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ABSTRACT

This manual is intended (1) to provide an information resource to supplement the formal training program for boilermaker apprentices; (2) to assist the journeyworker to build on present knowledge to increase expertise and qualify for formal accreditation in the boilermaking trade; and (3) to serve as an on-the-job reference with sound, up-to-date guidelines for all aspects of the trade. The manual is organized into 13 chapters that cover the following topics: safety; boilermaker tools; mathematics; material, blueprint reading and sketching; layout; boilershop fabrication; rigging and erection; welding; quality control and inspection; boilers; dust collection systems; tanks and stacks; and hydro-electric power development. Each chapter contains an introduction and information about the topic, illustrated with charts, line drawings, and photographs. (KC)

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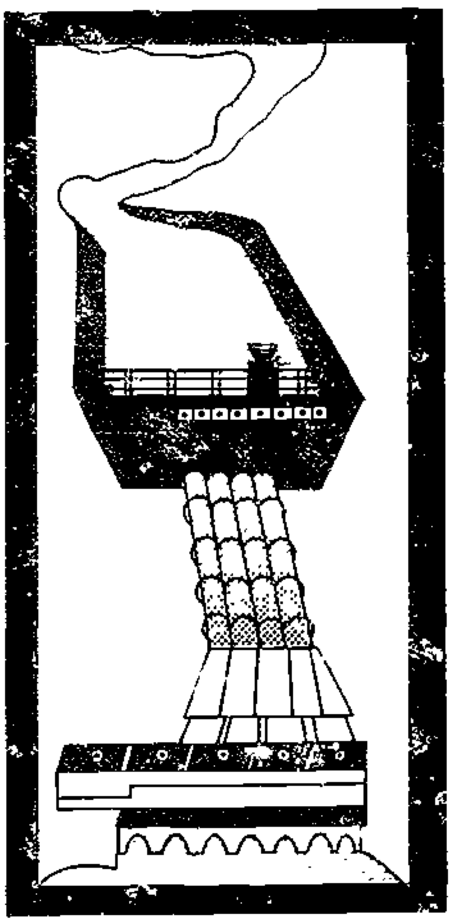
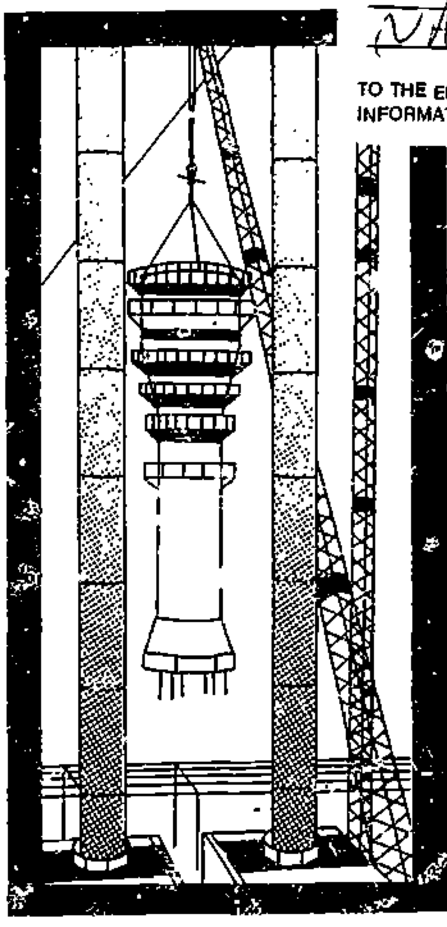
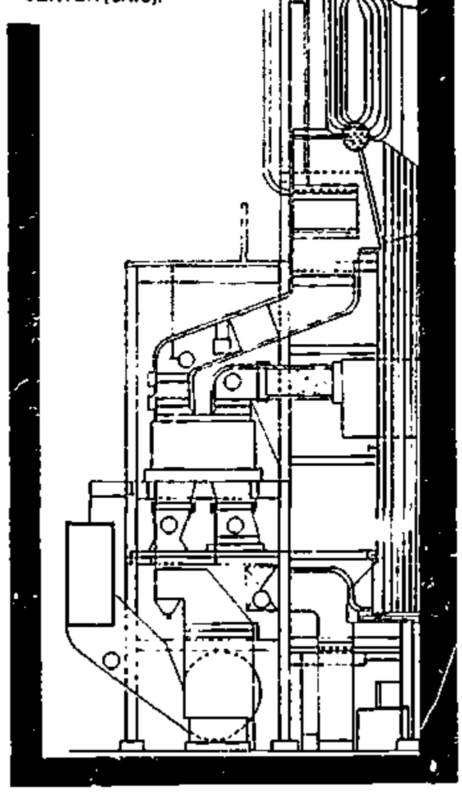
BOILERMAKING MANUAL

Province of
British Columbia







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INTRODUCTION

INTRODUCTION

The Boilermaking trade has a history dating back to the discovery of metals Among the forerunners of today's Boilmakers are the early metal workers, coppersmiths, blacksmiths and forgers

Today the Journeyman Boilermaker is expected to be knowledgeable about a wide variety of materials including those such as ferrous and non-ferrous metals, plastics and fibreglass The Boilermaker is also expected to possess highly developed skills in fabricating, erecting and repairing modern day plants.

Training personnel in the many facets of the trade usually occurs in one of three ways: Apprenticeship Programs, Journeyman Upgrading Programs and On-Job Training. Many craftsmen have had the advantage of all three kinds of training and are still upgrading their knowledge.

APPRENTICESHIP PROGRAMS

The basic principles of apprenticeship have endured for over 2,000 years The employer enters into a contract to provide the apprentice with the opportunity to learn the skills of the trade. The apprentice for his part promises to obey all reasonable demands made by the employer and to render faithful and diligent service during the period of apprenticeship. Apprenticeship training came to Canada with the early settlers, and at various times provincial legislation has been enacted throughout the country to formalize the program.

The main objectives of formalized training can be summarized as

1 The establishment of a regulated system of apprenticeship in industries dependent on skilled help.
2 The setting of regulations to ensure youth proper training and the opportunity to become skilled craftsmen under uniform and fair conditions
3 The correlation of technical education in the technical and vocational schools with practical training in industry so as to offer the best opportunity for the advancement of apprentices
4 The elimination of unfair practices in employing youth in industries suitable for apprenticeship training.

