores that are added will add two more links which are intercast together.

The design of the core box may be one in which the series of links have a common gating system, or each link may be provided with



23.196
Figure 11-30.—Core box setup for a chain.



23.197
Figure 11-31.—Core arrangement for a chain.

individual sprues, gates, and risers and poured separately even though several links are in the same mold. Note in figure 11-30 that the gating system has been omitted.

After the cores are pasted together it is recommended that they be backed up with green sand which serves as an added precaution against possible metal run-out.

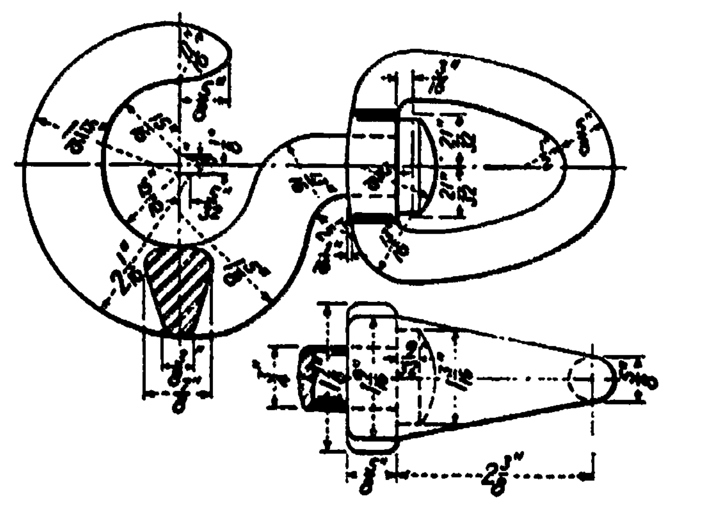
SWIVEL HOOK

Intercast members such as the swivel hook illustrated in figure 11-32 involve two molding operations: casting the hook is the first molding operation; casting the swivel about the shank of the hook is the second. The shank and head of the precast hook must be insulated against direct contact with the molten metal used to cast the swivel during the second molding and pouring operation. Adequate clearance must also be provided to permit a freedom of motion between the swivel and the hook in the finished casting. This is accomplished by applying core oil to the shank of the hook and sprinkling a fine grade of silica sand over the area. Then place the hook in an oven for drying. This procedure is repeated until a coating of sufficient thickness is built up. Pouring the swivel casting completes the job.

The step by step procedure is as follows:

1. As in all pattern work, draw the layout and plan the construction procedures. Two separate patterns are required for the swivel hook drawn in figure 11-32; a parted pattern for the hook, and a parted pattern for the swivel. Since the swivel hook shown is rather small, it will probably be carved out of a solid piece of hardwood stock. (Large swivel hooks can be constructed in a single course or a multiple course of segments—depending upon the size—and splined together for additional strength. The head and shank of large hook patterns are partially turned on the lathe and completed by hand-carving.)

2. Ram the mold for the hook in the conventional manner and pour the casting.



23.198X
Figure 11-32.—Drawing of a cast-steel swivel hook.

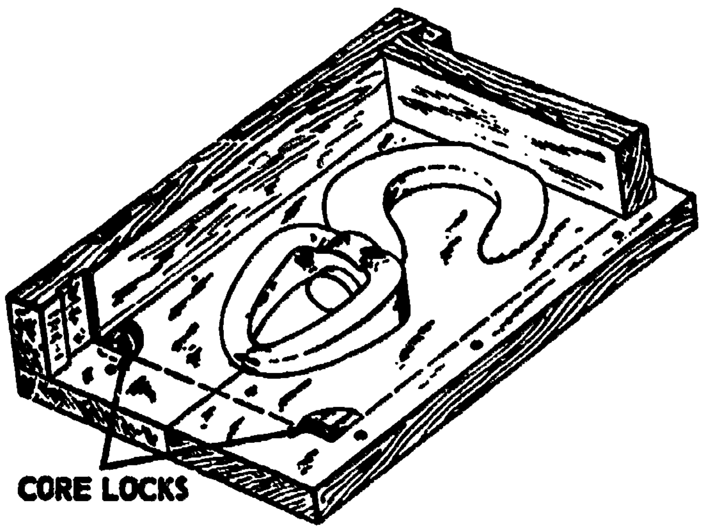
3. In addition to the patterns, you will need to make a core box to facilitate the second molding and pouring operation. The core box may be made in two halves with built-in core locks in order to make sure that the drag core lines up or registers perfectly with the cope core. Figure 11-33 shows the core box setup for the swivel hook. The front and side boards have been removed to enable you to see all the details.

An alternate method is to make a single half-box and to use the two halves of the hook pattern as interchangeable pieces in order to make a right and a left half of the core. If this latter method is used, do not forget to reverse the location of the riser, gates, runners, and core locks when making the second half of the core.

4. Construct a rectangular pattern with the same dimensions as those of the completed core to serve as a core print. This will provide the cavity into which the core may be firmly seated.

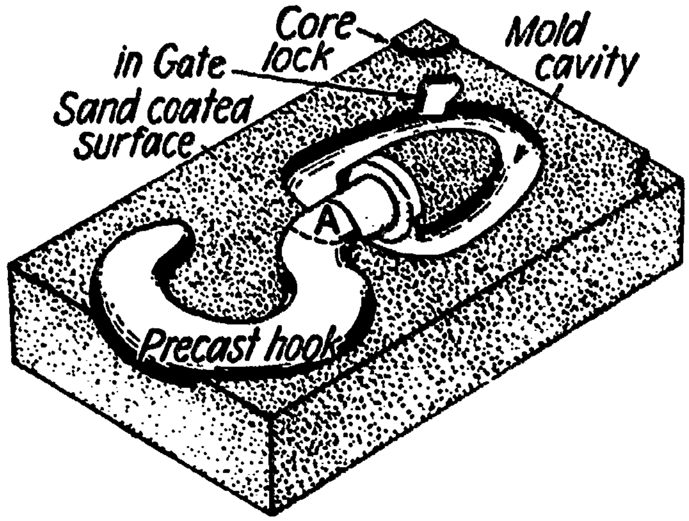
5. Make the cope and drag cores. Place the precast hook into the drag core as shown in figure 11-34. (The risers, runners, and gates are not shown.) Build up the protective sand layer to the required thickness around the shank of the hook.

6. Paste the cope core on top of the drag core, making sure that the core locks match perfectly.



23.199X

Figure 11-33.—The core box setup for the swivel hook.



23.200X

Figure 11-34.—Drag core with the precast hook in place.

7. Ram up the rectangular pattern in green sand, draw the pattern, and insert the entire core into the mold. Close the mold and set the pouring cup; now the mold is ready for pouring.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 12.

BOSS—A projection, on a casting, of circular cross section.

COHESIVE—The ability of foundry sand to stick together and hold shape.

PARTINE (PARTING COMPOUND)—Fine bondless commercial preparation dusted over the joint of a mold to prevent the contacting surfaces from adhering to each other.

PLASTIC—The ability of foundry sand to be shaped.

POROUS—Possessing or being full of holes.

REFRACTORY—Material having heat-resisting qualities.

SLICK—One of a number of tools used for mending and smoothing the surface of a mold.

STRIKE (STRICKLE)—Piece of material having a straight or curved edge used for removing excess sand from a flask or pattern.

STRIKING OFF—The act of removing excess sand from a flask or pattern with a strike.

TEMPERING—Dampening and mixing sand to produce a uniform distribution of moisture.

TROWEL—Tool used in slicking, patching, and finishing a mold.

TUCKING—Packing sand with the fingers around flask bars, gaggers, patterns, and other places where the rammer does not give the desired density.

CHAPTER 12

MAKING AND MOLDING A SIMPLE PARTED PATTERN

In chapter 9, you were given the procedure for making the layout for a hinge of a rangefinder port cover. In this chapter you will be given the procedure for constructing the pattern from the layout. If you have studied the blueprint carefully while you were scribing the layout, you should have a reasonably good idea of how to start the actual construction. You will find that most patterns can be made in many different ways, each of which may be equally suitable for the specific job.

In patternmaking, a quick job for the Patternmaker often results in more work for the Molder. One of the first considerations upon receipt of a job order is how many castings are required from the pattern. If only one or two castings are required, the pattern is usually made as simply and quickly as possible. Certain aspects of the work may be left for the Molder to do, such as forming a parting, or cutting a fillet in the sand. If a number of castings are required, the Patternmaker does everything possible to reduce the amount of work involved in making the molds. The Patternmaker makes the parting, attaches the fillets to the pattern, mounts the patterns on a match plate or follow board, and includes the gates and risers as integral parts of the pattern, if necessary. The choice of the particular type of pattern equipment and the detailed method of pattern construction should be determined through consultation (blueprint conference) between the Molder and the Patternmaker. They must select the type of pattern equipment that will enable the Molder to produce a sound usable casting quickly and cheaply. However, this procedure is not necessary for every pattern that is to be built.

CONSTRUCTING THE PATTERN

The type of pattern equipment selected for the hinge pattern under discussion is the single loose pattern. The method of construction selected is the split-half or parted pattern method. After you have completed and checked the pattern layout as described in chapter 9 and have decided upon the method of construction, you are ready to select the stock required for the job. Obtain the measurements from the layout and select two pieces of white pine of appropriate size, making allowance for waste. For this particular job it is not necessary to glue up pieces of stock to form the required shape of the pattern. As in preparing the layout board when making the pattern layout, you must also prepare the parting surface of the stock by jointing, planing, and sanding.

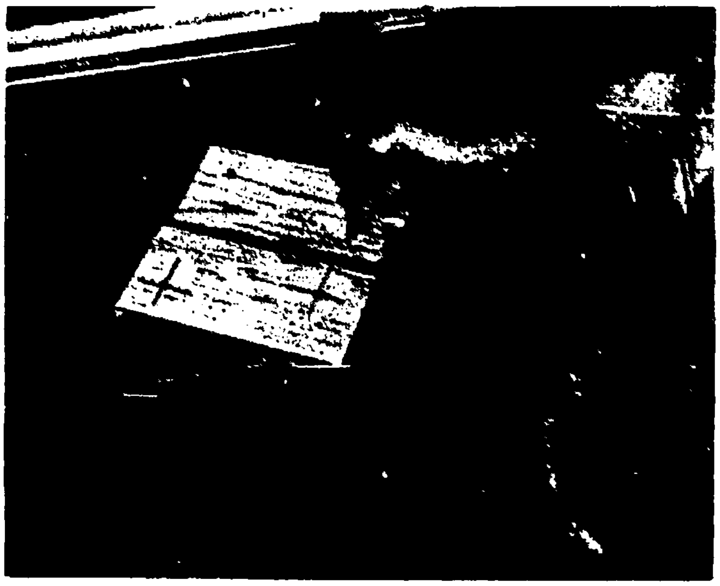
METHODS OF INSERTING AND ALIGNING DOWELS

Figure 12-1 illustrates the next step, boring holes for dowel pins. A metal dowel pin is usually employed to hold the pattern parts in alignment during the ramming-up process. The pins are placed on the underside of the stock as far apart as possible, in order to keep the halves in alignment. Either a drill press, hand drill, or a brace and bit may be used to bore the holes for the dowels. A special T-wrench is used for inserting the metal dowel pins.

Be sure to place the dowels into that part of the stock which will form the pattern. If you fail to do this, you might find that the dowels are cut away with the waste stock when the pattern is trimmed to size. Be sure, also, to locate the dowels so that the two halves of the pattern will only fit in one way—the correct way. This prevents the Molder from mismatching the parts in ramming up top (cope) and bottom (drag) halves of the pattern. If only two dowels are used, the best way to guard against mismatching is to use dowels of different diameters.

The male (pin) end of the dowel is always placed in the cope half of the pattern, and the female receptacle is always placed in the drag

44.20(68)
Figure 12-1.—Boring holes for dowel pins.



68.88
Figure 12-2.—Inserting dowel pins.

half of the pattern. This permits the Molder to place the drag half of the pattern face down and flush against the bottom molding board during ramming, as well as making it easier to strike off the face of the mold after it has been rammed and rolled over. Figure 12-2 shows the insertion of the male dowel pins. Holes are drilled; and dowel pins are inserted by using a special wrench. It is most important that the dowels be lined up perfectly so that they will prevent movement but permit easy separation of the parts.

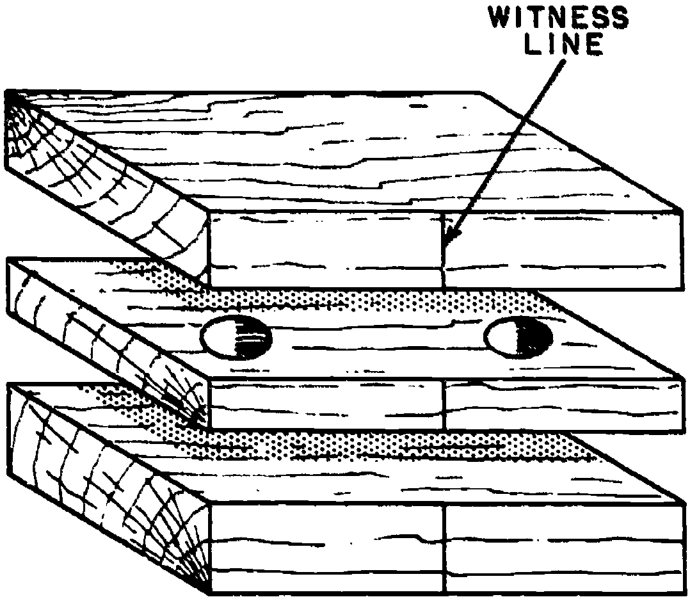
Drilling Method

The simplest method of drilling the dowel holes is the through drilling method. This method consists of placing the two halves of pattern stock face-to-face and toe-nailing them together. Mark the position of the dowel holes on one of the outside surfaces of the stock. Using the proper size drill for the metal dowel to be inserted, drill through the cope half of the pattern stock and into the drag half of the stock. The depth of the hole in the bottom half should be slightly greater than the length of the inserted portion of the dowel to keep the dowel from bottoming. (Bottoming is a trade term used to indicate that an object will not go into a hole to the desired depth because of a too shallow dimension.) Remove the toe-nails from the stock and insert the dowels. The holes left on the top side of the cope half of the pattern stock may be plugged with a wooden dowel.

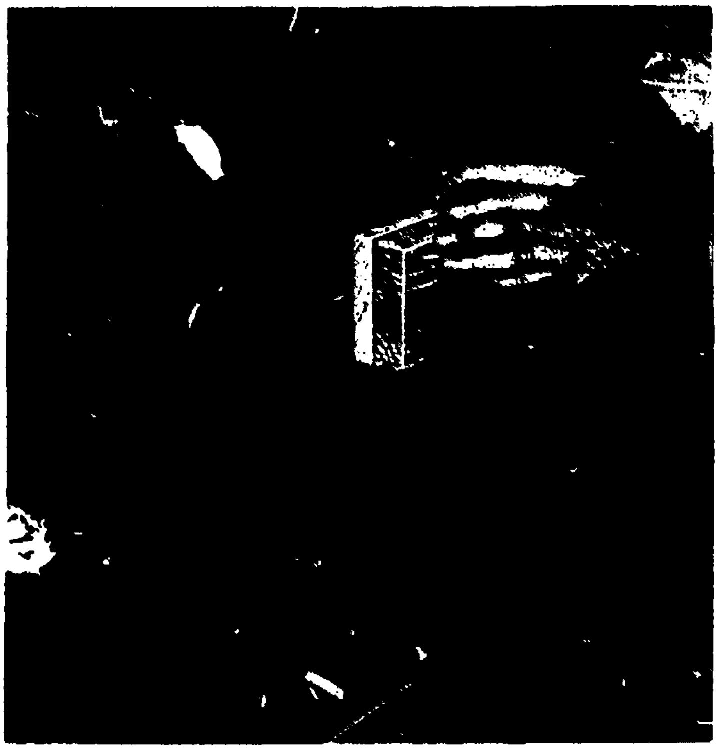
Sandwich Method

A simple way of lining up dowel holes in cope and drag halves is as follows: Drive two brads (one for each dowel) into one half of the stock. Cut off the heads of the brads leaving a small portion of the brad protruding beyond the surface of the stock. Place the two halves of the stock face-to-face and press them together firmly. The projecting brads will mark the centers for the dowels. This is a quick method that is suitable for most work of ordinary accuracy. Where close precision work is required, you should use a dowel template as shown in figure 12-3. The steps in the procedure are as follows:

1. Get out the stock for the pattern and square two edges with the parting surface.



68.89
Figure 12-3.—Using a dowel template.



68.90
Figure 12-4.—Truing up the working edge.

2. Get out a thin piece of stock about 1/8 to 3/16 inch in thickness and square one edge for use as a template.
3. Sandwich the thin template between the two halves of the pattern stock and scribe a witness line as shown in figure 12-3.
4. Remove the top half of the stock and brad the thin template to the bottom half of the pattern stock, making sure that the witness lines are lined up and that the edges are square.
5. Determine the location of the dowel holes and drill through the thin template into the stock to the correct depth for the dowel.
6. Repeat this procedure to drill the holes into the other half of the pattern stock. Line up the witness lines and drill through the holes in the template stock to the required depth.

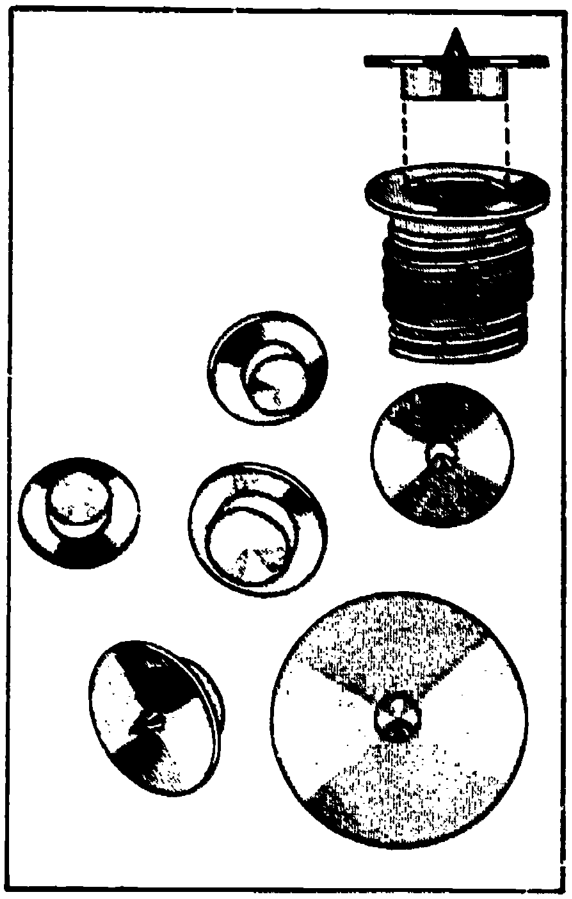
You frequently will find that the two pieces of stock will have shifted slightly after insertion of the dowel pins. True up the working edge of both pieces of stock on the jointer once again, as shown in figure 12-4. This gives you a square edge from which to make accurate measurements in laying out the working drawing on the pattern stock.

Transfer Point Method

When it becomes impracticable to bore holes for the dowels through the pattern or when it is inconvenient to use the sandwich method, it becomes necessary to use an entirely different method. Steel dowel centers known as transfer points (see fig. 12-5) are used to locate the center of the dowel hole on the opposite half of the pattern. The drag holes are bored and the female (socket) dowels are inserted. The transfer points are pushed into the sockets of the female dowel and by placing the cope half of the pattern or core box over the drag half, the exact center for the male dowels is accurately located. Notice in figure 12-5 that the transfer point just fits the sockets of the female dowel, ensuring an accurate location on the opposite side of the pattern for the male half of the dowel.

TRANSFERRING LINES TO PATTERN STOCK

Using the pattern layout as the basis, transfer the measurements of the hinge from the layout board to the pattern stock. The same procedure described in chapter 9 is employed: (1) the centerline is located; (2) bosses are scribed; and (3) the right end detail and then the left end detail of the hinge are completed. This brings the job to the point illustrated in figure 12-6.



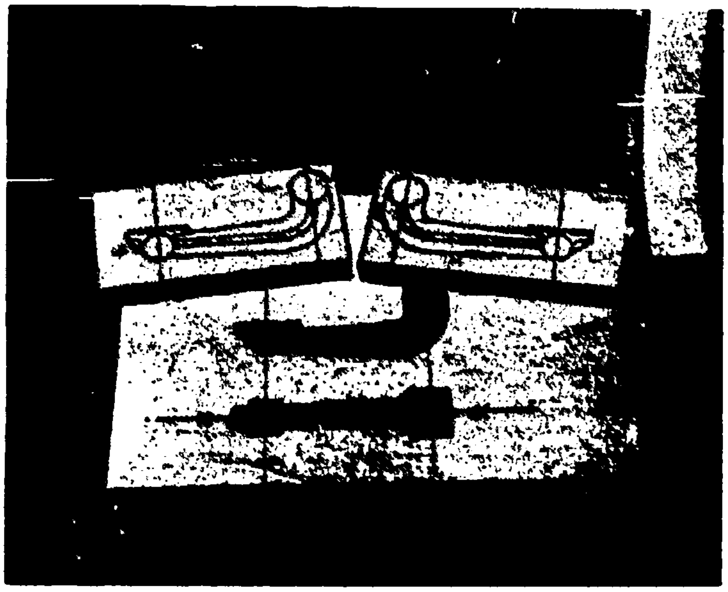
68.91
Figure 12-5. — Transfer points.

Be sure to lay out one right-hand and one left-hand view of the pattern and to avoid the common mistake of laying out two drag halves that will not match.

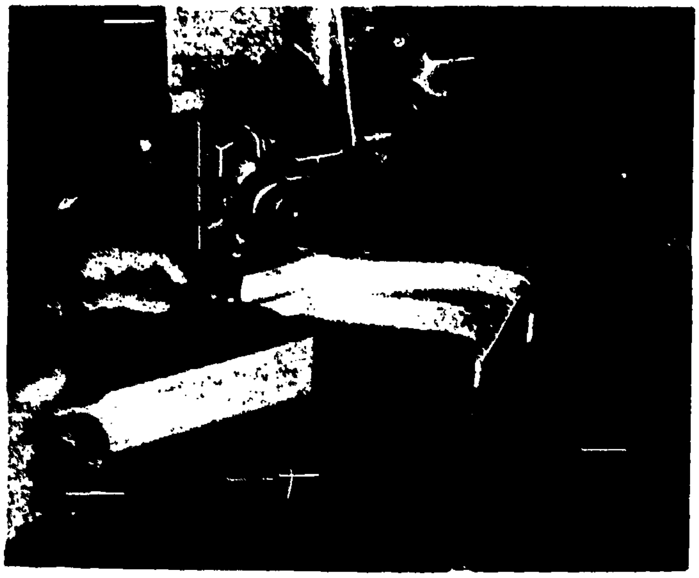
BANDSAWING AND MACHINE SANDING THE PATTERN

The next step is to cut the pattern to the desired length, width, and thickness. For some jobs, the lathe is used to turn the pieces with the ends of the parted pattern halves glued together for 1/2 inch at each end. In the hinge job, use a bandsaw to remove the excess wood, as shown in figure 12-7. You can use a circular saw to cut the stock to the desired width and length. The planer, drill press, and hand plane also can be used to reduce the stock to the thickness desired.

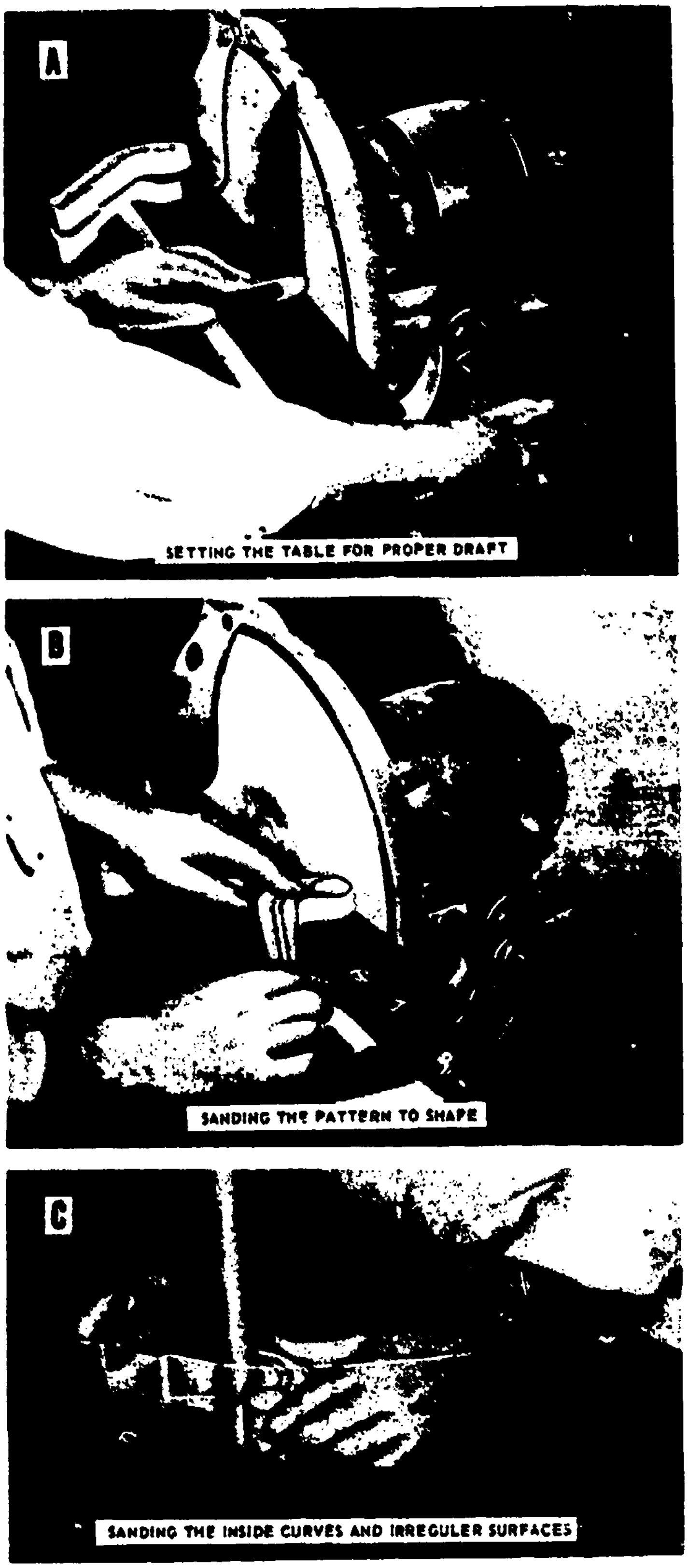
Now sand the outline of the pattern smooth to bring it to the exact dimensions desired, and to give the pattern draft. (See fig. 12-8.) In part A of figure 12-8 the Patternmaker is setting the tilting table at an angle so that the outside surface will be slanted. In part B of figure 12-8 he is completing the sanding job by operating a sander spindle to smooth out the inside curves.



23.27(68)F
Figure 12-6. — The pattern laid out preparatory to cutting.



29.137(68)D
Figure 12-7. — Sawing the pattern.



68.92
Figure 12-8.—Sanding.

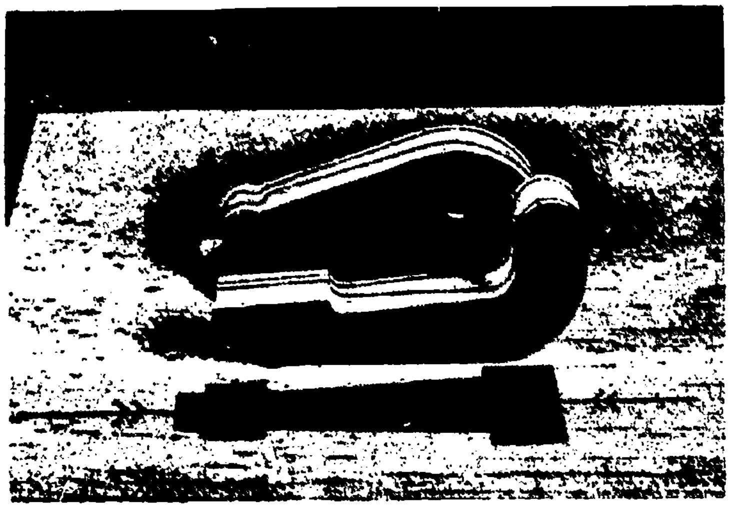
HAND-CARVING
THE PATTERN FILLETS

For the hinge pattern, you do not have to provide any cores, core prints, or core boxes. However, you must carve a rib for each side of the pattern. Figure 12-9 illustrates the start of this step. Here the Patternmaker has scribed the outlines of the ribs on the stock. He next proceeds to cut them out, as shown in figure 12-10. In part A of figure 12-10, the Patternmaker is boring away excess wood. Then he carves away some more of the excess wood, as illustrated in part B of figure 12-10, being careful to leave enough material for carrying the fillets.

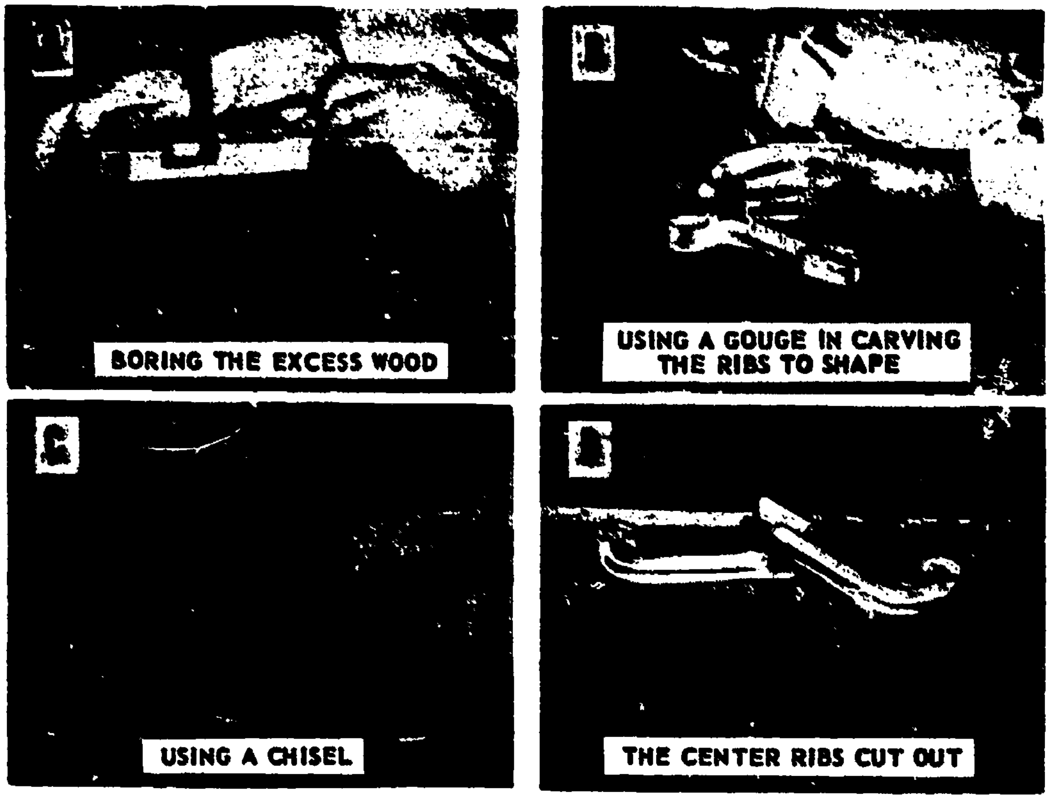
In part C of figure 12-10 he is completing the carving of the rib to shape with a chisel. In part D of figure 12-10 you see the center ribs cut out and the pattern ready for the carving of fillets.

In some cases it is possible to carve the fillet out of the pattern stock. This built-in type is comparatively durable and strong. It is commonly used for long straight angles or very flat curves. Figure 12-11 shows the Patternmaker cutting a fillet on the hinge pattern.

Leather fillets are run on patterns when speed is a factor and durability is not required. Two methods are employed to secure leather fillets to a pattern. One method is to use shellac as an adhesive agent, and the other method is to glue the fillets to the job.



23.27(68)G
Figure 12-9.—Laying out the sides.



68.93

Figure 12-10.—Cutting the ribs.

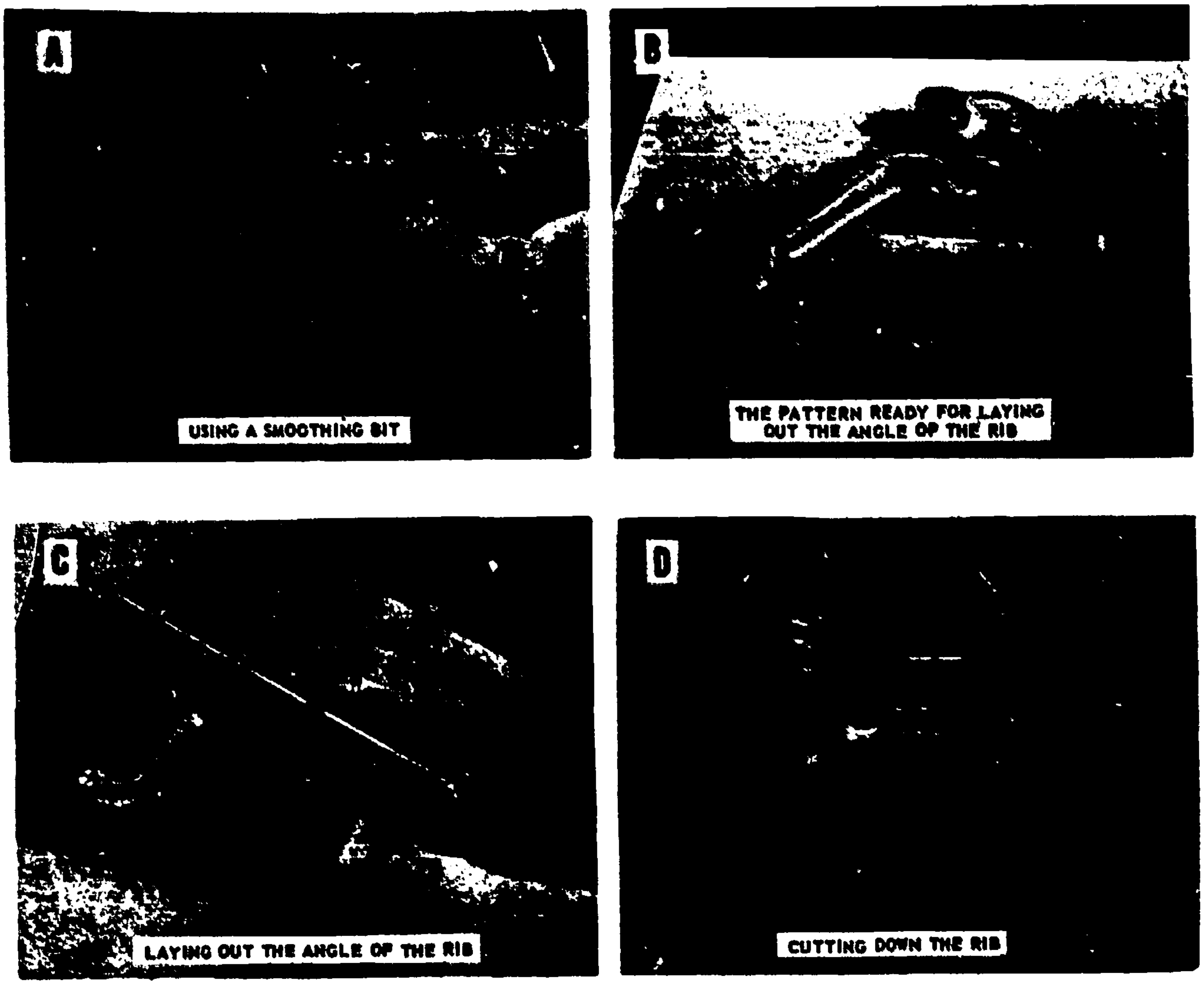
68.94

Figure 12-11.—Carving a fillet.

You are now ready to complete the pattern construction in the series of steps shown in figure 12-12. In part A of figure 12-12 you see the Patternmaker using a smoothing or Forstner bit to remove excess stock. Part B of figure 12-12 shows the pattern ready for final cutting of the rib. Part C of figure 12-12 shows the use of a surface gage in laying out the angle of the rib. Part D of figure 12-12 shows the use of a Forstner bit in cutting the rib down to the scribed line.

CHECKING AND FINISHING THE PATTERN

This brings you to the final step—which is finishing the pattern. (See fig. 12-13.) Part A of figure 12-13 shows one completed pattern ready for sanding. Part B of figure 12-13 shows one method of securing the pattern with a clamp in the bench vise to facilitate final sanding by hand. Next, brush the wood dust from the pattern and apply a smooth, even coat of shellac as shown in part C of figure 12-13. You should provide adequate ventilation when sanding and shellacking to reduce the harmful effects on the lungs of



68.95

Figure 12-12.—Completing the pattern.

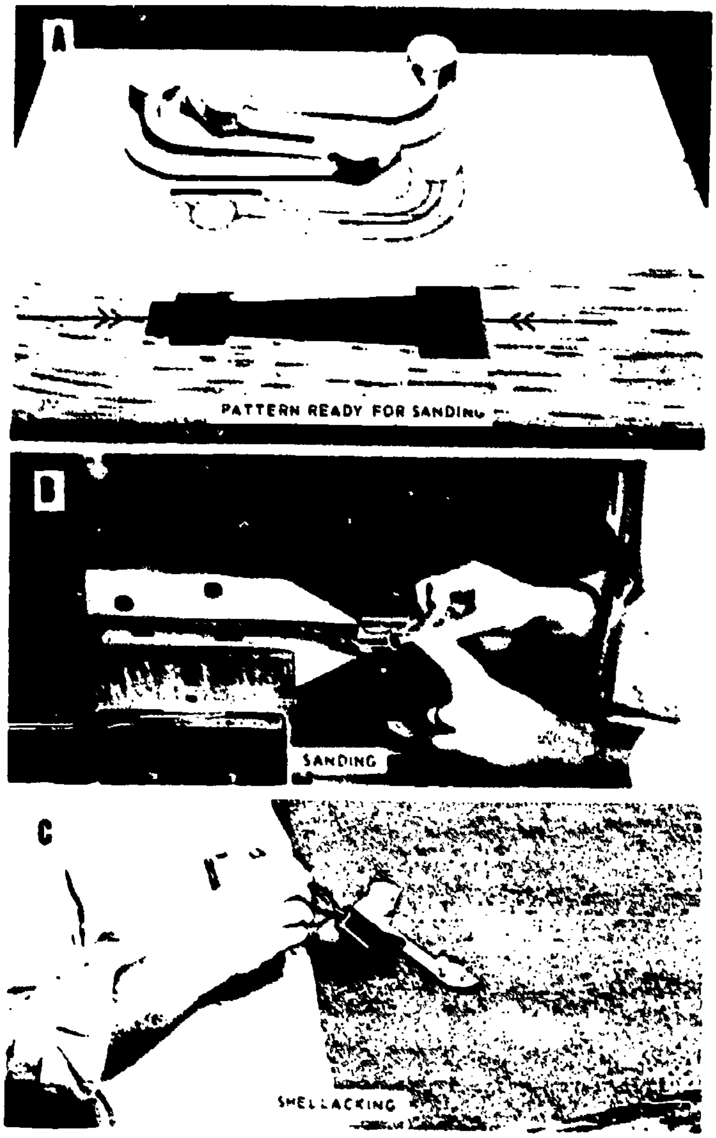
sandpaper dust and shellac fumes. Coat the pattern with appropriate colors in accordance with the standard pattern color code. After the final coat of shellac has dried, fasten the metal identification tape to the pattern with small brads; then doublecheck the completed pattern for accuracy against the layout and the blueprint. Figure 12-14 shows the completed pattern ready to go to the foundry for molding and casting.

The Patternmaker's job is to make a wooden pattern for the Molder to use. The Molder takes the hinge pattern, embeds it in treated sand, withdraws the pattern, and fills the cavity with the molten bronze. This process is discussed briefly and illustrated here. For a complete understanding of the Molder's job, read the Navy Training Manuals prepared for the Molder rating.

RAMMING AND POURING THE MOLD

Figure 12-15 shows the first step in the molding of the hinge pattern. The Molder has placed the bottom or drag half of the pattern on a smooth board, called the molding board or pattern board. The bottom half of the flask, known as the drag, has been placed upside down on top of the mold board. Notice that the pattern is set a little to one side of the center to provide space for the gating and risering systems to be added later in the molding procedure. A fine, dry material, called PARTING SAND or partine, is dusted on the pattern to prevent the moist molding sand from sticking to it.

Next, sand is sifted through a sieve, called a RIDDLE, until it covers the pattern for about



68.96
Figure 12-13.— Finishing a pattern.

23.27(68)H
Figure 12-14.— The completed pattern.

1 1/2 inches. Foundry sand is different from the sand you find at the seashore. It must be PLASTIC, so it can be formed into whatever shape is desired; COHESIVE, so that it will hold the shape; POROUS, so that the gases formed when the molten metal is poured into it can pass through it; REFRACTORY, so that it does not burn or melt. Sands used for molds are tempered by adding water and mixing them so that they have a correct moisture content.

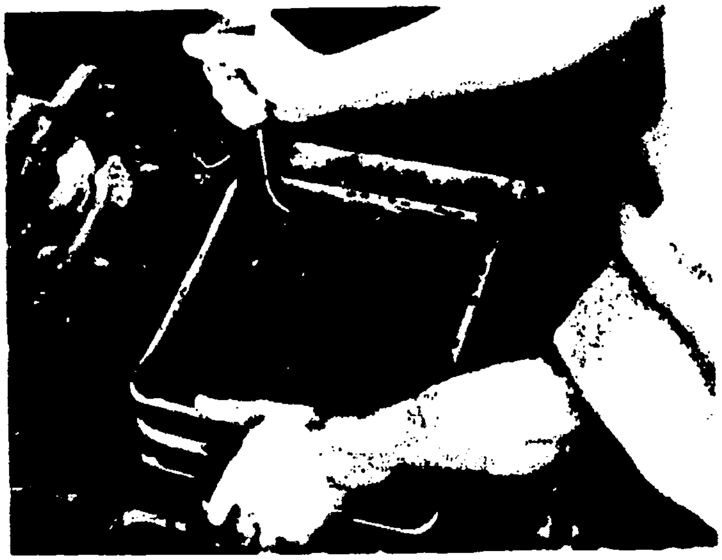
Using his hands for packing, the Molder tucks the sand firmly around the pattern and edges of the flask. Then he fills the drag with molding sand.

68.99
Figure 12-15.— The pattern in the drag.

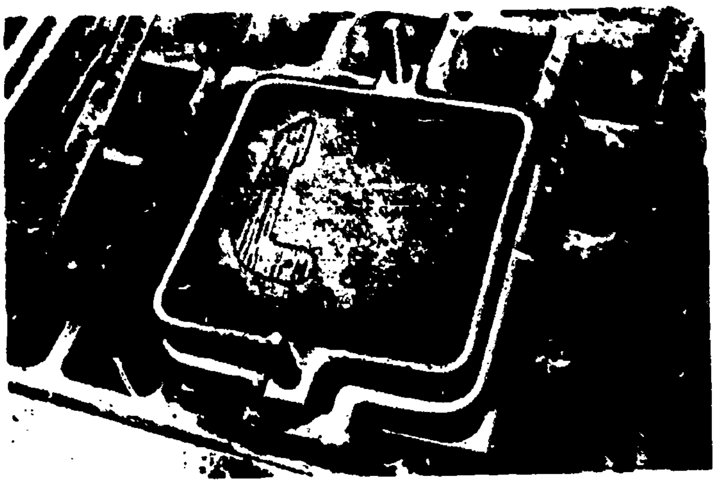
The next step is illustrated in figure 12-16. The Molder uses the peen end of a rammer and rams around the sides of the flask to ensure the sand hanging in well. He carefully rams around the pattern and then rams back and forth across the flask. More sand is added and the other end of the rammer, the butt end, is used to pack the sand firmly. With a straightedge, called a STRIKE, the Molder levels off the drag by striking off all excess sand. A bottom board is placed on top of the drag, the drag is turned over, and the mold board is removed. Figure 12-17 shows the drag completed.

The Molder now gets busy on the top half of the flask—the cope. He sets the cope on the drag. Some flasks, known as snap flasks, have corner hinges which must be placed at the same corner of the cope and drag. The top part (cope) of the pattern is placed on the bottom half (drag) making sure that the dowel pins seat firmly in the dowel holes. Parting sand is dusted over the surface of the drag and the pattern. This forms a non-binding film between the two mold sections so that they will not stick together when the Molder separates them later.

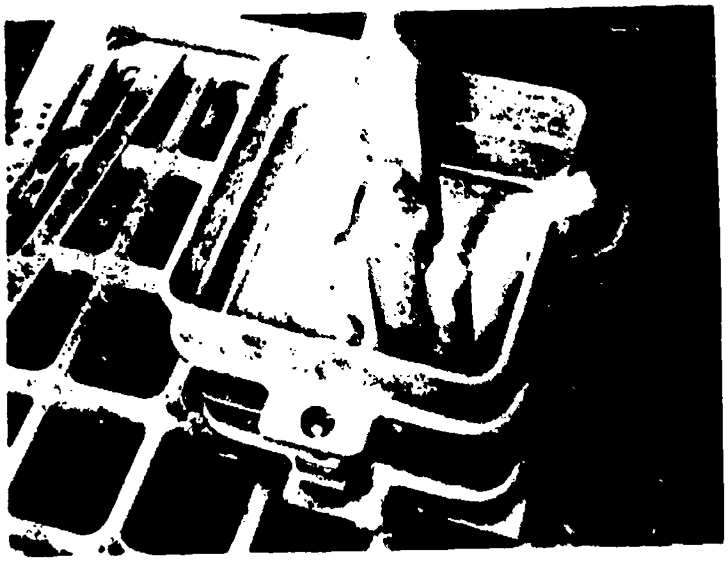
The Molder next prepares openings to permit the metal to be poured into the mold and to rise over the heavy sections of the casting. Figure 12-18 shows how the Molder has placed a wooden sprue stick near the corner, and two



68.100
Figure 12-16.—Ramming with the peen end of a rammer.



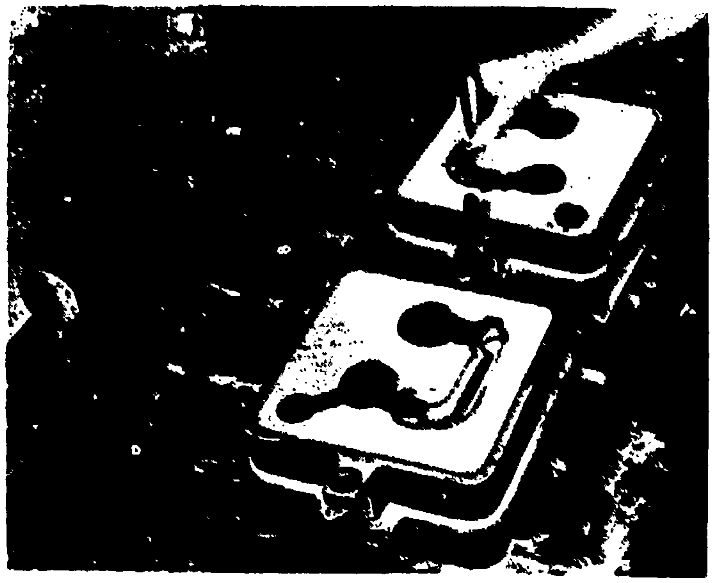
68.101
Figure 12-17.—The drag completed.



68.102
Figure 12-18.—The cope with sprue and riser sticks.

riser sticks near the pattern. The cope is now rammed with sand in the same way that the drag was prepared. When a packed, flat surface is obtained, the Molder partly shapes a pouring basin with a gate cutter, which is a small U-shaped piece of metal. Then he removes the sprue and riser sticks. Figure 12-19 illustrates the result of these steps. The Molder finishes the pouring basin with a trowel or slick. The cope is lifted off and turned over.

68.103
Figure 12-19.—Finishing the cope with a slick.



68.104
Figure 12-20.—Removing the pattern.

The next step is to draw or remove both halves of the pattern from the sand. Figure 12-20 shows the pattern removed from the cope and the Molder removing the pattern from the drag. He is using a draw spike which he has pushed into the center or balance point of the pattern. He will rap the draw spike lightly front, back, and crosswise with a mallet. In this way, he will loosen the pattern. Then he will gently draw it from the drag. If any breaks occur, the Molder repairs them.

Gates or passages are made with a gate cutter so that the metal, when poured, will flow from the pouring basin opening or sprue through the gating system into the cavity formed by the pattern and up into the riser openings. The mold is blown out clean with bellows. Graphite is sprayed or painted on the two surfaces. Figure 12-21 shows the mold ready for closing and the pouring of the metal.

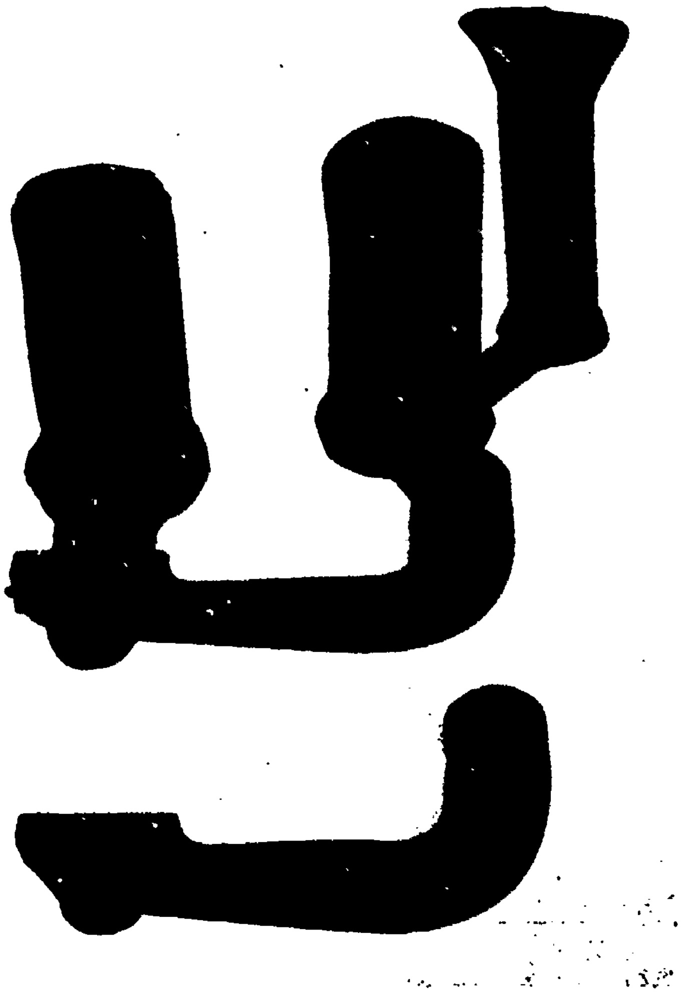
The cope is placed on the drag and the two parts weighted, snapped, or clamped together. The Molder then proceeds to make as many molds of the patterns as required by the job order. Figure 12-22 shows the Molder pouring the metal from a hand ladle into the sprue of the mold. The metal runs into the risers and

68.105
Figure 12-21.—Spraying graphite on the mold.

there serves as a supply while the casting cools. In this way, shrinkage cavities in the casting are prevented. Note in figure 12-22 that the Molder and his helper are wearing safety clothing. The Molder's helper, the skimmer, is skimming or holding back slag or impurities so they will not enter the mold.

Metal castings take from 5 minutes to 3 hours to solidify. Usually, the casting is left overnight to cool off. When the casting has become solid, it is shaken out of the mold. Be sure the casting has cooled sufficiently to permit safe handling. Figure 12-23 shows a comparison of the wooden pattern to the casting. The casting

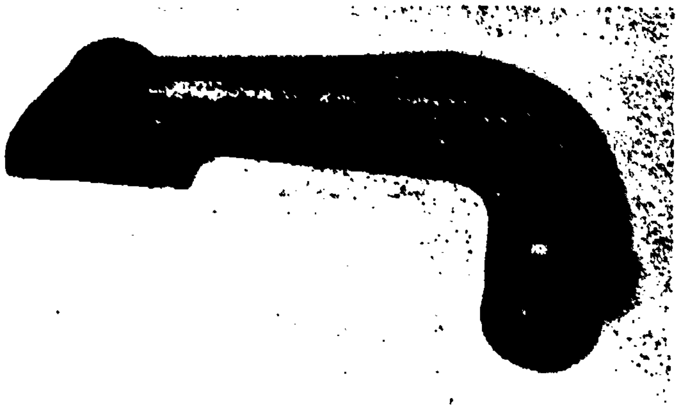
68.106
Figure 12-22.—Pouring molten metal into the mold.



23.27J
Figure 12-23.—Comparison of the casting to the pattern.

still has the sprue, gates and risers attached. The molder then uses a sprue cutter or metalcutting bandsaw to cut off the sprue and risers from the casting. (See fig. 12-24.) The casting is now ready for its final step in the foundry. It is cleaned by a high pressure stream of compressed air and sand or shot. Then it is ground on an emery wheel and hand filed. The hinge casting now appears as shown in figure 12-25 and is ready to go to the machine shop for machine finishing. The pattern is sent back to the pattern shop for storage.

68.107
Figure 12-24.—Cutting the sprue and risers from the casting.



23.27K
Figure 12-25.—The casting as it appears when ready to leave the foundry.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 13.

COPE OVERHANG—An additional draft allowance to cope core prints of a split pattern used to minimize the possibility of crush while seating the cope half of the mold.

MACHINE FINISH—Operation of turning or cutting an amount of stock from the surface of metal in order to produce a finished surface.

MACHINE FINISH ALLOWANCE—An allowance made on a pattern to give additional metal thickness on the casting for the purpose of machining.

STRESS—Inner forces of opposite directions developed in castings during solidification.

CHAPTER 13
CONSTRUCTING A CYLINDRICAL PATTERN AND CORE BOX

As a Patternmaker on a repair ship or tender, you will be required to build a great variety of patterns. It is practically impossible to describe the construction procedures for each and every kind of pattern job you may get. Every job is different and oresents its own distinctive problems of construction. The best that can be done in the limited space available in a training course is to describe a few typical pattern jobs that provide the basic construction procedures. Chapters 9 and 12 presented the detailed procedures for laying out, making, and molding a parted, flat-back hinge pattern which required a combination of hand-carving and machine operations. The hinge pattern was relatively simple and required no cores. The construction procedures described in making the hinge pattern are basic and may be adapted to the construction of many other kinds of parts, such as brackets, hooks, and levers. This chapter will take up the procedures for making the pattern for a hollow cylindrical casting, which calls for more skill, in that a core is necessary in producing the casting. This core requires the construction of a core box.

The representative sample used in this chapter is the pattern for a periscope eyepiece housing. Most of the construction procedures involve lathe turning operations. Much emphasis is given to the precision workmanship required in building the core box. These construction procedures are also fundamental to the construction of patterns and core boxes for many other cylindrical castings, such as bushings, rollers, hollow mandrels, pipes, and spools.

BLUEPRINT CONFERENCE

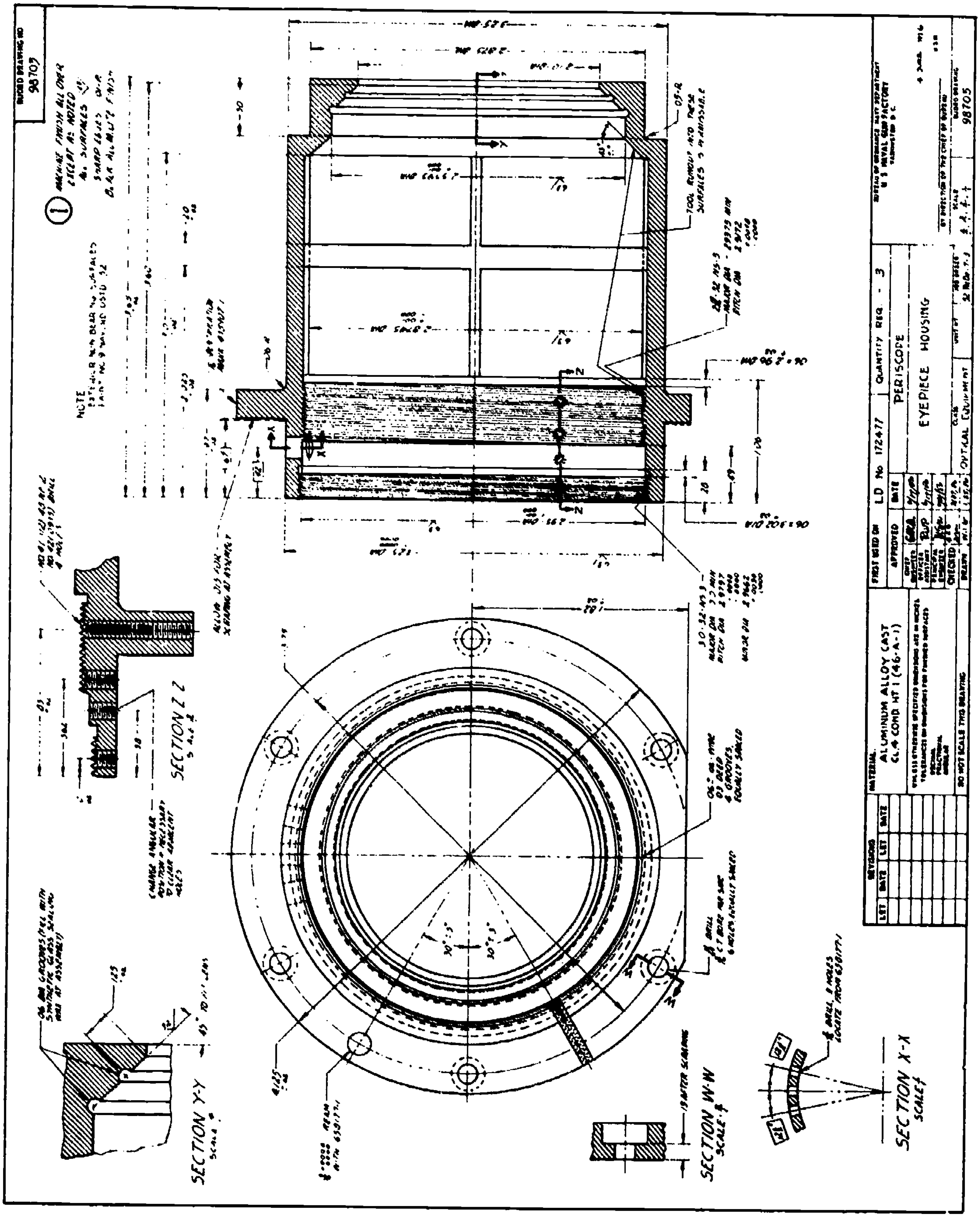
Although the blueprint conference, if any is required, will probably be between the senior Patternmaker and the senior Molder, you as a PM3 or PM2, should know how the planning of a pattern takes place. The blueprint conference aids all parties concerned in obtaining a better understanding of each other's problems and results in the production of a satisfactory pattern and a sound casting in the shortest time and at minimum expense. This conference is usually very informal and consists of two phases: a study of the nature and function of the casting with regard to size, form, and relation to other parts of the assembly; and a study of the methods of construction, and the molding and machine finishing processes required.

Figure 13-1 shows the blueprint of the periscope eyepiece housing which will be discussed in this chapter. Refer to the title block which gives you the following information:

(1) Nomenclature of the part—periscope eyepiece housing;
(2) Kind of metal to be used—aluminum;
(3) Number of castings required—three;
(4) Scale and nature of the object in relation to other parts;
(5) Revisions to the print, if any;
(6) Kind of finish;
(7) Heat treatment data, if required.

In very complicated jobs, the Chief Molder may assist the Chief Patternmaker in determining the size and shape of the core prints required. For other jobs, the Chief Machinery Repairman may offer suggestions concerning the amount of machine finish allowance to be added and possible methods of construction to facilitate machining.

The PMC and the MLC agree that for this particular job a parted pattern with a straight parting line would be the most suitable method of construction. After the details of the pattern construction and molding procedures have been settled, you will receive your instructions from the PMC. The complexity of the specific job usually determines how detailed your instructions will be. For the complex jobs, you may



68.131

Figure 13-1.—Blueprint for periscope eyepiece housing.

be told what views are required for the layout, what shrink rule to use in drawing the layout, what kind and size of fillets are required, and what allowances should be made for machine finish and for draft. For comparatively simple jobs, the PMC will rely on your ability to solve these problems for yourself. This procedure helps to develop your own skills and initiative. Of course, the chief is always ready to offer assistance if you have any difficulty.

DRAWING THE LAYOUT

Remember that the blueprint shown in figure 13-1 is a copy of a drawing made to scale with the conventional mechanical drawing instruments. As a Patternmaker, you use the blueprint as the original source of all measurements, dimensions of the part to be made, and other data. However, you must redraw the part on a layout board with the proper shrink rule, taking into consideration the specific molding requirements, such as shrinkages, finishes, partings, cores, and core prints. The accuracy of the pattern depends upon the accuracy with which you draw the layout.

First, you must study the blueprint so that you know it thoroughly and have an accurate mental picture of the size and shape of the casting. Particular attention should be given to the notes on fillet sizes and other data on the blueprint. Since the title block of the print shows that the casting of the periscope eyepiece housing is to be made of aluminum, you will use a 5/32-inch shrink rule in drawing the layout. When making the layout, use as many views as necessary to give the complete picture of the job.

For this particular job, two full-scale orthographic views (one front view and one side view) will be required. The top view is unnecessary because it does not add significant construction features to the other two views.

The general procedure is to lay out all the solid outline lines, then add the interior or hidden lines. The next step is to add the machine finish in red crayon or black pencil, then add the core prints to complete the layout. Allowance for draft is not usually shown on the layout so you must remember to add it at the time of actual construction of the pattern. For instruction purposes, the layout procedure will be described step by step. It is suggested that you follow these instructions and prepare your own layout for practice.

Select and prepare a layout board large enough for the views to be drawn. (If the layout board is more than 10 inches wide, reinforce it with battens to prevent warping.) Allow additional space for the core prints. Plane the surface of the board smooth. Plane the bottom edge straight and square to use as a working edge in making measurements.

Lay out all outline lines to full-scale on both front and side views. For instruction purposes, the side view will be drawn first. In actual practice, the Patternmaker will lay out his measurements on both views at the same time to avoid any errors that might be caused by the re-setting of his layout tools. With experience, each Patternmaker will develop his own short cuts. Refer to figure 13-2, which contains all the measurements taken from the blueprint, and which also indicates the various steps in drawing the layout. The sequence of steps represents only one procedure for drawing the layout. Each Patternmaker will probably develop his own work routine. Remember, too, that the Patternmaker actually works from the blueprint and that this extra sheet of measurements is shown for instruction purposes only. Refer to the table of decimal equivalents, shown in chapter 8, which you will find to be a great convenience in drawing the layout. You are now ready to start the layout.

Lay out the horizontal centerline, which represents the parting line, and the vertical centerlines, allowing adequate space for the required views. Use the combination square to draw the vertical centerlines, and the panel gage to draw the horizontal centerline. These lines must be drawn with great accuracy, because they will be used as the basic reference lines for subsequent measurements.

LAYING OUT THE SIDE VIEW

In laying out the side view the steps are as follows:

STEP 1: Measure and scribe a line 3.65 inches (approximately 3 21/32 inches) to the right of the vertical centerline. A check of the table of equivalents shows that 3 21/32 inches is actually equivalent to 3.6563 inches rather than 3.65 inches. A good rule to follow in patternmaking is to be slightly on the heavy side rather than to run the risk of having an insufficient thickness of metal in the casting. Moreover, the minute extra thickness of a

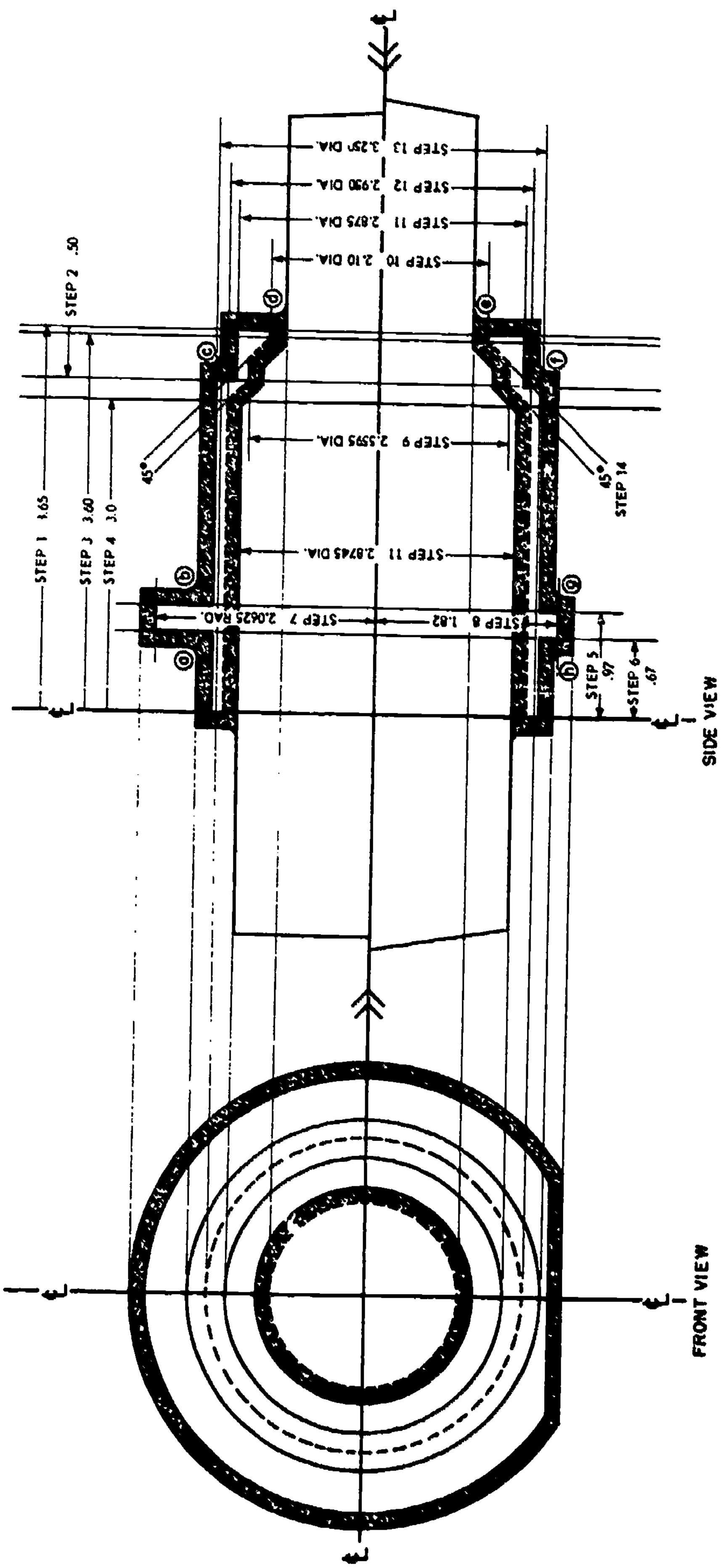


Figure 13-2.—Layout showing measurements and steps.

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particular part of the pattern may always be taken down by one or two light strokes with finishing sandpaper. This policy will be followed throughout the layout procedure and will serve to explain slight discrepancies between fractional and decimal equivalents.

STEP 2: Measure and scribe a line .50 inch to the left of the line drawn in step 1.

STEP 3: Measure and scribe a line 3.60 inches to the right of the vertical centerline.

STEP 4: Measure and scribe a line 3.0 inches to the right of the vertical centerline.

STEP 5: Measure and scribe a line .97 inch to the right of the vertical centerline.

STEP 6: Measure and scribe a line .67 inch to the right of the vertical centerline.

STEP 7: Measure and scribe a line 2.0625 inches upward from the horizontal centerline to locate the top of the flange.

STEP 8: Measure and scribe a line 1.82 inches downward from the horizontal centerline to locate the bottom of the flange.

Doublecheck all your measurements as you go along. Do not wait until the entire layout is completed to try to locate any errors. Also, blacken in the knife lines of the outline of the pattern as you go, to avoid the confusion of a mass of scribed lines.

STEP 9: Set the dividers and scribe an arc above and below the horizontal centerline to lay out the diameter of 2.5595 inches.

STEP 10: Set the dividers and scribe an arc above and below the horizontal centerline to lay out the diameter of 2.10 inches.

STEP 11: Set the dividers and scribe an arc above and below the horizontal centerline to lay out the diameters of 2.875 inches and 2.8745 inches.

STEP 12: Set the dividers and scribe an arc above and below the horizontal centerline to lay out the diameter of 2.950 inches.

STEP 13: Set the dividers and scribe an arc above and below the horizontal centerline to lay out the diameter of 3.250 inches.

STEP 14: Scribe the two 45° angles called for on the blueprint.

STEP 15: Add the machine finish allowance. Referring to the blueprint, you will notice that all the surfaces are to be machine finished. Next, consult table 10-2, Machine Finish Allowance Guide, in chapter 10, for the amount of machine finish required for an aluminum casting under 12 inches. You will note that the machine finish allowance is 1/16 inch. Add an extra 1/16 inch to the outside dimensions, as well as to the internal bore of the layout. When adding machine finish allowance to internal surfaces, the finish allowance is actually subtracted from the finished dimension. In other words, the finish allowance will make the internal bore on the layout smaller. (See fig. 13-2.) For some jobs, you may have to confer with the Machinery Repairman to determine whether or not he agrees with the use of the machine finish allowance listed in the guide. To identify the surfaces that require machine finish, color them with red crayon or with black lead pencil. To facilitate machining, finish allowance is usually added as a panel of uniform thickness. Use your best judgment in providing a sufficient thickness of metal for machining, and at the same time, avoid excessive thichnesses which may cause hot spots or shrinkage cavities in the casting.

STEP 16: Scribe a fillet with a radius of 1/16 inch at points, a, b, c, d, e, f, g, and h, shown on figure 13-2.

STEP 17: Add the core prints.

In very complicated jobs, the Patternmaker will confer with the Molder at this stage of the layout. Since there are no special complications on this job, you, as a PM3 or PM2, will probably use your own judgment or receive instructions from the PMC. You know that in order to support the core in the mold, it is necessary to extend the core prints from each end of the pattern. The core prints are usually the same in diameter as those of the respective cores, and are long enough to bear the weight of the core plus the stress of the molten metal as it fills the mold.

The following is a general rule for determining the length of core prints that has proved satisfactory in practice: "For horizontal cores, the length of the core prints should equal one-half the diameter of the core plus one inch." Remember that this is only a general rule and that each job must be considered in relation to its own specific requirements. For example, in this particular job, since the core will be anchored at each end, the possibility of shifting is remote. Therefore, a slight deviation from the general rule may be permitted. For convenience in construction, the length of the core prints decided on is approximately 2 3/16 inches at each end. Scribing the taper and crush (cope overhang) at the ends of the core prints completes the side view of the layout. The cope overhang on the ends of the core prints is illustrated as "X" in figure 13-3.

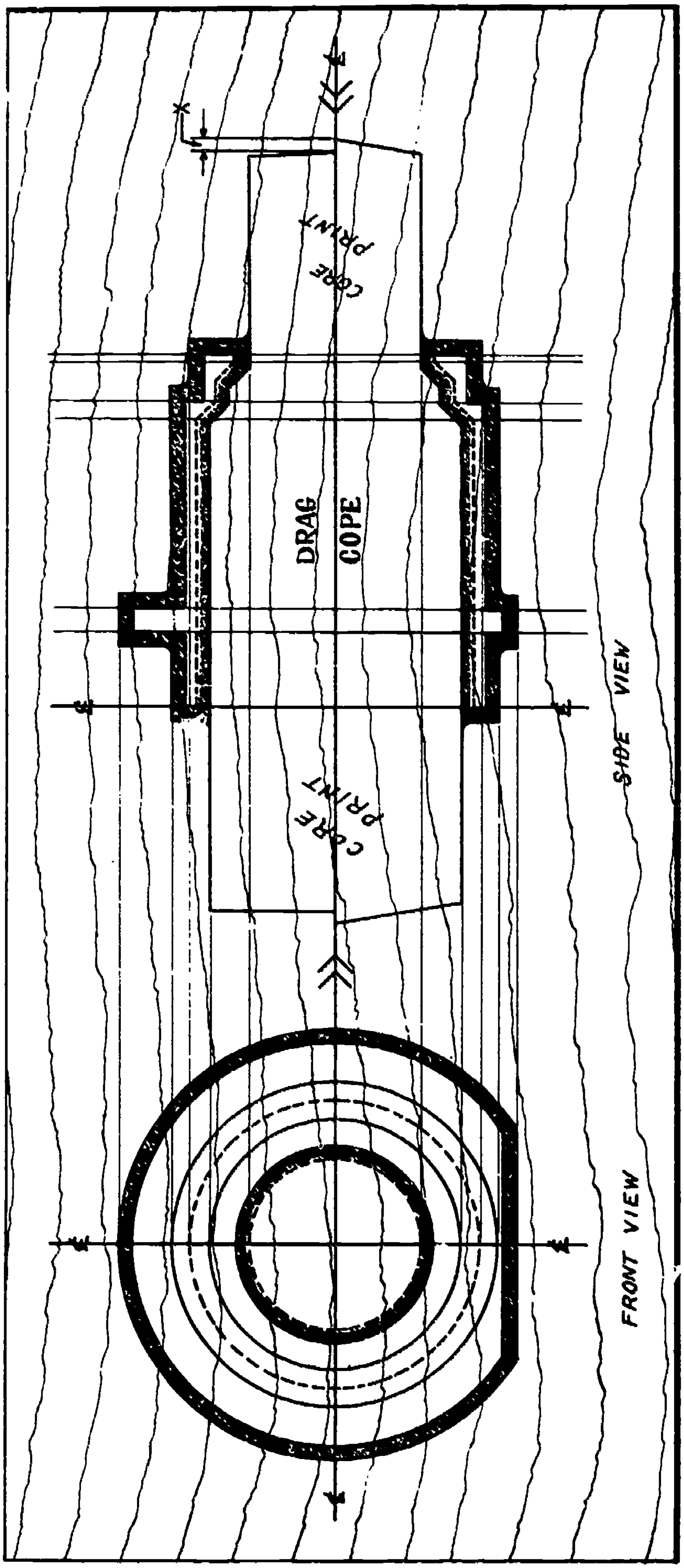

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Figure 13-3. — The completed layout.

LAYING OUT THE FRONT VIEW

Using a panel gage, transfer the necessary measurements from the side view to the front view. Scribe the required circles with dividers. Be sure to flatten the bottom half of the flange shown on the front view. Add the machine finish allowance.

The layout is now complete; your work should look like the drawing in figure 13-3. Identify the parting line by marking it with the symbol:

→ → ———————— ← ←

Check the completed layout against the blueprint to verify all dimensions and to ensure accuracy. It is a good policy to encircle each dimension on the blueprint as you check your work to make sure that you have accounted for all of the important dimensions. These light pencil marks may be erased after checking the layout. You are now ready to proceed with the actual construction of the pattern.

CONSTRUCTING THE PATTERN

After completing and checking the layout for accuracy, study it carefylly and try to visualize the breakdown of the pattern into its component parts for construction purposes. At this point in the procedure, plan all the work processes. Decide which phases of the construction will be accomplished by power machines; which phases will require the use of handtools; what templates will be needed; which fillets can be turned on the lathe, hand-carved, or run in with leather. Always keep in mind the direction of grain of the stock for the following reasons:

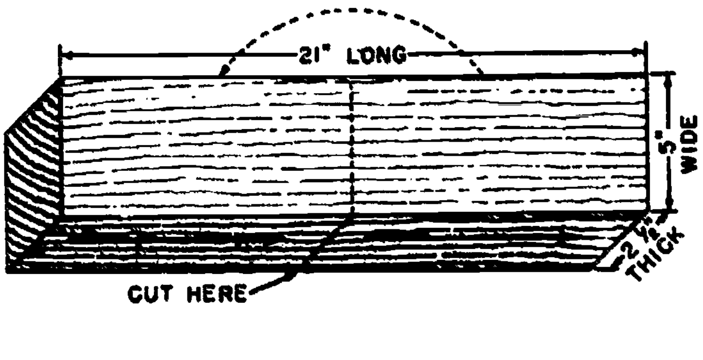
1. To minimize end grain and short grain.
2. To obtain a pattern of maximum strength.
3. To utilize the direction of grain to counteract the warpage of adjacent pieces of stock.
4. To avoid cutting or planing against the grain during actual construction.

The pattern for the periscope eyepiece housing being discussed in this chapter is relatively simple and probably will not require extensive conferences with the Molder. The type of pattern equipment selected is the single, loose pattern. The parted pattern method of construction will be used. You are now ready to get out the stock.

SELECTING AND PREPARING THE STOCK

Referring to the layout shown in figure 13-2, note that the largest overall dimensions, including the core prints, are 8 1/4 inches long by 4 1/4 inches wide, by 2 1/8 inches thick. Allow an extra inch or so on each end of the longest dimension for waste stock. Select a piece of white pine approximately 21 inches long by 5 inches wide by 2 1/2 inches thick. Plane one face of the stock on the jointer. This surface must be perfectly straight and smooth, because later it will become the actual parting surface of the two halves of the pattern. Also, plane one edge of the stock on the jointer to provide a true and square working edge from which you can make accurate measurements. Mark an arrow on the stock with black lead pencil to indicate the direction of the grain. Mark the center of the stock as shown in figure 13-4.

Cut the stock in half along the centerline and place one piece over the other, just as the cope half would fit over the drag half. Locate the dowels in cope and drag halves by measuring from the working edge of the stock. Make sure that the male and female dowel fittings are inserted in the pattern portion of the stock and not in the waste stock at each end. (Refer to the previous detailed instructions for inserting dowels of different size.) Very often the insertion of the dowel pins will cause a slight misalignment of the two pieces of stock. To correct this error, true up the working edges of both pieces of stock once again. Use a hand

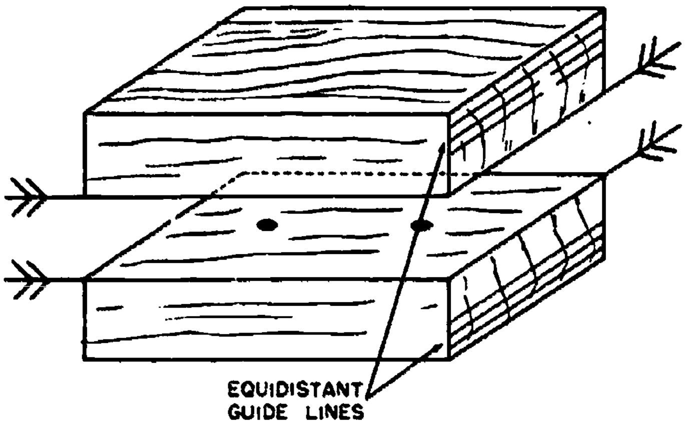


68.134
Figure 13-4.—Selecting and preparing the stock.

jointer plane if the stock is too small to be used with safety on the jointer machine.

When preparing the stock for turning this parted pattern, you must make sure that the parting line, or joint in this step of the job, is exactly in the center. This is necessary so that two symmetrical halves will be turned. This pattern can be drawn from the sand more easily when the maximum diameter is at the parting line. One good way of doing this is by gaging a series of lines equidistant from the parting joint on each end of the stock before the two pieces are fastened together for lathe turning. See figure 13-5. Fasten the parted pieces together by inserting wood screws into the waste stock at each end of the pattern, with the screw holes on one piece counterbored so that the screw heads are below the outside surface. It is very important that the two halves be joined securely to reduce the danger of the work flying apart while it is being turned on the lathe.

Mount the work in the lathe, centering the stock as precisely as possible by sight. Check the accuracy of the mounting by turning a test space about 1/8 inch long at each end of the stock to a perfect circle. If the edge of the circle coincides with two of the gaged lines, one on each side of and equidistant from the parting joint, it indicates that the work has been properly centered. If not, you will have to tap the stock lightly with a rawhide mallet on one side or the other to center the work. You can also make this test by marking off the distance on each side of the parting joint



68.135
Figure 13-5.—Centering parted pieces for lathe turning.

with a pair of dividers. If the distances are the same, then the work is properly centered.

LATHE TURNING OF THE PATTERN

Begin the lathe turning operations by turning the largest diameter required first, and working in sequence down to the smallest diameter. Referring to the layout in figure 13-3, note that the diameter of the flange is the largest diameter required for this pattern. Turn the entire length of the stock to this diameter. When you first start the lathe turning operation, you will notice that the gouge tends to vibrate the stock a good deal. You must be especially careful at this stage to prevent grabbing and to prevent dislodging the work from the lathe. As the corners of the stock are removed and as the work approaches a cylindrical form, the vibrations will decrease and will practically disappear when the piece becomes a true cylinder. It is advisable, in most cases, to start the lathe turning at low speed and then to increase the rpm as the stock approaches a true cylindrical form.

At this stage in the procedure, you must scribe two reference lines to help you locate the pattern on the turned cylinder so that the pattern will be centered with approximately the same amount of waste stock at each end of the cylinder. (Remember that you allowed an additional inch of stock at each end for waste and for the wood screws.)

Actually you use only one of the reference lines at one end of the stock as the guide from which you can make accurate measurements in transferring dimensions of the pattern from the layout to the turned cylinder. This is a critical reference line that must be scribed with care. Locate this reference line on the turned cylinder by measuring a distance of 1 inch inward from one end of the turned cylinder. Touch this point lightly with the tip of a lead pencil or with the pointed leg of a pair of dividers, while the work is revolving in the lathe. Be very careful that the work does not grab while you are marking or scribing this line.

From the layout, pick up the measurement representing the distance between the flange and the beginning of the waste stock. This is approximately 5 inches. Note that it is not necessary to obtain the precise measurement because you have a sufficient surplus of 1 inch of waste stock to compensate for any slight deviation in measurement. Step this dimension off with dividers, as shown in figure 13-6. In a similar way, scribe the line representing the thickness of the flanges, which is 7/16 inch.

Because it is sound pattern practice to turn fillets in the lathe wherever possible, allow an additional 1/16 inch on each side of the flange. After allowing an additional 1/16 inch for turning the fillets at (a) and (b) in figure 13-7, you will find that the total thickness of the flange is 9/16 inch.

Turn the next largest diameter of 3 3/8 inches. Allow an additional 1/16 inch of stock for turning the fillet at (c) in figure 13-7. Turn up the diameter of 3.0 inches on the right-hand side of the pattern. Using the dividers, step off the distance to the end of the pattern and to the beginning of the core print on each side. Turn up the diameter of the core prints. The diameter of the core print on the right-hand side is 1.975 inches; on the left-hand side it is 2.75 inches. Allow an additional 1/16 inch of stock for the fillet between the end of the pattern and the beginning of the core prints at points (d) and (e) in figure 13-7. The fillet between the pattern body and the core print is sometimes called the CRUSH because it reduces the crushing of the sand mold during the molding procedures. Transfer

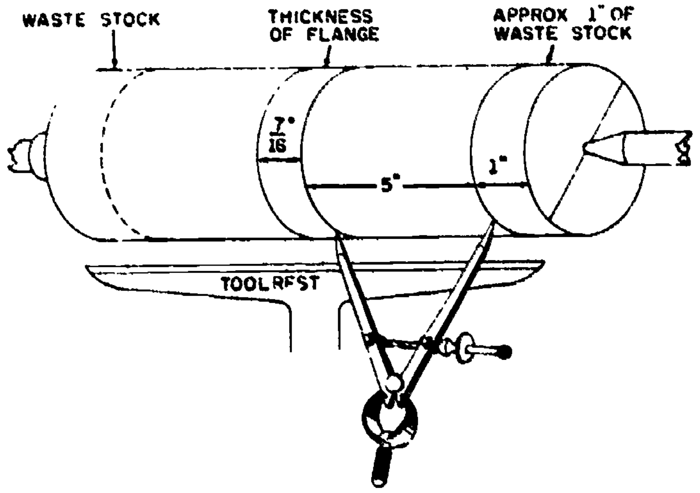


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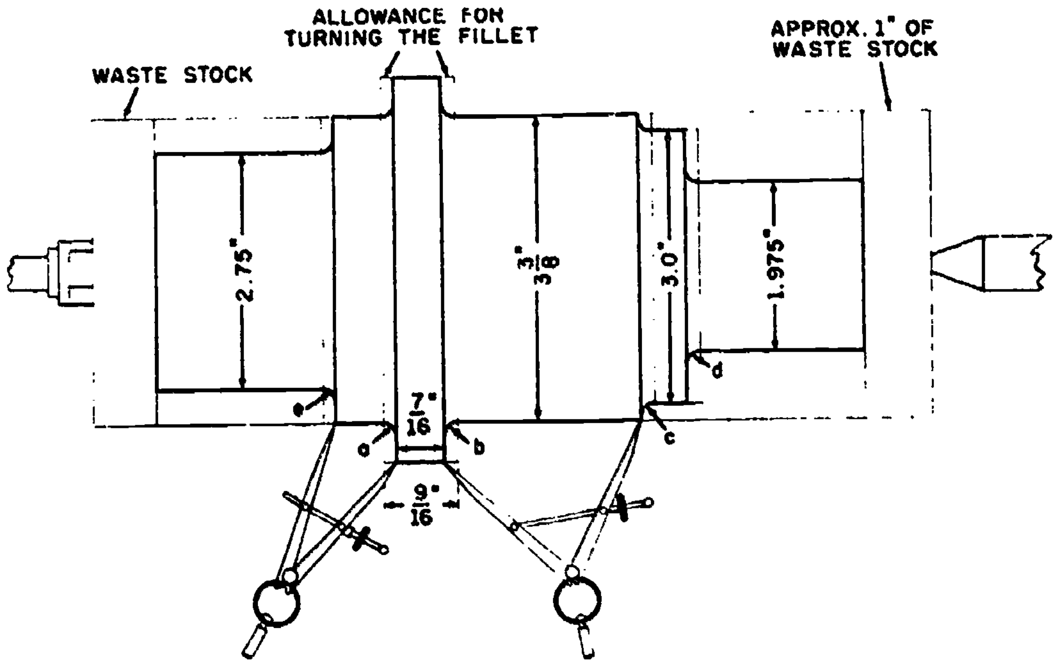
Figure 13-6.—Using dividers to transfer dimensions from the layout to the stock in the lathe.



68.137

Figure 13-7.—Locating the flange of the pattern.

the length of the core prints from the layout to the stock, using dividers. To simplify construction, both core prints are made 2 3/16 inches long.

FINISHING
THE PATTERN

While the work is still mounted in the lathe, apply one or two coats of "yellow" shellac. Sand lightly between coats. Remove the pattern from the lathe, separate the cope and drag halves, and shellac and sand the parting surfaces. Compare the cope and drag halves of the pattern with the layout for accuracy. Notice that the flange on the cope side of the pattern is flattened. Pick up the measurement from the layout and mill off the 2-inch flat surface on a drill press or router, using a Forstner bit followed by a smoothing bit. Saw off the ends of the core prints, allowing for draft on the drag side and draft plus COPE OVERHANG on the cope side. Sometimes cope overhang is also referred to as CRUSH because it prevents tearing of the sand when the mold is closed over. Sand the core prints to the required lengths. Lay off the outline of the core on the parting surface of the drag half of the pattern (Molder's Blueprint). Shellac the completed pattern according to the Standard Color Code. Insert rapping plates and add embossed metal tape pattern letters or figures for identification. Figure 13-8 shows the completed pattern. Note that the pattern shown in figure 13-8, intentionally has NOT been shellacked according to the Standard Color Code to make it easier for you to see the details of the construction of the lathe-turned fillets.

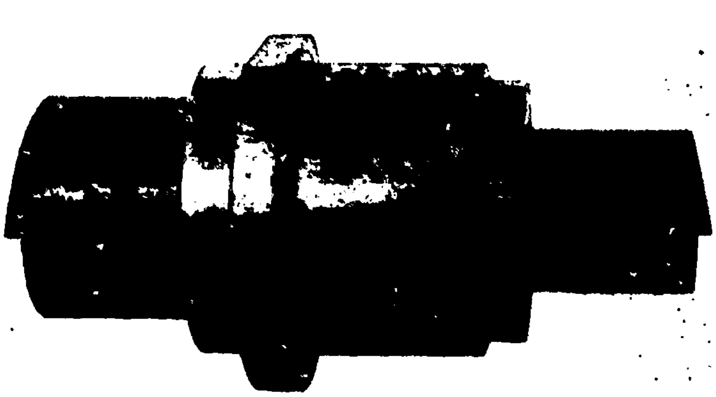
CONSTRUCTING THE CORE BOX

A study of the layout and of the completed pattern of the periscope eyepiece housing will help you to decide on the appropriate method of constructing the core box. For this particular job, an open-end core box of parted construction will probably be most suitable for maximum accuracy. See figure 13-9.

You will notice that the core box is made in two halves which are equivalent to the cope and drag halves of the pattern. Each half of the core box is made up of two blocks of wood fastened together with glue and reinforced with screws. The particular shape of the core makes this method of construction especially desirable, because it reduces the amount of hand carving required and it saves molding time. The Molder can stand the core box on end on a core plate and ram the cylindrical core in one solid mass of sand. The solid core is placed in the core oven to bake, and is soon ready for use in the mold.

For certain similar jobs, where precision is not too critical a factor, you can also use the half-box method of construction. However, before you decide upon this alternate method you must consider very carefully the relative advantages and disadvantages of the half-box. The main advantage of the half-box is that it reduces the amount of work for the Patternmaker, because only one-half of the core box need be built. The disadvantages are twofold:

1. Double work is required for the Molder because he has to ram two halves of the core,



68.138
Figure 13-8.— The completed pattern.

68.139
Figure 13-9.—Core box for the periscope eyepiece housing pattern.

bake them in the core oven, and then paste the two halves together.