JOURNEYMAN UPGRADING PROGRAMS

Advances in technology are increasing the need for personnel with highly specialized knowledge and skills. As new ideas and procedures are introduced to the trade, it is imperative that the time-served boilermaker not be forgotten. The craft will always depend on the experience of journeymen, and an avenue of learning must be available to them.

ON-JOB TRAINING PROGRAMS

The least publicized kind of training is probably the most important. Only "on the job" can new skills and knowledge be evaluated effectively. Practising boilermakers should have reliable reference material available as a guide to safe and efficient performance consistent with current techniques and procedures of the trade.

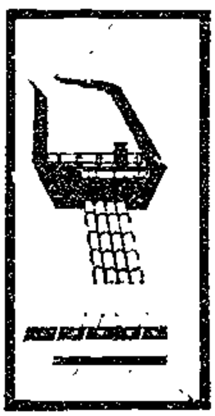
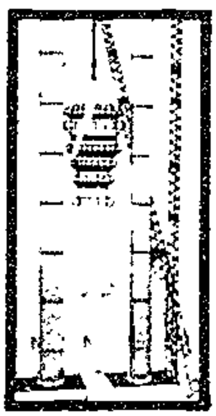
OBJECTIVES OF THIS MANUAL

1 To provide an information resource to supplement the formal training program for boilermaker apprentices.
2 To assist the journeyman to build on his present knowledge to increase his expertise and qualify for formal accreditation in the trade.
3. To serve as an "on the job" reference with sound, up-to-date guidelines for all aspects of the trade.

Constraints of size limit this manual to a general treatment of most subject areas. Extensively detailed treatment of individual topics would create an unwieldy volume of encyclopedic proportions The manual's purpose is to complement on-job training and technical training. It does not provide a home study course that would prepare a student to become a boilermaker. The manual's foundation value lies in its contribution to the greater proficiency of craftsmen through better understanding of their trade.

CONTENTS

Chapter 1
SAFETY


INTRODUCTION

Safety precautions protect the Boilermaker just as cleanliness protects the doctor or nurse. The Boilermaker's working environment can be very hazardous unless each worker is aware, alert and cautious at all times.

Safety is a shared responsibility with implications for management and labour as well as for government which enforces safe working practices

Management is responsible for:

1. Providing and maintaining safe equipment
2. Providing protective devices and special clothing when required
3. Enforcing safe working procedures.
4. Providing adequate safeguards on machinery, walkways, cranes, rigging, etc.
5. Observing accident prevention regulations.

Labour is responsible for:

1. Knowing and working in accordance with the safety regulations pertaining to their trade and sphere of influence.
2. Working so as not to endanger themselves or fellow workers even when specific regulations are not in force.

Government is responsible for:

1. Establishing Accident Prevention Regulations
2. Ensuring observance of these regulations by periodic inspections and enforcing safety standards.
3. Establishing on-going Accident Prevention programs.
4. Providing advice and assistance in establishing safe working conditions in the ever-changing technological working environment.

Regardless of rules, regulations and committees the major factor in safety is the individual employee and his attitude and personal outlook on safety.

This chapter presents an overview of industrial safety issues for Boilermakers, but safety and safe working habits are integrated into each chapter of this manual.

BASIC SAFETY RULES FOR THE BOILERMAKER

CLOTHING

1. All personnel must at all times wear approved hard hats and safety footwear.
2. Clothing should be appropriate for job conditions.
3. Gloves should be worn when handling wire cable, steel or rough material.
4. Protective eyewear should be worn when using grinders, chippers, welders, cutting torches, etc. and when there is a danger from flying objects and harmful liquids, gases or rays.
5. Safety belts and lines of approved design must be used when working conditions require them.
6. Approved life jackets must be worn when working over water.

EQUIPMENT

1. All equipment such as cranes, derricks and hoisting gear must be of sufficient size and strength to maintain a proper safety factor which must not be exceeded.
2. All blocks, hooks, shackles and wire ropes must have a proved safe working load.
3. Proper tools in good condition should be used for each job and the manufacturer's instructions on applications and limitations should be followed.
4. Power tools should be inspected frequently and properly adjusted for safe and optimum performance.
5. Hoisting machinery should be inspected frequently to ascertain that clutches, brakes and dogs are in good condition.
6. Structural parts of cranes and hoisting equipment should be inspected regularly for cracks, deformation or signs of strain.

RIGGING AND ERECTION

1. Before moving cranes, derricks, poles or rigging equipment, the area should be checked to assure it is clear of high voltage power lines and staging.
2. Only one designated person in each crew should give signals to an equipment operator.

3. Outriggers should be in place and well blocked before heavy loads are lifted.
4. Heavy loads, machinery and rigging equipment should be checked under load before swinging
5. Heavy loads should be moved slowly Care should be taken when a load is stopped because inertia increases the load effect
6. Extreme care is required when lifting in strong or gusty winds.
7. Tag lines should be used to prevent loads being lifted from swinging sideways
8. Loads should not be swung needlessly over the heads of persons working below
9. Slings and tackle should be inspected frequently, and frayed, kinked, worn, corroded or suspect equipment must be replaced
10. Shackles rather than hooks should be used whenever possible

LADDERS AND STAGING

Boilermakers do not often use ladders as their work normally calls for a more stable working platform, however, in certain situations a ladder may be required temporarily The below information may be used as a guide for constructing ladders (Figure 1-1).

LADDER CONSTRUCTION

Rungs Flat rungs must be at least 1" x 2 1/2" secured by 3 nails or screws to each siderail. Round rungs must be at least 1 1/4" diameter with tenons 1/4" less, secured by screw or nail at the midpoint in each siderail. A wire tie should be inserted under the rung.