2. When the two halves of the core are pasted together, a certain amount of precision is lost, because the thickness of the layer of paste may vary from core to core. Making the core in two halves also results in the formation of a seam or ridge. Usually, in grinding away the ridge, some of the core is also ground away, which, in turn, affects the wall thickness of the casting. The undersized core will not seat properly on the core prints in the mold and will result in an excessive amount of metal wall thickness on one side and an insufficient amount of metal wall thickness on the other side of the casting. This may well cause rejection of the casting.

After considering all these factors, it was decided, for precision, to build the core box using the open-end method rather than the half-box method of construction. The steps of construction are as follows:

1. The first step in constructing the core box is to get out the required stock. You will need four pieces of stock: two for the cope half, and two for the drag half. Picking up the measurements from the layout, you will need two pieces of stock 5 1/2 inches long by 6 1/2 inches wide by 3 1/4 inches thick, and two pieces 3 inches long by 6 1/2 inches wide by 3 1/4 inches thick. These measurements are a little oversize to provide for waste stock. (Length of stock is always measured in the direction of the grain of the wood.) It is advisable to mark an identifying number or letter, in pencil, on each piece of stock to avoid mismatching the parts. See figure 13-10, which shows the dimensions of the stock required for the drag half of the core box. Notice the two adjoining ends of the stock; they must be sanded smooth, straight, and square in perparation for gluing. This glued joint must be perfectly true because you will make many of your measurements from this line.

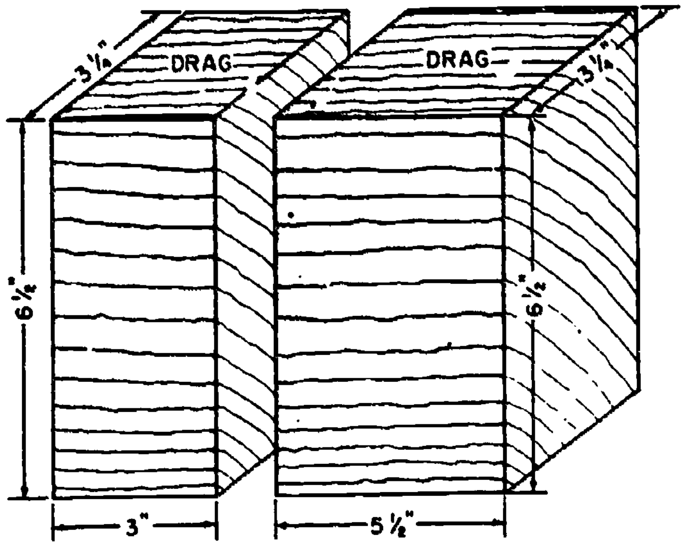
2. Fasten the two parts with screws. temporarily so that the outline of the core can be scribed on the flat parting surface. Use no glue at this point in this procedure.

3. Dress the parting surface on the jointer. Repeat this procedure for the cope half of the core box.

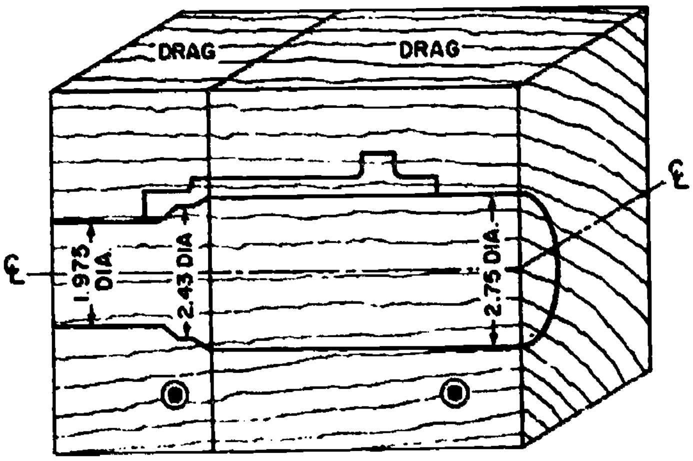
4. Locate the dowels in the parting surface, making your measurements from the joint between the two attached blocks. This joint is used as a vertical reference line to ensure that the male and female dowel fittings line up perfectly.

5. Place the cope half of the core box on top of the drag half and dress one edge on the jointer to give you a true working edge from which you can make accurate measurements during the rest of the construction procedures.

6. Lift the cope half off the drag half and lay out the outline of the core on the parting surface as shown in figure 13-11. Because the



68.140
Figure 13-10.—Getting out the stock for the core box.



68.141
Figure 13-11.—Laying out the outline of the core on the parting surface of the core box.

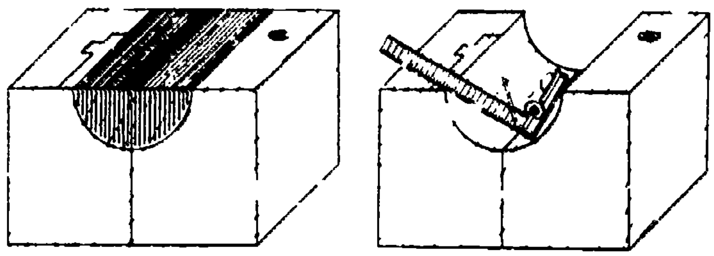
core is perfectly symmetrical about the horizontal axis, you need only to show the wall thickness of the casting on one side. The other side would be identical. Obtain the measurements from the layout, making sure to subtract the machine finish allowance on the interior of the casting. For example, according to the blueprint, the diameter of the small opening of the casting is given as 2.10 inches. An allowance of 1/16 inch (.0625) was made for machine finish on each side. The total allowance for machine finish is then 1/8 inch (.125) which must be subtracted from 2.10 inches to give the exact diameter (1.975) of the core cutting through this part of the pattern.

Allowing for the threads to be cut on the inside wall of the casting, the inside diameter of the main body of the casting is shown on the blueprint as 2.8745 inches. Subtracting .125 inch for machine finish allowance, will give you 2.75 inches as the diameter of the core cutting through the main body of the pattern.

7. Remove the screws and separate the two blocks of stock so that the semicircular outline of the core can be scribed on the ends of the stock.

8. Make a series of kerf cuts on the table saw as shown in part A of figure 13-12, and carve to the line with a gouge. Sand the cavity by hand or on a spindle sander. Test the semicircular cavity with a square as shown in part B of figure 13-12.

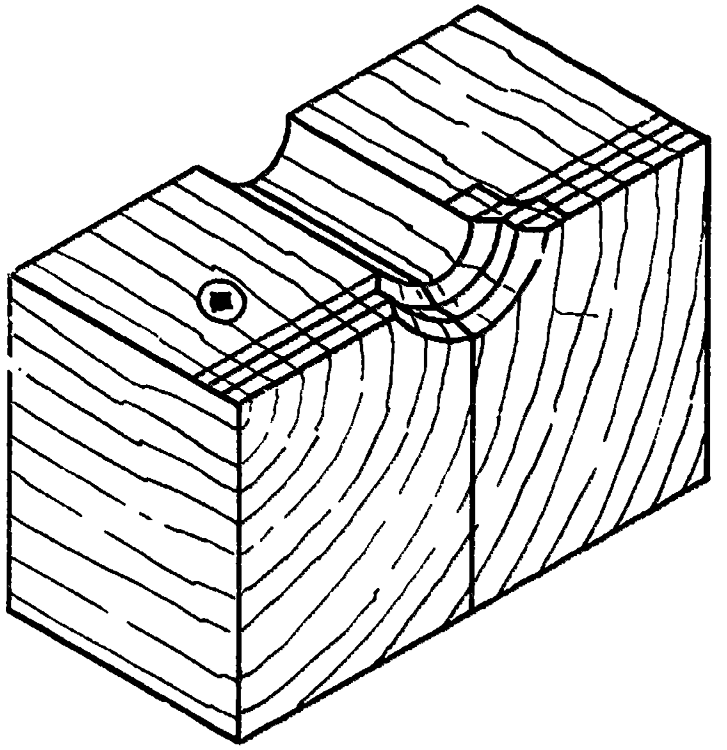
9. Repeat this procedure with the smaller block of stock to form the remaining part of the core and the other core print. Lay out the guide lines on the parting surface of the smaller block of stock and work the 45° angles from line to line by hand as shown in figure 13-13.



A B

68.142

Figure 13-12.—A. Removing waste stock by a series of saw kerfs. B. Testing a semicircular core cavity with a square.



68.143

Figure 13-13.—After completion of the hand carving operations.

10. Reassemble the two parts of the drag half of the core box, gluing and screwing the blocks in place. Plug the screw holes.

11. Obtain the overall length of the core, including the core prints, from the layout and cut and sand the core box to this length. The overall length of the core is taken from the length of the drag half of the layout. Use the glued joint on the parting face as the reference line from which to make your measurements. Sand and shellac the core box using the Standard Color Code.

12. Repeat the procedure in constructing the cope half of the core box. See figure 13-9, which illustrates the completed core box. Note that the core box shown in figure 13-9 has NOT been shellacked in the Standard Color Code, intentionally, so that you would be better able to see the details of construction. The pattern and core box are checked for accuracy and are then sent to the foundry for the molding and casting operations.

GLOSSARY OF TERMS

The following definition of a term is used in chapter 14.

JIG TEMPLATE—Any device made to receive and hold a piece of material for checking or outlining.

CHAPTER 14

FLANGED FITTINGS

This chapter will describe a few of the various methods of constructing flanged fittings and their core boxes. It should be increasingly apparent that there is no single, best method of construction in patternmaking. Each job order must be considered on the basis of its individual specifications before you decide upon the method of construction. Although there are some very general principles of sound pattern construction, there is no fixed set of rules to help you make the correct decision in every instance. You will have to rely on your own experience or on the experience of the senior Patternmaker in the shop.

In making your final decision upon the method of construction, you must consider such representative factors as the following:

1. Number of castings required.
2. Size and shape of the casting.
3. Intended use of the casting.
4. Urgency of the job.
5. Amount of precision required.
6. Number of anticipated reorders.
7. Strength and expected life span of the pattern.
8. Molding procedures to be used.
9. Kind of metal to be cast.
10. Equipment and skill of personnel available.

In each of the various methods of construction described in this chapter, note praticularly the fundamentals of pattern joinery involved. The fundamentals for laying out and constructing a simple parted pattern, a simple cylindrical pattern, and core boxes were previously described in chapters 9, 11, 12, and 13. Once you achieve complete mastery of these fundamentals, you will be able to make the many other types of wood patterns and core boxes required of a PM3 or PM2, including the flanged patterns described in this chapter.

The construction methods involved for flanged patterns will be illustrated by describing samples of the more common fittings such as straight connections, curved connections, Tee-connections, cross connections, and lateral connections. It should be noted that the basic surface developments described in chapter 8 can be applied to this phase of patternmaking.

The representative samples of the patterns mentioned in this chapter, which serve for instructional purposes, illustrate required techniques for good patternmaking practice. Patterns for pipe up to 6 inches in diameter are usually made of solid stock split lengthwise into cope and drag halves. Patterns for pipe larger than 6 inches in diameter are usually stepped up or built up of staves and headers. When only one casting, or just a few castings are required from very large pipe patterns, you will probably use the more economical skeleton method of construction. If you use this method you must also construct SWEEPS or STRICKLES to aid the Molder in the molding procedure. See figure 14-1 for an illustration of skeleton construction.

Although it is not likely that you will ever be required to build a pattern of such large size while serving aboard a repair ship or a tender, the skeleton construction method is illustrated here to give you a greater appreciation of the scope and practical industrial applications of this method of construction.

STRAIGHT FLANGED PATTERNS AND CORE BOXES

A straight flanged pipe fitting (spool, or concentric and eccentric reducers) is basically a short length of pipe with an attached flange on each end. The core required for these fittings should provide uniform wall thickness and strength to all parts of the casting. In the manufacture of a flanged pattern, the inside and the outside may seem simple, but the

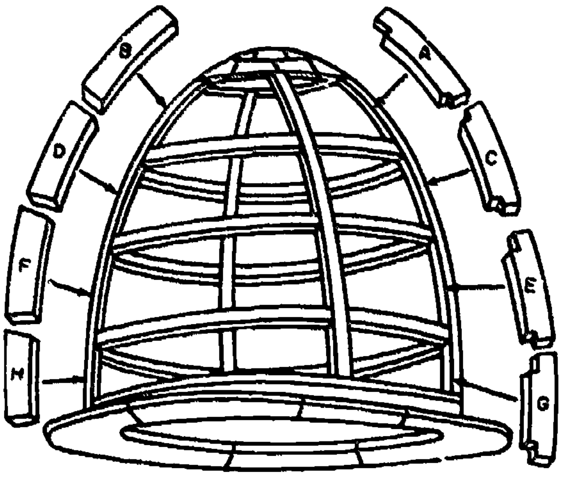


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Figure 14-1.—Constructing a skeleton pattern.

construction methods and pattern joinery used require visualization and considerable skill to construct the pattern and core box.

PIPE SPOOL PATTERNS AND CORE BOXES

The first step in constructing a pipe spool pattern, as in all pattern construction, is to study the blueprint or working drawing (part A of fig. 14-2), and to prepare a full-sized layout (part B of fig. 14-2) using the appropriate shrink rule, and including the core prints and the machine finish allowance. In addition, the layout should include all good pattern construction features, such as, thickness of flange material for flange inserts, position of screws for holding the flange material, and position of dowels. The sequence of operations in the construction of a cast iron pipe spool is illustrated in figure 14-2. Part A of figure 14-2 illustrates a working drawing of a cast iron pipe spool; part B illustrates the complete layout including all necessary information as to its construction; part C illustrates the parted pattern stock turned to rough dimensions; part D illustrates how to determine the thickness of the flange material; part E illustrates the layout of the flange material; part F illustrates the proper insertion of the flange material; part G illustrates the rough turned pattern stock and the inserted flanges prior to the final turning of the pattern; and part H illustrates the finished pattern, the core box, and the casting produced by the pipe spool pattern.

The size of the pattern to be made often determines the method of construction. Because of its relatively small size, this pipe spool pattern will be made of solid stock. The parting line divides the body of the pattern longitudinally into cope and drag halves. Select and dress two rectangular pieces of stock of appropriate size for the construction of the pattern. Fasten the two pieces of stock together face-to-face with screws, center in the lathe for spindle turning, and rough turn to the dimensions, as shown in part C of figure 14-2.

While the body is mounted in the lathe, turn up the recesses into which flanges P and R (part F of fig. 14-2) will be inserted. The recesses must be turned deep enough to provide a firm seating of the flange. In addition, the depth should be below the surface of the pattern to eliminate any feather edges on the fillets.

The inserted flange method of construction is also used in the construction of flanged pipe spools, globe valves, and reducing connection patterns. Inserted flange construction has advantages in that it:

1. Saves material by enabling you to turn up the flanges apart from the main body. (If the main body and the flanges were to be turned up as a unit in one turning operation, it would naturally require that you start with a much larger block of stock.)
2. Makes a stronger pattern because short grain is eliminated.
3. Reduces the tendency of the pattern to warp and provides greater dimensional stability.
4. Makes the lathe turning operation simpler and provides a smoother surface.
5. Simplifies construction by permitting the turning up of the flange fillets while the work is mounted in the lathe and the smooth fairing of the fillets into the main body of the pattern.

Determine the thickness of the flange material by referring to parts B and D of figure 14-2. The thickness of the flange material will include:

1. The fillet turned on the pattern; plus
2. Draft on the inside of the flange; plus
3. Thickness of the flange; plus
4. Finish allowance; plus
5. Draft on the outside of the flange; plus
6. The crush fillet between the outside of the flange and the core print.

Flanges P and R are made separately from the body. Select stock for the construction of the flanges so that the grain of the wood will run transverse to the grain of the wood in the main body. (See part E of fig. 14-2.) This will eliminate structural weakness in the pattern due to short grain. Cut out the flanges, using a bandsaw. Sand the inner scribed semicircle on a spindle sander splitting the line.

Use the flange as a template for turning the recesses in the body of the pattern. Remove the rough turned stock from the lathe and separate the halves of the body of the pattern. Referring to parts B and D of figure 14-2, drill pilot holes for wood screws in the center of the flange from the parting surface of the pattern. Insert wood screws in the pilot holes and secure the flanges in position for reinforcement of the joint. Insert and glue the flanges to the body as shown in part F of figure 14-2. (Note: When determining the position of the wood screw, the position should be in the center of the flange, NOT in the center of the flange insert. See parts B and D of fig. 14-2. Placing the wood screws in the center of the flange eliminates the possibility of running into the screws with lathe handtools when turning the flange and the fillets from the insert.) The edges of the flange inserts are permitted to project above the parting surface of the body in order that they may be planed true to this surface after the glue has set.

Remount the work in the lathe (part G of fig. 14-2 which shows the pattern prior to finish turning), and finish turn the main body, flanges, and core prints to the required size. Fair the body fillet and the crush fillet smoothly into the pattern.

Before removing the work from the lathe, sand the work and apply a light coat of pattern covering. After the covering is dry, sand it lightly. Remove the work from the lathe and separate the halves of the pattern. Cut and sand draft on the drag half of the core prints, matching the length to the layout. Set the cope half of the pattern on the drag half and mark the length of the cope overhang; cut to this length and sand the proper draft. Apply pattern coating in accordance with the Standard Pattern Color Code. The finished pattern will appear as shown in sketch X of part H of figure 14-2.

The pipe spool core box is actually a half dump box. Two half-cores are formed by the box and pasted together to form the completed core. Select and dress stock to the proper size for the box. Using the measurements taken from the layout, scribe the outline of the core and core prints onto the parting face of the solid stock. Scribe the semicircular outlines of the core on the ends of the stock. Cut a series of saw kerfs lengthwise between the semicircular scribed lines. Use a core box plane or a sole plane to smooth out the semicircular cavity for the core. Check the core box as previously described in chapter 3 under the section on the core box plane.

Sand the box smooth and close the ends of the box by attaching end pieces at the proper length and draft angle. The length of the core box is determined by the length of the drag half of the pattern. When two half-cores are pasted together, the length of the cope half of the pattern minus the length of the drag half of the pattern, then divided by two, determines the amount of cope overhang allowance.

Sand the core box and apply a coat of pattern covering in accordance with the Standard Pattern Color Code. The finished core box will appear as shown in sketch Y of part H of figure 14-2. The final casting produced by the pipe spool pattern (X) and the core box (Y) is illustrated as sketch Z of part H of figure 14-2.

REDUCING CONNECTION PATTERNS AND CORE BOXES

A straight reducing connection is basically a pipe spool with a tapered body. (See figs. 14-2 and 14-3 for comparison.) The reducing connection pattern may be parted horizontally as previously described for the pipe spool pattern. However, since the body shape has a taper and is a pressure fitting, the molding procedure for high quality castings may be used. This molding method requires more cores (a cover core as well as a center core) and a larger number of molding operations than does the horizontally positioned parted pattern method. (See chapter 11, Cores and Core Boxes, for a description of molding a pattern with a cover core.)

The sequence of operations for the construction of a straight reducing connection is illustrated in figure 14-3. Part A of figure 14-3 illustrates the working drawing of the reducing connection; part B illustrates the complete

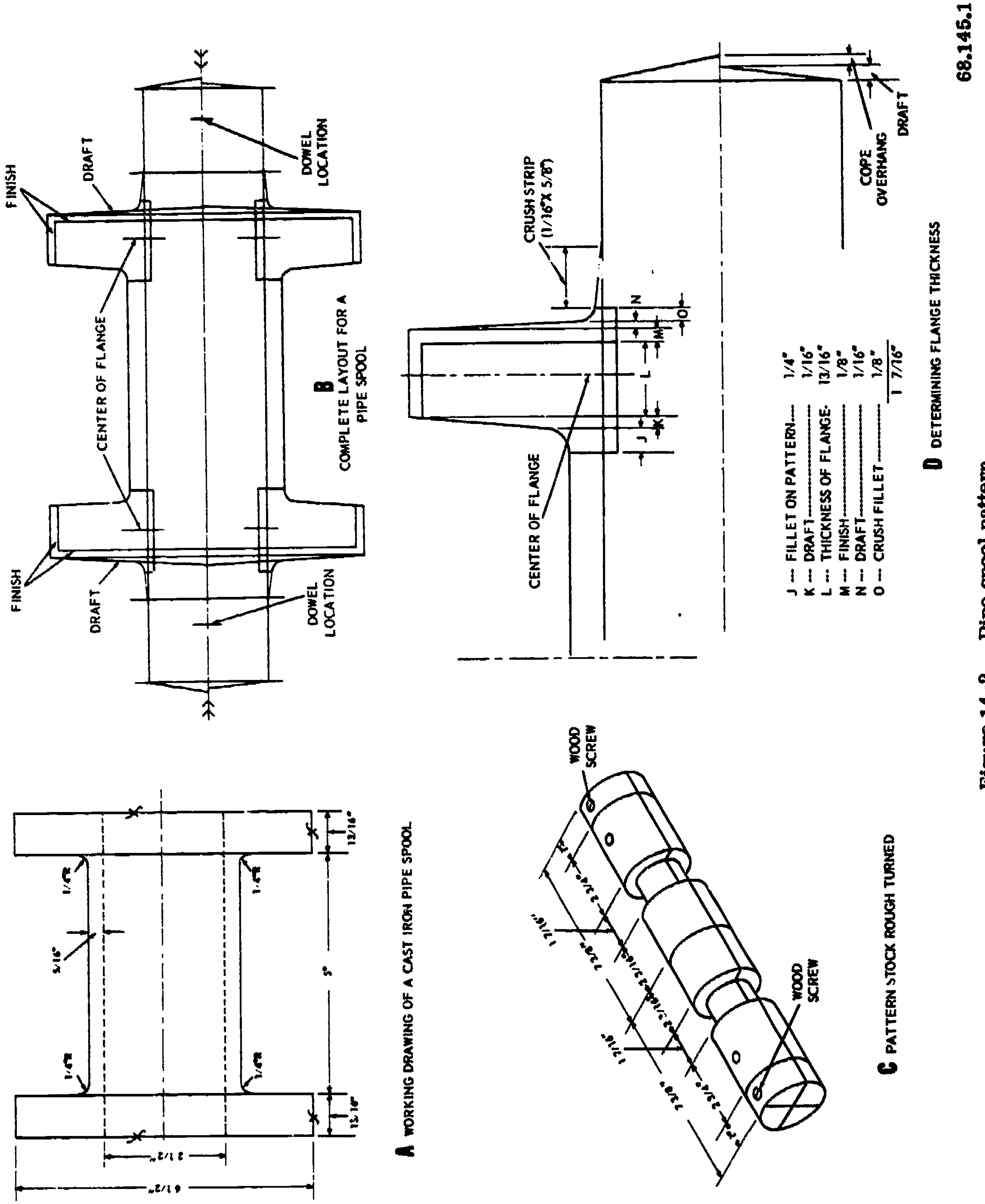

Figure 14-2.—Pipe spool pattern.

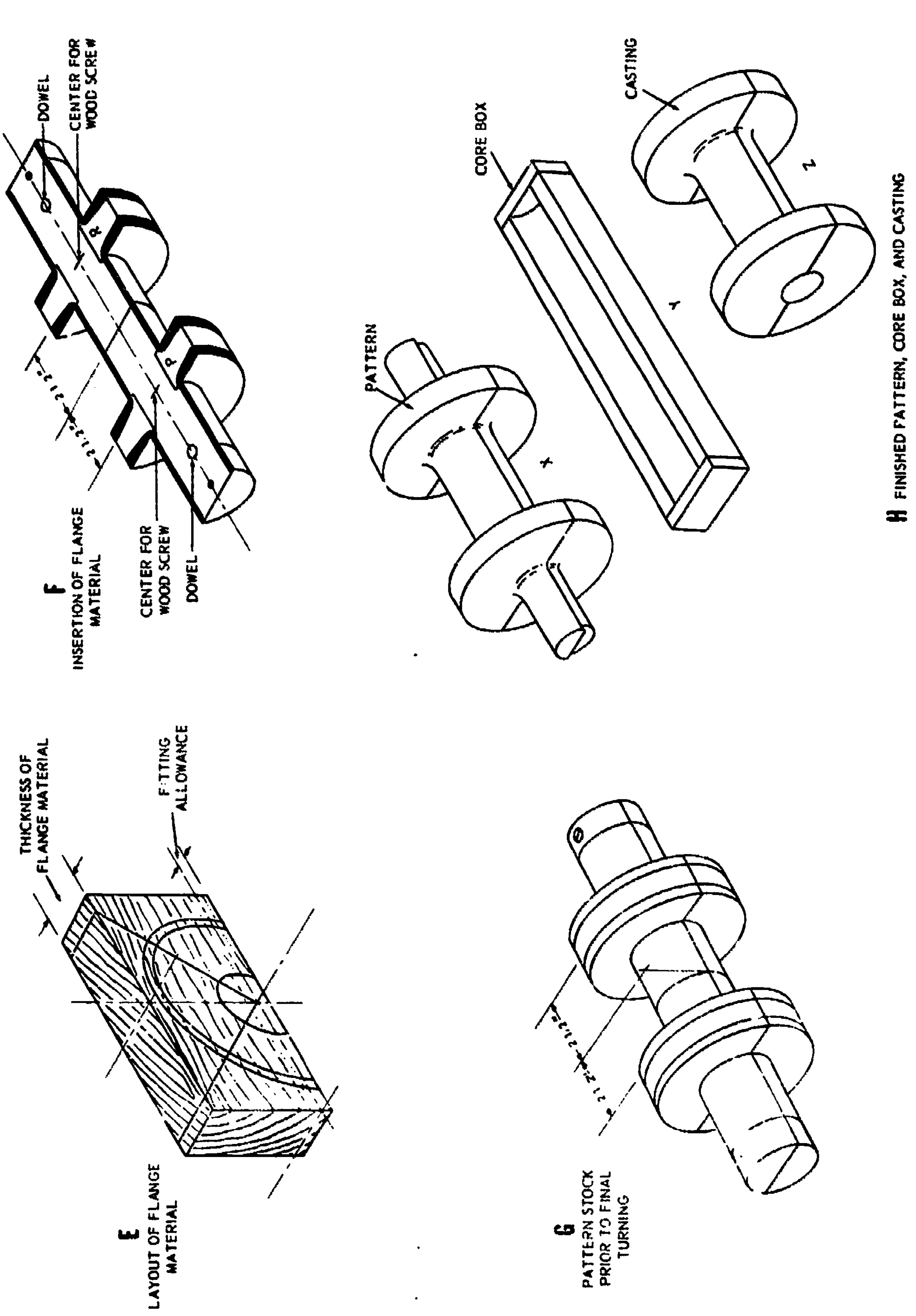

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Figure 14-2. — Pipe spool pattern — Continued.

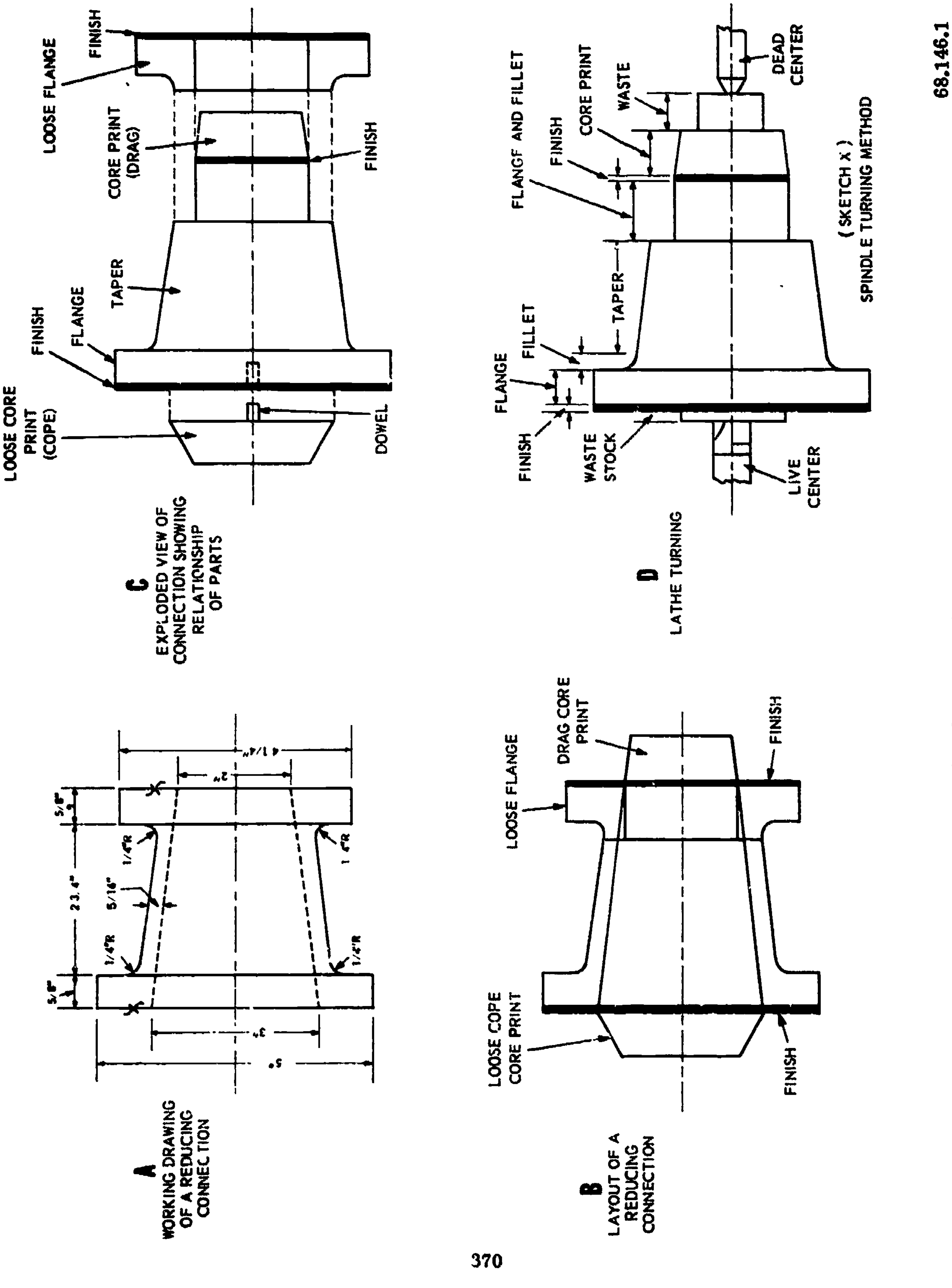

Figure 14-3.—Straight reducing connection pattern.

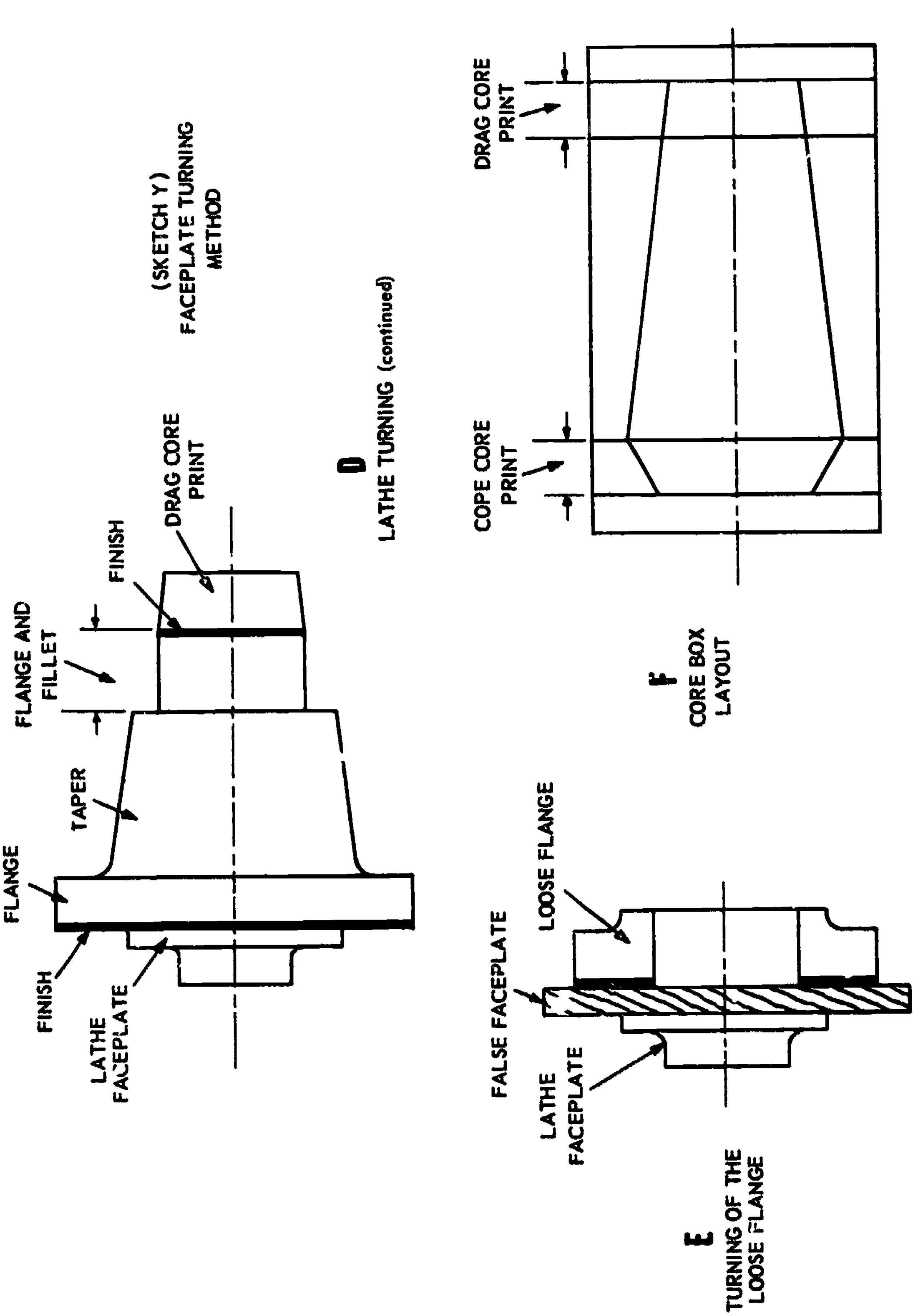

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Figure 14-3.—Straight reducing connection pattern—Continued.

layout; part C illustrates an exploded view of the pattern with the various parts in relationship to each other; part D illustrates two methods of turning the pattern (sketch X shows the spindle turning method and sketch Y shows the faceplate method) part E illustrates the turning of the loose flange; and part F illustrates the layout of the core box.

Select a block of wood of appropriate size for the pattern, including the core print on the small end. (See parts A and B of fig. 14-3.) For the spindle turning method allow waste stock on both ends, for the faceplate turning method allow only enough waste stock for truing up the work. Notice in part C of figure 14-3, that the large cope core print and the small flange are loose as required for vertical molding.

For the spindle turning method, mount the pattern stock between centers and turn the pattern to the dimensions taken directly from the layout. Note the straight section on the pattern for the loose flange. This length includes the thickness of the flange plus finish on one side plus the fillet on the opposite side. Before removing the turned pattern from the lathe, apply a light coat of pattern covering, allow to dry, and sand it lightly. Upon completion of turning, the pattern body will appear as sketch X in part D of figure 14-3. Remove the pattern from the lathe, and place a small drill chuck in the taper spindle of the headstock of the lathe. Place the small end of the pattern on the dead center and drill a dowel hole in the large flange end through the waste material into the body of the pattern. This dowel hole will line up the cope core print to the main body of the pattern. Saw and trim the waste material from both ends of the pattern.

For the faceplate turning method, mount a false faceplace on the lathe and turn to a true surface. Mount a drill chuck in the tailstock and drill a dowel hole into the center of the false faceplate. Insert a short length of dowel into the hole in the false faceplate. This dowel will serve as a centering aid for mounting the pattern stock on the false faceplate. Drill a dowel hole in the center of the end of the pattern material and mount the stock on the false faceplate with wood screws. Turn the pattern stock to the dimensions taken directly from the layout. Before removing the turned pattern from the lathe, apply a light coat of pattern covering, allow the covering to dry and sand lightly. Upon completion of turning, the pattern will appear as sketch Y in part D of figure 14-3.

Mount stock thick enough for the loose flange on a false faceplate and turn to the proper dimensions. (See part E of fig. 14-3.) The hole turned in the center of the flange will have a running fit over the straight turned section on the main pattern body. Then apply a thin coat of pattern covering. Allow the covering to dry and sand it lightly.

The loose core print may be turned on a faceplate by mounting in the same manner as previously described for the main body of the pattern. Another method of shaping the loose core print is to lay out the size of the core print on the proper thickness of pattern stock, cut out to the angle of draft and sand to size on the disk sander. Sandpaper the completed pattern and apply pattern covering in accordance with the Standard Color Code.

The straight reducing connection core box is actually a half dump box. Two half-cores are formed by the box and are pasted together to form the completed core. Select and dress stock to the size of the box. Note in part F of figure 14-3, that the length of the taper includes the drag core print. Using the measurements taken from the layout, scribe the outline of the core and small core print onto the parting face of the solid stock. Scribe the outline of the ends of the core on the ends of the stock. Cut a series of saw kerfs to the small end of the scribed circle. With a paring gouge cut out the rest of the waste material in the box and check with a straightedge to complete the tapered box cavity. From the proper thickness of stock, lay out the cope core print, cut out to an angle on the bandsaw and sand to the line on a spindle sander. Secure the cope core print stock to the core box and check the semicircular cavity as previously described. Sand the box smooth and close the ends of the box by attaching end pieces. Sand the work and apply a coat of pattern covering in accordance with the Standard Color Code.

EXPANSION JOINT PATTERNS AND CORE BOXES

Metal pipe expands and contracts with changes in temperature, lengthening when hot, and contracting as it cools. For example, when a 100-foot length of copper piping is raised in temperature from 80° to 450°, its length increases by almost 4 inches. If this same length of pipe were secured in a system in such a way that no expansion were possible, the stress developed by the rise in temperature would readily rupture the pipe. To provide the necessary expansion required due to heat and pressure, specially designed expansion joints are used. Bends, loops, and bellows are introduced into piping systems to prevent the development of leaks, and to absorb machinery vibration, bulkhead and deck stresses, and sudden shock caused by the firing of heavy guns. Special expansion joints such as those shown in figure 14-4 are "jumped into" a line that cannot be looped. Because of their bellows construction, these joints serve to absorb shock and strain. Convex type joints are the kind most widely used, but a concave type joint is preferable for installation in a short time.

Expansion joints in a number of sizes are available aboard ship, however, if some emergency arises which requires you to make such a joint, you may follow the suggested method indicated by figure 14-5. Part A of figure 14-5 illustrates a working drawing of a single-convex bellows type expansion joint; part B illustrates the layout for the expansion joint; part C illustrates the core box layout; and part D illustrates the faceplate turning of the center section of the core box.

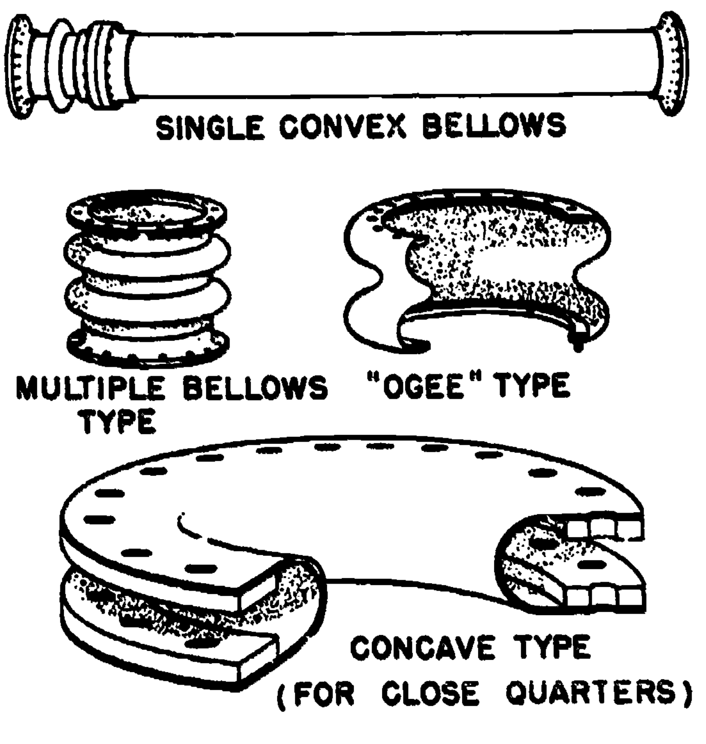

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Figure 14-4.—Expansion joints.

The construction of a bellows type expansion joint is similar to that of a pipe spool pattern. The parting line of the pattern divides the body of the pattern longitudinally into cope and drag halves. However, the 1/8-inch wall thickness as shown in part A of figure 14-5 indicates the accuracy required in the turning of the pattern and the construction of the core box. Note the finish indicated on the working drawing and added to the layout, in parts A and B of figure 14-5. In addition, there are no flanges. The finished casting is machined where finish is added, and either brazed or sweated into the flanges.

Select and dress two rectangular pieces of pattern stock of appropriate size for the construction of the pattern. The two pieces of stock are doweled and fastened together face-to-face with screws, centered in the lathe for spindle turning, and turned to the dimensions as indicated by the layout. The center section of the pattern, shown by lines X and X' in part B of figure 14-5, may be turned to shape with the aid of a template. The use of a template will ensure accuracy when turning the curved contour of the bellows. Fair in all fillets carefully into the body of the pattern. Before removing the turning pattern from the lathe, sand the pattern and apply a thin coat of pattern covering. Allow covering to dry and sand it lightly. Remove the work from the lathe and separate the halves of the pattern. Cut and sand draft on the ends of the core prints, matching the length of the drag half of the layout. Apply pattern covering in accordance with the Standard Color Code.

From the layout of the expansion joint (part B of fig. 14-5), make a layout of the core box as shown in part C of figure 14-5. Mount a false faceplate on the lathe, face off and mark the center while the faceplate is revolving. By geometric construction establish a centerline on the false faceplate. The material for the center section X-X' of the core box is prepared from two pieces of pattern stock. The two pieces are planed parallel to the thickness of "X" and jointed on one edge for matching to the centerline Y-Y' on the false faceplate. Mount the pattern stock on the false faceplate, matching the parting surface (jointed edges) to the established centerline on the false faceplate. Turn the circular cavity, matching to a template as shown in part D of figure 14-5. Sand the circular cavity lightly and apply a thin coat of pattern covering. Allow the coating to dry and sand it lightly.

Remove the turned center section of the core box from the lathe and fasten the two pieces

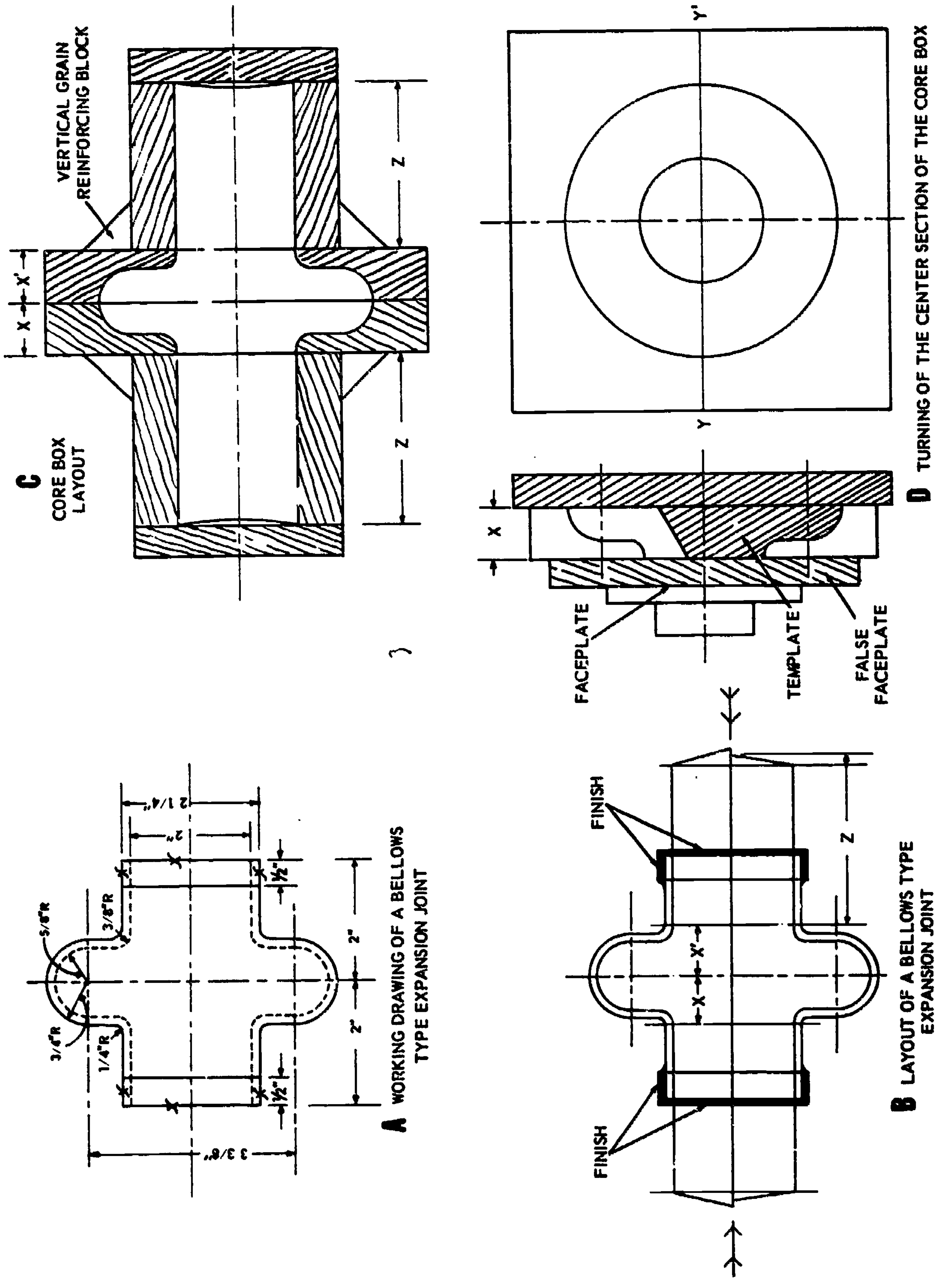

Figure 14-5.—Bellows type expansion joint pattern.

face-to-face to form section X-X' as shown in part C of figure 14-5. From material of appropriate thickness for the straight section of the core box, lay out the semicircular cavity, cut out, check for accuracy, and sand lightly. Referring to part B of figure 14-5, the length of the straight section of the core box (Z) is transferred to the straight core box stock. Cut the core box to length, and secure in position. Sand draft on each end and fasten end pieces to complete the box. Reinforce the core box to attaching plankwise stock to the bottom of the box and attach vertical grain blocks to the outside corners. Sand the box and apply a coat of pattern covering in accordance with the Standard Color Code, or Tentative Standard Pattern Color Code.

CURVED FLANGED PATTERNS AND CORE BOXES

Curved pipe patterns are essentially a length of pipe bent or curved to a given angle. They may be any angle of curve from a straight connection to a 180-degree return bend. A flange may be attached at one or both ends of the curved section. The methods of construction for both straight and curved pipe patterns are somewhat similar, however, the manner of fitting curved sections to straight parts may vary from job to job. When deciding whether to hand-carve or to turn the curved sections of the component parts, various factors should be considered, such as waste of stock, strength of the pattern, and saving of time.

Basically, the rules governing the determining factors for hand carving or turning the curved sections are as follows:

1. If the radius of the curved section is large, and the degree of sector is small, the curved section should be carved.
2. If the radius of the curved section is small, and the degree of sector is large, the curved section should be turned.

Since the differences between the two extremes are great, the manner of producing these curved sections should be a matter of good, sound patternmaking judgment.

PIPE ELBOW PATTERNS

Mitered construction, segmental construction, hand carving, and lathe turning are the methods used to produce curved pattern component parts. These methods are described in the following paragraphs.

Although the 90° pipe elbow is used as a sample pattern for curved sections of pipe, the methods described in this section may be used on any pattern involving bends or screws.

Mitered Construction

Preparing the layout will help you to decide upon the method of construction. Prepare a working drawing showing the construction features as illustrated in part A of figure 14-6. Note that approximately 1/8-inch machine finish is added to one face of each flange to allow for the f_2 finish required. The other side of the flange will require approximately 1/32-inch machine finish allowance for the f_9 spot face. Core prints are made long enough to provide a firm seat for the curved core. The following is a brief summary of the method of construction to be used.

Because the elbow is less than 6 inches in diameter, the pattern will be constructed of solid stock, parted lengthwise at the parting line into cope and drag halves. Note that each half (cope and drag) of the pattern is made in two parts which are glued together on a 45° miter and reinforced by means of a spline. Both parts may be turned in the lathe in one turning operation. Turn up the recesses into which the flanges will be inserted. Attach the flanges to the main body. Fair the fillets smoothly into the main body of the pattern. Remove the work from the lathe and cut the stock in half. This will give you two pieces of stock for the cope and two for the drag half of the pattern. Glue the two pieces of the drag on a 45° miter and reinforce the joint with a spline. Lay out the 90° curve on the parting surface and hand-carve to the lines. This procedure is merely one method of construction. Alternate methods will be presented later.

With a clear understanding of the method of construction to be used, you will be better able to select your stock with a minimum of waste. Because both parts of the main body of the pattern are to be turned in only one lathe turning operation, you will need two lengths of stock approximately 2 1/4 inches thick by 4 1/2 inches wide by 18 inches long securely fastened together face-to-face to form a rectangular block. After completing the turning operation and inserting and turning the flanges, cut the stock in half, making two 9-inch lengths.

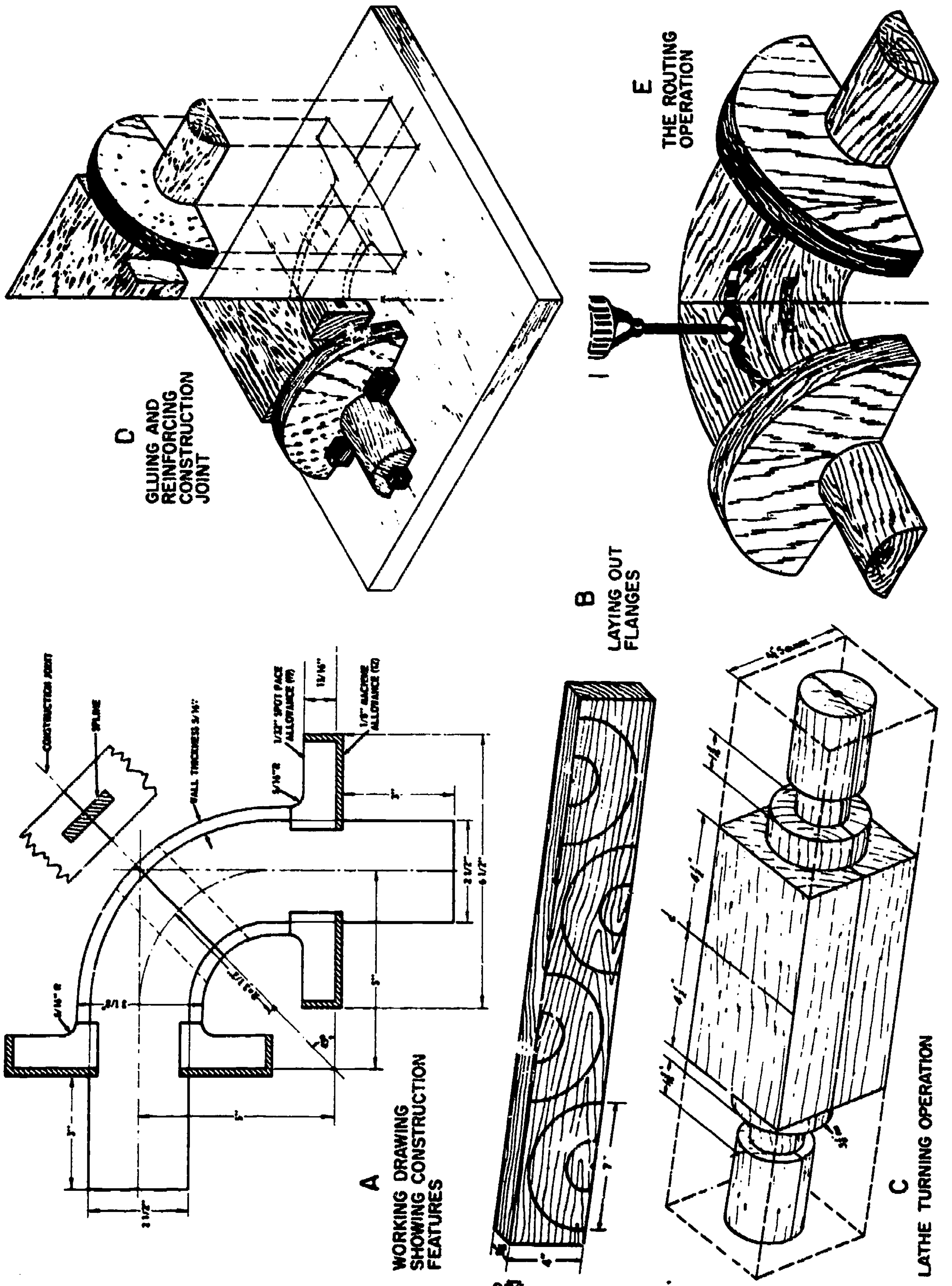

Figure 14-6.—A 90° elbow pattern (mitered construction).

The inserted flanges will be made from a length of stock dressed to the same thickness as the width of the recess turned in the main body. Lay out the four semicircular flange sections (two for the cope half and two for the drag half) as shown in part B of figure 14-6.

Center the rectangular block of stock in the lathe. Turn up the diameter of the core print (2 1/2 inches) at each end of the stock. Next turn the recesses into which the flanges will be inserted. Note that the recesses must be made wide enough to include the 5/16-inch fillet, and must be deep enough (3/16 inch is suggested) to provide a firm setting for the flanges (part C of fig. 14-6).

Dress a suitable length of stock to a thickness equal to the width of the turned recess. Lay out, and on the bandsaw, cut the semicircular flange sections. Note that the grain of the wood in the flange stock runs transverse to the grain of the wood in the main body. Remove the work from the lathe, separate the cope and drag halves, and glue the flange sections in place. Reinforce the joint with one or two screws. The heads of the screws are countersunk and covered with wooden plugs. The edges of the flange section are permitted to project above the parting surface so that they may be planed perfectly true to this surface after the glue has set. Fasten the two halves of the pattern together and remount the work in the lathe. Turn up the flanges to the required dimension, allowing approximately 0.02 inches draft. Fair the fillet smoothly into the main body of the pattern. This completes the lathe operation, and leaves a rectangular block of stock about 9 inches long, at the center of the turned work from which the elbow will be hand-carved.

Remove the work from the lathe. Separate and mark the cope and drag halves so that there will be no mismatching of parts. Scribe the horizontal centerline on the parting surface of each half of the pattern. Cut the stock in half; this gives the two parts of the cope half and the two parts of the drag half of the pattern. Resume the construction with the drag half of the pattern. Superimpose each part of the drag on the layout board in order to establish the location of the construction joint. Cut and fit the second part of the drag to match perfectly with the first part on a 45° miter. Glue together the two parts of the drag half of the pattern. Insert a spline to reinforce the glued joint. Toenail the parts directly to the layout board to prevent any shifting while the glue is setting. Draw the two parts together with pinch dogs. (See part D of fig. 14-6.)

Scribe the 90° arcs on the parting surface of the rectangular block of stock. On the bandsaw, cut along the arcs and sand to the lines on the spindle sander. Rout the curved elbow down to the required height on the boring mill as shown in part E of figure 14-6.

Hand-carve the elbow with the aid of a template. Be especially careful to carve a true semicircle in order to avoid backdraft. Precision is of utmost importance because any variations from a perfectly semicircular shape in the pattern will affect the wall thickness of the finished casting. If the wall thickness is not within the tolerance specified, the casting will probably be rejected. Construct the cope half of the pattern in the same manner and match it perfectly with the completed drag half.

Sand the completed pattern until smooth. Insert rapping plates in the parting surfaces. Shellac the pattern in the Standard or Tentative Standard Color Code. Add identification tape if required.

Segmental Construction

The curved portion of the 90° elbow pattern may also be shaped by using an entirely different technique. One method involves turning plankwise stock into the shape of the doughnut. Still another method, is the hand carved segment method. Each method will be described in the following paragraphs.

PLANKWISE TURNING METHOD.—Select plankwise stock (stock with the grain going in only one direction) slightly thicker than half the thickness of the finished pattern and large enough to admit the outline of the curved section. Bandsaw the outside diameter slightly larger than required by the finished dimensions. Mount the plankwise circular stock on a false faceplate with the wood screws on the centerline of the doughnut. Placing the screws on the centerline will prevent the lathe operator from turning into the screws when shaping the doughnut. True up the face of the plankwise stock to one-half the thickness of the finished doughnut. Scribe the inside and outside diameters of the doughnut on the face of the plankwise stock. Turn the waste material from the scribed lines straight (90°) into the wooden false faceplate. Check the work with a combination square from the face of the plankwise stock or with inside and outside calipers.

Prepare a template of the half-round cross section of the doughnut. Turn the doughnut to shape, checking with the template, and leave a small amount of stock for sanding. Before removing the turned doughnut from the lathe, establish the 90° quadrant joint lines by using a surface plate and a surface gage. NOTE: The **quadrant** joints should be in the correct position on the plankwise turned doughnut (parts A and B of fig. 14-7) to have the direction of the grain in the curved part follow as nearly as possible to a circle. Remove the doughnut from the false faceplate; and bandsaw close to the scribed lines. The bandsaw cut should be in the waste portion of the doughnut. Sand square on a disk sander, splitting the scribed lines. From this point, the construction of the remainder of the elbow pattern will be similar to the mitered construction previously described. (See fig. 14-7.)

QUADRANT TURNING METHOD.—In the quadrant turning method, two 90° segments of appropriate thickness (one-half the thickness of the finished doughnut) are laid out with the grain of the wood following as close to a circle as possible. The other two 90° segments may be of scrap material. Cut the pattern stock close to the line and sand the straight radial ends square

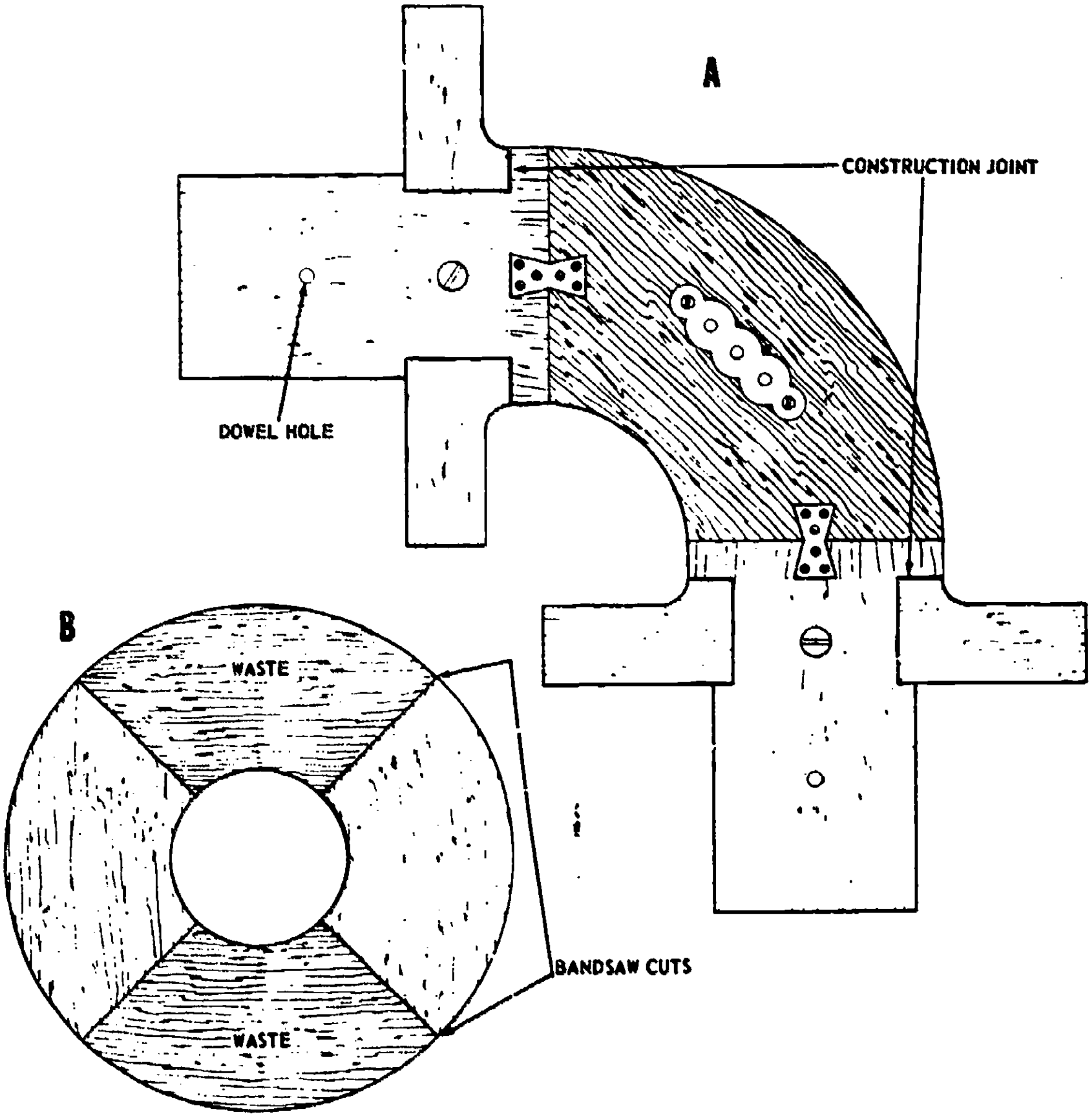

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Figure 14-7.—90° elbow pattern showing construction features.

on a disk sander. The four 90° segments are matched to the vertical and horizontal centerlines on the face of the false faceplate. Use at least three wood screws in each segment in securing the pattern stock to the false faceplate. Turn the pattern stock to the required doughnut shape as previously described. Remove the four 90° doughnut quadrants from the false faceplate and dispose of the two scrap segments. From this point, the construction of the elbow pattern has been previously described.

HAND CARVING METHOD.—In the previous paragraphs, the curved section of the pattern was formed by turning on the lathe and using parts of the doughnut for additions to the main body of the pattern. However, there are several reasons why this method is not always practical and sometimes is impossible. For instance, the lathe in the shop may be inoperative or it is possible that the curved section would not be a true radius, such as a reducing bend. A reducing bend (covered later in this chapter) is similar to an elbow with the exception that the diameter of one end is larger than the diameter of the other end.

For the hand carving method, only two 90° segments are used (one cope and one drag), matched to the pattern and hand-carved with the aid of a template.

From the layout, determine where the construction joints will be. The flanged end sections of the pattern are cut and toenailed to the layout board so that the joints are properly aligned with the construction line. With the grain of the wood following the direction of a circle, fit a block of the proper thickness between and to the two flanges. This block is the segment which is to be hand-carved.

Using dividers, scribe the centerline on the segment block. Also scribe the inside and outside diameters of the curve. Remove the block, bandsaw close to the line and sand, splitting the line, on a disk sander and spindle sander. Make sure the sanded surfaces are square with the parting of the block.

On the straight radial ends scribe semicircular lines representing the diameter of the end. Scribe 45° lines extending from the top surface of the block to the curved sides, tangent to the semicircular lines on the radial ends. Scribe additional diameter lines on the top surface as guidelines for roughing out the 45° chamfer on the edges of the segment. This chamfer will establish five definite reference points for hand carving. Chamfer the top corners of the segment to the 45° lines scribed on the ends, using the additional diameter lines as guides.

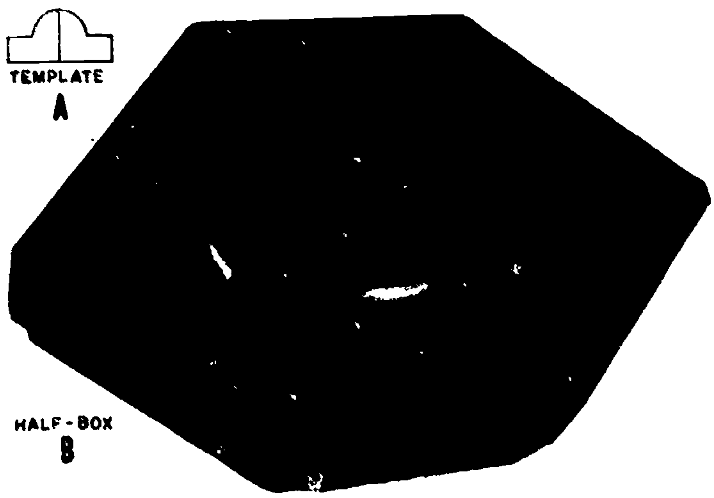
With the aid of a semicircular shaped template used on a radial line from the center point of the curved section, hand-carve the segment block. Glue the carved segment block to the flanges previously toenailed to the layout board.

When the glue has dried, match and secure the cope flanges to the drag half of the pattern and insert the cope half of the segment block. Repeat the procedure for hand carving of the curved section and glue in position. When the work is assembled and the glue has dried, fair any differences in diameters by paring and sanding.

PIPE ELBOW CORE BOX

The half-box method of constructing the core box for a 90° elbow pattern is the fastest but not necessarily the most accurate method of construction. However, you will find it a very useful construction technique because of the urgency of much of the pattern work required on repair ships and tenders.

Pick up the measurements from the pattern layout. Select and prepare the stock for construction. Plan the construction so that the most difficult part of the job, that is, the curved portion of the elbow, can be turned on a faceplate in the lathe. Use a template of the form shown in part A of figure 14-8 for greater



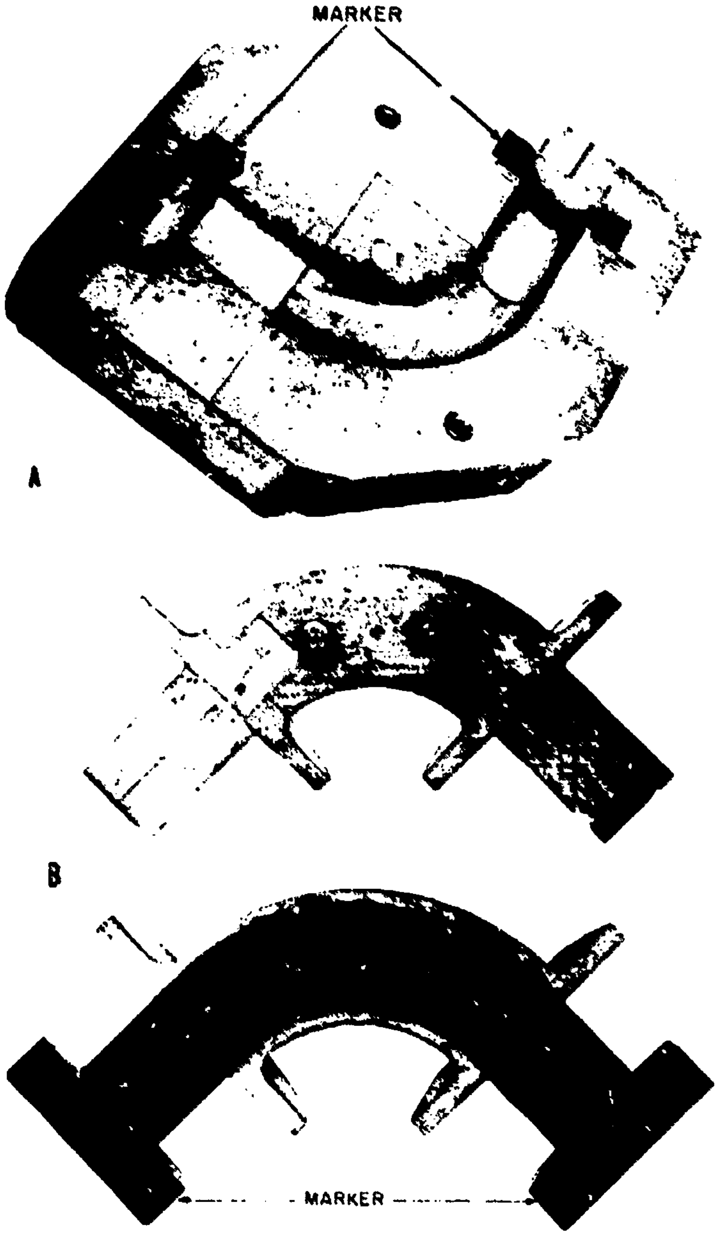
68.151

Figure 14-8.—90° elbow core box.

accuracy in turning the desired semicircular cavity. The core prints can be hand-carved in one lone piece and afterward cut to the required lengths. The component parts are then glued and screwed to a backing board to give the core box strength and rigidity. The end pieces are added to the core prints to retain the core sand within the core box during the ramming procedure. Part B of figure 14-8 shows the completed half-box.

To overcome the disadvantages of the half-box method of construction, it is suggested that you build the core box in the more conventional manner, using parted half or cope and drag sections. The ends of the cope and drag halves of the core box must be closed in order to retain the core sand within the box during the ramming procedure. It is also recommended that you modify the parted half construction method by adding markers to the core prints. A MARKER is a shape which is added to the core prints to ensure a correct setting of the core in the mold. In order to give you a better appreciation of the value of markers, let us first consider what effect a core made WITHOUT markers would have on the poured casting of a 90° elbow. One of the difficulties of using a core for a 90° elbow made in the conventional manner, without markers, is to keep the core from shifting position in the mold while the molten metal is being poured. One of two things may happen during the pouring procedure to change the position of the core in the mold. If the curved core sags in the middle, it will result in the lower side of the casting being too thin. If the core floats on the molten metal, it will result in the upper side of the casting being too thin. In either case, the resulting wall thickness of the casting will not be uniform.

One way of solving this problem is to make the core prints extra long in relation to their diameters so that enough bearing surface is provided to seat and to balance the core firmly in the mold. For certain pattern jobs it may not be practical to increase the length of the core prints to the extent required to seat the core properly. In such cases, the Patternmaker may use MARKERS. The process of molding a marker as an integral part of the core is sometimes referred to as "registering a core." The marker not only helps the Molder to seat the core but it also eliminates the possibility of placing the core in the mold in any other position than the correct one. The marker is usually built into the drag half of the core box. See part A of figure 14-9.



"A"—Drag Half of Core Box.
"B"—Cope and Drag Pattern Halves.

68.152
Figure 14-9.—A 90° elbow pattern and core box with markers.

When you are planning to use markers to help register the core, you must include the specific shape of the markers on the layout prior to the construction of the pattern. This procedure ensures accuracy in the location of the markers and also reduces the possibility of forgetting to add the markers to the drag half of the pattern at the time of construction. Part B of figure 14-9 illustrates markers built on the core prints of the drag half of a 90° elbow pattern.

When a large number of 90° elbow castings are required, you can save a considerable amount of time by constructing a double elbow pattern and core box. See part A of figure 14-10 which illustrates the construction features of a double elbow pattern. Note that double construction is not quite the same as building two complete and separate patterns and core boxes, and yet it enables the Molder to make two castings at a time in one mold.

First, cut the semicircular flanges on the bandsaw. Then turn up a doughnut-shaped ring to form the curved portion of the double elbow pattern. Select your stock in gluing up the required course of segments so that short grain is eliminated. In the lathe, turn the core prints and connecting tenons in one piece, as shown in part B of figure 14-10. Note that shoulders are turned to provide a firm seat against which the inserted flanges will butt. Remove the work from the lathe and cut along the lines shown in part B of figure 14-10. Separate the cope and drag half-sections. Assemble the component parts of the drag as follows: Glue the flanges to the core prints and reinforce the joints with wood screws. Cut the doughnut-shaped ring into quarters to form the curved portions of the elbow pattern. Carefully bore into the ends of the quartered sections to receive the connecting tenons on the core prints. Use the layout scribed on the layout board as an aid in aligning the component parts of the drag half of the pattern. Hold the parts in place by nailing small blocks of wood at strategic points on the layout board. Fasten the component parts together with glue and reinforce the joints with wood screws. Make sure that the parts have not shifted position during the gluing procedure. Run in leathers fillets to fair the junction between the flanges and the curved parts of the double elbow pattern. Sand and shellac the completed pattern. Add identification tape.

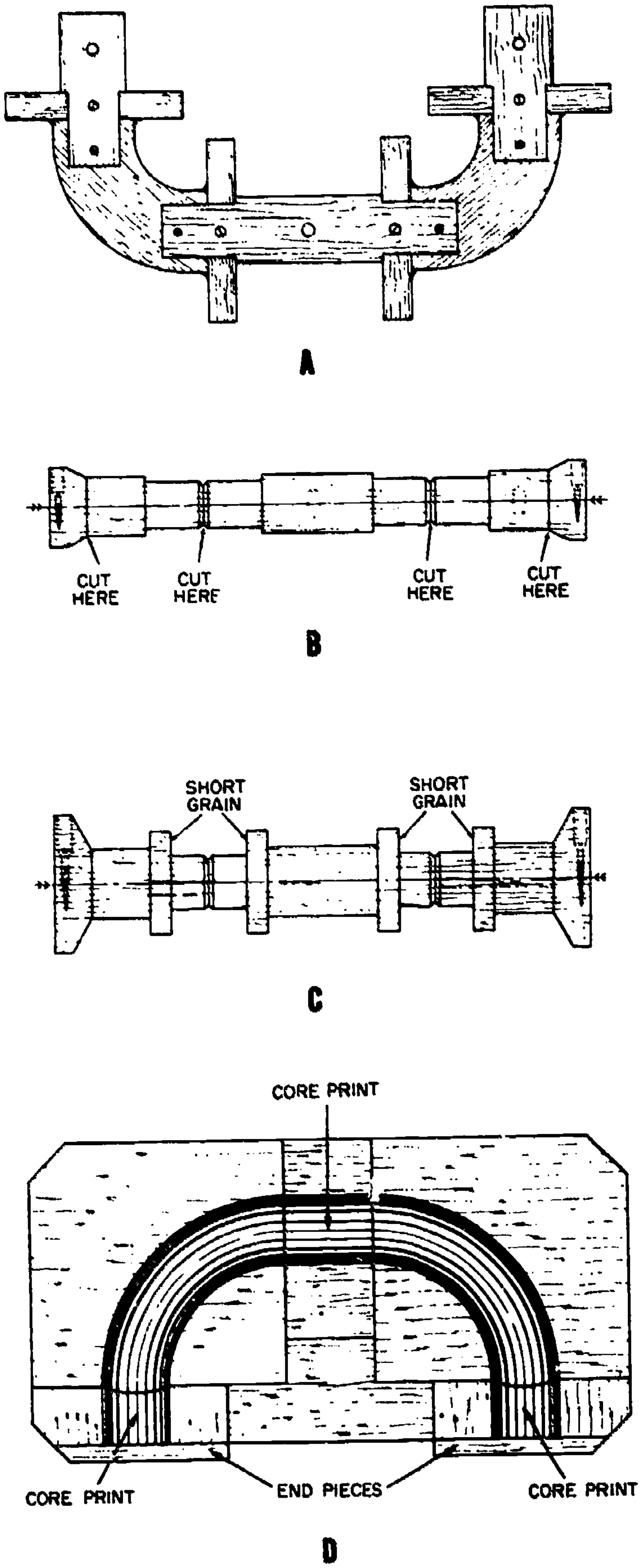


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Figure 14-10.—A double elbow pattern

Certain emergency situations will come up from time to time when the urgent need for a pattern will prevent you from taking the additional time required to use the inserted flange method of construction. For these rush jobs, you may turn the core prints, tenons, and flanges in one operation on the lathe. See part C of figure 14-10. The main objection to this method of construction is that there will be short grain in the flanges. The overall diameter and thickness of the flanges of the specific job will determine whether or not the flanges should be turned in the lathe. The greater the portion of the flange projecting above the main body of the pattern, the easier it is for the flanges to be accidentally broken off in the molding procedures. Thus, while you may have saved some time in building the pattern, you may find that the resulting pattern is not sturdy enough to hold up during the molding procedure. There are no set rules to help you make the right decision. You will have to rely on your own experience or on the experience of the senior Patternmaker in the shop.

The core box for the double elbow pattern is constructed in the same manner as the core box for the single elbow pattern. Turn the curved portions of the elbow on a faceplate on the lathe. Hand-carve the core print out of one long piece of stock and afterward cut it to the required lengths. Glue and screw the component parts to a backing board to give the core box strength and rigidity. Add end pieces to the core prints to retain the core sand within the core box during the ramming procedure. See part D of figure 14-10.

RETURN BEND PATTERNS

In making a pattern for a return bend, nearly all of the work may be done on the lathe. Compare the mass production method for an elbow pattern to the method used in the return bend. (See figs. 14-10 and 14-11.) Note the slight difference in the manner of construction.

Part A of figure 14-11 illustrates the layout for a return bend and a possible method for two patterns; part B illustrates the turning of the doughnut for the pattern; part C illustrates the flange and core print setup; part D illustrates the drag half of the pattern built up on the layout board; part E illustrates the cope half matched to the drag half of the pattern; part F illustrates the core box turning; and part G illustrates the core box setup.

From the layout of the return bend (part A of fig. 14-11), select stock of appropriate size for the body of the pattern. The stock for the body is prepared from two pieces of pattern material slightly thicker than one-half the thickness of the finished pattern. The jointed edges are placed together, matched to the centerline of the false faceplate and secured for turning. Face off and turn the doughnut body to size and shape checking with a template (part B of fig. 14-11). Select stock of appropriate size for the two core prints. The core prints are made of two pieces of stock, mounted in the lathe for spindle turning, turned to size and sanded. Prepare the flanges O and P and secure to the parted halves of the core prints as shown in parts C and D of figure 14-11.

Match the attached flanges and core prints to the layout board and set one half of the turned doughnut in place (part D of fig. 14-   Glue and secure all drag parts in position. After the glue has dried, build up the cope half of the pattern on the drag half as shown in part E of figure 14-11. Reinforce the construction joints with a dovetail and apply a coat of pattern covering.

The core box stock for the 180° curve of the return bend is made by matching, mounting, and turning the pattern stock as shown in part F of figure 14-11. A feature of good pattern practice is to have the grain in the wood on the pattern follow the same direction as in the core box. This in effect will help to prevent any misalignment between the pattern and the core box by the stresses and strains of the wood due to the swelling and shrinking of the wood cells.

The straight portions of the core box are made of one piece of stock, laid out as shown in part G of figure 14-11. The stock is roughed out with a series of kerf cuts and with the aid of a core box plane or gouges, trued to size. The two pieces of core box stock are glued together and secured to a bottom piece for added strength. When the straight portion of the core box has been cut to length and sanded with the appropriate draft, end pieces are secured to the ends. Finally, sand and apply pattern coating in accordance with the appropriate color code.

REDUCING ELBOW PATTERN

Laying out a reducing elbow pattern is practical experience in the use of the concentric circle method of drawing an ellipse. Figure 14-12 shows a reducing elbow, size 2 1/2 inches reduced to 1 1/4 inches. It is necessary to show only one quadrant on the layout because that is all you need to build the pattern. The outer curve of the elbow is referred to as the HEEL; the inner curve is referred to as the THROAT. The throat and heel portions of the elbow represent quarter (90°) segments of an ellipse and are developed from the major and minor axes shown in part A of figure 14-12. Note that 1/8-inch machine finish is added to one face of each flange to allow for the f_2 finish required. The other side of the flange will require 1/32-inch machine finish allowance for the f_9 spot face. Core prints are made long enough to provide a firm seat for the curved core.

The method of constructing the reducing elbow pattern varies only slightly from the method of constructing the 90° elbow pattern. However, to illustrate the comparison of a straight taper used on a straight reducing connection and the tapered curve of a reducing bend, it is necessary to use the station line and station point method of layout and hand carving. (See part B of fig. 14-12.)

In the construction of the reducing bend, the parting line parts the pattern lengthwise into cope and drag halves. Each half is made up of three parts, glued together and reinforced with screws and a dovetail-shaped key. The core prints and recesses for inserting the flanges are turned on the lathe, separated into halves, cut, sanded, and matched to the layout.

Select stock of the thickness of the large end of the tapered curved segment. The grain in the wood should run as close as possible to a circle. Lay out the throat and heel outlines for the curved segment of the elbow. Cut close to the line of the throat and heel outline and sand square (90° to the parting surface) on a spindle sander and a disk sander. Transfer the station lines from the layout to the curved pattern stock. Part C of figure 14-12 illustrates the station lines and their varying diameters. At each station line, establish thickness points at that section of the bend. Fair the top surface between the station lines to a flat curved taper. This will establish the correct taper for the curved segment.

As previously mentioned under hand carving of the elbow pattern, knock off the corners (triangular strip shown as Y in part C of fig. 14-12) to establish additional reference points on each station line. With the aid of a series of templates (station templates 1, 2, 3, 4, and 5 as shown in part C of fig. 14-12), hand-carve the bend. Fit to the flanges that are matched to the layout, (Part D of fig. 14-12). Fair any irregularities between the bend and the flanges. The cope half is built up on the drag half as previously described for the elbow pattern. The pattern is sanded and finished in the usual manner. (See part E of fig. 14-12.)

The core box is constructed in the same manner as the pattern, that is, hand carving the 90° segment for the bend, and then final assembly. The 90° carved portion of the core box may be roughed out by drilling a series of holes with a Forstner bit along the curved centerline and finished by hand carving using station templates at the various station lines.

Figures 10-11 and 10-12 are full page illustrations. The discussion on Branch Pipe Patterns and Core Boxes begins on page 388.

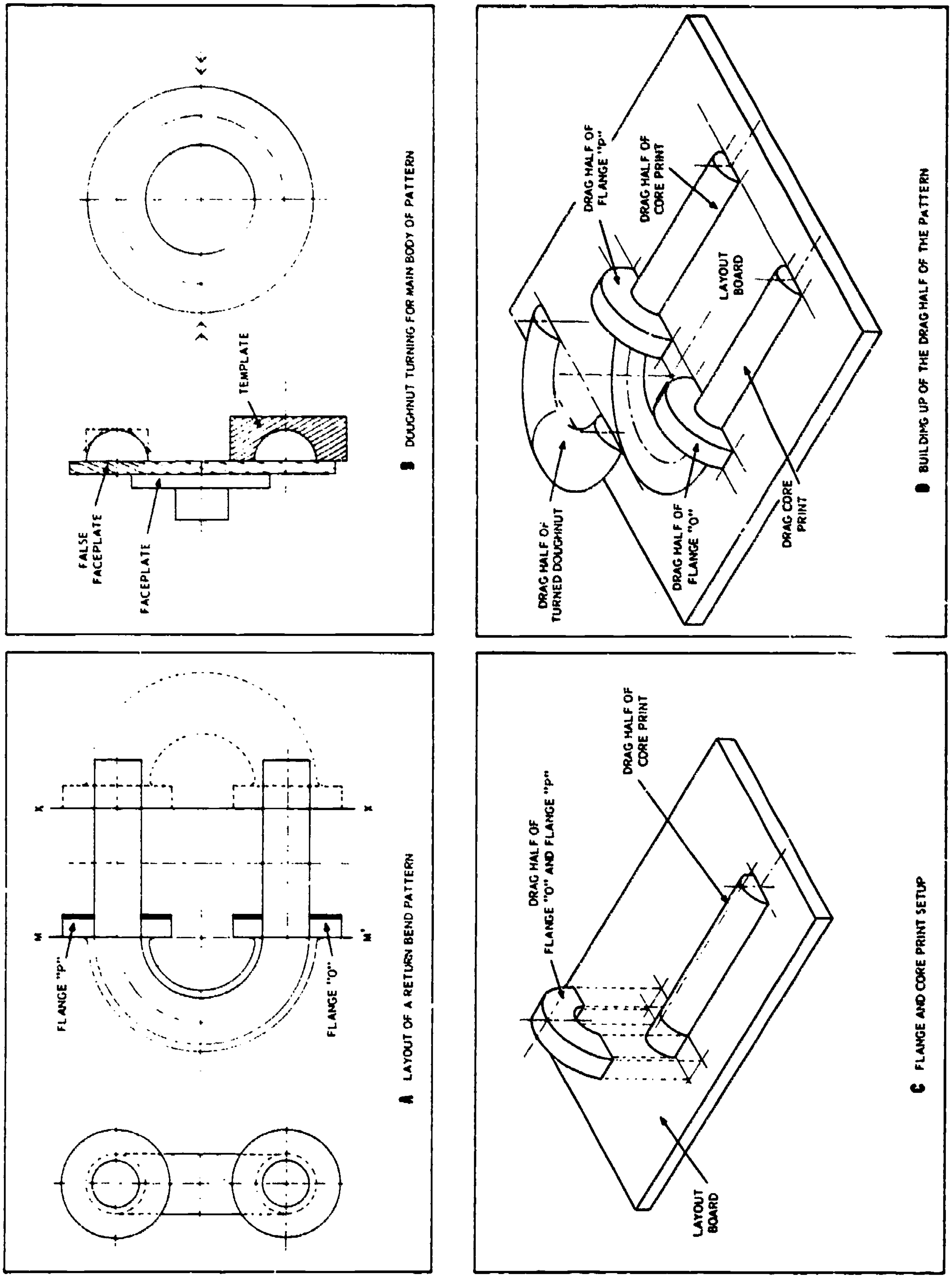

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Figure 14-11.—180° return bend pattern.

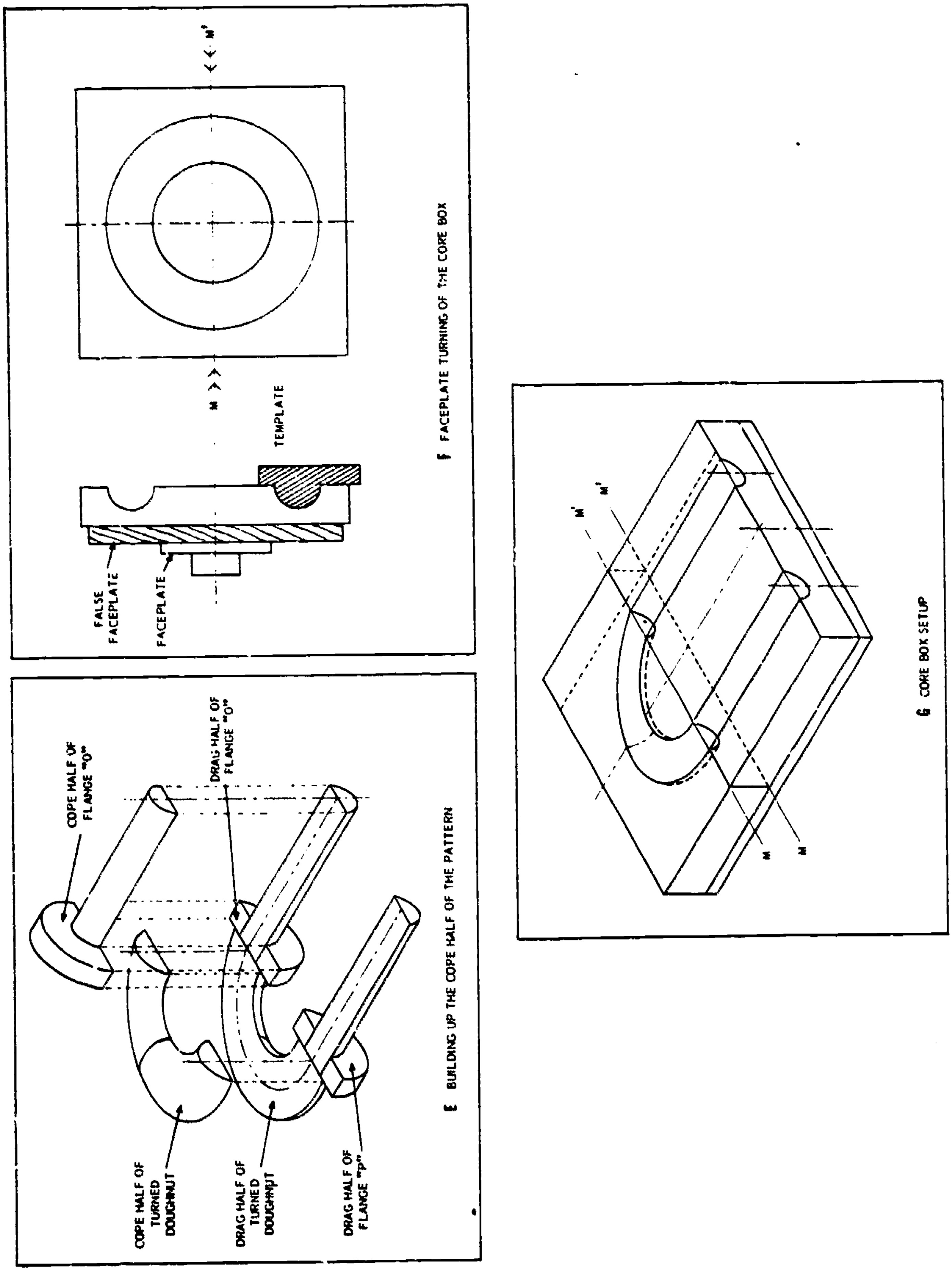

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Figure 14-11.—180° return bend pattern—Continued.