Lap The minimum lap of extension ladder sections must not exceed 3' for extensions up to 38', 4' for extensions up to 44'; 5' for extensions over 44'. Patented non-skid feet of various types

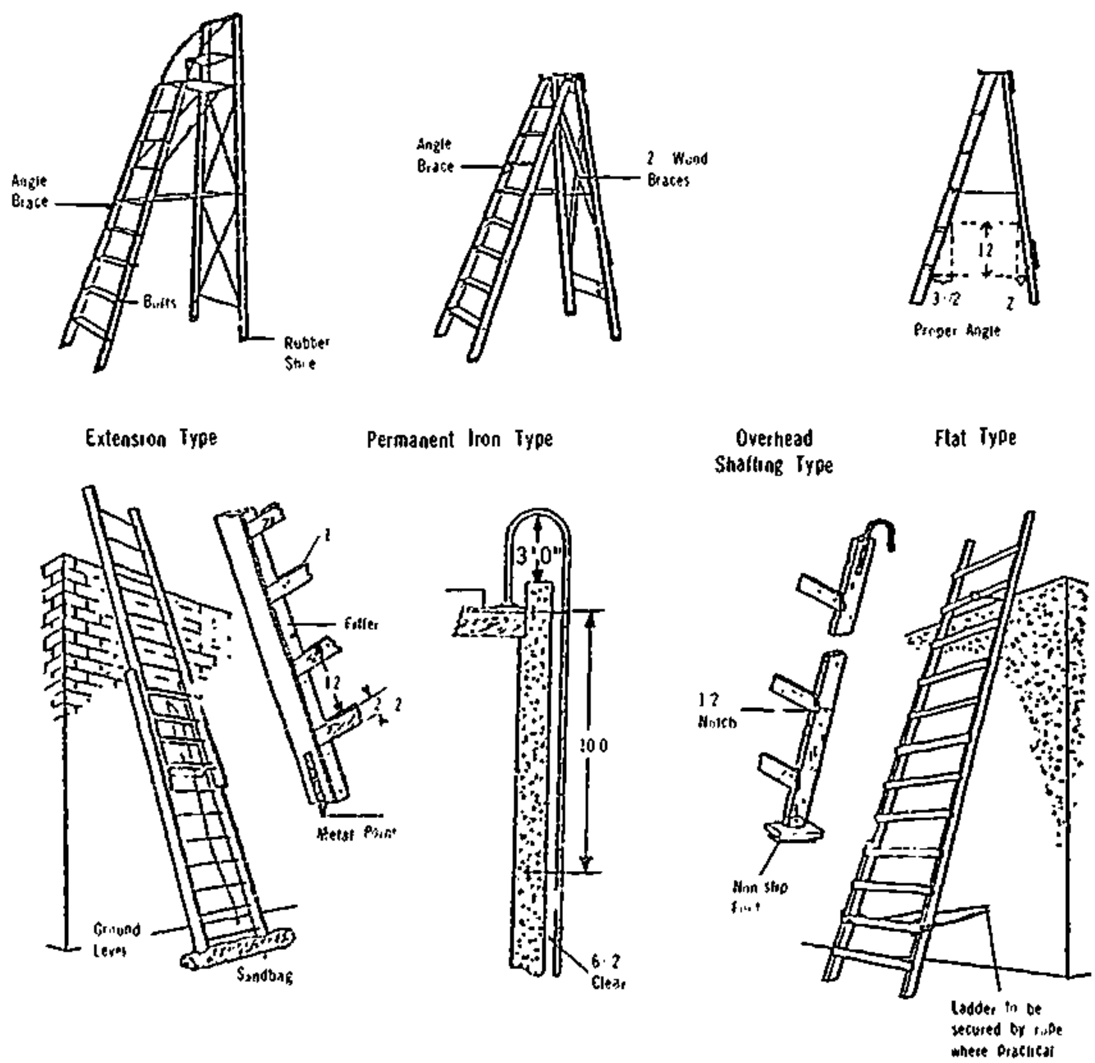


Figure 1-1. Approved Ladders with Safety Specifications

can be bought for ladders to be used on smooth floors

Metal Ladders In places where the basic construction is of steel or fire proof material, ladders are often made of 3/4" to 1" diameter pipe or rod rungs welded to approximately 1/4" x 2" flat bar rails or 1" to 1 1/4" diameter pipe rails. The material on hand usually determines the size of the ladder components, but it should meet all safety standards Aluminum ladders are light and easily handled, but generally need special care to avoid being damaged

Step Ladders Step ladders and extension ladders are usually purchased, and their construction should meet safety regulations. Portable step ladders over 20' are not to be used

SAFE USE OF LADDERS

Before climbing a ladder, three points should be checked automatically to ensure no danger to the climber

1 The ladder must be in good condition. The siderails must not be cracked or broken and the rungs must not be broken or missing.
2 The ladder must have safety feet (both holding) either braced against a weight or cleat on the floor or lashed to a fixed object (Figure 1-2)

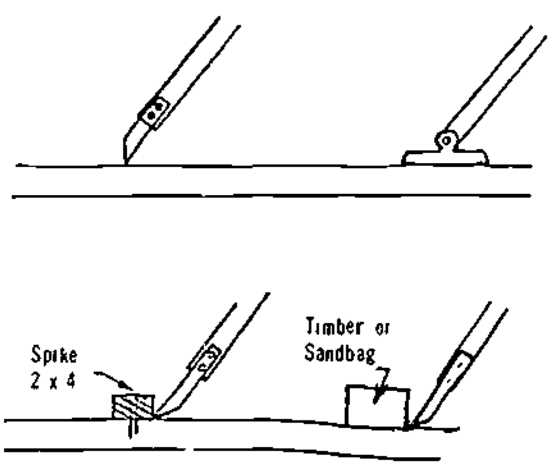


Figure 1-2. Types of Safety Feet for Ladders

3 The top of the ladder should rest on a strong solid support with both rails touching. The ladder must be long enough to reach the job without being positioned at too steep or too flat a pitch (Figure 1-3). If possible, work should be done no higher than four rungs from the top Unless a ladder is securely fastened at the top, it is dangerous to do any sideways reaching or any heavy pushing or pulling More than one workman has pushed himself into an accident

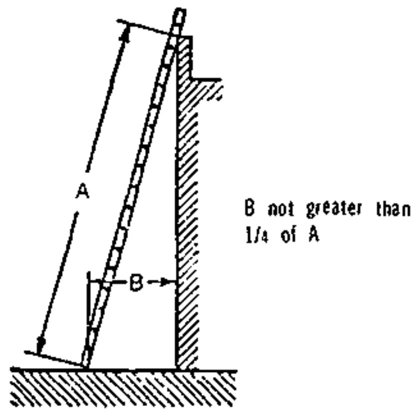


Figure 1-3. Correct Positioning of a Ladder

PERMANENT LADDERS

Permanent ladders must be securely fastened at the top and bottom The rails or one rail should extend at least 3' above the landing or work area, and there should be at least 6 1/2" toe space clearance between the rungs and the wall

Maintaining these ladders primarily involves keeping rungs repaired and ensuring that the ladder is nailed or bolted in position Most fixed ladders are in a vertical or near vertical position; if not securely fastened, they will fall over when a load is placed on them.