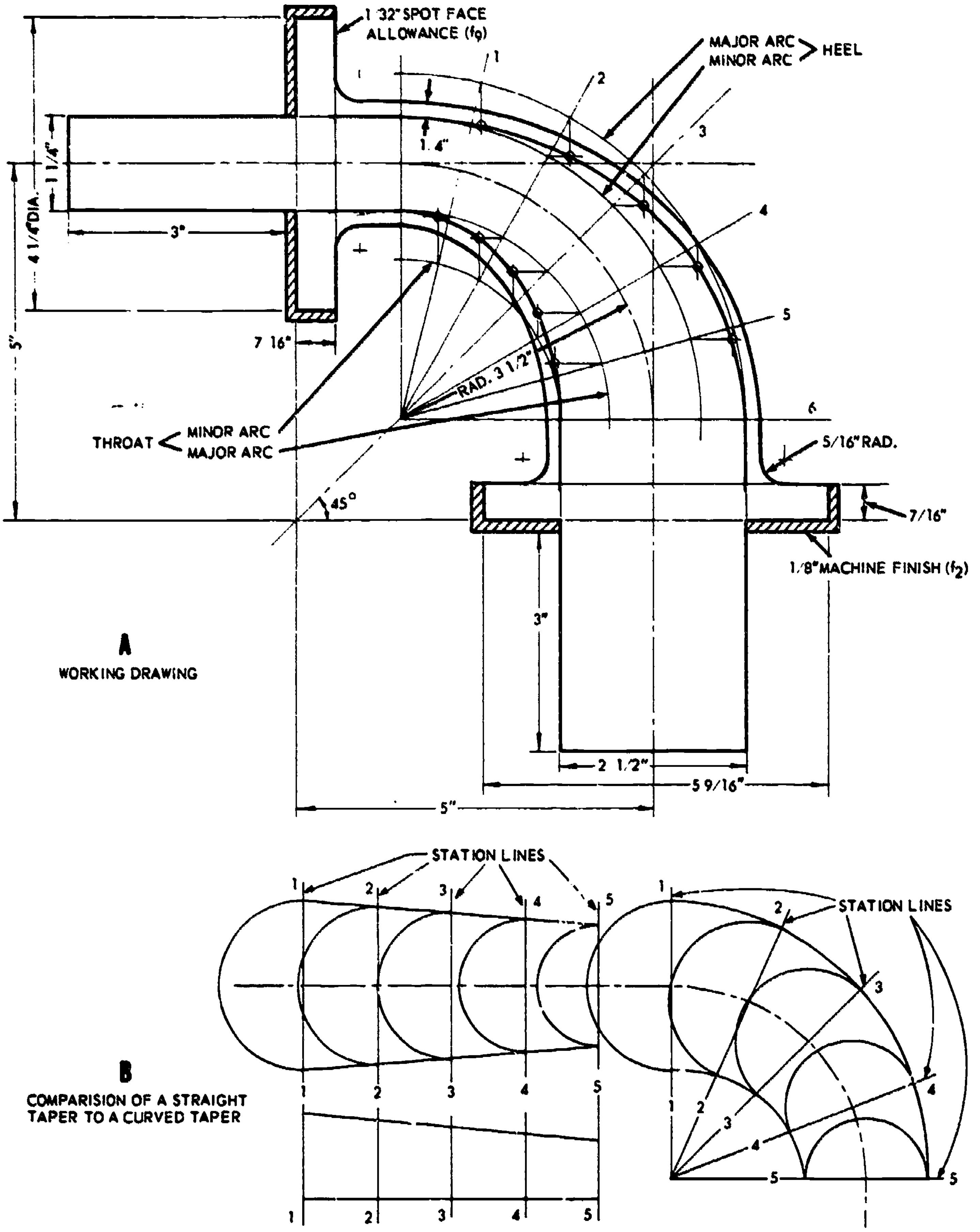

Figure 14-12.—90° reducing bend pattern. 68.155.1

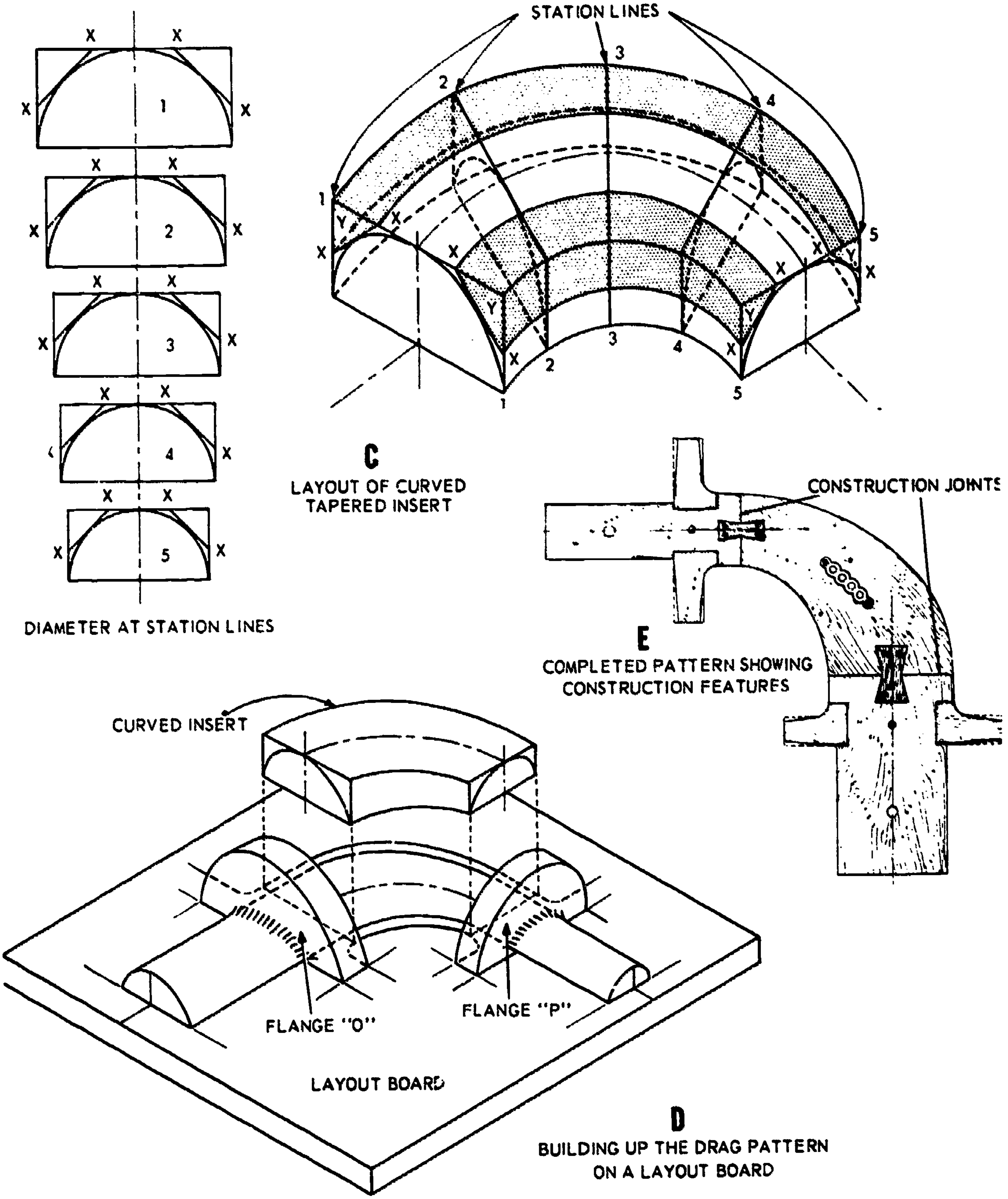

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Figure 14-12. — 90° reducing bend pattern — Continued.

BRANCH PIPE PATTERNS AND CORE BOXES

The patterns for branch pipe fittings have many features in common with the previously described pipe fittings. However, the main difference in the manner of construction lies in the forming of the joint between the main body of the pattern and the branch piece.

Figure 14-13 illustrates the variations of design of branch pipe fittings. These fittings may be in the form of a Tee-fitting or a double-Tee (cross) fitting. Others may be of the lateral design such as the 30° Y and 45° Y branch fitting or the double-Y branch fitting.

When the main body and a single branch are at right angles to each other (part A of fig. 14-13), the fitting is called a TEE. When two branches are opposite each other and at right angles to the main body (part B of fig. 14-13) the fitting is called a DOUBLE-TEE or CROSS fitting. When the main body and a single branch are at an angle other than 90° (see parts C and D of fig. 14-13), the fitting is called a "Y"-fitting or a SINGLE LATERAL connection. When the main body has two branches opposite to each other and at an angle other than 90° (part E of figure 14-13), the fitting is called a DOUBLE-Y LATERAL connection.

TEE-CONNECTION PATTERNS AND CORE BOXES

Select pattern material of appropriate size for the main body and the branch piece. The stock is fastened together face-to-face with countersunk screws, centered in the lathe for spindle turning, and turned to shape as indicated by the layout. The flanges are secured to the pattern by the inserted flange method. The main body (X in part B of fig. 14-14) will have a core print on each end. The branch piece (Y in part B of fig. 14-14) will have a core print only on the flanged end.

Remove the stock from the lathe and scribe centerlines on the turned pattern stock for transferring the 90° mitered joint from the layout to the main body and the branch piece. From the layout (part A of fig. 14-14), determine the length of the centerline for the branch piece. Transfer this length to the branch piece longitudinal centerline. Lay out the 90° mitered joint on the parting surface of the branch piece. Cut close to the line and sand square to the parting surface (Y in part C of fig. 14-14). A 90° corresponding notch is cut into the main body of the pattern (X in part C of fig. 14-14). Match and toenail the main body of the pattern to the layout board. Glue and brad the branch

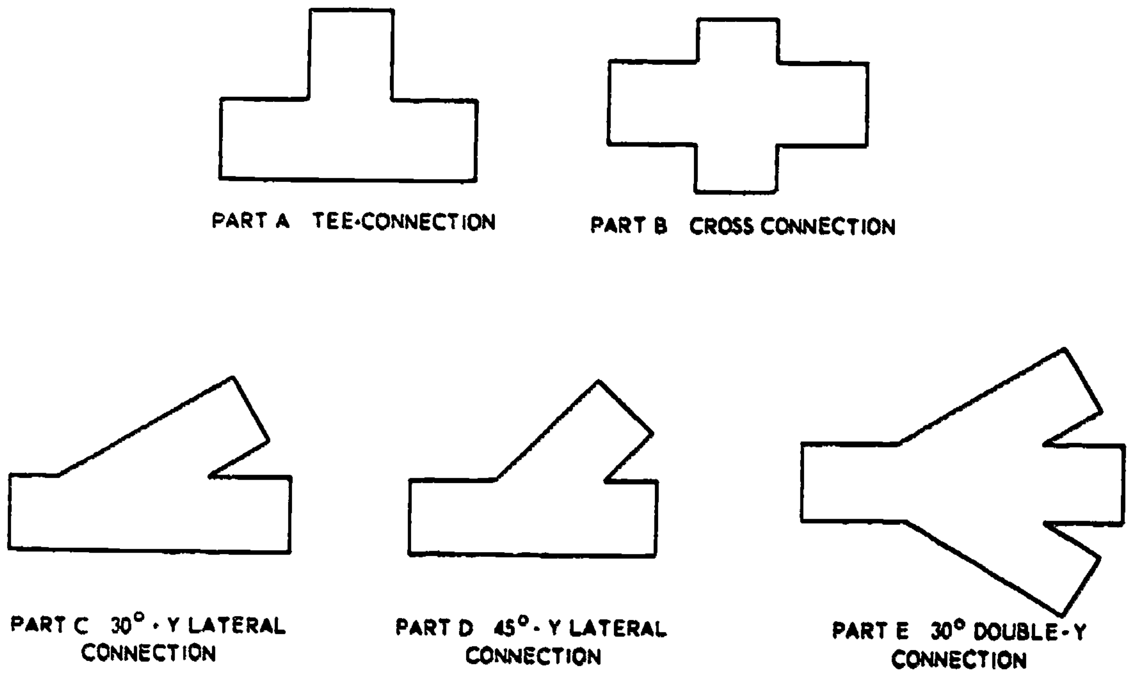

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Figure 14-13. — Branch pipe connections.

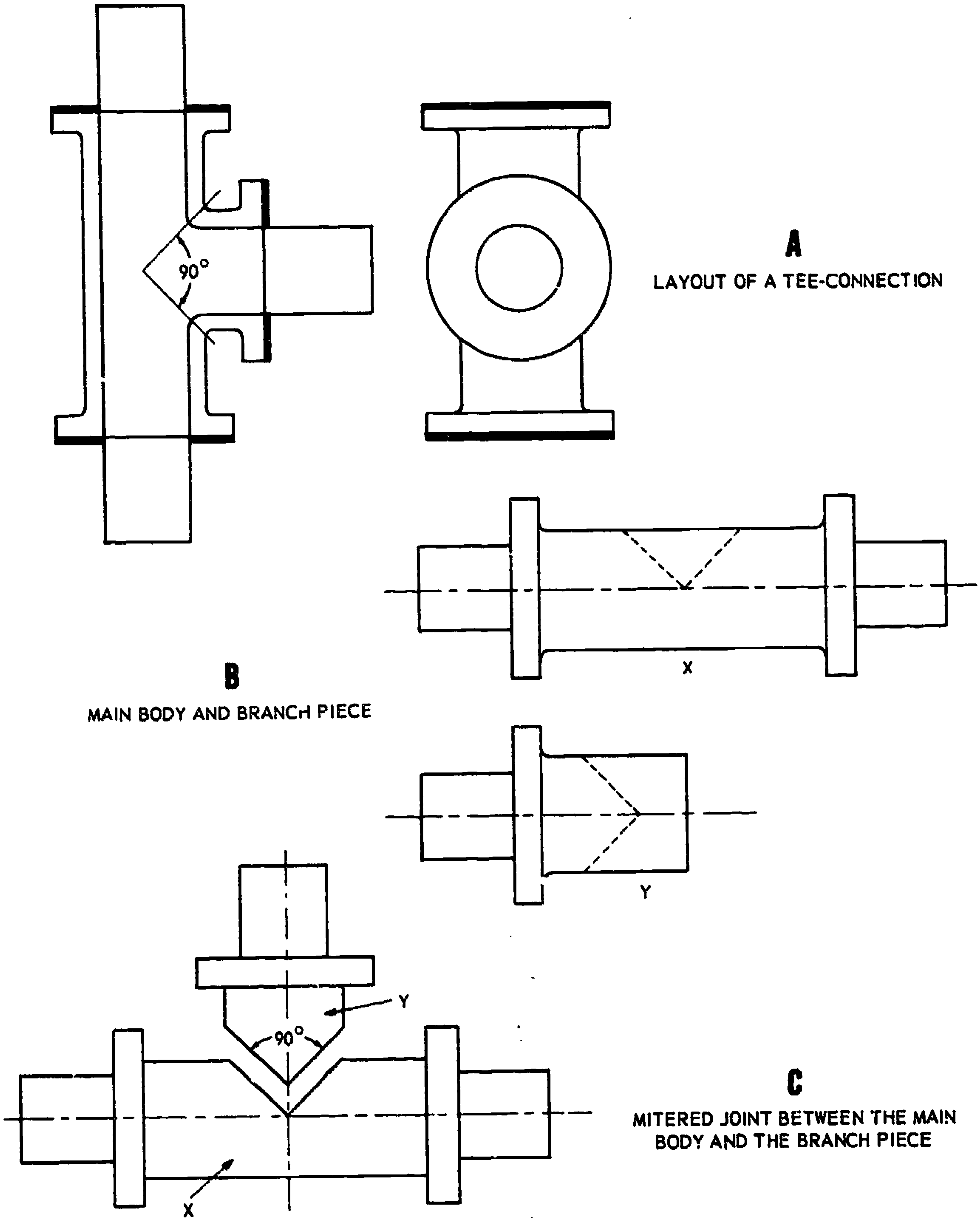

Figure 14-14.—Tee-connection pattern. 68.157

piece in position. After the glue has dried, remove from the layout board and construct the cope half of the pattern directly upon the drag half. Reinforce the 90° mitered joint with a **dovetail**, sand and finish the pattern in the usual manner.

The core box for the tee-connection is constructed in the half-box manner except the side opening for the branch piece has a mitered joint the same as the pattern. After joining the main body core cavity and branch piece cavity, fair the fillet along the mitered joint on the inside of the box. Secure the assembled box to a bottom piece for extra strength, cut the core prints to length, sand the appropriate draft and attach end pieces. Sand and finish the core box in the usual manner.

CROSS CONNECTION PATTERNS AND CORE BOXES

As previously mentioned, a cross connection pipe fitting is one in which the two branches are opposite each other and at right angles to the main body (part B of fig. 14-13 and part A of fig. 14-15). The main body of the pattern and the two branch pieces are turned on the lathe as described for the Tee-connection. The centerlines are transferred to the main body and the centerlines and length transferred to the two branches as though the joint were to be a mitered joint. However, the mitered joint construction method weakens the main body of the pattern considerably by cutting halfway through to form the notch for the mitered joint. In addition, if at a later date, it is desired to change the location or diameter of the branch piece, it would be necessary to make a new pattern for the main body. Therefore, the surface development (wraparound) method is used. (Refer to chapter 8, "Surface Development.") Part B of figure 14-15 illustrates the comparison of the mitered joint to the wraparound or surface developed joint. The wrap-around method is presented to illustrate the use of templates for the forming of the joint between curved members of the pattern.

The layout of the developed curve on the branch piece (layout paper) is aligned to and wrapped around the branch piece and scribed with a layout knife. Cut the scribed curve to the line and hand fit to the main body. Match and toenail the main body of the pattern to the layout board, attach the two branches by gluing and bradding in the proper position (part C of fig. 14-15). As an aid in securing the branches to the main body, apply glue and clamp the pattern to the layout board. To further strengthen the developed joint, a dovetail piece is inserted flush with the parting surface of the pattern. Construct the cope half of the pattern directly upon the assembled drag half. Sand and finish the pattern in the usual manner.

The half core box consists almost entirely of straight work. The main body and the two branch pieces of pattern stock may be roughed out by removing the larger part of the waste stock for the semicircular cavity with circular saw kerfs and finishing with a core box plane or gouges. The two side openings for the branch can be formed by placing the branch boxes against the side surface of the main body box. Transfer the lines across the main body box and remove the waste stock with gouges. Fair in the fillet between the main body core and the side opening. The ends of the box are provided with draft as usual, and the completed box may be strengthened by fastening to a bottom board.

LATERAL CONNECTION PATTERNS AND CORE BOXES

Lateral connections are the fittings which have the main body and the branch or branches set at an angle other than 90°. These fittings may be in the form of a 30°-Y fitting, a 45°-Y fitting or a double-Y fitting. (See parts C, D, and E of fig. 14-13.) As previously discussed, it was shown that the mitered joint weakens the pattern by the cutting of a notch in the main body. To overcome this weakening of the pattern, the surface developed method may be used. However, there may be an instance where time is essential, and the surface developed method may be time consuming. Therefore, a quicker way of fitting these members is necessary. The quicker method is called the TEMPLATE BOARD method. The template board is merely a specially constructed jig or device used to expedite the cutting of the correct shape for mating component pattern parts.

Figure 14-16 illustrates a 45°-Y fitting that will be used for this discussion. However, any one of the branch fittings may be easily constructed by this method. Part A of figure 14-16 illustrates the jig arrangement; and parts B and C illustrate the cutting of the matching curve. The jig arrangement for the template board (part A of fig. 14-16) is constructed and used as described in the following paragraphs.

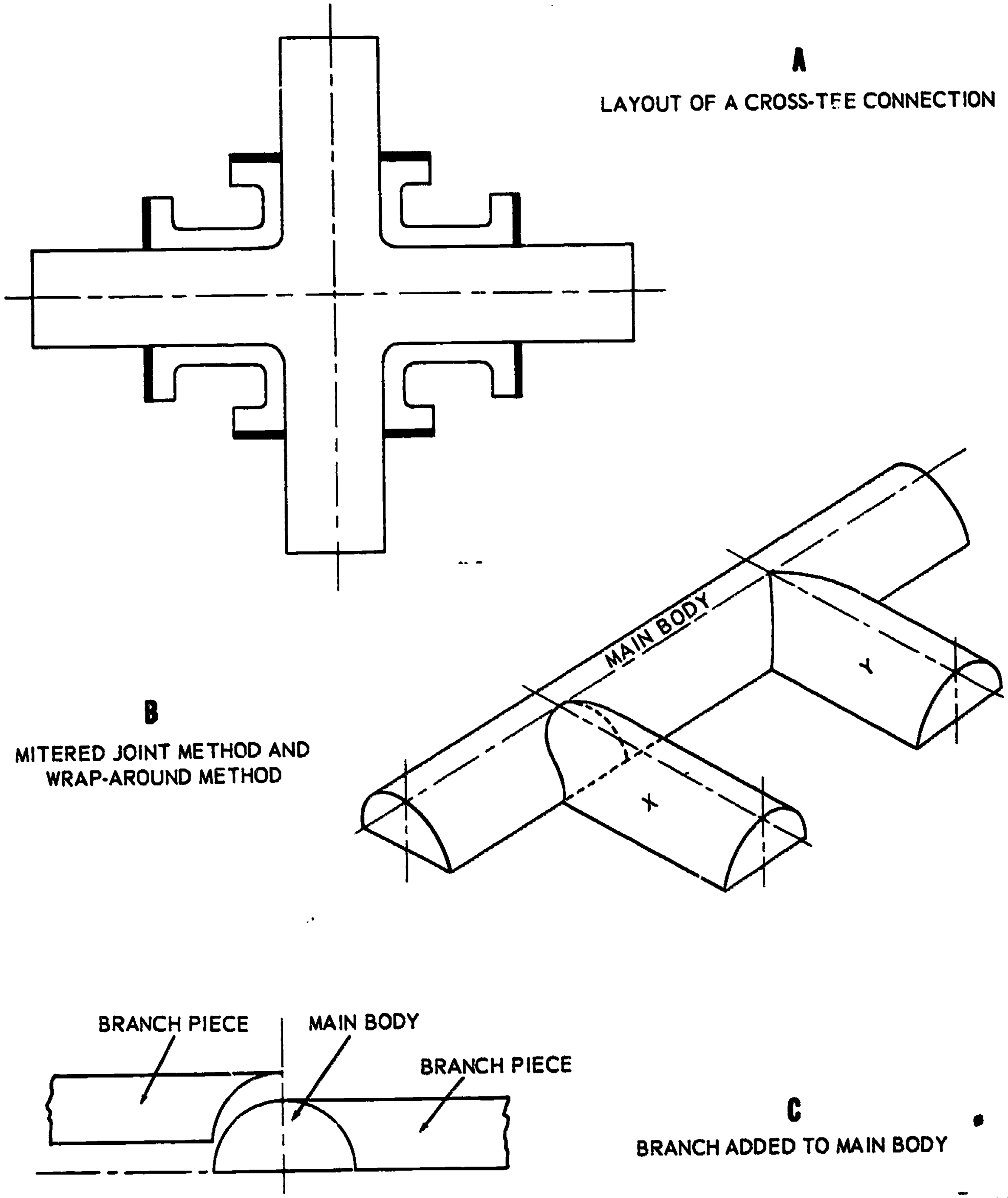

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Figure 14-15.—Cross-Tee connection pattern.

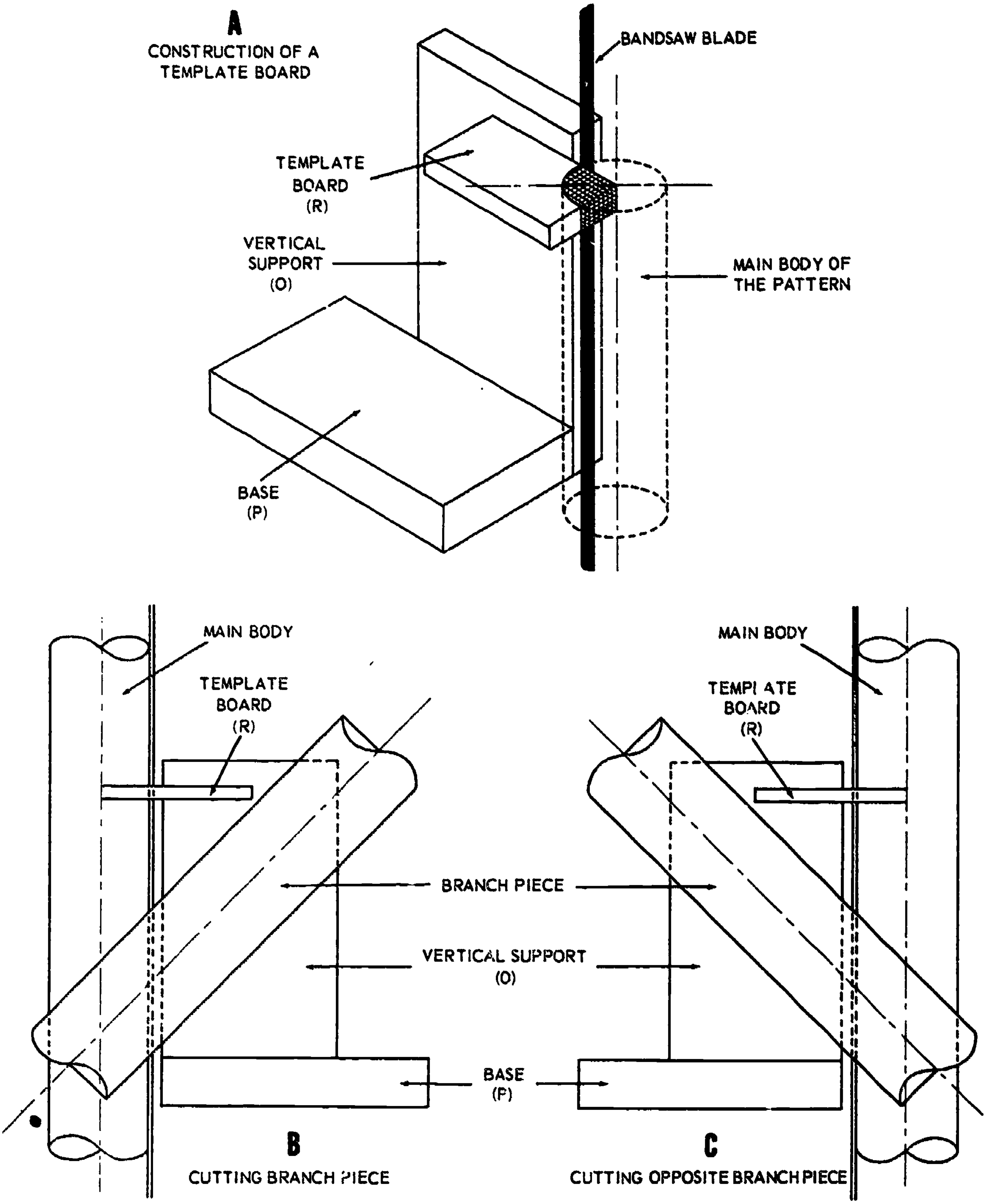


Figure 14-16.—Wraparound method of joining component parts. 68.159

A vertical piece (O) is fastened to a heavy base (P). (The base and the vertical piece MUST be at a 90° angle to each other.) A template board (R) is secured to the vertical side piece (O) in a position parallel to the base (P). Between the template board (R) and the base (P) sufficient distance should be allowed to secure the branch pattern at the correct angle for the matching curved cut. If required, additional side supports may be added.

To use the template board arrangement, the branch pattern is located on the vertical piece (O) at the same angle that the branch is to make with the main body. The template board is scribed with a quarter circle having the radius equal to the radius of the main body. (See part A of fig. 14-16.) The scribed circle represents the true position of the main body of the pattern. The jig is then rotated so that the bandsaw blade will follow the quarter circle scribed on the template board. The saw blade will cut a section out of the branch pattern, leaving the correct shape to fit the main body. The opposite half of the branch pattern is cut in the same manner, but in the reverse position using the same two template boards as shown in part B and C of fig. 14-16.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 15.

HEADING — Permanent or temporary heads over which lags or staves are laid.

HUB — A projection which is round or otherwise and is usually the center of some rotary movement.

SPIDER — An open web whose members radiate from the center like the spokes of a wheel.

STITCHING — A method of securing butt joints by alternate tongues and grooves; each is the thickness of a saw cut.

WEB — A plate or thin member lying between heavier members.

CHAPTER 15
SEGMENTAL AND STAVED PATTERNS AND CORE BOXES

Any pattern of a circular nature built up on layers or rows (courses) of pattern material is known as a segmentally constructed pattern. Segmental construction consists of using segments and/or sectors glued one upon another, to build up stock to the desired height, for any curved shape such as rings, ribs, or any other pattern member requiring strength or rigid construction.

There is no fixed rule as to the number of courses to be used for a given job. The number will largely depend upon the durability requirements of the pattern, the thickness of the available lumber, and how it corresponds to the total thickness of the job. Since wood shrinkage generally occurs across the grain, resulting in an elliptical form instead of a circular form, circular patterns are generally built up in segment form.

By using at least three courses of segments in multiple-course construction, the opposing stresses and strains, generated by the shrinking and swelling of the wood cells, are effectively equalized, thus minimizing distortion. Therefore, single-course segmental construction should not be used. However, single-course segmental construction is sometimes used in making patterns for thin sections such as wheels, sheaves, ribs, or pipe flanges if they are properly splined or stitched (reinforced).

The advantages of segmental construction are that it:

1. Provides greater pattern strength.
2. Reduces end grain.
3. Provides greater dimensional stability.
4. Produces greater staying qualities.
5. Saves material.

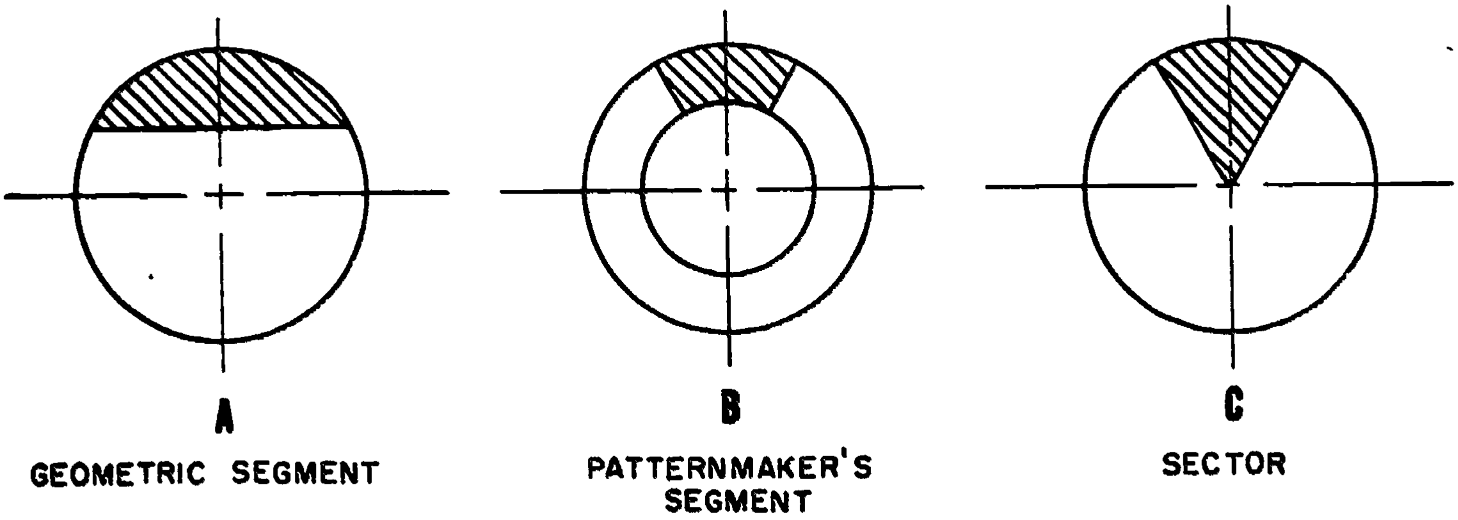
To understand the terms segment and sector, see parts A, B, and C of figure 15-1 and compare the following definitions: A GEOMETRIC SEGMENT is a portion of a circle bounded by an arc of that circle and a chord. In patternmaking, a SEGMENT is that part of a circular shape bounded by two arcs or concentric circles and common radial lines. A SECTOR is a figure bounded by two radii and the included arc of a circle, ellipse, or other central curve.

This chapter deals primarily with segmental and staved construction. However, additional information regarding a standard billet system, wheel patterns, bell-shaped patterns, a simple impeller pattern, and the fitting of bosses to curved or oblique surfaces is included because of its close relationship to turned segmental construction.

SEGMENTAL DIVISIONS

A circle may be divided into any number of equal segments. However, the most convenient procedure is to use six segments per course, for the simple reason that the longest chord of each of the six segments is exactly equal to the radius of its circle. The central angle of each of the six segments is exactly 60°. This is found by dividing the total number of degrees in a circle (360°) by the number of segments to be used. Using these facts simplifies the procedure of laying out and cutting segments to approximate size. Similarly, the amount of subsequent turning in the lathe is reduced.

The number of segments to be employed in any course is controlled by the diameter of the course, while the thickness is controlled by the available material. Small work that is turned only on the outside may have four segments to a course. If the piece is to be turned on the inside, six segments to a course is the least number that should be used, to eliminate end grain at the joints.



68.160

Figure 15-1.—Comparison of a segment and a sector.

In determining the number of segments or sectors per course, a general rule to follow is:

1. For diameters up to 8 inches, use four or six segments.
2. For diameters from 9 inches to 14 inches, use six to eight segments.
3. For diameters from 14 inches to 24 inches, use 8 to 12 segments.
4. For diameters over 24 inches use 12 or more segments.

Segments may be laid out by a trial and error procedure, that is, by stepping off the dividers as many times as necessary until the circumference of the circle is divided into an equal number of parts. The most accurate way of calculating the number of segment divisions of a circle is by using trigonometry, that branch of mathematics which deals with the relationships between the sides and angles of triangles. Although there may be other procedures, the two mathematical methods that are most commonly used are the sine method and the tangent method.

THE SINE METHOD

Table 15-1 is given as a ready reference for determining the chords of segments. To obtain the length of a chord, multiply the diameter of the circle by the factor listed opposite the number of segments required.

Table 15-1.—Chords of Segments or Sectors

Number of segments	Factor	Number of segments	Factor
3------------	0.8660	14-----------	0.2225
4------------	.7071	15-----------	.2079
5------------	.5877	16-----------	.1950
6------------	.5000	17-----------	.1837
7------------	.4338	18-----------	.1736
8------------	.3826	19-----------	.1646
9------------	.3420	20-----------	.1564
10-----------	.3090	21-----------	.1490
11-----------	.2817	22-----------	.1423
12-----------	.2588	23-----------	.1361
13-----------	.2393	24-----------	.1305

68.186

Table 15-1 is based on circles having a diameter equal to 1 inch. For circles of other diameters multiply the factor by the diameter of the circle. For example, if eight segments are used to make a circular course 11 inches in diameter, the chord length of each segment is found by multiplying the factor 0.3826 by 11. Thus the chord length is 4.21 inches.

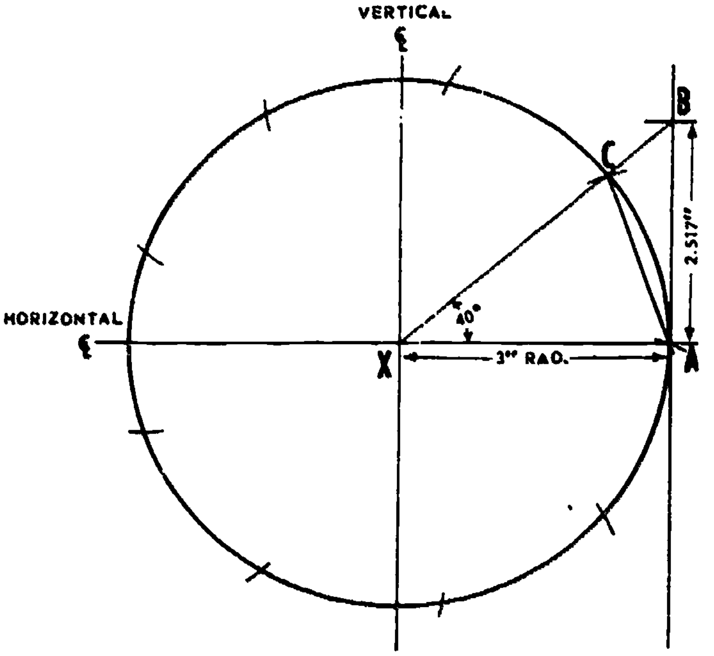
THE TANGENT METHOD

Some patternmakers prefer the tangent method of dividing circles, which involves the use of tables of natural trigonometric functions. To illustrate this method, we shall present the procedure for dividing a circle with a diameter of 6 inches into nine equal segments. (See fig. 15-2.)

The steps in the procedure are as follows:

1. Scribe horizontal and vertical centerlines intersecting at point X.
2. Scribe a circle from center X using dividers set to a radius of 3 inches.
3. Erect tangent AB perpendicular to line AX.
4. Because nine segments are required, divide 360° by 9. In this way the central angle AXB is found to be 40°.

It may seem that the whole problem is solved just because you have found that the central angle is 40°. You are probably wondering why you cannot adjust and set a bevel gage or protractor to 40° and transfer the measurement directly to the layout. This is NOT recommended because it is almost impossible to adjust a bevel gage or protractor (using the naked eye) to any given angle with sufficient accuracy for precision patternmaking. For maximum accuracy of work, it is recommended that the angle be calculated and laid out using trigonometry.



23.68
Figure 15-2.--The tangent method of laying out the central angle and segment divisions (chords) of a circle.

5. Calculate the length of AB using the following formula: The tangent of angle AXB is equal to the length of the opposite side, AB, divided by the length of the adjacent side AX. Substituting terms and solving the equation, we find that AB is equal to the tangent of 40° multiplied by the radius of the circle. You will find by consulting a table of natural trigonometric functions, that the tangent of 40° is 0.83910. Multiplying 0.83910 by 3 inches, the radius, will give the length of AB as 2.51730. The computations may be summarized as follows:

$$\text{Tangent of Angle } AXB = \frac{AB}{AX}$$

$$\text{Tangent of } 40° = \frac{AB}{3 \text{ inches}}$$

$$AB = (\tan 40°)\ (3)$$

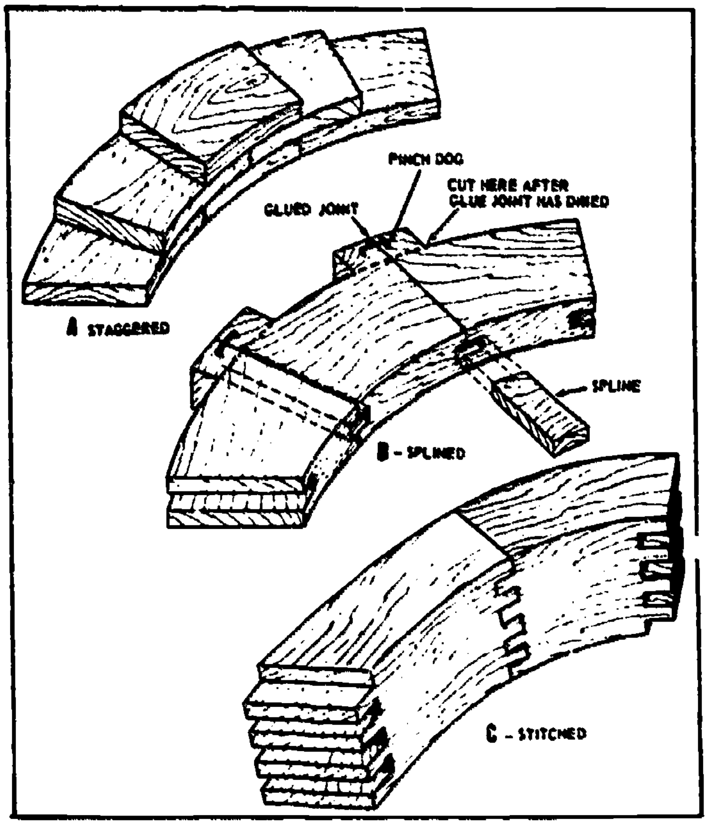
$$AB = (0.83910)\ (3)$$

$$AB = 2.51730$$

6. Interconnect points B and X to obtain the central angle AXB.
7. Line AC is the chord of the segment. Adjust the dividers to this length and step off the nine equal segments on the circumference of the circle.

JOINING SEGMENTS IN A COURSE

There are three methods of joining segments, as shown in figure 15-3. In multiple-course segment construction the standard practice is to use staggered joints as shown in part A of figure 15-3. Note that the segment joints of one course are placed halfway between the joints of the course immediately above and below. The splined joint is used in single-course segment patterns. Note that the spline is cut with the grain running in the same direction as the grain of the segments. This ensures maximum strength. Shaping the segment as shown in part B of figure 15-3 facilitates the gluing procedure without defacing the surface of the pattern. Drive the pinch dogs into the waste stock in order to draw the joint surfaces together during



68.161X
Figure 15-3.—Methods of joining segments.

the gluing operation. Saw off the projections after the glue has dried.

The stitched joint (part C of fig. 15-3) is used in constructing dome-shaped patterns or shapes that curve rapidly away from the perpendicular; if this type of pattern were made of plain segments as shown in part A of figure 15-3 the exposed glued course joint would be long and thin (feathered). The feathered edge would tend to curl or peel away from the pattern due to the moisture penetrating back into the wood cells.

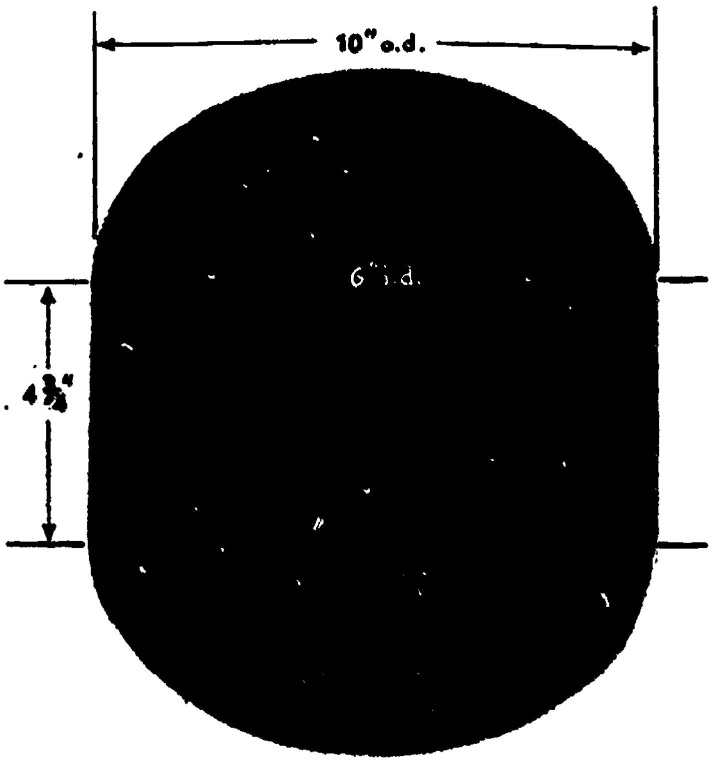
Slash-cut boards make better segments because the grain follows the outline of the segments. This permits the turning of a smoother job in the lathe.

Segment patterns which are to be turned on the lathe are built directly on a false faceplate that has been trued for the purpose. For safety, secure the glued segment pattern to the false faceplate with wood screws before turning the work on the lathe.

A TYPICAL SEGMENT PATTERN

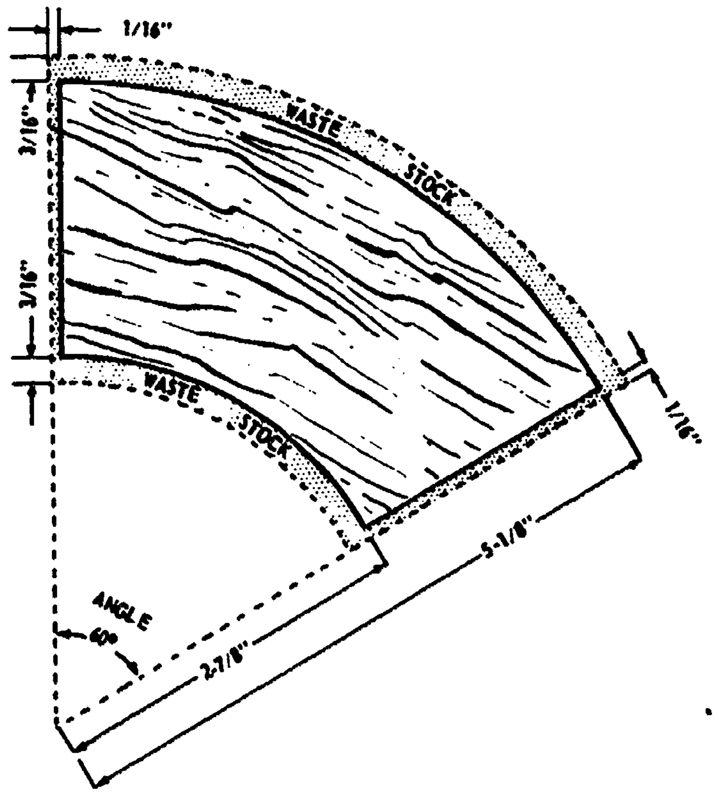
For instruction purposes, a detailed description is presented for the construction of the segment pattern used in casting the bushing shown in figure 15-4.

1. Prepare the layout using measurements taken directly from the worn bushing, or from the blueprint if it is available. (See fig. 15-5.) Use the appropriate shrink rule for the metal to be cast. Since this bushing will be finished all over (FAO), an extra 1/8 inch must be allowed for finishing. The completed pattern will therefore be 5 inches high, with an inside diameter (ID) of 5 3/4 inches and an outside diameter (OD) of 10 1/4 inches.
2. Calculate the number of courses required for the job. The height of the pattern will be 5 inches. If using 1 1/8-inch stock dressed down to 1 inch, you will need five courses of segments.
3. Use six segments for each course, Lay out and construct the template for the individual segments (fig. 15-6). Note that the diameter



68.162
Figure 15-4.—A casting of a cylindrical bushing.

68.163
Figure 15-5.—Layout of the cylindrical pattern.



68.164
Figure 15-6.—Construction features of the template.

of each course is the same, therefore all the segments will be exactly alike. Add 1/8-inch machine finish allowance and additional waste stock to the layout of the template. Since each mating edge of the segment is cut at a 30° angle, the total angle of the segment is 60° at the center of the circle. Cut out the template on the bandsaw.

4. Stack the dressed stock and mark the outlines of the template on the top board as shown in figure 15-7. This saves time by permitting you to cut out all the segments in one operation.

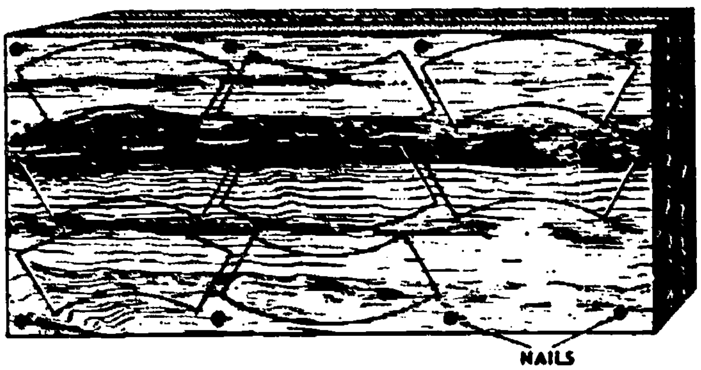
5. Glue the first course of segments on the layout board, or directly on the faceplate. Glue the succeeding courses, making sure to stagger the joint seams of the segments. After the glue has dried remove the work from the layout board and true up the bottom course of segments by taking a few light cuts with a plane.

6. Attach the glued segment pattern to a faceplate for lathe turning. Be sure to center the work properly. In the process of building up five courses of segments, the glued joints between courses will increase the height of the pattern slightly. Recheck the height using a depth gage. Take a light cut across the face of the work to bring the height of the pattern back to the correct dimension and to true up the top surface of the pattern.

7. Turn the inside diameter of the pattern, including draft. Adjust the tool bit and the carriage of the lathe to cut the proper draft.

8. Turn the outside diameter of the pattern including draft.

9. While the work is in the lathe, sand it smooth and apply the first coat of shellac.



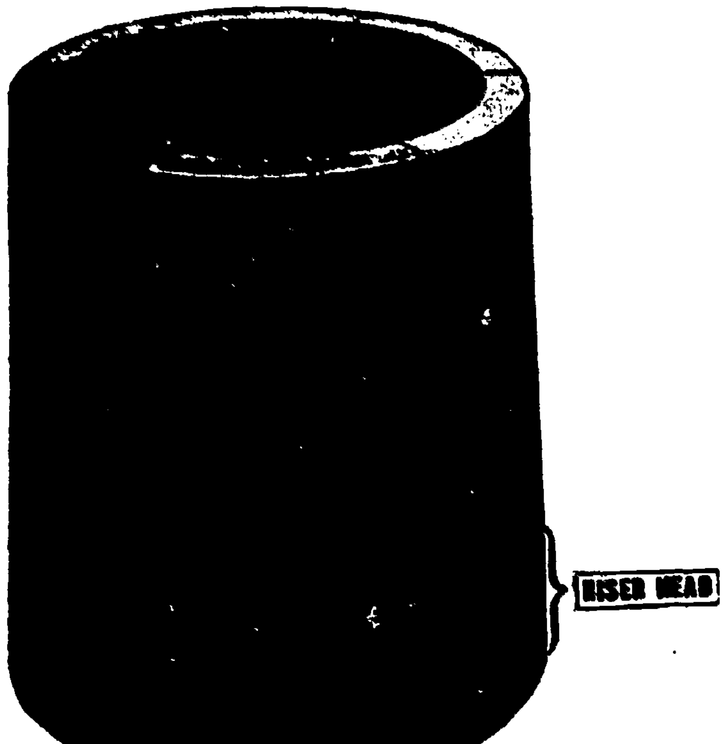
68.165
Figure 15-7.—Multiple sawing of segments.

10. Finish the pattern while it is still in the lathe. Remove the work from the lathe. Plug the holes left by the faceplate screws. Sand the bottom face smooth; shellac, and add rapping plates if necessary. Recheck the completed pattern against the layout and add identification tape.

In some cylindrical or conical-shape jobs, it may be necessary to build up a riser head as an integral part of the pattern. This technique saves molding time and helps to promote directional solidification of the molten metal. Figure 15-8 shows a riser head constructed as part of the cylindrical pattern. Note that the method of off-setting courses for conical sections is used. This is essentially the same method of construction used in bell-shaped patterns.

BILLET PATTERNS

Commercial billets of a standard size are cast by the centrifugal casting process. However due to the limited space and equipment aboard a repair ship or tender, billets cannot be centrifugally cast, they are sand cast. Usually, billets are cast vertically but they may be cast horizontally. Billets are used in the machine shop for the manufacture of bearings, cylinder liners, pistons, piston rings, and special cylinder barrels. The patterns needed for casting billets may be one-piece (solid or parted), stave-constructed, or segmentally constructed (ring patterns).



68.166
Figure 15-8.—Segment pattern including riser head, dragside up.

Cast billets of various sizes are needed in the machine shop from time to time. Usually the supervisor of the foundry (ML1 or MLC) will check with the supervisor of the machine shop (MRC) to see what sizes are needed so that the foundry can keep ahead of the machine shop's immediate needs in supplying cast billets. Since the various sizes needed are numerous, instead of constructing billet patterns of a particular size and length only when needed, a series or a set of patterns are constructed in standard lengths and diameters. Therefore, a complete set of billet patterns (Standard Billet System) are on hand at all times, saving time in the pattern shop and foundry which in turn will save time in the machine shop to complete a job order.

A set of billet patters may consist of the following (this list is intended merely as a guide):

1. One series constructed for vertical molding with interchangeable core prints.
2. One series constructed for horizontal molding.
3. One series of ring type patterns constructed for vertical molding.

Billet patterns are constructed in a set or series ranging from 2-inch to 18-inch outside diameter with standard lengths of 6, 9, 12, 15 or 18 inches. The patterns are made in 1/2-inch diameter increments, while the core boxes are made in 1/4-inch increments. Interchangeable cope and drag prints are used in conjunction with the set of patterns, making it possible to cast billets of the same outside diameter but of different inside diameters.

In the manufacture of a set of billet patterns to be molded VERTICALLY, it is suggested that the following methods of construction be used:

1. Up to 5 inches in diameter, use solid construction.

2. From 5 inches to 8 or 10 inches in diameter, use staved or lagged construction.
3. Above 10 inches in diameter, use the ring type billet pattern.

It is suggested that 1/16-inch to 1/8-inch draft per foot be used for vertically cast billets. (See chapter 11 for vertical core print proportions.)

In the manufacture of a set of billet patterns to be molded HORIZONTALLY, it is suggested that the following methods of construction be used:

1. Up to 5 inches in diameter, use solid construction.
2. Above 5 inches in diameter, use staved or lagged construction.

(See chapter 11 for core print proportions to be used for horizontal cores.)

WHEEL PATTERNS

The making of patterns for wheels of various designs is a common job aboard repair ships. Wheels that are made with a solid center or plate are called webbed wheels. Lightening holes are sometimes cut through the web to decrease the weight of the wheel. Other types of designs are flanged, and armed or spoked wheels. An assembled set of spokes is referred to as a spider. A wheel with a double set of spokes or two spiders is called a drum. Figure 15-9 shows the method of constructing a webbed wheel pattern. Note that a recess is turned in the central courses at A to provide a seat for the circular web. This is sound construction technique because it prevents the end grain of the web from extending completely through the rim of the wheel. It also eliminates a featheredge at the fillet at point B. The cope hub is constructed as a loose piece and is made to fit the recess in the web at C, in order to eliminate a featheredge and to simplify molding procedures.

Figure 15-10 shows the method of constructing a single-course, spoked wheel pattern. Several principles of sound pattern construction are illustrated in this figure. The single course of segments which make up the rim of the wheel is splined for greater strength. The spokes are recessed into the rim of the wheel to eliminate end grain and to prevent a featheredge. The spokes of the spider are attached to the rim at points midway between the splined segment joints. This also makes the pattern stronger.

Other features of sound pattern construction may be seen in figure 15-11 which shows three methods of joining spokes in building up a spider.

When constructing a wheel pattern, consider the design of the spoke to minimize stresses and to avoid casting strains. (See fig. 15-12.) Note that the odd number of curved spokes are used to reduce internal stresses in the wheel design, which result from uneven shrinkage at hot spots.

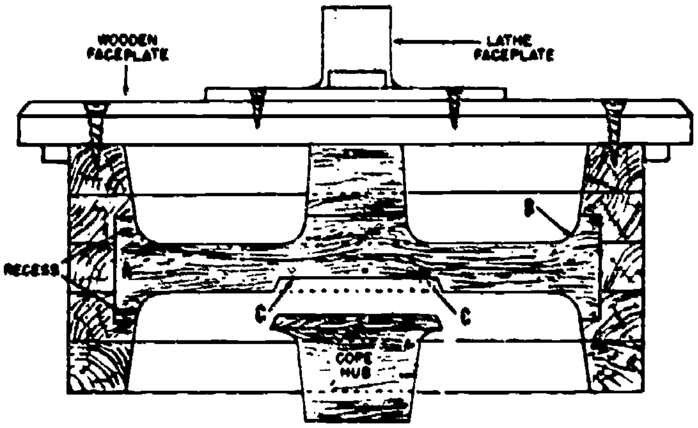


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Figure 15-9. — Construction features of a webbed wheel pattern.

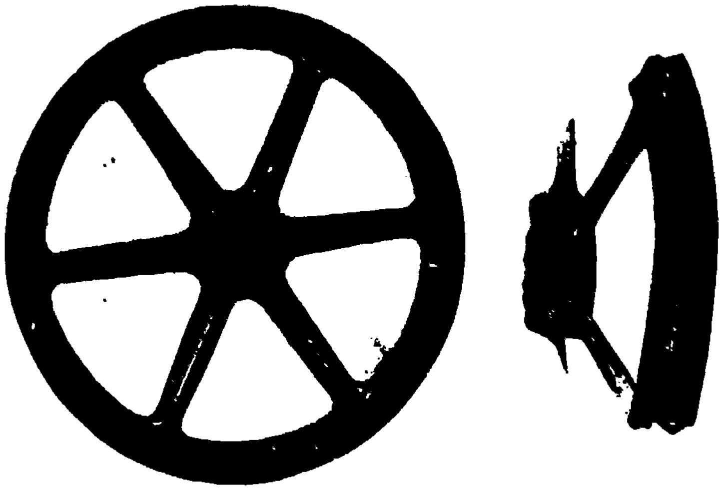

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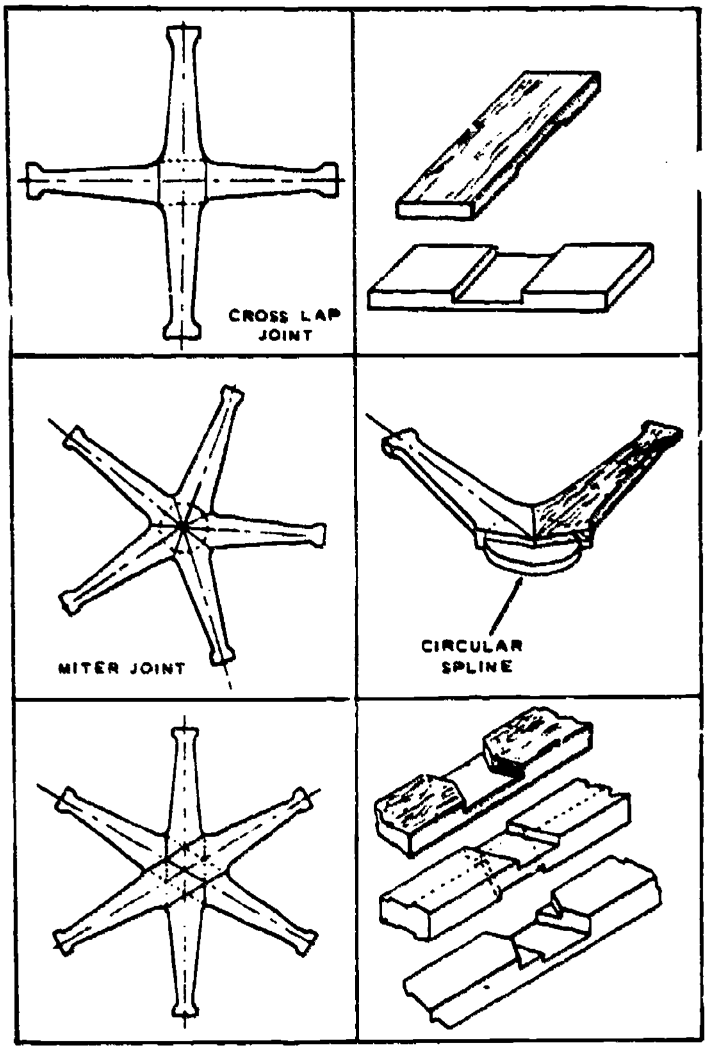
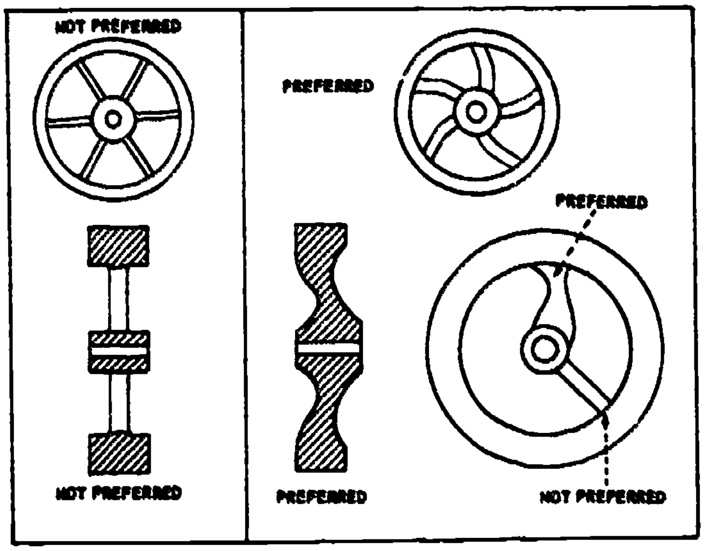
Figure 15-10. — Method of constructing a single-course, spoked wheel pattern.



68.169
Figure 15-11.—Methods of joining spokes.



23.9X
Figure 15-12.—Spoke design.

When the straight spoke design is used, (fig. 15-12) the stresses developed are absorbed by the hub while the metal is still in the plastic state. The secondary phase of shrinkage that takes place in the straight spoke, shortens the spoke and tears it away from the hub. But curved spokes under stress tend to straighten out rather than to be torn away from the hub. Note also in figure 15-12, that the sections are blended into one another so that all cross sections will cool as evenly as possible. Although an odd number of spokes is preferred for design reasons, you will no doubt get jobs that will require deviating from this rule.

BELL-SHAPED PATTERNS

The construction of a bell-shaped pattern is somewhat similar to that of the bushing or cylindrical pattern. The bell pattern, however, is complicated by the fact that each course of segments differs in diameter. Each course of segments must be laid out individually. The stacking of the stock and multiple sawing of all the segments for all the courses cannot be accomplished in one operation.

The preferred method of closing off the top of the bell is by using a course consisting of four segments cut at 90° angles. See view B in figure 15-13. Note the direction of the grain of the individual segments.

The segment course that forms the top of the bell is mounted on a false faceplate and faced off. Two or three courses of segments are glued in place and faced off. Then the distance of the course joint from the false faceplate is checked. The inside of the glued-up segments is turned to the required shape, which is determined by using a template. Additional courses are added until another suitable depth is reached and then turned as previously described. This operation is repeated in two or three course lengths until the entire length of the bell is reached and turned on the inside. Before the stock is removed from the lathe, a short distance on the outside is turned to size. This short, turned length will serve as an aid in rechucking. The inside of the turned pattern is sanded and a thin coat of pattern covering is applied.

The pattern is removed from the false faceplate and another false faceplate (chuck)

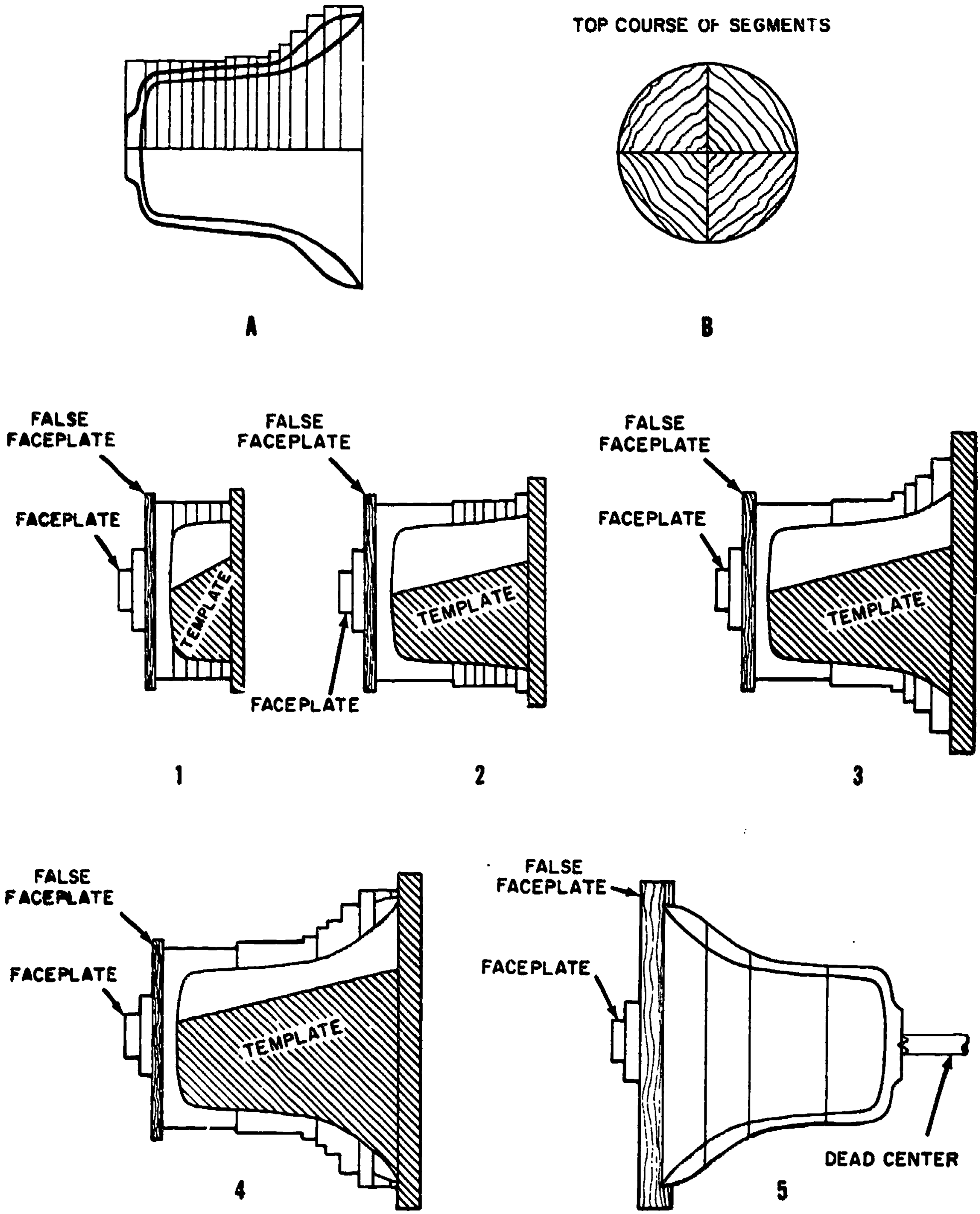


Figure 15-13.—The layout of a bell-shaped pattern showing its construction features. 68.170

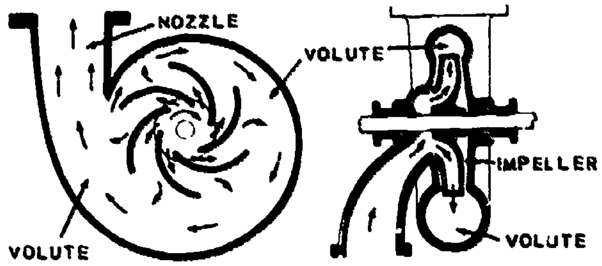
is turned to receive the short, turned length of the outside of the pattern. The pattern is fastened to the turned chuck with screws and the outside shape is turned to the required contour. As an extra safety factor when the outside contour of the bell is being turned the dead center of the tailstock is run into the top of the bell to serve as extra support.

SIMPLE IMPELLER PATTERNS

Knowing how a component or unit works is just as important as having practical experience in constructing various parts. It is not the intention (or within the scope) of this training course to explain all of the various pieces of equipment which you may be required to manufacture. However, this training manual presents typical samples of the various parts that you as a PM3 or PM2 may be required to manufacture, such as a pattern of a single suction impeller for a volute pump. To further your understanding of impellers and centrifugal pumps, a brief discussion is given to explain what happens inside a centrifugal pump, the type most commonly used in the Navy.

In the centrifugal (volute) pump, the liquid enters the pump at the center through the EYE, and is given a rotary motion in the pump chamber by the rotation of a number of blades (the IMPELLER). The rotation of the impeller in a true centrifugal pump does two things to the liquid; centrifugal force drives the liquid outward from the center, setting up a greater pressure at the outer edge of the chamber than at the eye; at the same time the liquid is pushed around and around in the chamber by the turning of the blades, and is given more and more velocity as it moves farther out from the eye. The liquid finally escapes into the discharge pipe. By gradually widening the discharge pipe and thereby reducing the velocity of the liquid, most of the velocity produced by the centrifugal pump is transformed into pressure. In this form it is more available for doing work.

The impeller blades of most centrifugal pumps are curved, the nature of the curve and the dimensions of the pump chamber and the discharge pipe being determined by the kind of flow desired. Note that the direction of rotation of the impeller shown in figure 15-14 is clockwise, so that the liquid is pushed around the chamber by the blades, rather than being carried in them.



23.18.0
Figure 15-14.—A single suction centrifugal pump.

LAYOUT OF A SINGLE SUCTION IMPELLER

According to the blueprint (fig. 15-15), the impeller is to be cast from Navy Specification 46-M-6 ("G" metal), machine-finished on the outside and finally, balanced. Because the blueprint indicates that the impeller is to be cast from "G" metal (bronze), you will use a 3/16-inch shrink rule when making the layout. The layout is made exactly as specified on the blueprint and all draft allowances are made at the time of construction.

The general procedure is to lay out all the solid outline lines; then add the interior lines. The next step is to add the machine finish, then add the required core prints. Add construction joints, location of dowels, or other construction features as necessary. It may be noted, that for this particular job, only two full-scale orthographic views (one top view and one side view) are necessary. The front view is unnecessary because it does not add any significant features to the other views.

For instructional purposes, the layout procedures will be described step by step. It is suggested that you follow the instructions (steps numbered 1 through 20 in the next section) and prepare your own layout. Refer to figures 15-16 and 15-17 which identify the various steps by numbers. This system of number identification will enable you to follow the directions given. Remember that the Patternmaker actually works from the blueprint. Figures 15-16 and 15-17 show the steps in sequence but in separate figures for instructional purposes only. Remember that all dimensions taken from the horizontal centerline are to be laid out on both sides of the horizontal centerline because the horizontal halves are identical. But all dimensions taken from the vertical centerline on the left side are different than the dimensions

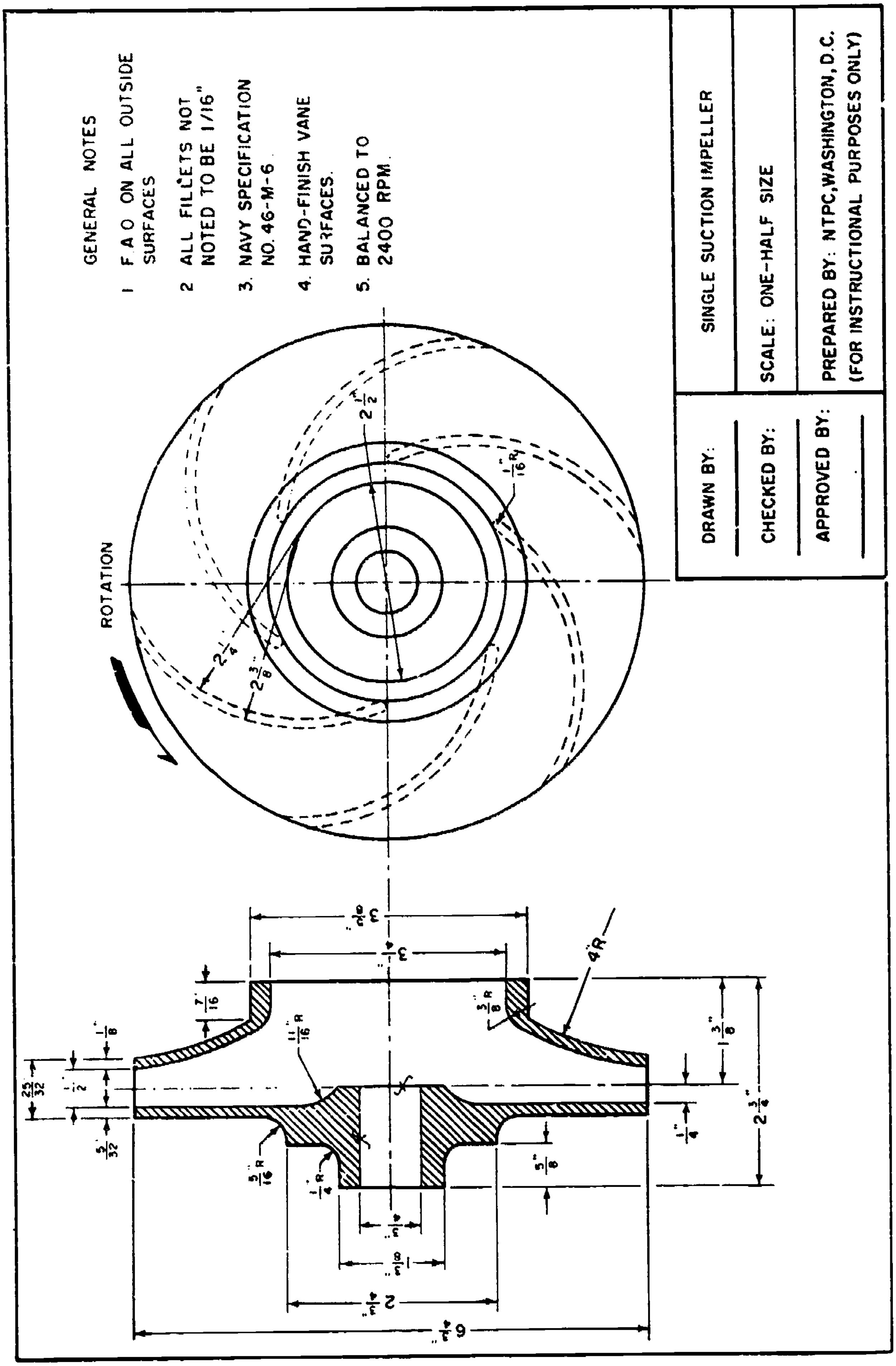


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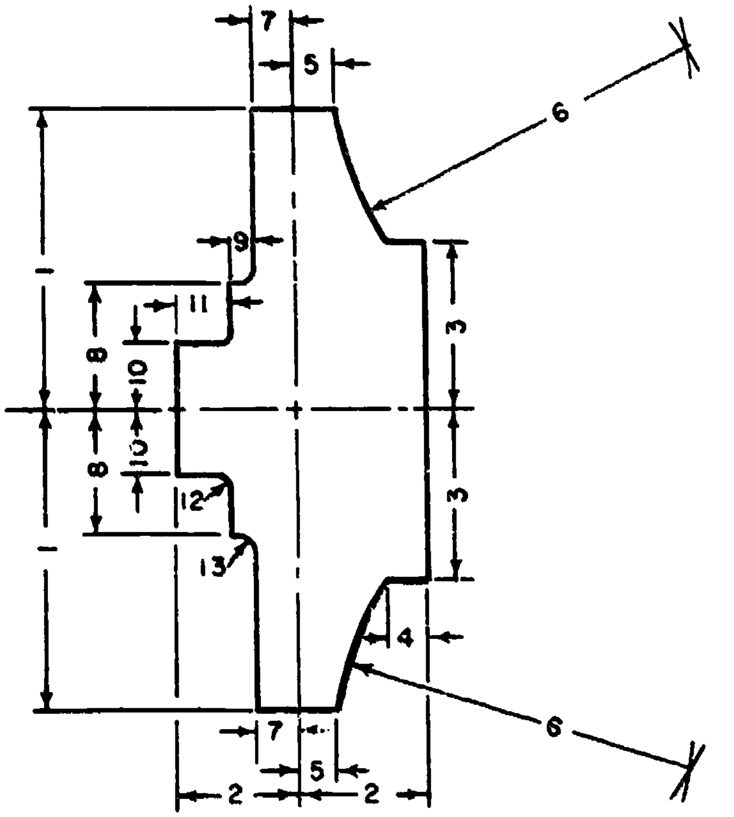
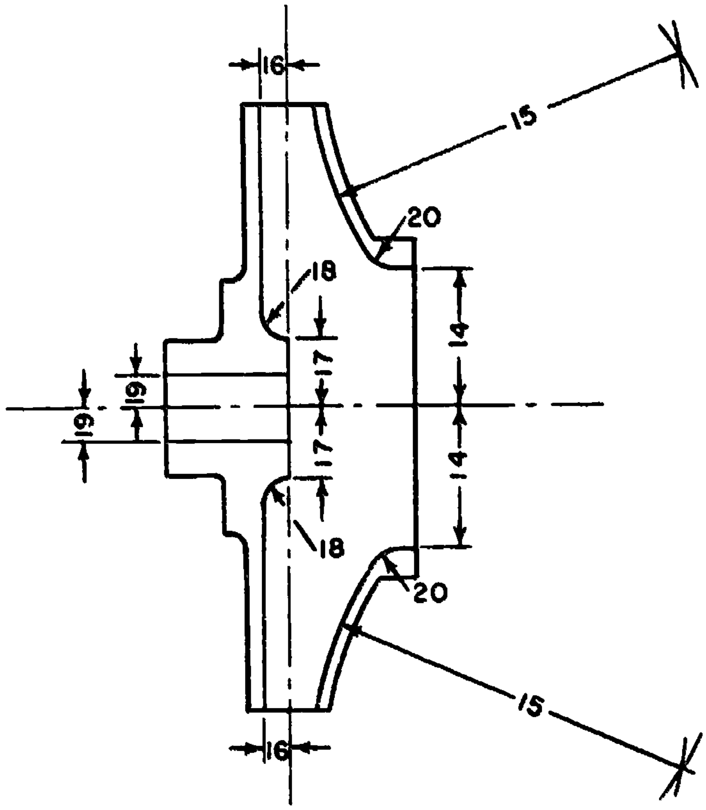
Figure 15-15.—Blueprint of a single suction impeller.



23.27(68)
Figure 15-16.—Layout of outside shape of impeller.



23.28(68)
Figure 15-17.—Layout of wall thickness.

on the right side because the shape of the left side is straight while the shape of the right side is curved.

Select a layout board of appropriate size and lay out the horizontal centerline and the two vertical centerlines, allowing adequate space for the required views. These centerlines will be used as the basic reference lines for subsequent measurements.

1. Establish the full diameter of the impeller by using the intersection of the horizontal and vertical centerlines (fig. 15-16) as the center point to scribe a line 3 3/8 inches from the horizontal centerline and parallel to it.

2. Lay out the full width of the impeller by measuring and scribing a line 1 3/8 inches from the vertical centerline and parallel to it.

3. Establish the diameter of the outside hub by measuring and scribing a line 1 13/16 inches from the horizontal centerline and parallel to it.

4. Establish the length of the outside hub by measuring and scribing a line 7/16 inch long, to the left of the right full width (step 2) and along the scribed line made in step 3.

5. Establish the width of the curved side face to the right of the vertical centerline at the outside diameter of the impeller by measuring and scribing a line 3/8 inch in length, extending from the vertical centerline and parallel to the horizontal centerline.

6. To establish the curved face of the impeller, scribe an arc of 4-inch radius from the width of the right side face on the outside diameter (step 5) and another arc of 4 inches from the length of the outside hub (step 4). At the point where these two arcs intersect, scribe an arc from the outside diameter to the length of the hub.

7. Establish the width of the straight side face to the left of the vertical centerline at the outside diameter by measuring and scribing a line 13/32 inch long, and parallel to the vertical centerline.

8. Establish the diameter of the largest hub to the left of the vertical centerline by measuring and scribing a line 1 3/8 inches from the horizontal centerline and parallel to it.

9. Establish the length of the largest hub to the left of the vertical centerline by measuring and scribing a line 11/32 inch long and parallel to the straight side face.

10. Establish the diameter of the smallest hub to the left of the vertical centerline by measuring and scribing a line 11/16 inch from the horizontal centerline and parallel to it.

11. Establish the length of the smallest hub to the left of the vertical centerline by measuring and scribing a line 5/8 inch long, to the right of the left outside width of the impeller and parallel to the straight side face.

12. Add a 1/4-inch radius between the smallest and the largest hubs to the left of the vertical centerline. The procedure for establishing the centers for this radius is basically the same procedure as given in step 6.

13. Add a 5/16-inch radius between the largest hub on the left side of the vertical centerline and the straight side face of the impeller. The procedure for establishing the center for the radius is basically the same as the procedures in steps 6 and 12. Darken the knife lines to complete the outside shape of the impeller as shown in figure 15-16.

14. Establish the inside diameter of the outside hub (eye of the impeller) by measuring and scribing a line 1 5/8 inches from the horizontal centerline and parallel to it. (See fig. 15-17.)

15. To establish the inside curve, use the center of the intersecting arcs (step 6). Scribe a 4 1/8-inch radius from the outside diameter to the inside diameter of the eye.

16. Establish the 1/8-inch wall thickness by measuring and scribing a line 1/4 inch to the left of the vertical centerline at the outside diameter and parallel to the vertical centerline.

17. Establish the inner hub diameter by scribing a line on the vertical centerline an equal distance of 11/16 inch on each side of the horizontal centerline.

18. Add a 11/16-inch radius between the inner hub diameter and the vertical line established by step 16.

19. Establish the shaft hole diameter by scribing two parallel lines, each 3/8 inch from the horizontal centerline. These two parallel lines extend from the vertical centerline to the left outside width of the impeller.

20. Add a 3/8-inch radius between the inside wall of the side curved face and the inside diameter of the eye. Darken the knife lines to complete the wall thickness of the impeller as shown in figure 15-17.

The procedure for ADDING MACHINE FINISH is as follows:

1. Add 1/8-inch finish on the outside diameter.

2. Add 1/8-inch finish on the length of the outer hub (eye).

3. Add 1/8-inch finish to the outside diameter of the outer hub (eye).

4. Add 1/16-inch finish on the side face curve.

5. Add 1/8-inch finish to the shaft hole diameter.

6. Add 1/8-inch finish to each end of the hub for the shaft hole.

7. Add 1/8-inch finish to the straight side face.

8. Add 1/8-inch finish to the outside diameter of the smallest hub left of the vertical centerline.

9. Add 1/8-inch finish to the length of the largest hub left on the vertical centerline.

10. Add 1/8-inch finish to the outside diameter of the largest hub left of the vertical centerline.

11. Add 1/8-inch finish to the radii on the smallest and largest hubs left of the vertical centerline.

Darken the knife lines and color the finished surfaces with a red pencil as shown in figure 15-18.

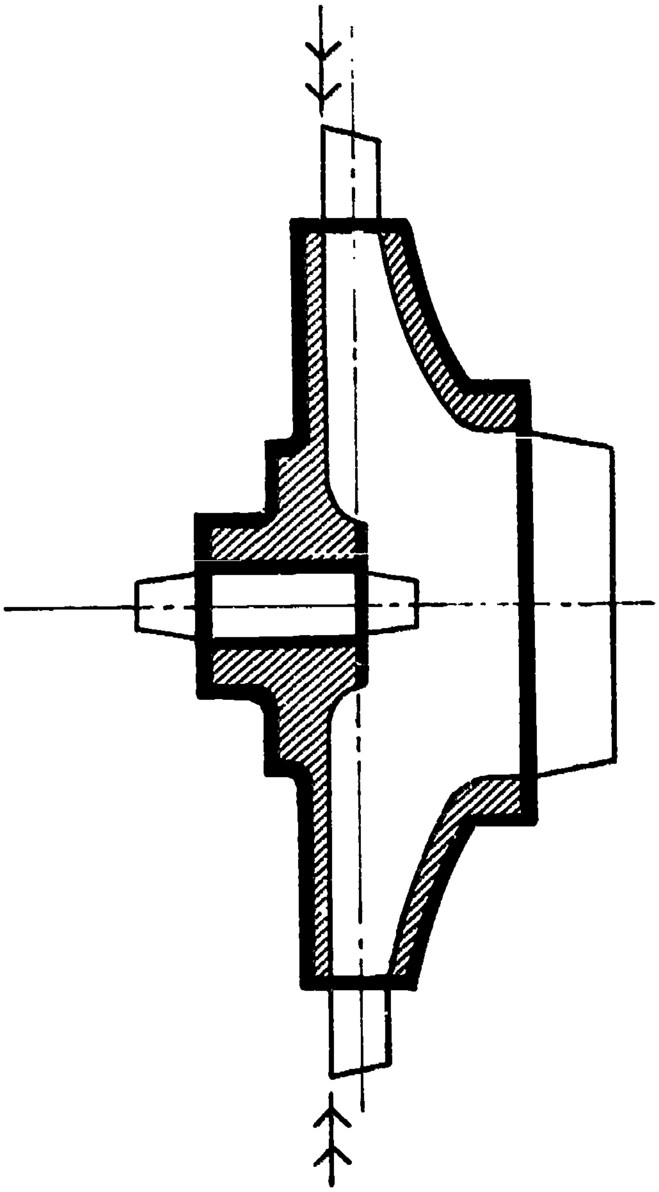
At this point in the layout, it is possible to see how the single suction impeller may be parted as shown in figure 15-18. The pattern may be parted along the upper surface of the suspended core print. In addition to the parting of the pattern, turned male and female dowels must be used for cope and drag pattern alignment.

The procedure for ADDING CORE PRINTS is as follows:

1. Add a core print to the drag half of the pattern layout for the eye opening of the impeller, 5/8 inch high, tapered from the inside of the eye opening to 2 3/4 inches in diameter.

2. Add a core print to the outside diameter for support of the suspended core. Extend the inside curved face line parallel to the parting line of the pattern. One inch from the outside diameter finish line on the parting line, scribe a line parallel to the draft established for the eye opening core print.

3. Add a vertical core print to the center hub as established by the core print dimensions



68.171
Figure 15-18.—Layout with finish allowance.

set forth in chapter 11 Darken the knife lines to complete the core prints as shown in figures 15-18 and 15-19.

The procedure for ADDING THE CONSTRUCTION JOINT LINES is as follows:

1. On the drag half of the pattern layout, starting at the limit of the eye opening core print, segment course A is scribed even with the finish line on the eye opening.

2. Segment course B is scribed even with the intersection of the curved side face and the eye opening hub.

3. Segment course C is located even with the finished line of the curved side face.

4. Segment courses D and E are combined to establish the distance from the finished line of the curved side face to the upper face of the suspended core print.

5. On the cope half of the pattern layout, segment course F is scribed from the finished line of the straight side of the impeller. Note the thickness of segment course F to include the male dowel.

6. Segment course G is the distance from the finished line of the straight side of the impeller to the finish length of the largest hub.

7. The smallest hub and the vertical core print are made of vertical grain material, and inserted into segment course G.

Note that the segment courses for the pattern are in such a location as to eliminate any featheredges on the turned pattern.

Darken the knife lines to complete the construction joint lines as shown in figure 15-19.

The procedure for laying out the curved vanes is as follows:

From the cross-sectional view of the single suction impeller blueprint (fig. 15-15), transfer only the necessary lines to develop the top view. To avoid confusion in the top view, finish allowance and the coreprints are eliminated from the layout as shown in figure 15-20. Using the dimensions as shown on the blueprint (fig. 15-15), develop the layout for the location and the curve of the vanes. The completed layout for the construction of the pattern for a single suction impeller is shown in figures 15-18, 15-19, and 15-20.

Check the completed layout against the blueprint to verify all dimensions. You are now ready to proceed with the actual construction of the pattern.

CONSTRUCTION OF SINGLE SUCTION IMPELLER PATTERN

After completion of the layout, you should have a reasonably good idea of how to start

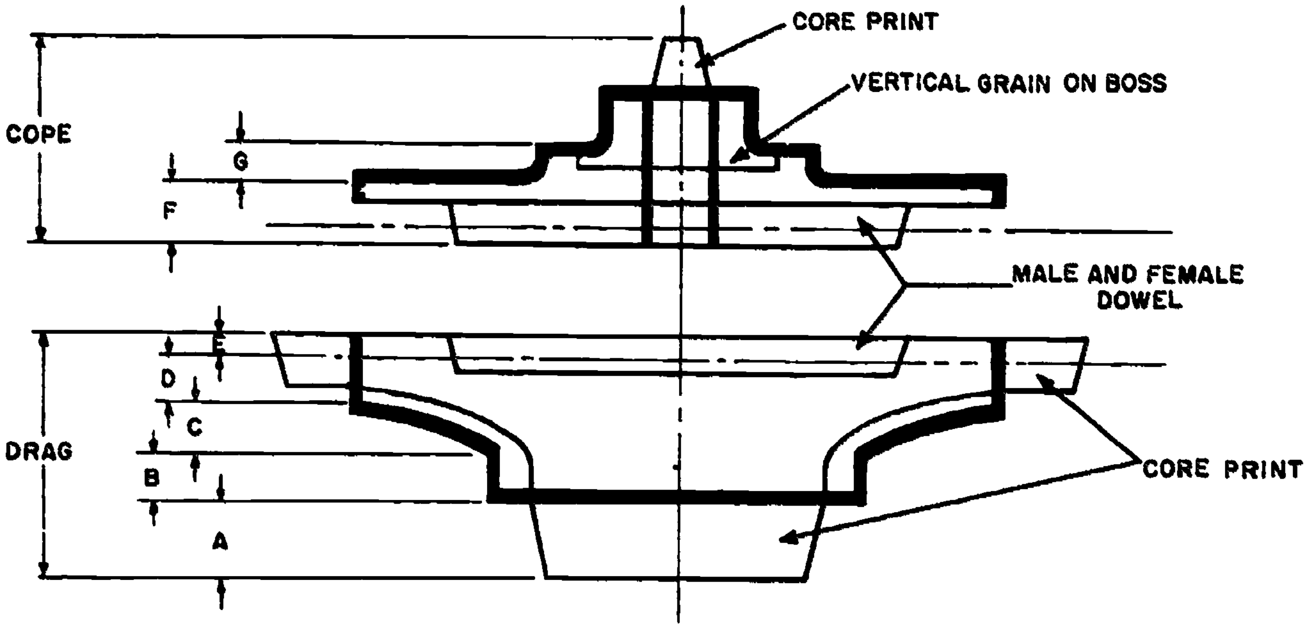


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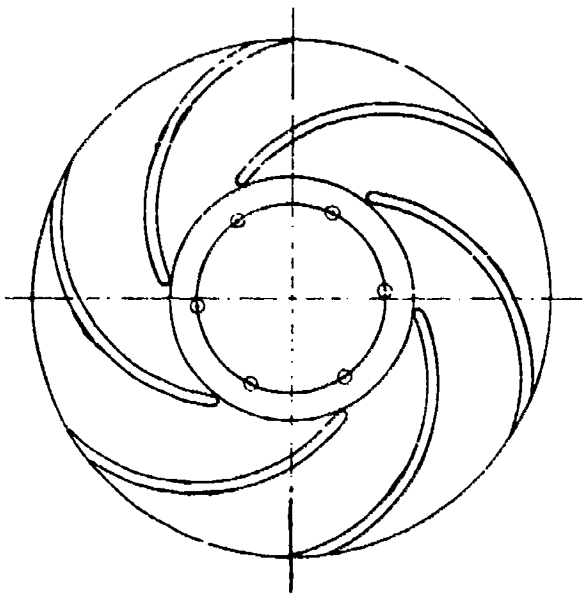
Figure 15-19. — Layout with construction joints for pattern.