Docks and wharves requiring a ladder reaching from dock level to low water level frequently use a flexible ladder with 1/2" to 5/8" galvanized cable for rails and 5/8" to 3/4" round rod clamped on for treads (Figure 1-4).

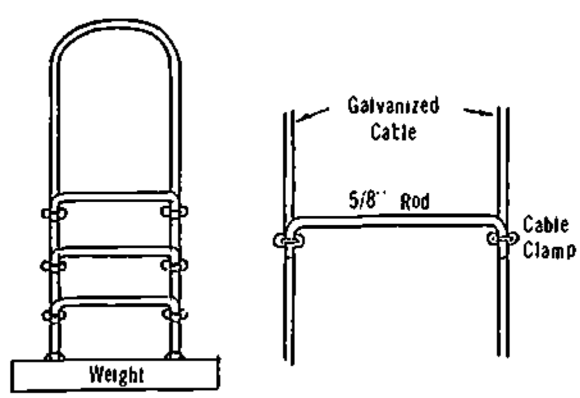


Figure 1- 4. Flexible Dock Ladder

ROUTINE MAINTENANCE OF LADDERS

Portable ladders should be handled carefully to avoid cracking or splitting siderails or rungs. When not in use, they should be stored in a dry place, but kept away from any extreme heat source such as a steam line or radiator. Ladders should be inspected carefully at frequent intervals and any defects should be repaired. Round rungs must be checked to ensure they do not rotate. If safe repairs cannot be made, the ladder must be discarded.

SCAFFOLDING

TYPES OF SCAFFOLDING

Scaffolds must be designed, constructed, erected and maintained with extreme care to prevent serious accidents. Four types of scaffolding are commonly used on Boilermaker products.

1 Bracket scaffold
2 Swingstage scaffolding
3 Needle beam scaffold
4 Prefabricated tubular scaffold.

Bracket Scaffolding Bracket scaffolding provides a temporary working platform on tanks or large vessels such as digesters or stacks (Figure 1-5). The planks are supported on large metal staging brackets hung from metal staging bracket clips welded to the surface of the structure (Figure 1-6) The metal staging bracket clips are welded to the surface of the structure along the top edge of the clip only, as designated by the arrow in Figure 1-7. When the scaffolding is to be removed the clips can be easily detached by prying in an upward direction with a bar

Figure 1-5. Bracket Scaffolding on Large Tank

Figure 1-6. Staging Bracket

Figure 1-7. Staging Bracket Clips Welded Along the Top Edge

Swingstage Scaffolding Swingstage scaffolding is a frame supported at both ends with wire rope that is suspended from an overhead structure such as overhead steel. A wooden deck is seated on the frame and the scaffold can be raised or lowered by automatic locking winches on the cables. Tirfor hand winches or power winches may be used (Figures 1-8, 1-9 and 1-10).

Needle Beam Scaffolding Needle beam scaffolding is a temporary work platform resting on two 4" x 6" wooden beams suspended from an overhead structure (Figure 1-11).

Ropes are used to suspend the beams as follows:

1. Scaffold hitches with self-centring bowlines are tied toward the ends of the beams to secure them against rolling or turning over (Figure 1-12).
2. A round turn, two half hitches is used to attach the ropes to the overhead structure (Figure 1-13).

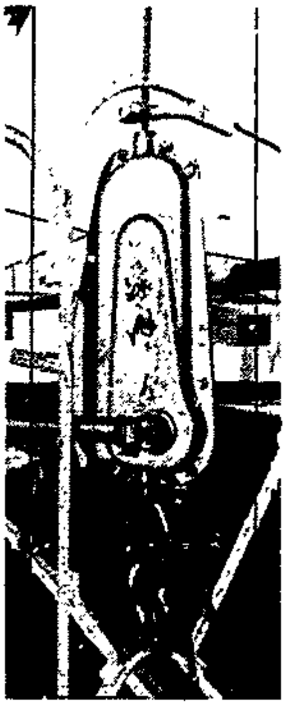


Figure 1-8

Figure 1-9

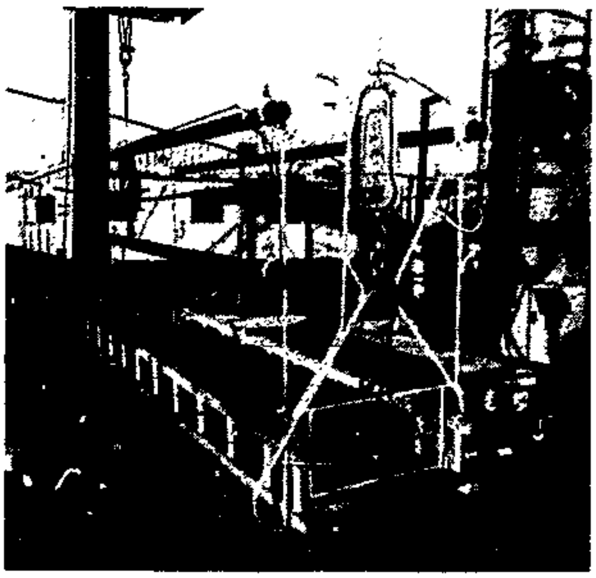


Figure 1-10

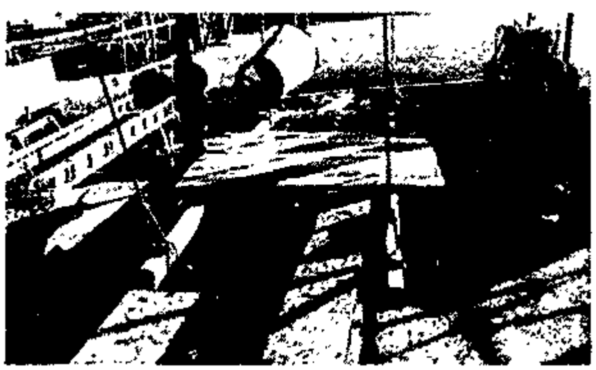


Figure 1-11

Figure 1-12

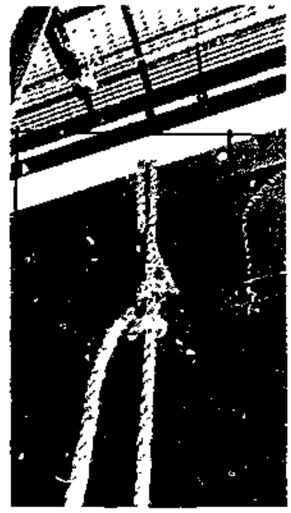


Figure 1-13

Tubular Scaffolding Tubular scaffolding is widely used as a working platform primarily because of the advantages of 1) Strength. 2) Lightweight construction. 3) Ease of assembly and disassembly. 4) Portability of prefabricated parts.

Figure 1-14 shows an exploded view of a tubular scaffold illustrating the following parts:

A Base plate — provides a footing when the unit is erected on a level surface

B. Screw jacks — provide an adjustable footing when the base surface is uneven

C. Castor (locking) — provides mobility

D. End frame

E. Cross brace — provides a means for joining two end frames

F. Sway brace — stabilizes scaffolding unit

G. Deck — used to provide a working surface at any level (planks may be used as an alternative)

H. Frame coupling pin — provides a means of erecting successive levels of scaffolding

I. Guard rail post — used in conjunction with guard rail as a safety feature.

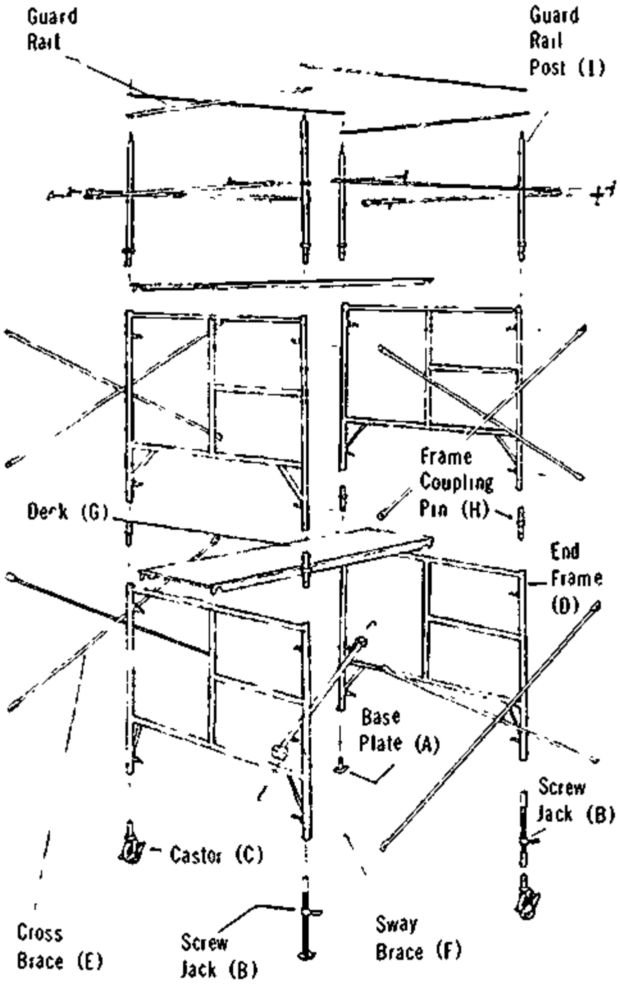


Figure 1-14. Exploded View of Tubular Scaffold

SCAFFOLD MATERIALS

Scaffold Planking

1. Must meet provincial regulations for Select Structural Scaffold Lumber
2. Must be not less than 2" x 10" nominal dimensions

Wooden Scaffold Framing

1. Must be of Construction Grade or better, or #1 Structural or better.
2. Thrust-out beams (for swinging scaffolds) and needle beams must be not less than 4" x 6"

Ropes

1. For scaffold suspension, must not be less than 3/4" diameter fibre for swinging scaffolds or 1" diameter fibre for needle beam scaffolds. If wire rope is used, equivalent rated capacity must be applied. First grade rope in new condition must be used in all cases.
2. For guardrail ropes, must be 5/8" diameter fibre or 3/8" wire rope.

Fittings All fittings (scaffold brackets, winches, cornice hooks, etc.) must meet provincial regulation standards.

MATERIAL TESTING

If scaffold material is not certified "Tested" prior to shipment to the job, it must be field tested before use. To test scaffold planks, place each plank on 6" x 6" blocks (Figure 1-15). Have two men (combined weight approximately 360 lbs.) spring several times on both sides of each plank. Boards should be rejected if any cracking sound or visible defect develops during the test. Brackets and other fittings should be inspected for defects before use.

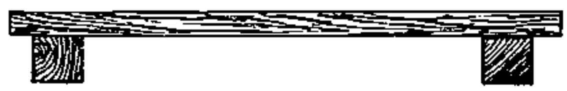


Figure 1-15. Arrangement for Testing Scaffold Planks

SCAFFOLD CONSTRUCTION

1. The ends of each scaffold plank should be bolted or banded to prevent splitting. For bolting, use 1/4" rod with square nuts. For banding, use rough or coated nails
2. Planks must extend not less than 6" and not more than 12" beyond the supporting members.
3. Planks must be supported at intervals not exceeding 10' for light work and 7' for heavy work
4. Platform width is specified by provincial regulations, the minimum being two 10" planks side by side (20")
5. When scaffold platform width is greater than 30", additional planks must be used so that no opening exists greater than the width of one plank.
6. Guardrails (or guard ropes) must be provided around open sides of all scaffold installations. Guardrail specifications for height and rope tension are set out in provincial regulations.