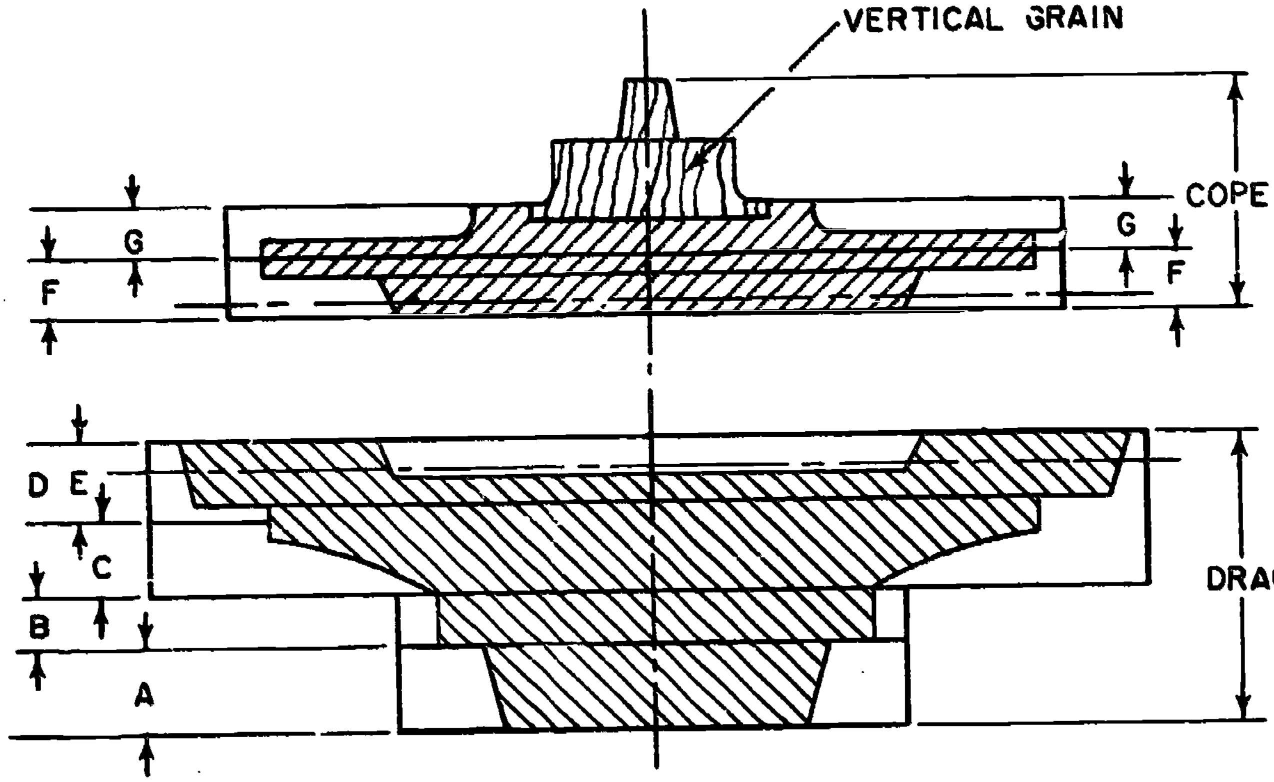
23.34

Figure 15-20. — Layout of curved vanes.

the actual construction of the pattern. However, after completing the layout, study it carefully and try to visualize the breakdown of the pattern into its components for construction purposes. (See fig. 15-21.) The value of careful planning at this stage can best be appreciated by visualizing the size and shape of the pattern, and the inside or cored sections, to determine the best possible method of construction. Careful planning at this stage will also serve as a stepping stone from the blueprint to the completed pattern.

The cope half of the pattern for a single suction impeller is built up of two courses of segments of different thicknesses and of vertical grain pattern stock for the boss and vertical core print. The drag half of the pattern is built up of five courses of segments of different thicknesses and of varying diameters. The main body (drag) of the pattern will include a core print around its periphery to locate and hold the suspended core. The body will also include a core print for the eye opening. The cope and drag halves of the pattern are aligned by turned male and female dowels.

A step-by-step procedure for the manufacture of a single suction impeller pattern as



23.35(68)

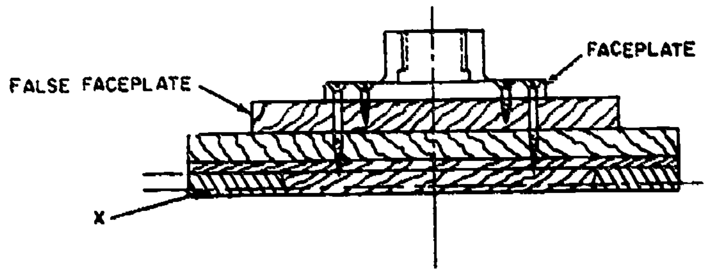
Figure 15-21.—Built-up cope and drag.

shown in figure 15-15 is described in the following paragraphs.

From the layout determine the thickness of each course of segments. Use six segments for each course. Lay out and construct templates for the various diameters of segments. Trace the outline of the segment template on the dressed stock and cut on the bandsaw. Sand the mating edges and glue the courses in the proper sequence as previously described.

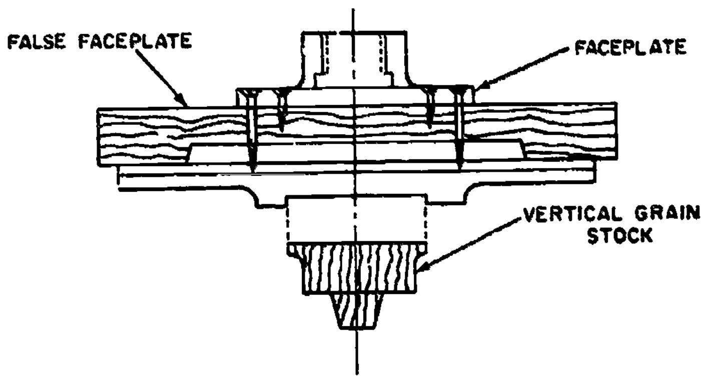
To save time, while the glue is drying, construct the template for the outside curved face of the impeller. After the glue has dried, true up the top surface of the built-up stock for the cope half of the pattern and mount on a false faceplate as shown in figure 15-22. Turn the male dowel to the dimensions of the layout as shown by X in figure 15-22. The male dowel is generally turned first so that it may be used as a template when turning the mating female dowel in the drag half of the pattern.

Turn a false faceplate to the reverse (female) shape of the male dowel. Rechuck the cope half of the pattern to the false faceplate and turn to size and shape as shown in figure 15-23. Turn a recess equal to the limits of the fillet on the boss. The depth should be approximately



23.36

Figure 15-22.—Turning of the male dowel.



68.173

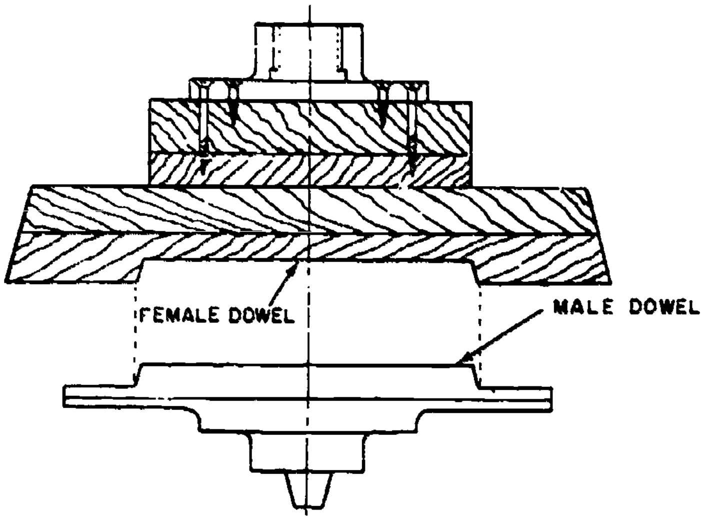
Figure 15-23.—Rechucking of the cope.

1/8 inch. Turn vertical grain pattern stock by the spindle turning method to the proper diameter and approximate length for the boss and the vertical core print. Glue the turned vertical grain stock into the turned recess in the cope half of the pattern. When the glue dries, finish turning the cope half of the pattern. While the work is still mounted on the lathe, sand it and apply the first coat of pattern covering. Remove the pattern from the false faceplate and plug the holes left by the faceplate screws. Recheck the cope half of the pattern against the layout.

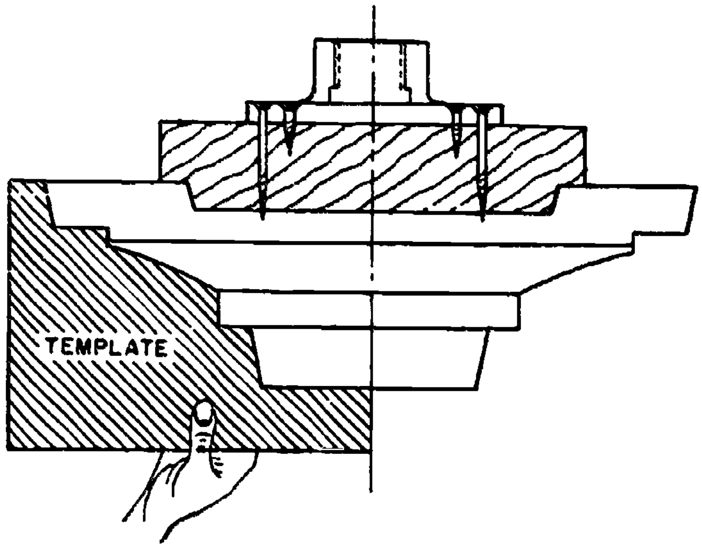
Mount the previously glued-up segment courses on a faceplate and turn the recess for the female dowel. Use the male dowel on the cope half of the pattern as a template for matching of the female dowel (fig. 15-24). When the proper matching of the male and female dowel is accomplished, turn an extra 1/32 inch from the depth, and 1/32 inch from the side angle and diameter of the female recess. This allowance permits expansion of the male dowel and shrinkage of the female receptacle caused by the application of the pattern coating. Turn the outside diameter and the angle of the core print on the periphery of the pattern (fig. 15-24).

Turn a false faceplate to the reverse (male) shape of the female dowel. Recheck the drag half of the pattern to the false faceplate and turn the opposite side (face curve) of the pattern to a template as shown in figure 15-25.

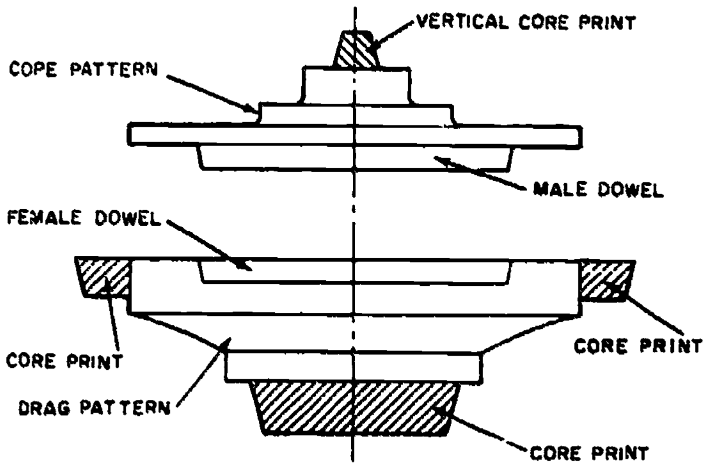
Before removing the work from the lathe, sand and finish the drag half in the same manner as described for the cope half. Recheck all dimensions and the shape of the pattern (cope and drag) against the layout. After the final checking, apply pattern coating in accordance with the Standard Color Code. The completed pattern is shown in figure 15-26.



68.174
Figure 15-24.—Turning of the female dowel and suspended core print.



23.39
Figure 15-25.—Rechucking of the drag.



23.40(68)
Figure 15-26.—Completed pattern for a single suction impeller.

CORE BOX FOR A SINGLE SUCTION IMPELLER

From the detailed study of the blueprint and the layout, it was decided to incorporate a suspended core to form the interior of the single suction impeller. In chapter 11 a suspended core was defined as one having the seat so formed that it may be suspended above the mold. (See figs. 15-18 and 15-19.) The core is of such shape in order to cast the vertical curved vanes accurately and to transfer a smooth surface to the casting which will be true to the desired contour.

Two core boxes are required for the single suction impeller. One establishes the eye opening on one side of the impeller and the vane openings on the periphery of the casting. The other box casts the hub shaft hole. The two cores when baked and assembled are set into the mold cavity as one complete unit.

A step-by-step procedure for the manufacture of the main body core box for a single suction impeller is described in the following paragraphs.

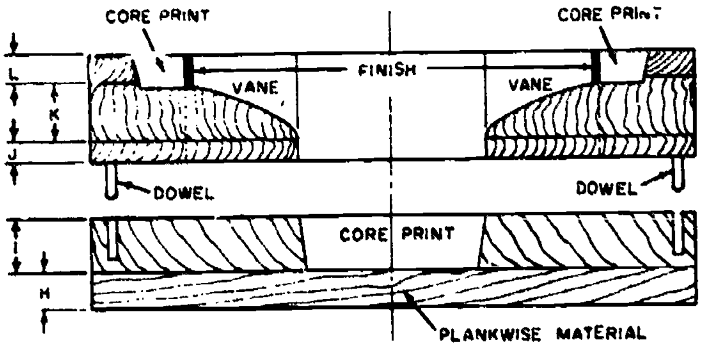
The thickness of the various segment courses are taken directly from the layout. Refer to figure 15-18 for the complete layout of the core boxes. Figure 15-27 shows the breakdown of the main body core box with a view of the course thickness and the temporary parting for the insertion of the curved vanes. The placing of the different course thicknesses in their proper order for the two halves of the main body core will permit production of a core box having the same staying qualities as the pattern. These course thicknesses also serve as a depth gage while turning the core box on the lathe.

Select plankwise stock (stock with the grain going in only one direction) of convenient thickness and of the proper diameter for H (fig. 15-27); mount it on a false faceplate and face off. This plankwise stock is used for the base of the main body core box. Lay out, cut, and sand segment course I as shown in figure 15-27, allowing stock for turning. Glue and clamp course I directly upon the plankwise stock. Face off segment I to the proper height.

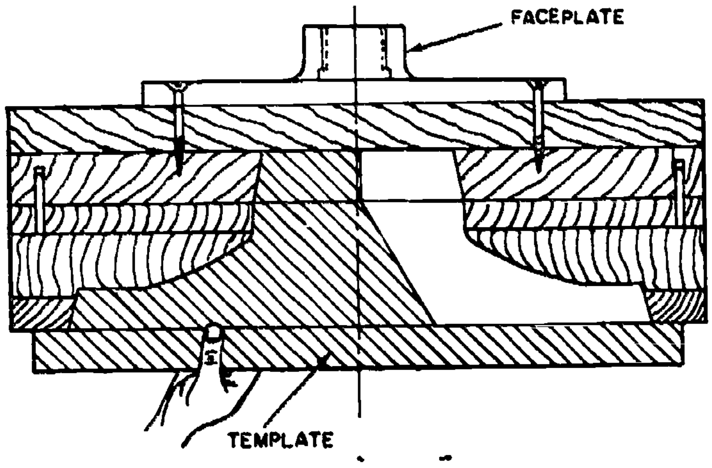
Lay out, cut, and sand segment courses J, K, and L. Glue and clamp these three courses together in the proper sequence, placing the course end joints midway between the end joints on the preceding course. After the glue has dried, plane the underside of segment J to make a perfect joint between courses I and J.

Clamp the upper section (courses J, K, and L) to the lower section (course I and the plankwise stock, H), bore two 1/4-inch holes through the upper section into the lower section, and insert dowels. (See fig. 15-27.) Placing of dowels in the box before turning the cavity ensures an accurate method of realigning the two sections of the box after the curved vanes are inserted. Drill clearance holes for wood screws through the lower section and secure both sections together. Place the screws so that they will not interfere during turning. Mark each complete unit for future reference.

Lay out and construct a template to the dimensions of the required cavity of the main body core as shown in figure 15-28. Using the proper surface feet per minute for the size of



23.42
Figure 15-27.—Layout of the body core box.



23.43
Figure 15-28.—Turning the main body core box to a template.

the box, turn the cavity to the template as shown in figure 15-28. Note how the segment courses serve as an aid in determining the depth of the various sections of the box. Before removing the box from the lathe, sand the box and apply the first coat of pattern coating. Remove the box from the lathe, but DO NOT remove the core box from the faceplate because, after the vanes are inserted, the top edges of the vanes have to be turned to a template.

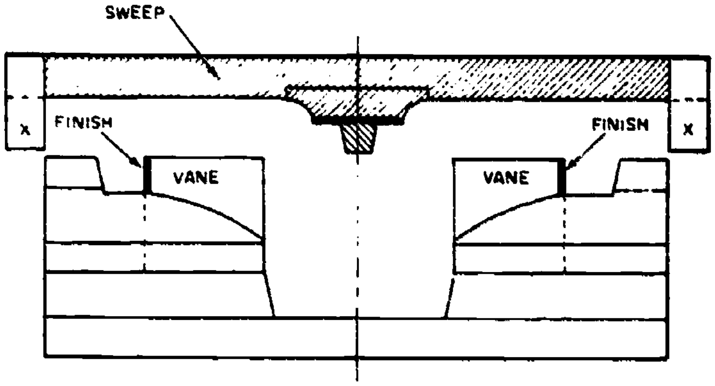
Remove the top section of the core box. Place the parting line of the box face down; put a temporary block of scrap stock in the eye opening flush with the parting surface of the upper section. The temporary block should be a snug fit because the true center of the box will be laid out on this block. On the surface of the parting of the box, lay out the curved vanes as shown in figure 15-20.

Remove the temporary block from the center of the box and cut out the vane sections to the line on the jigsaw. Referring to figure 15-20 which shows the layout of the curved vanes, lay out a template from thin template stock. Using end grain material slightly higher than courses J, K, and L, of figure 15-27, trace the vane template on the stock. Cut out and sand the curved surfaces to a slight draft.

Glue and insert the curved vane sections into the cutouts made in the core box. Insert the vanes from the curved cavity of the box to eliminate chipping of the curved surface. Plane the parting of the top section to remove those portions of the curved vane that may extend above the surface. Glue and clamp the two sections of the box in their proper position, using the dowels for alignment.

Remove the box from the faceplate, sand where necessary, and apply one coat of pattern coating to the box. Fill in all holes or voids between the vanes and the curved surface of the box. Run a leather or wax fillet between the vanes and the curved section of the box. Paint according to the Standard Color Code.

To complete the main body core box, a sweep is necessary to form the top surface of the core for the inner hub as shown in figure 15-29. The center section (inner hub and radius) may be turned between centers on the lathe and inserted into the sweep material. The sweep must be long enough to extend over the full outside diameter of the core box. A curved block (matched to the outside diameter) is fastened to each end of the sweep to align the center boss on the sweep in the correct position. (See X in fig. 15-29.)



68.175
Figure 15-29.—Vane insertion and sweep for main body core box.

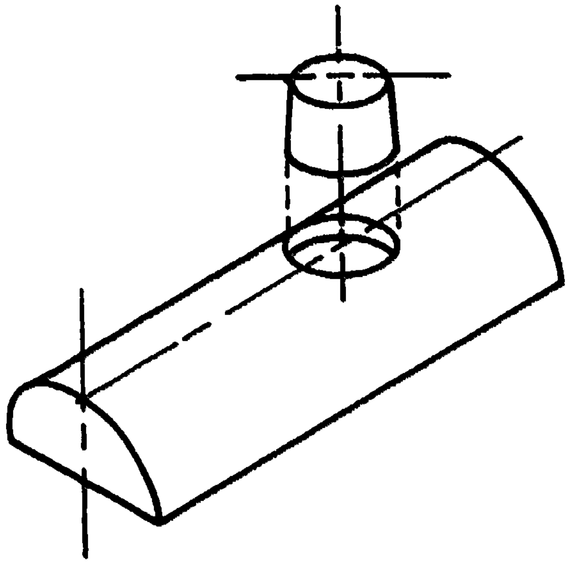
COUNTERSAWING OF PATTERN MEMBERS

The fitting of bosses and other pattern members to the main body of a pattern may be difficult due to the shape or contour of the pattern. As a PM3, you will be required to know enough of pattern joinery to overcome the difficulties encountered in laying out and cutting these members. Therefore, an understanding of countersawing is necessary for attaching those pattern members located on curved or oblique surfaces.

Countersawing, as the name implies, is two or more sawing operations used for the shaping of pattern members. The pattern member is laid out, sawed in one direction, bradded back together, and sawed and sanded in the opposite direction. As in all phases of patternmaking, absolute accuracy (through the use of centerlines) is necessary for laying out, cutting, sanding and fastening of the various parts of a pattern.

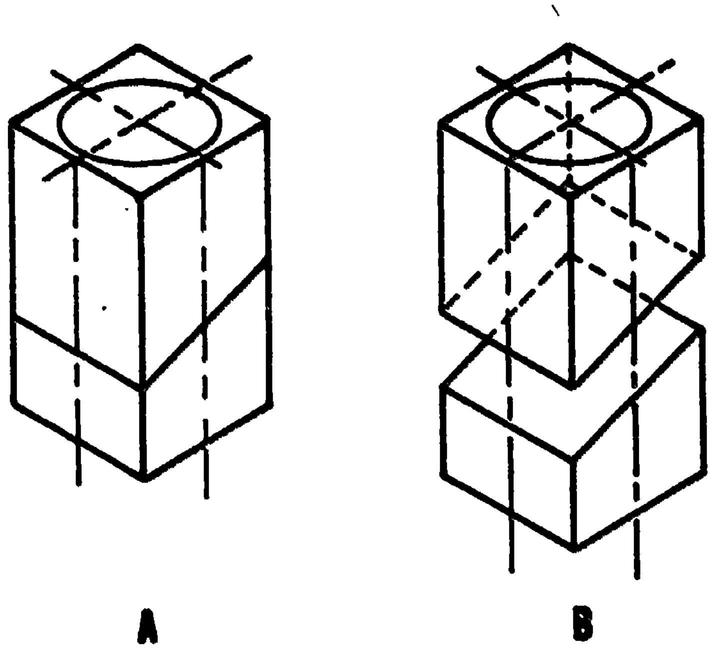
Ways of laying out and countersawing various shapes of pattern members are discussed in the following paragraphs.

The simplest method (fig. 15-30) for locating small bosses to a curved surface is to bore a hole in the pattern body at the proper location and insert the boss. This method has the advantage of having the boss permanently attached to the main body of the pattern. However, if an alteration to the pattern for the location of the boss is necessary, the bored hole would have to be plugged and the inserted plug faired to the main body.



68.176

Figure 15-30.—Boring into main body for boss insert.



68.177

Figure 15-31.—Laying out and cutting bosses vertical to an angle.

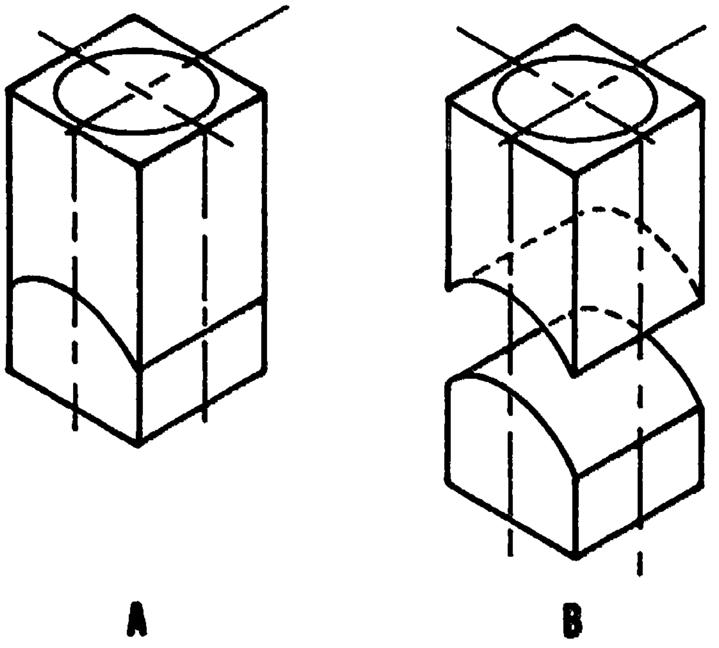
For pattern members, such as a boss that is located vertical to an oblique surface (fig. 15-31) on the main body of the pattern, a more definite method is recommended. Select a block of appropriate size for the boss. The length of the block should be greater than the length of the boss. The block should be slightly wider than the diameter of the boss. The extra width will allow for the draft to be sanded on the sides of the boss. In addition, the block must be sanded square to each surface.

Lay out the centerlines on all surfaces of the block and the diameter of the boss as shown in part A of figure 15-31. From the top surface of the boss, transfer the length of the vertical centerline of the boss from the layout to the squared block. The angle of the underside of the boss is laid out on the side surface of the block with the angle intersecting the vertical centerline and the transferred length of the boss. Cut the block to the angle laid out on the side surface of the block. Brad the two blocks back together, aligning the top section to the bottom section with the proper centerlines. (See part B of fig. 15-31.) Cut the circular shape of the boss (top of the block) and sand draft to the side surface. Reestablish the vertical centerlines on the vertical surfaces of the boss. Remove the top section of the shaped block from the bottom section. The top section is then aligned by the centerlines on the vertical surfaces of the boss and the oblique surface of the main body of the pattern.

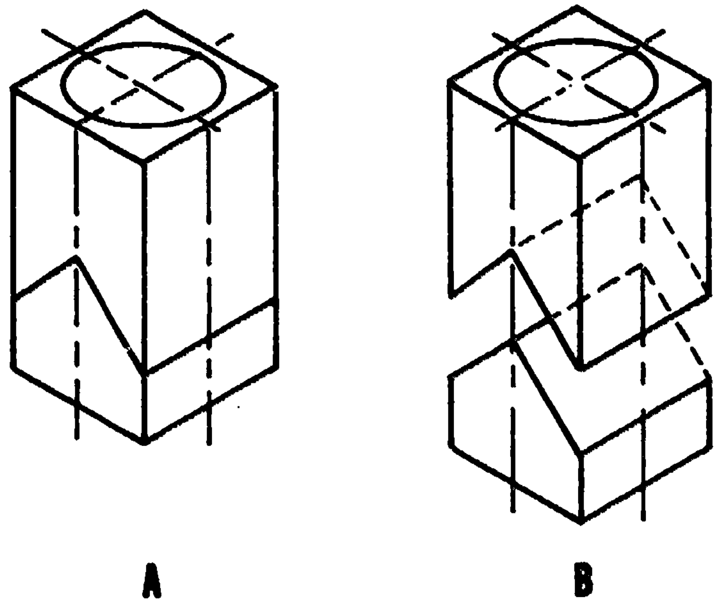
Figure 15-32 illustrates the method of laying out and countersawing a boss to match a curved surface on the main body of the pattern. Figure 15-33 illustrates the method of laying out and sawing a boss to match surfaces of two angles.

When pattern members are to be added to a circular curved surface, such as that shown in figure 15-34, an entirely different procedure is necessary. The bottom piece is turned on the lathe as a false faceplate. This bottom piece will be used in the same manner as were parts B of figures 15-31, 15-32, and 15-33; that is, to hold the boss material in position during the cutting and sanding operation. The top piece is matched to the false faceplate and the pattern members are cut out from the matched pieces.

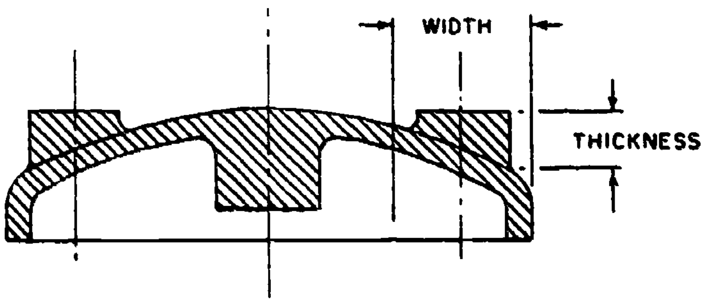
From the layout (fig. 15-34) determine the width and thickness of the circular ring necessary for the pattern members. Select stock of appropriate size, mount on a false faceplate and turn to the reverse shape of the outside of the pattern. The reverse shape of the curved outside of the pattern is actually the shape of the bottom side of the pattern member. (See fig. 15-35.) Remove the circular ring from the false faceplate. Turn a false faceplate of sufficient thickness, as shown in figure 15-36, to the shape of the curved outside shape of the pattern. A center boss corresponding to the



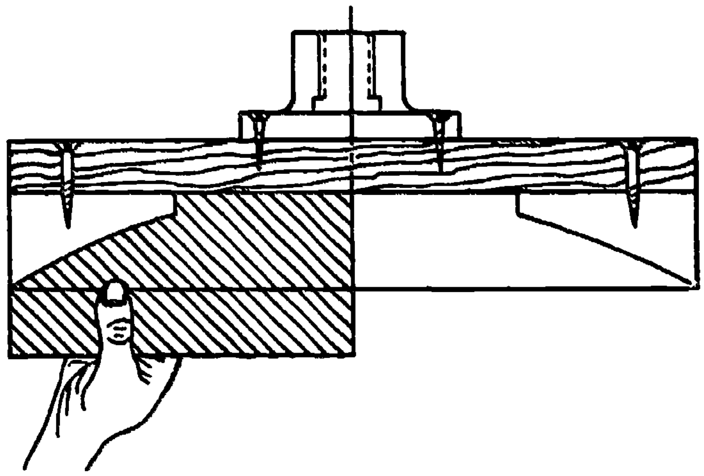
68.178
Figure 15-32.—Laying out and cutting bosses vertical to a curved surface.



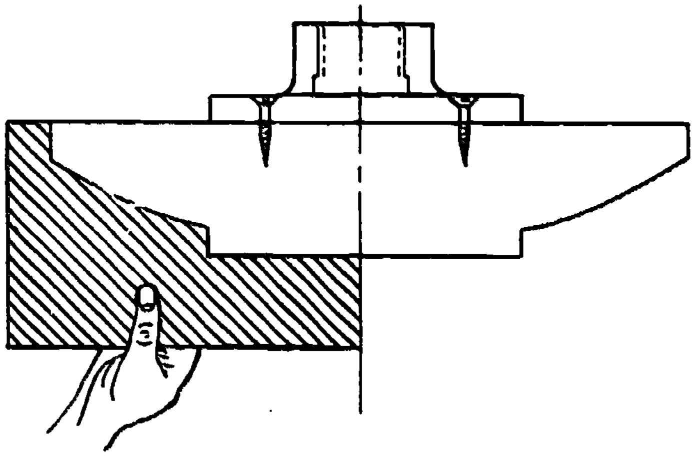
68.179
Figure 15-33.—Laying out and cutting bosses vertical to a compound angle.



68.180
Figure 15-34.—Laying out bosses on a curved surface away from the centerline of the pattern.



68.181
Figure 15-35.—Turning boss material to a template.



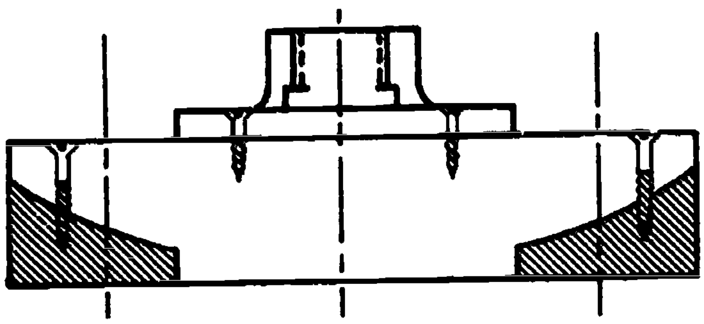
68.182
Figure 15-36.—Turning of a false faceplate.

inside diameter of the circular ring is also turned on the false faceplate. This center boss is used as an aid to locate the boss material (circular ring) in position for cutting and sanding. Rechuck the circular ring on the false faceplate, as shown in figure 15-37. Before removing the work from the lathe, scribe a centerline on the surface of the circular ring, corresponding to the diameter of the boss circle. Remove the false faceplate and the attached circular ring from the lathe. Lay out the boss diameter or pad size on the top surface of the circular ring. The intersection of the circular centerline scribed on the top surface of the ring and radial lines scribed from the center of the false faceplate are used as centers (fig. 15-38).

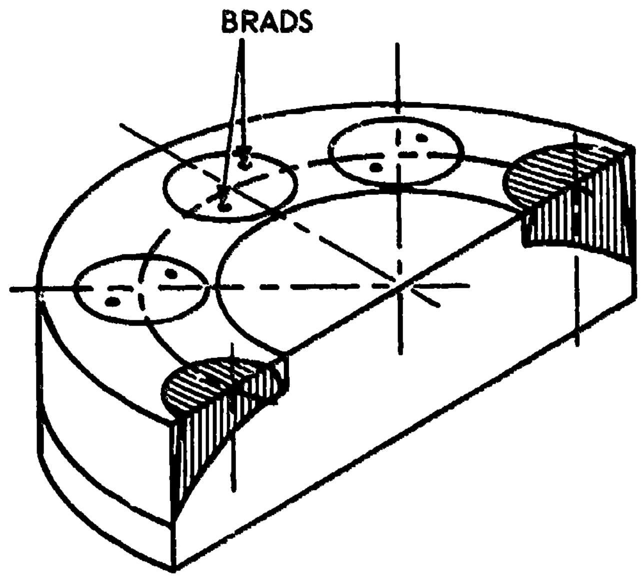
The circular ring and the turned base (false faceplate) are secured together with brads. The brads are driven through the scribed boss diameter (circular ring) and into the base piece (fig. 15-38). Cut the boss or pad on a bandsaw and sand it on a disc sander as previously described. Establish vertical centerlines on the side surfaces of the boss. Attach the boss to the main body of the pattern using the scribed centerlines as an aid in aligning members.

STRAIGHT STAVED CONSTRUCTION

Large patterns or core boxes 8 to 10 inches in diameter, or either cylindrical or conical shape, may be constructed by using staved construction. Staved construction is used when



68.183
Figure 15-37.—False faceplate and boss material.



68.184
Figure 15-38.—Layout and cutting of bosses on a circular curved surface.

patterns or core boxes cannot be made economically from solid stock. The advantages of staved construction are that it:

1. Provides a combination of lightness and strength.
2. Produces a pattern that is more likely to retain its dimensional form.
3. Permits building close to the finished outline of the pattern so that there is comparatively little excess stock to be removed.

Briefly, this method of construction consists of fastening narrow pieces of stock called STAVES or LAGS to foundation pieces called HEADERS. To stiffen the construction and to provide means for rapping and drawing the pattern from the mold, a STRONGBACK is dadoed into the headers as shown in figure 15-39. Four of the staves are called JOINT STAVES and are usually cut a little wider to allow for hand-planning the parting joint.

In selecting the number and thickness of staves to be used, you must exercise sound judgment based upon a consideration of the diameter of the work, strength desired, size of available stock, and the amount of gluing surface between the staves. In general, the greater the number of staves, the closer you will be able to build the pattern to the finished outline.

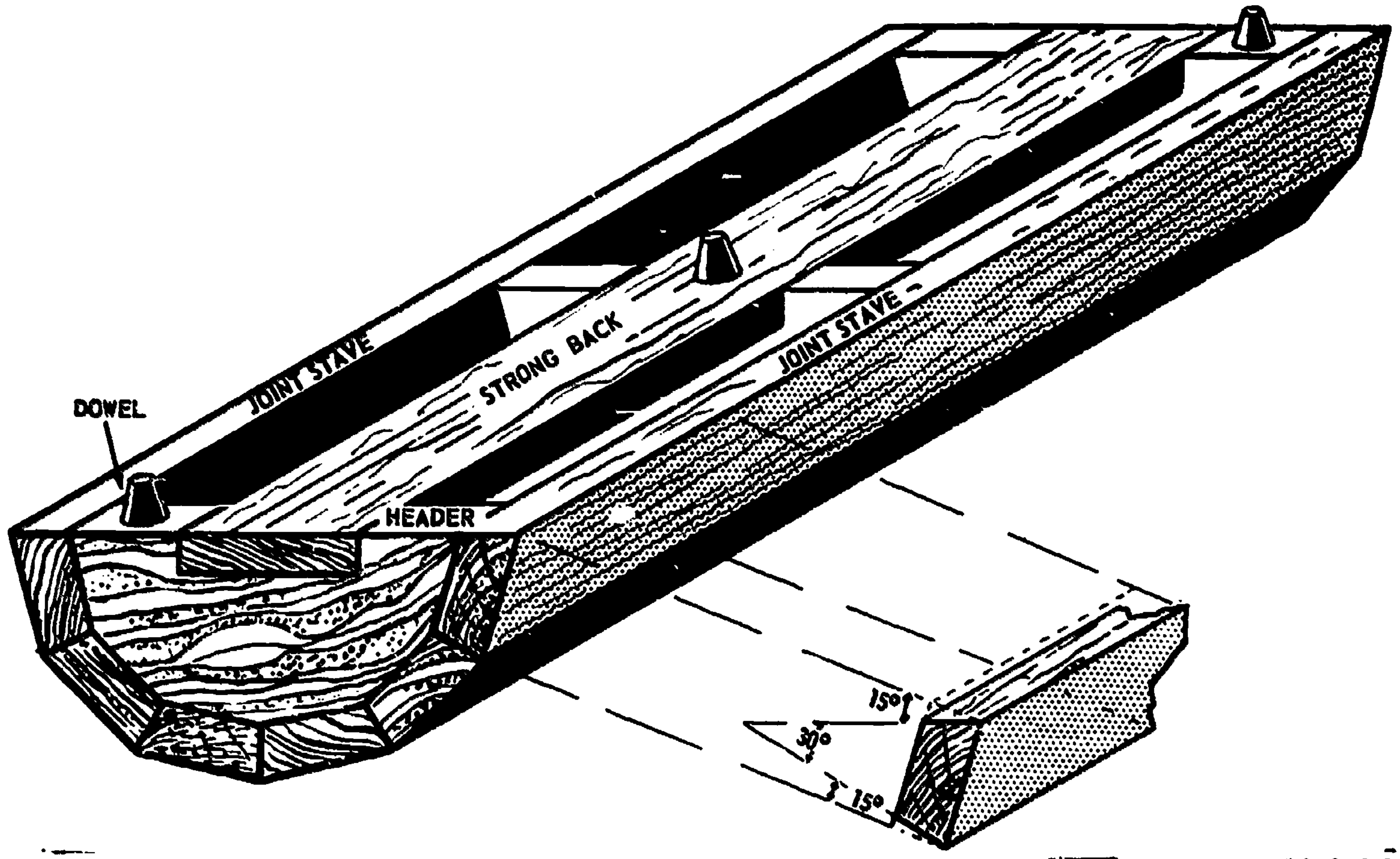


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Figure 15-39. — Typical staved construction.

The following general rules may be helpful in staved construction:

1. Staved construction is recommended in the building of long cylindrical or conical patterns and core boxes exceeding 8 to 10 inches in diameter.
2. The gluing surface at the stave joints should not be less than 3/4 inch.
3. The thickness of the headers should be approximately 1 1/2 times the thickness of the staves.
4. The distance between the headers should be from 9 inches to 12 inches depending on the size and strength required.

LAYOUT OF STAVES AND HEADERS

The following general procedure is used for laying out the headers and staves of a typical staved job. Remember that this is not the only way of doing the job. Many Patternmakers have their own particular method of working. So long as the various methods are equally effective it is well to respect the individual differences you may find in your crew. Figure 15-40 shows the layout for staves and headers:

1. Scribe a horizontal and a vertical centerline on the layout board.

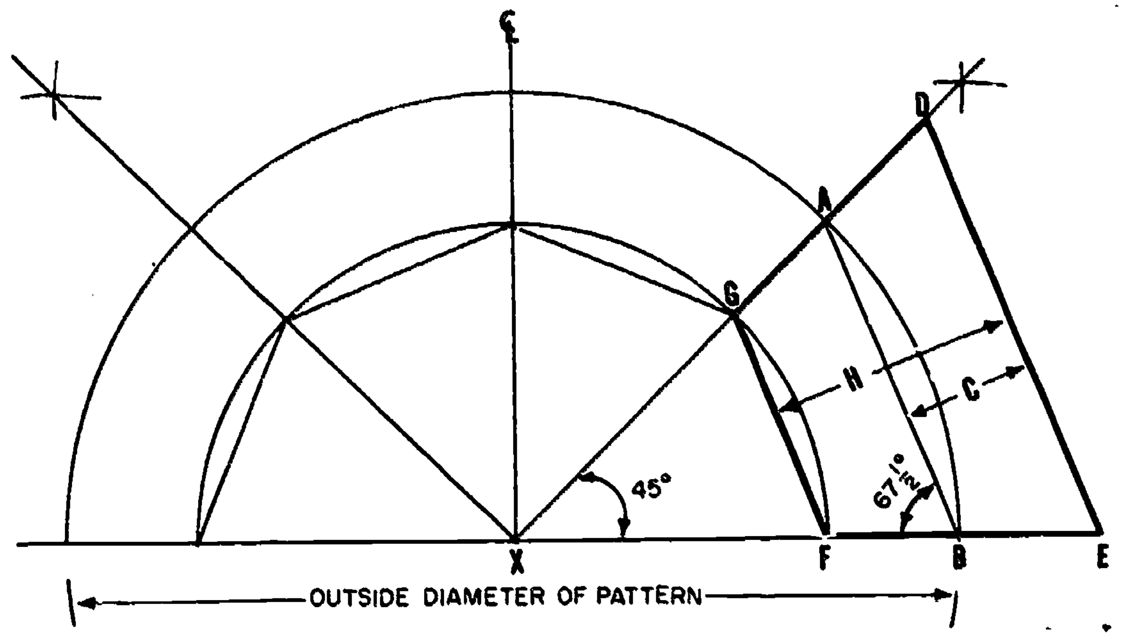

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Figure 15-40.—Method of laying out staves and headers.

2. On the horizontal centerline scribe a semicircle having a diameter equal to the outside diameter of the pattern under construction.

3. Divide the semicircle into four equal parts. Remember that figure 15-40 shows only one-half of the cylindrical pattern and that eight staves are actually used for the complete job. Thus, when you are using the table of chords to calculate the length of the chord required, be sure to multiply the diameter of the job by the factor listed in the table for eight segments.

4. Scribe chord AB in order to establish a fixed reference line from which the thickness of the stave may be laid out.

5. Lay off the distance C which includes allowance for lathe turning.

6. Adjust and set the bevel gage to angle ABX and scribe line DE parallel to line AB. Line DE represents the outer face of the stave including waste stock. Angle ABX is found to be 67 1/2°, by subrtacting 45° from 180° and dividing by 2. (The total of the three angles of a triangle is always 180°.)

7. Scribe line FG parallel to DE to give you the thickness (H) of the stave to be used. Line FG represents both the outline of the header and the inner face of the stave. Figure DEFG represents the template for the staves.

8. If the gluing surface at the stave joints (AG) is less than 3/4 inch in thickness, select a greater number of staves and repeat the layout procedure.

9. For patterns which require circular headers for inside turning, scribe a semicircle using XF as the radius.

Figure 15-41 illustrates three different methods of constructing polygonal headers. The illustrations are self-explanatory.

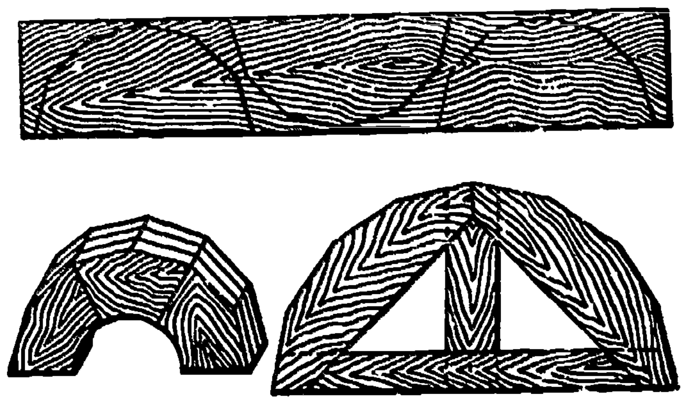

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Figure 15-41.—Methods of constructing headers.

STAVING ON CIRCULAR HEADERS

Staving may be done on round or circular headers by concaving the inner face of the stave to fit the header. The staves are laid out in the conventional manner. The concave arcs are cut on the table saw as illustrated in figure 15-42. First, set the saw blade to project above the table a distance equal to dimension X. If the desired radius of the stave is larger than the diameter of the saw, two or three cuts may be necessary on each stave as shown in A, figure 15-42. After the height of the blade is adjusted, swing the fence or straightedge to such an angle that the saw will cut only the width of the narrow side of the stave shown as dimension Y. Lay off dimension Y on a flat steel square. Place the square against the straightedge and adjust the straightedge as shown in B, figure 15-42. It will be necessary to readjust the straightedge slightly before clamping it in place because of the bevel on the edge of the stave. Move the straightedge away from the tip of the saw blade to a distance equal to the overhang of the bevel on the edge of the stave.