7 Needle beams must be rigged with the greater dimension vertical and secured in that orientation by scaffold hitches in the suspension lines Wire ropes and cable clips must be used where a danger of heat or chemical damage exists A comparably secure suspension method is required for the beams. Ropes must be padded to prevent damage from sharp corners and secured not less than 12" from the ends of the beam

8 On needle beam scaffolds, planks must be secured together by cleats or other means to prevent movement.

9 Any welding required in attaching brackets to a structure should be done by qualified welders, inspected and initialled. Brackets must be installed in a true vertical orientation to provide rated support capacity

10 If scaffolding is to extend over three or more supports, planks should overlap in one direction for a minimum of 9".

11 For swinging scaffolds, requirements for thrust-out beams (material, safety factor, counterweights, tiebacks) and cornice hooks are set out in provincial regulations

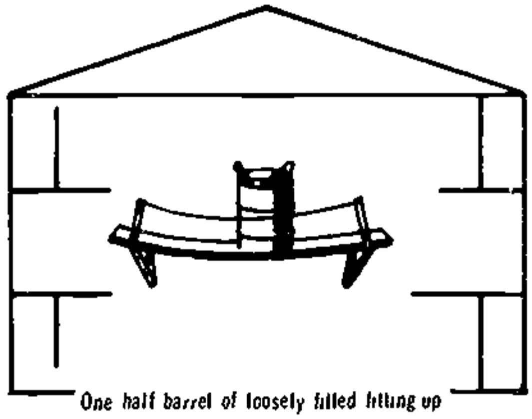
12 All hooks used in swinging scaffold suspension must be moused or fitted with safety latches as required by local regulations

13. The winch suspension must have an automatic locking mechanism and consist of one double upper and one single lower block (minimum) for each hanger. Suspension ropes must be of sufficient length to permit lowering the working platform to a safe landing position.

14 For all scaffolding higher than 10' above grade or a safe landing, life lines must be independently secured to firm structures with adequate strength. Ropes must be of approved design conforming with provincial regulations.

SAFE PRACTICES FOR SCAFFOLDING

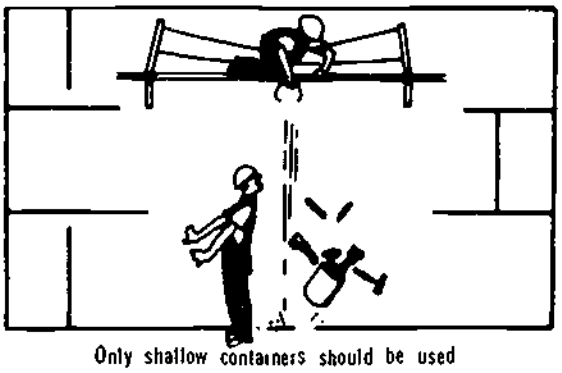
1. Where a life line is provided for work 10' or more above grade, an approved safety belt must be worn.
2. Scaffolds must be inspected each working day and required maintenance carried out
3. Scaffolds should be kept free of ice, snow, mud, oil, etc. and other substances or materials that create hazards to workmen. Planks may not be turned over until ice has been removed.
4. Excessive storage or accumulation of materials on scaffolds should not be permitted (Figure 1-16).



One half barrel of loosely filled fitting up equipment weighs approximately 350 lbs This is too much weight to place on a scaffold

Figure 1-16. Never Overload a Scaffold

5. Loose objects not in use must be placed in containers provided for that purpose (Figure 1-17).



Only shallow containers should be used for loose tool storage on scaffold Five gallon pails get top heavy and the pail handles sometimes pull off

Figure 1-17. Use of Approved Containers

6. When raising and lowering scaffold planks, damage to lumber must be avoided.

WORKING HAZARDS FROM NOISE

Noise affects workmen both psychologically and physically. The psychological effects of exposure to high level noise include annoyance, irritability, mental fatigue and decreased ability to maintain attention and alertness for prolonged periods Some workmen adapt to the noise environment and are unaffected by it. and although a few people tolerate a noisy environment. it is desirable to suppress excessive noise

Noise also interferes with spoken communication and contributes to delays. difficulties and errors in transferring information Where ideal spoken communications are required. low noise levels are essential.

The physical effect of noise on workmen is confined to the hearing. and degrees of deafness and tinnitus (noises in the head) are produced The effects of noise on hearing vary with sound frequency and intensity and with degree of exposure Individual susceptibility is also an important factor

The sound intensity is the amount of energy in the sound wave. and sound level is usually expressed in decibels. Intensity is interpreted as loudness by the listener The threshold of hearing — the weakest sound that can be heard — is zero decibels. and the threshold of pain is 130 decibels

Typical sound levels:

Jet motor at 75	130	decibels
Rock drills	115	"
Kraft paper winder	111	"
Wood chippers	110	"
Newsprint machine	108	"
Cut-off-saw	95	"
Street corner traffic, large city	60	"
Typical office	60	"
Normal conversation in average size living room	40	"

Impairments in hearing acuity due to exposure to high level noise usually begin above the so-called speech range. that is. above 3000 cycles per second At first. hearing impairment is temporary or transient and disappears in hours Temporary impairments are due to "fatigue" of the hearing mechanism

In most cases permanent hearing impairment develops only after susceptible ears have been subject to high level noise on numerous occasions over long periods of time. In such circumstances. hearing becomes impaired not only for high frequency sound. but also for sound in frequencies essential for understanding speech

PERSONAL PROTECTION

Several types of ear muffs and insert ear plugs that provide protection from high level noises are available on the market All these devices decrease the noise at the ear Noise reductions up to 35 decibels are obtained with good ear protectors properly worn Dry cotton in the ears does not afford adequate protection from high level noise

Ear muffs and ear plugs do not deprive workmen of useful hearing on the job. warning signals and speech in noisy areas can be heard better when ear protectors are worn.

GUIDELINES FOR USING EAR PROTECTIVE DEVICES

1 Plugs should be pliable and fit each ear tightly
2 Plugs will work loose. and must be reseated regularly
3 Plugs or muffs do not cause infection. but should be kept reasonably clean
4 Ear protectors make it easier to understand speech or signals in noisy environments.

FIRE PREVENTION

FIRE THEORY

Every Boilermaker must have complete and up-to-date knowledge of fire prevention and the use of fire fighting equipment.

Three conditions must be met for a fire to start

1. Air must be present
2. A combustible material or fuel must be present
3. There must be a means of ignition.

Air Since air is an inherent part of the environment. it must be accepted as permanent

Combustive Materials Combustible material should always be contained in specially designated areas and isolated from possible sources of fire. Solvents and other containers of inflammable material should be covered when not in use and any spillage should be wiped up immediately and the area treated to neutralize possible hazards. Proper housekeeping should be enforced. and any rags. papers or other inflammable materials should be deposited in the designated disposal area

Ignition Common sources of ignition are matches, lighters, cigarette stubs, electrical motors, static electricity, sparks caused by friction and sparks from electric arc welding, oxyacetylene welding and cutting

For small local fires there are a variety of extinguishers each with a specific use (See Table 1-1)

CLASSIFICATION OF FIRES

Fires are divided into four main classes

CLASS A — Fires in ordinary combustible materials such as wood, sawdust, paper, rags, etc.

CLASS B — Fires in gasoline, oils, petroleum products, solvents, etc.

CLASS C — Fires involving electrical equipment.

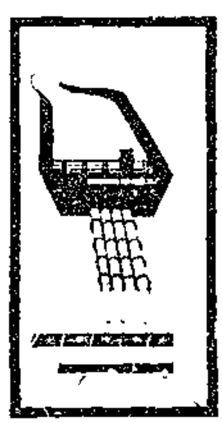
CLASS D — Fires in metals such as magnesium, potassium nokalloy, etc.

TABLE 1-1. FIRE EXTINGUISHER DETAILS

TYPE	CONTENTS	KINDS OF FIRE	HOW TO START	DISCHARGE
CARBON DIOXIDE 	Liquid carbon dioxide under pressure	CLASS B (oil, gasoline, paint, grease)	Pull pin and open valve	6 8 ft About 42 sec (15 lb size)
VAPORIZING LIQUID 	Carbon tetrachloride and other chemicals	CLASS C (live electrical equipment)	Turn handle, then pump by hand	20 30 ft 40-45 sec (1 qt size)
DRY CHEMICAL 	Bicarbonate of soda with other dry chemicals and cartridge of carbon dioxide gas	These extinguishers also have some effect on CLASS A fires (wood, paper, textiles)	THREE TYPES Pull pin or collar & then 1 Open Valve (or) 2 Press Lever (or) 3 Turn Over & Bump Then squeeze nozzle	About 14 ft 22 25 sec (30 lb size)

TYPE	CONTENTS	KINDS OF FIRE	HOW TO START	DISCHARGE
SODA ACID 	Bicarbonate of soda solution and sulfuric acid	CLASS A (wood, paper, textiles, etc	Turn over	For 2½ gal size 30 40 ft 50 55 sec
PUMP 	Plain water		Pump by hand	
GAS CARTRIDGE 	Water and cartridge of carbon dioxide gas	CLASS A ("Loaded stream" is also good on small CLASS B)	Turn over and bump	
FOAM 	Solution of aluminum sulfate and bicarbonate of soda	CLASS A and CLASS B (oil, gasoline, grease paint)	Turn over	

Chapter 2
BOILERMAKER TOOLS



INTRODUCTION

The Boilermaker trade requires the use of a variety of both hand-and power-driven tools. This chapter describes each of the Boilermaker's tools, emphasizing three central issues:

1. Each tool is designed to perform a specific range of functions. The correct tool must be selected for each job to ensure safe and efficient work.
2. Each tool is designed to perform its function only if it is used correctly.
3. Tools must be adequately maintained to retain their capacities to perform their intended functions.

As a general rule, a Boilermaker's ability can be inferred from his handling of the tools of his trade. A good craftsman can look over a project, determine the tools required and have them at hand when they are needed. He is aware that an incorrectly used or poorly maintained tool may be more a hazard than a help.

HAND TOOLS

If possible, tools should be kept in a toolbox that can be locked to prevent theft. Loaning tools is probably the easiest way to lose them, so the wise tradesman does not lend his tools and soon develops the habit of keeping his toolbox locked.

Tools only used occasionally or tools too large for the toolbox are generally drawn from the tool crib. The tradesman usually has to sign out these tools or give one of his tool tags in exchange. This precaution enables the tool crib attendant to keep a record of the tools out on loan. Tools should be cleaned before being returned to the crib. Any breakages, defects or malfunctions should be reported to the attendant so that the tool can be repaired or replaced. Damaged or broken tools from the toolbox should be returned to the crib for replacements.

The following tools are normally found in a Boilermaker's tool kit:

Ballpeen Hammer	Prick Punch
Chipping Hammer	Centre Punch
8" long Cold Chisel	10" Adjustable Wrench
12" Adjustable Wrench	12" Combination Square
8" Lineman's Pliers	8" Dividers
10" Slip Joint Pliers	2 Foot Steel Folding Rule with "Circumference Scale"
Tri-Flint Lighter (Striker)	Trammel Points
Standard Tip Cleaners	9" Torpedo Level
Burning Goggles	Padlock
Safety Goggles	Tool Tags
Wire Brush	Toolbox
Hack Saw	
Scriber	
Soap Stone Holder	
12 Foot Tape — 3/4" wide	

HAMMERS

The Boilermaker uses many different types and styles of hammers: the most commonly used are described here. Specialized hammers such as the Bricklayer, Stonemason, sheet metal, Railroad spike and ornamental metal work hammers are only rarely required for Boilermaking projects.

Sledge Hammers Sledge hammers come in weights from 4 to 20 lbs. The 8 lb. sledge is a popular hammer for the Boilermaker's work; it is heavy enough for most driving wedges and for general work use. Heavier sledges may be required for fairing tank seams or for driving wedges on heavy plate work. Sledges used in the trade often have two maul faces (Figure 2-1) but they may have one maul face and one Cross peen (Figure 2-2) or straight peen face. The combination peen-maul is more commonly used in shipyards.