Adjust the height of the blade so that at least two cuts must be taken to remove the waste stock. For smooth work, the last cut should be very light and the stock should be fed slowly over the saw in the direction of the arrow shown in B, figure 15-42. Cut the first stave and check it for accuracy before proceeding with the rest of the staves. Always make two or three extra staves while the saw is set up.

Another method of setting the angle of the straightedge is by using a parallel frame as shown in figure 15-43. The parallel frame method is the simplest and most convenient method for setting the angle for concave sawing. The angle on the inside edge of the side pieces of the frame is equal to the angle on the edges of the stave.

Using one of the staves as a template, adjust the frame to the stave, remove the stave, and place the frame over the saw blade with the narrow side of the frame face down on the saw table. (See fig. 15-43.) Adjust the height of the blade for the full depth of the concave on the stave.

Swing the frame around until one of the inner edges of the frame comes in contact with the back of the blade and the other inner edge comes in contact with the front of the saw tooth as shown in figure 15-43. This frame can be used as a straightedge but must be clamped to the table top.

To use this parallel frame only to obtain the angle to set the fence or straightedge, observe the following procedure: Trace the angle obtained from the parallel frame on the surface of the saw table. Select a board to be used as a straightedge, bevel one edge to the angle of the stave. The length of this straightedge should be approximately the length of the angle traced on the table top. Clamp the straightedge along the line that was transferred from the parallel frame as shown in figure 15-44.

Regardless of which setup method is used for cutting the concave on the staves, the following points concerning safety should be observed:

1. Use a sharp saw blade.

2. Make all cuts against the rotation of the saw blade to prevent the saw from dragging the work into the saw and thus decreasing the operator's control of the workpiece.

3. Do not force the work over the blade.

4. Do not attempt to cut more than 1/16 inch in depth at one time. The slower the stock is passed over the saw blade and the smaller the cut is in depth, the smoother the surface will be.

5. Make at least two cuts.

TAPERED STAVED CONSTRUCTION

Tapered staved construction is similar in some respects to straight staved construction. But the headers required for tapered staved construction vary in diameter; the staves must be tapered throughout their entire length. In addition the edges of the headers must be cut at an angle. Figure 15-45 illustrates a longitudinal layout for tapered staved construction. Note that this layout provides the required edge angle for the headers and shows how the stave varies in diameter. (See the auxiliary view of the staves in fig. 15-45.)

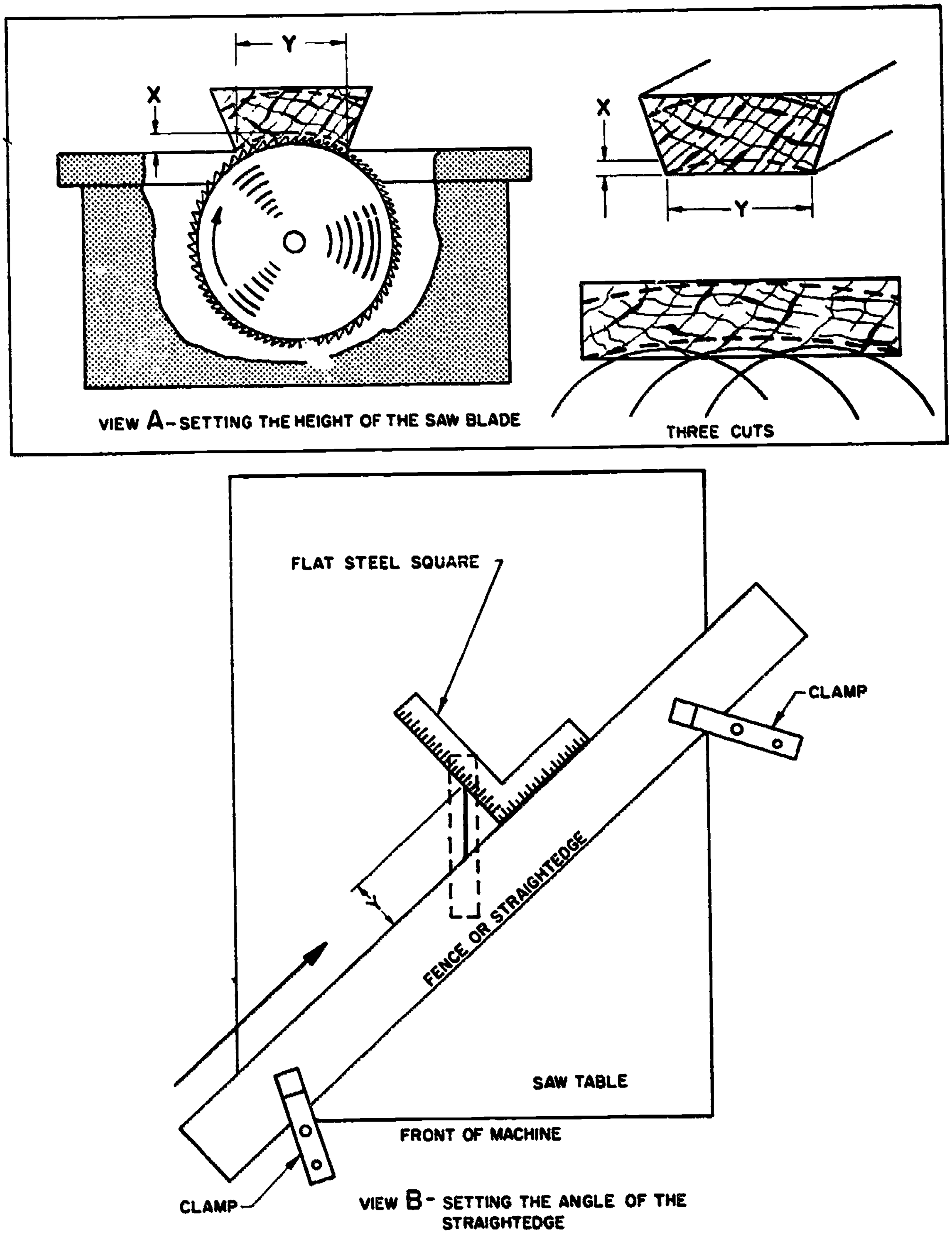

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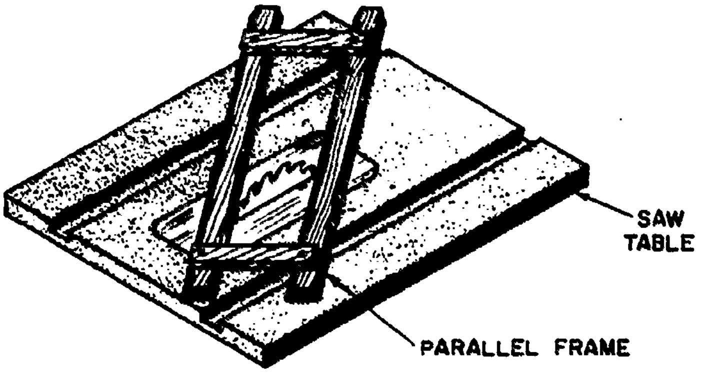
Figure 15-42.—Method of concaving staves by using the table saw.



23.73
Figure 15-43.—Method of determining angle with a parallel frame.

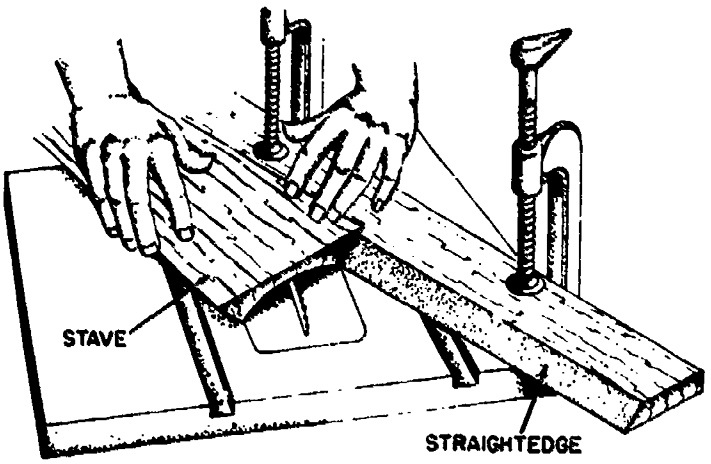


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Figure 15-44.—Method of clamping a bevel straightedge for concaving staves.

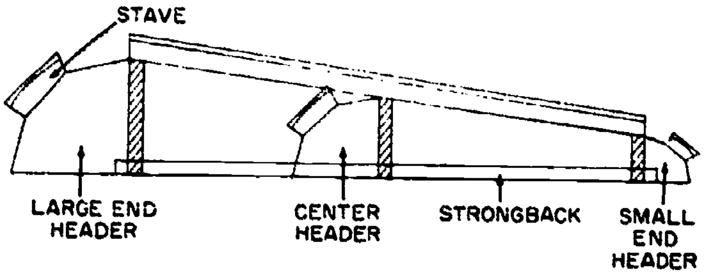

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Figure 15-45.—Longitudinal layout for tapered staved construction.

Since there is a constantly increasing (or decreasing) diameter of the taper, it is best to lay out the headers as polygons instead of as circular shapes. Polygonal headers prevent having to hand-cut the staves to the concave shape required to ensure a proper fit on the header.

If the taper is not too great between the end headers, it is best to cut the staves parallel, then taper and bevel the edge on the jointer. If the taper is great, cut the staves with the taper and then bevel the edge on the jointer. Either method will require the use of compound angles.

Tapered staves may be secured to either round or circular headers, but it is time consuming. Because different radii are involved at each end of the stave, resulting in constantly changing radii throughout the length of the stave, cutting and matching the staves to the headers is difficult. To overcome this difficulty, polygonal headers are recommended because they enable you to use a flat surface to secure the staves to the headers.

GLOSSARY OF TERMS

The following definitions are of terms used in chapter 16.

BONDING—The act of integrating an existing metal part into a casting by melting together.

BUSHING—A cylindrical lining of an opening used to limit the size of the opening, resist friction or abrasion, or serve as a guide.

COMPOSITE CASTING—A casting that is poured around inserted sections of a different metal.

KNURLING—Forming a series of small ridges or beads on a metal surface to aid in gripping.

PLUGGED IMPRESSION—Impressions formed by inserting a plug of required shape through a pattern into the sand.

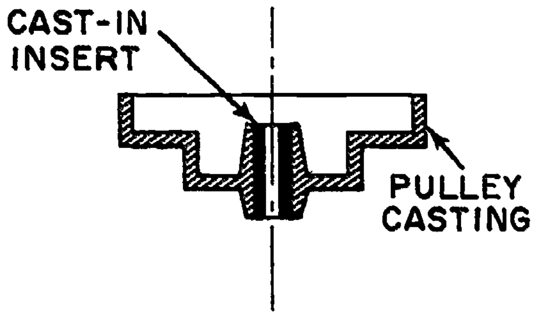
CHAPTER 16

PATTERNS FOR COMPOSITE CASTINGS

Special characteristics which are desirable in a certain part of a casting may be obtained by using metal inserts of a different material than the main body of the casting. These inserts are frequently cast in place and are called composite castings.

Frequently a steel or bronze bushing is cast into an aluminum pulley to give a special characteristic of lightness to the casting and a hard bearing surface for the shaft (See fig. 16-1.) Brake drums are another good example of the use of cast inserts. The outer shell is a steel stamping into which a liner of cast iron is poured. (See fig. 16-2.) Steel or bronze shells for holding soft metal liners for bearings are the most common use of cast-in inserts that the Patternmaker will be required to manufacture. (See fig. 16-3.)

A mechanical means of bonding the two different metals together is necessary. The most common forms of bonding an insert to a casting are knurling, slotting, or grooving of the insert. Examples of the various methods of using cast-in inserts are described in this chapter.



23.86
Figure 16-1.—Aluminum pulley with a metal cast-in bushing.

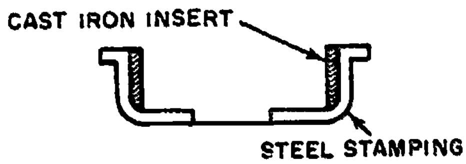


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Figure 16-2.—Brake drum with cast iron insert.

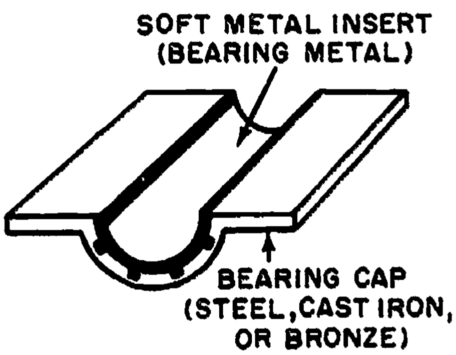

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Figure 16-3.—Bearing cap with soft metal insert.

MOTOR END BELL WITH A STEEL BUSHING

In the design of any cast-in insert for a specific job, the increase in the casting cost must be justified by the special characteristics desired. For example, if a cast iron jacketed motor end bell is accidentally broken in the engineroom and no spare end bell is available at the time, the engineer officer, repair officer, Machinery Repairman, and the Patternmaker may decide at an emergency conference to manufacture and install an end bell of a modified design to enable placing the pump back in operation during the time interval necessary for ordering the proper end bell from the supply center.

No modification of the motor shaft is required for use of a smaller bearing in the end bell because of having to build up the shaft again for the end bell on order. The modified design would include a straight steel bushing instead of a ball or roller bearing. Instead of machining the end bell to size and pressing the steel bushing into the thin walled casting, the bushing would be cast in place during the casting process.

In this case the Patternmaker is the leadman in the design of the end bell; basic design rules must be applied. (See chapter 2 of this training manual). While cast-in inserts tend to reduce shrinkage to the extent that no shrinkage allowance is required, it is advisable to allow sufficient metal around the insert to eliminate any cracks or draws during the solidification of the main body of the casting.

LAYOUT AND CORE BOX FOR INSERT

Using the basic dimensions of the broken cast iron end bell (fig. 16-4), make a layout with the proper shrink rule, including all modifications for the steel bushing, as shown in figure 16-5. From the pattern layout make a sketch of the bushing, showing the semifinished dimensions and the mechanical means of bonding the bushing to the cast iron end bell. (In fig. 16-6 slots are used to keep the bushing from turning and grooves to keep the bushing from pulling away from the casting.)

Allow finish on the inside of the bushing and on each end for final machining of the end bell and of the bushing. Send the sketch to the

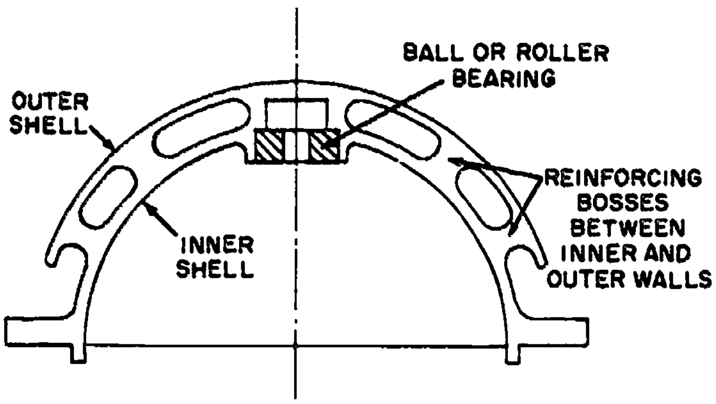

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Figure 16-4.—Jacketed end bell with ball or roller bearing.

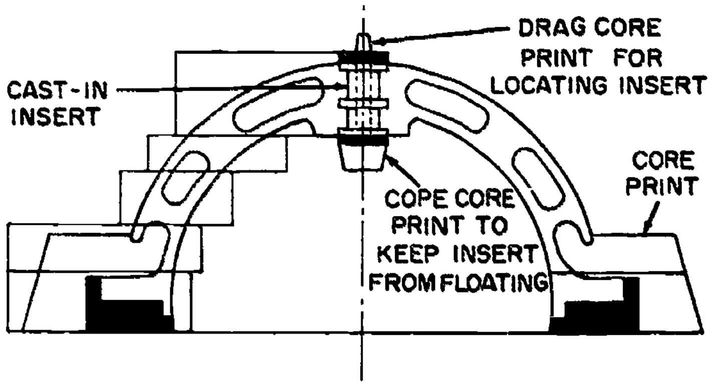

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Figure 16-5.—Jacketed end bell modified for a cast-in steel bushing.

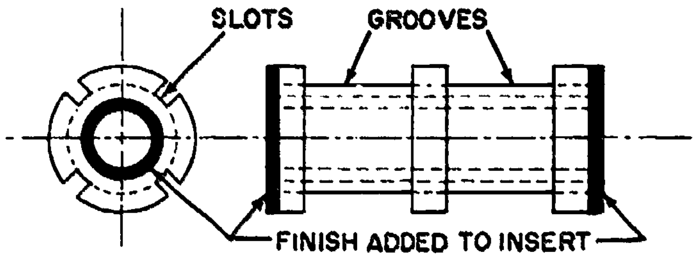

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Figure 16-6.—Sketch of semifinished steel bushing.

machine shop so that the semifinished bushing can be manufactured from the proper material. When the semifinished bushing is returned, construct a special core box for the core that will locate and hold the bushing in the proper position in the mold cavity during the pouring of the metal into the mold. (Fig. 16-7 illustrates the insert and the core.)

In figure 16-5, note how the core is set. When the cope half of the mold is placed in position, the insert will be kept from floating by the green sand in the cope.

CONSTRUCTION OF A JACKETED END BELL PATTERN

The construction of a jacketed end bell pattern is similar to that of cylindrical or bell shaped patterns. The jacketed end bell pattern is more complicated because each course of

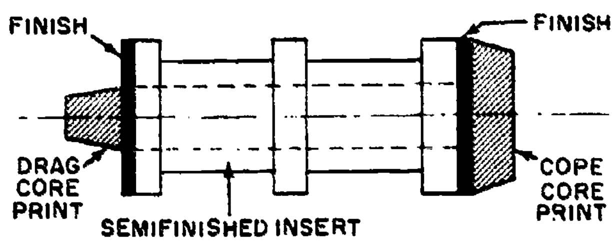

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Figure 16-7.—Semifinished bushing showing core arrangement.

segments differs in diameter and in the coring for the opening between the inner and outer walls.

The pattern is made of segmental construction and turned on the lathe. The finished pattern will be shell-like with a core print around the outside periphery to locate and hold the suspended core required for the space between the inner and outer walls of the casting. Locating and holding the insert in the mold are made possible by the addition of a vertical core print on the pattern.

Before proceeding to build up the pattern for the jacketed end bell, a full-size (shrink rule) section of the end bell should be laid out. From the layout, the thickness, the width, and the required number of segment courses are determined. The number of segment courses will depend upon the shape and size, and upon the personal preference of the Patternmaker. With dry lumber, the pattern is built up as shown in figure 16-5, taking care to allow stock for finish where so indicated on the layout. Five courses, as illustrated, have been selected for the jacketed end bell pattern in figure 16-5.

While the glue is drying, two templates are made from thin template material, one for the inside shape and one for the outside shape of the pattern. The shape of the template should be the same as that of the cross section of the end bell transferred from the layout to the template material. The step on the face of the pattern, intended to receive the motor, may be ignored as it can be easily turned in afterwards by the machine shop.

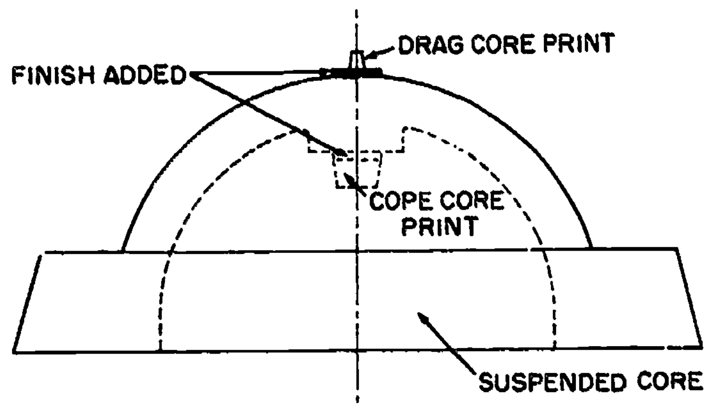
The inside of the pattern is turned to correspond to the shape of the inside template, and a cope core print added for the cast-in insert core, after which the pattern is removed from the faceplate. The pattern should be rechucked to a false faceplate to permit the outside of the pattern to be turned. Add the drag core print for the cast-in insert core on the intersection of the centerlines on the surface of the pattern. Before removing the finished pattern from the false faceplate, sand the pattern and apply a thin coat of pattern coating. The finished pattern will appear as illustrated in figure 16-8.

CONSTRUCTION OF THE CORE BOX FOR A JACKETED END BELL

The core box is built up of segmental construction and turned on the lathe. The finished core box will have eight loose pieces for the plug type impressions for the reinforcing bosses between the inner and outer walls. In addition, the core box will have four loose pieces that form the inner wall thickness and one sweep that forms the inside shape of the inner wall. (Fig. 16-9 shows only four of the plugs for the reinforcing bosses.)

The shape of the inside of the inner wall is the same size and shape as the inside of the pattern. Therefore, the four openings developed by the loose pieces for the inner wall thickness will kiss the green sand of the cope when the completed core is set and the mold is ready for pouring.

MAIN BODY CORE BOX.—From the layout, the segment course size and thickness is determined. Using dry lumber, the core box is built up and allowance is made for added finish and turning. During the time the glue is drying, three templates are made from thin template material; one for the inside wall of the outer



23.93
Figure 16-8.—Completed pattern for a jacketed end bell.

shell, one for the outer wall of the inner shell, and one for the inner wall of the inner shell.

The main body core box is mounted on a faceplate and the shape of the inside wall of the outer shell is turned to a template. (See fig. 16-10.) Before removing the core box from the faceplate, establish the horizontal and vertical centerlines. Drill a hole through the bottom of the box to serve as a pivot point for the sweep. Sand the main body core box and apply a thin coat of pattern coating.

PLUG IMPRESSION CORE PRINTS.—The locations of four of the plug type impressions (reinforcing bosses between the inner and outer walls of the end bell) are arranged on the vertical centerline and are radial to a common center point (CP). (See fig. 16-9.) The remaining four plugs are arranged in the same manner but are located on the horizontal centerline.

Manufacture two jigs for the purpose of drilling the eight radial holes for the plug type impressions. (See fig. 16-11.) Jig #1 is made to correspond to the angle of the four upper radial holes. Jig #2 is made to correspond to the angle of the four lower radial holes. Mount the core box on jig #1 and drill the four upper radial holes through the side of the box. Remove the core box from jig #1 and remount on jig #2 and drill the remaining four holes through the bottom of the box. (Note: Two different size drills are required for each hole. One drill is used for the stop for the plug and the other drill is used for the remaining portion of the hole.)

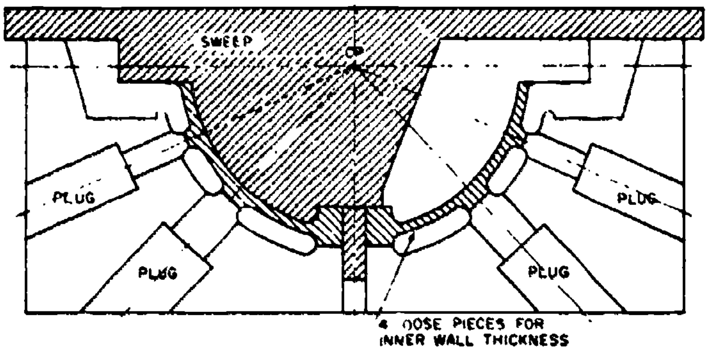


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Figure 16-9.—Layout of core box for a jacketed end bell.

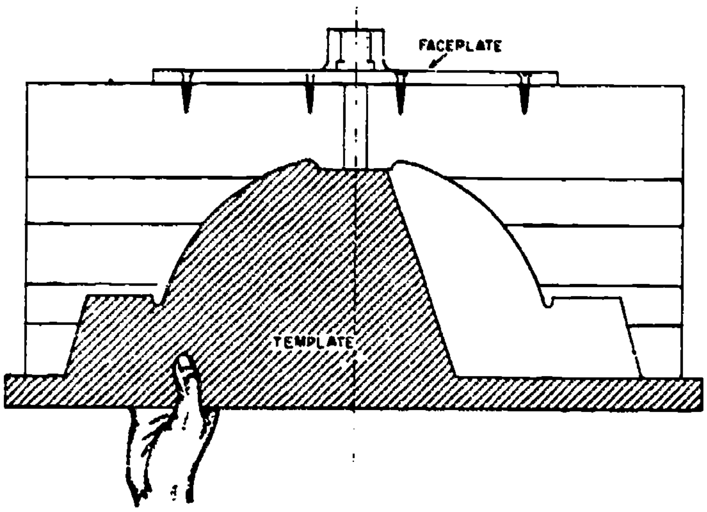

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Figure 16-10.—Turning the main body core box with the aid of a template.

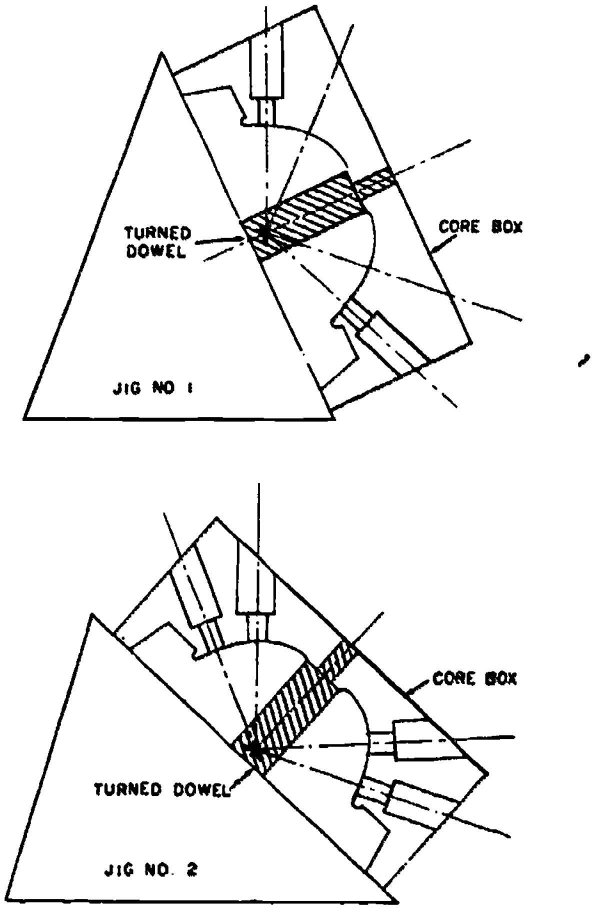

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Figure 16-11.—Main body core box mounted on a jig for drilling the radial holes for the plug type impressions.

Turn the eight plugs between centers and check against the holes in the box for correct size. Also check to make sure the stops are in the proper position. The outside end of the turned plugs are cut to match the outside shape of the box so that the inside end will be in the proper position during the ramming of the core. (See fig. 16-9.) Mark each plug and corresponding hole.

LOOSE PIECE FOR INNER WALL.—The four loose pieces that form the inner wall thickness are made of segmental construction. The pattern stock is glued up in the usual manner, but after drying, the stock is divided into four (90°) quadrants. The four quadrants are sanded, glued together with paper between the joints, and turned. The turned shape is then taken apart at the quadrant joints. The paper used in the glue joints will part easily, and only light sanding will be necessary to restore the quadrant joint.

The pattern stock for the inner wall thickness is mounted on a false faceplate and turned to correspond to the shape of the inside of the pattern. (See fig. 16-12.) Rechuck the stock turn the shape of the outer wall, bore a hole in the center for the sweep pin, and remove from the false faceplate. (See fig. 16-13.) Transfer the shape of the cutouts to the pattern for the inner wall thickness, cut and sand to a common radial center point. (See fig. 16-14.) Break the edges of the cutouts to eliminate sharp corners.

On the turned cavity of the main body core box, establish a second set of centerlines midway between the previously established centerlines. These centerlines will serve in locating the four quadrants. Insert a short length of dowel in the sweep pin hole and locate the loose piece for the inner wall thickness in the core box by matching the quadrant glue joints to the second set of centerlines.

After matching the centerlines, brad the loose piece temporarily in place. Use a transfer punch corresponding to the size of the hole for the plug type impressions and establish a center point on the outer surface of the inner wall. This center point is used for locating the eight small bosses that shape one-half of the reinforcing bosses between the inner and outer walls of the end bell.

Remove the loose piece from the core box and shape and glue the eight small bosses in position, checking the height against the proper plug. Replace the loose piece in the core box and brad in position. Drill a small dowel hole through the eight bosses and into the end of the plugs. Drill a small dowel hole through the

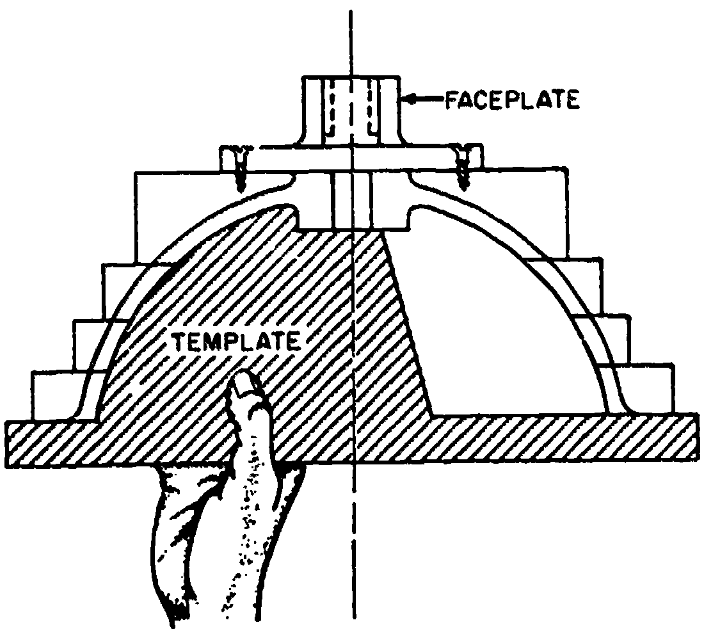

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Figure 16-12.—Turning the inside shape of the loose piece for the inner wall thickness.

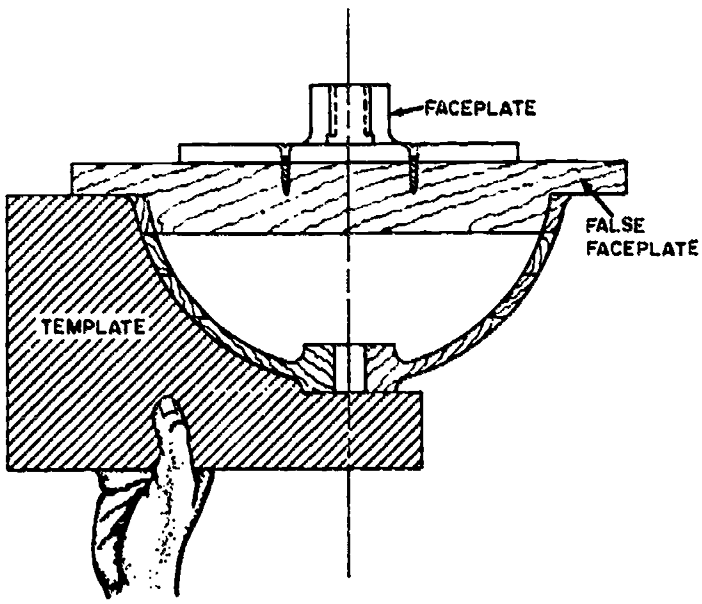

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Figure 16-13.—Turning the outside shape of the loose piece for the inner wall thickness.

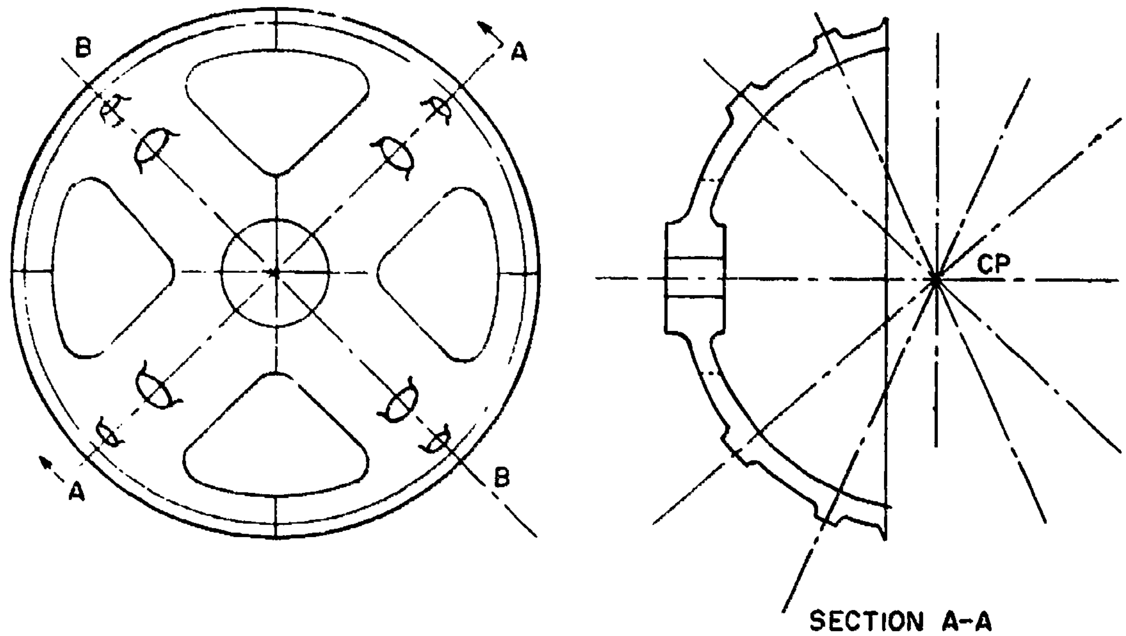

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Figure 16-14. — Layout of the side cutouts on the loose piece for the inner wall thickness.

four quadrants into the center boss turned in the main body core box. Mark the four quadrants and their corresponding seats in order to prevent accidental mismatching of parts.

Remove the loose piece from the core box and break the paper joint. Lightly sand the joint and place dowels into the drilled holes. Run the proper size fillets in place and apply a thin coat of pattern coating. After the thin coat of pattern coating has dried, apply a second coat according to the standard color code.

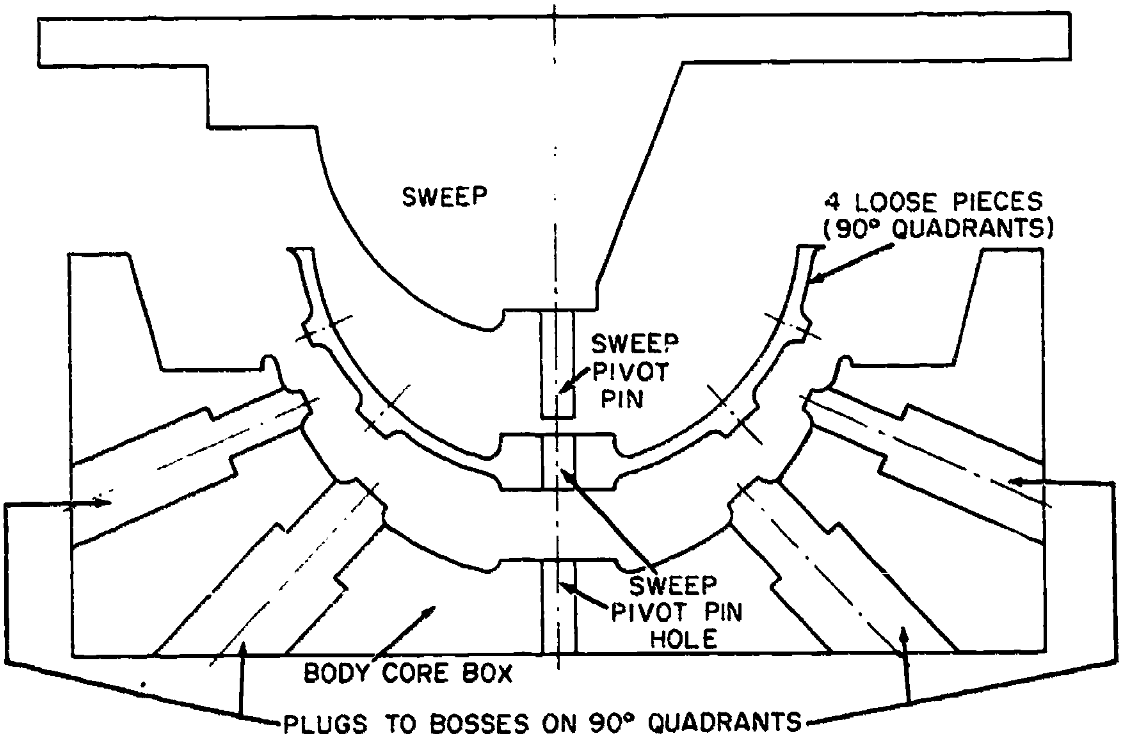
SWEEP. — Construct a sweep in the shape of the inside of the pattern (inner wall shape of the loose piece) and insert the sweep pin in the hole at the bottom of the box. When completed, the core box with its loose pieces will appear as illustrated in figure 16-15.

WEARING SURFACES ON NONFERROUS CASTINGS

Ferrous inserts on nonferrous castings can be used for wearing surfaces but the chief disadvantage of these inserts in both production and fabrication is warpage. This may result from the different expansion characteristics of the two metals fused together, or from the unbalanced arrangement of the components so that the stresses of one section do not offset those in another section.

Basically, all composite castings require a mechanical means of bonding one metal to another. When designing wearing surfaces, any design that uses anchors should be small and the anchors used sparingly. Simple anchors used for mechanical bonding are formed by drill points or by plain grooves. Although dovetail anchors are generally used, the T-head anchor has more holding power. The shrinkage of the neck of the T-shaped anchor holds the metal faces together. As an extra aid in bonding steel to brass or bronze, the insert may be copper plated.

Any insert used for wearing surfaces will act as a chill to the main body of the casting and should be designed accordingly. The insert is designed, machined, and can be used when the pattern and insert are rammed up in the mold together. The pattern is withdrawn from the mold, leaving the insert in the proper position in the mold cavity. An insert placed in the mold cavity should be as clean as possible to eliminate any oxidation between the two different metals.



23.100

Figure 16-15. — Exploded view of the completed core box for a jacketed end bell.

TRANSVERSE HOLES IN CASTINGS

Another style of insert is the sheet metal form: such inserts are used primarily for transverse holes in castings. Sheet metal forms were developed for casting holes for hinge pins on stove or furnace frames. These forms were so successful that their use was adapted to other types of castings where holes must be produced crossways above or below the parting line.

Inserts can be used to form a hole or recess in a casting with sharper corners, smoother surfaces, and greater accuracy than can be obtained directly from green sand. An insert may be designed, manufactured, and used on the principle of ram-ups as previously mentioned. Before ramming in the mold, the hole through the insert should be rammed with molding sand.

The rammed sand in the insert will help to distribute the heat from the insert to the sand in the mold. In addition, the sand will keep the thin wall of the insert from collapsing during the pouring and solidification of the main body of the casting.

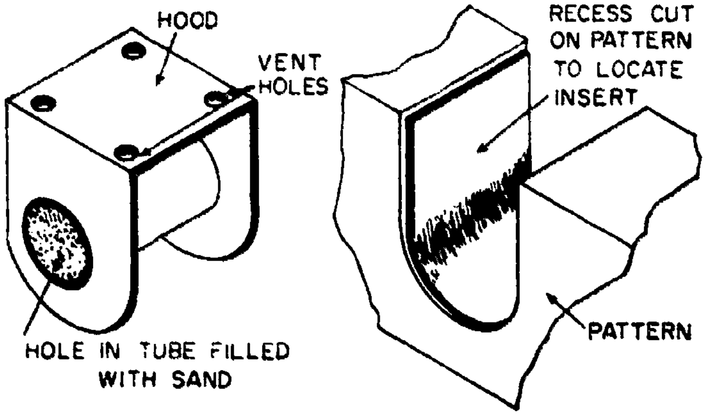
The insert (being protected by the sand on one side) does not melt but welds itself to the casting, forming a permanent union between the insert and the casting. The sheet metal insert is a form of internal chill and should be treated as such.

On shaking out, the casting will have the insert bonded to the casting in the proper position. The sand, rammed in the hole of the insert, will fall out, leaving a clean hole of the required shape and size for the design.

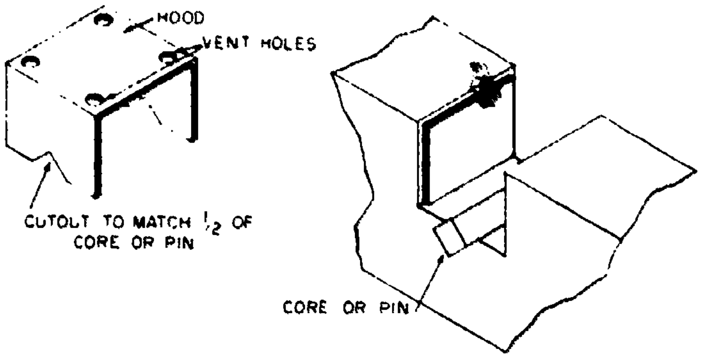
The type of inserts most commonly used for forming holes or recesses are described in the following paragraphs.

HINGE TUBES are used for forming holes transverse to the draw of the pattern. The insert consists of two parts, a hood and a tube (fig. 16-16). The pattern is provided with a notch (recess) for locating the tube in the required position. The notch is parallel to the direction of the draw and shaped so that the insert will stay undisturbed in the mold upon withdrawal of the pattern.

HALF HOOD TUBES are a modification of the hinge tube, and are used when the proper size hinge tube is not available. (See fig. 16-17.) The half hood is primarily used in conjunction with cores or when a pin or bar is to be anchored in the casting. When the pattern is withdrawn



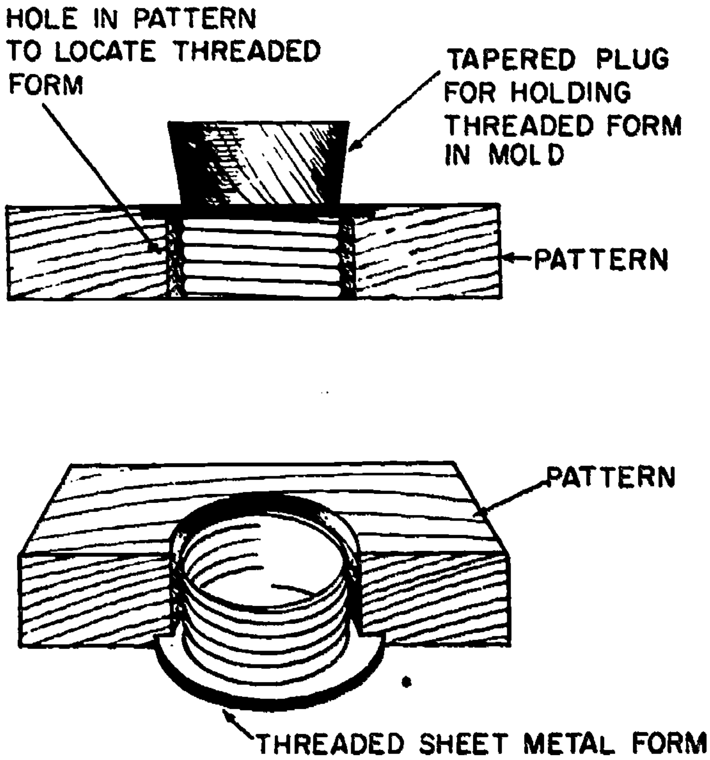
23.101
Figure 16-16.—Hinge tube type of metal insert.



23.102
Figure 16-17.—Half hood type of metal insert.

from the mold, the core or pin is left anchored at both ends with the half hood below it.

SQUARE SLOTS, as the name implies, are inserts used to cast square holes or slots when it is desirable to avoid the use of cores. The insert is placed in position on the pattern, then rammed up. The pattern is withdrawn from the mold leaving the insert undisturbed in the mold. The molten metal enters the insert from both ends and fills solid. It may be necessary to provide vent holes on the inserts to allow gases to escape.



23.103
Figure 16-18.—Threaded insert for casting threads in castings.

THREADED SHAPES sufficiently accurate for many purposes, can be cast with special inserts as shown in figure 16-18. The insert is set in place on the pattern and a wooden plug is screwed into the threaded insert. The wooden plug is tapered and forms a shank which is gripped by the molding sand to hold the insert in place when the pattern is withdrawn from the mold.

Green sand and foundry nails may be used, instead of the tapered wooden plug, for securing the insert.

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