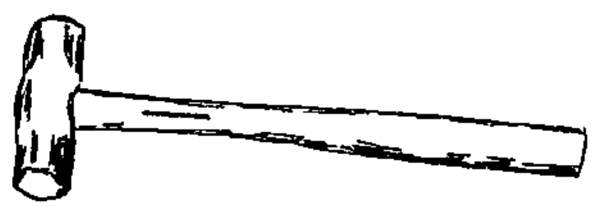


Figure 2-1. Maul Face Sledge Hammer

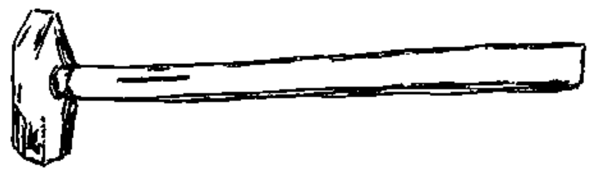


Figure 2-2. Cross Peen Sledge Hammer

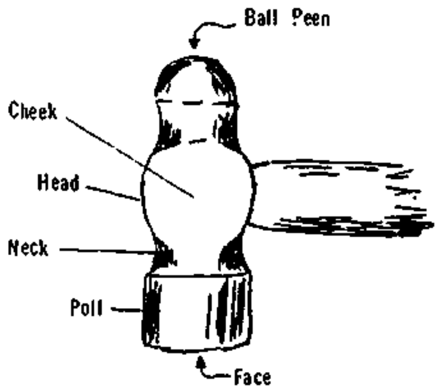


Figure 2-3. Ball Peen Hammer

Ball Peen Hammer The ball peen hammer (Figure 2-3) is a must in every toolbox. They are available in a range of weights from four ounces to three pounds, the lighter tools being designed for fine layout work. The peen is used to form and stretch metal, the poll face is used for driving wedges, chisels, centre punches and other operations too small to require a sledge.

Four Pound Sledge The four pound sledge (Figure 2-4) is a favourite with fitters. Its face is larger than that of the ball peen, and the extra weight makes it ideal for driving in bull pins for lining up bolt holes. Riggers often carry the four pound sledge on their rigging belts.

Figure 2-4. Four Pound Sledge Hammer

Chipping Hammers Chipping hammers are used by welders and mechanics to chip slag off a weld or burned edge. They are made with heads of forged alloy steel hardened and drawn for maximum toughness and may have handles of flexible wire or hardwood. The heads are designed with long, slender cone points and thin, tapered chisel bits to reach slag in confined areas. These hammers can be resharpened many times before they become too blunt for use. Three types of chipping hammers are available: 1) cross and straight chisel, 2) cone and cross chisel, and 3) cone and straight chisel (Figure 2-5).

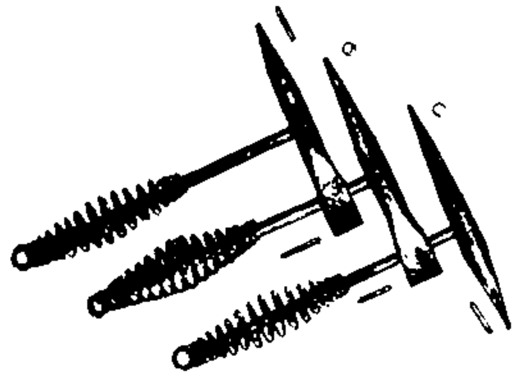


Figure 2-5. Chipping Hammers

CLAMPS

Clamps are used to hold parts in alignment for various operations such as welding, drilling, punching, etc. The most common are C-Clamps, manufactured in sizes up to 18" in a variety of materials, cast iron, cast steel, forged steel, pressed steel and aluminum alloys (Figure 2-6). The depth of throat varies as does the shape of the body. An acme thread on the screw is generally preferred.

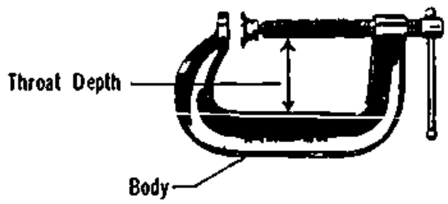


Figure 2-6. C-Clamp

For larger clamping operations, a bar clamp is used (Figure 2-7). Another version of this is the pony or pipe clamp which permits practically unlimited reach as the clamp jaws can be mounted separately on any length pipe.

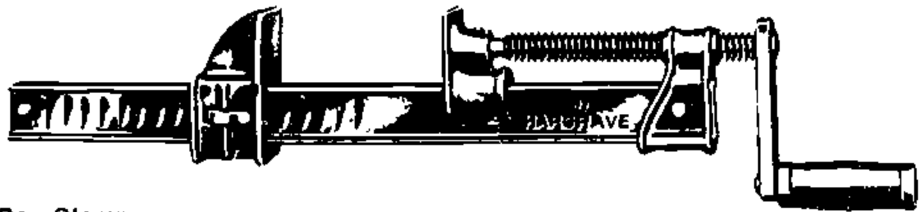


Figure 2-7. Bar Clamp

Correct Use of Clamps

1. Choose clamp size so that the jaws are never separated to the maximum opening. Overextending the screw will cause it to bend.
2. Do not overload a clamp because the body may bend or break.
3. Do not use wrenches on the screws unless the clamp is a heavy duty type with a bolt head designed to accept a wrench.
4. When welding, use clamps of the shielded thread type to prevent damage to the threads from spatter.

LAYOUT PUNCHES

Layout punches are used to make indentations in materials for marking: 1) the course of scribed lines; 2) the location of points; 3) the centres of divider points, trammel points or holes to be drilled or machine punched.

Layout punches are made of hardened and tempered steel with a knurled handle for good finger grip. There are two principal kinds of layout punches: the prick punch and the centre punch.

Prick Punch The prick punch (Figure 2-8) is a commercially designed tool approximately 4" to 6" in length used mainly in layout or by template makers for precision work. The punch end is ground to a 30° to 60° point.

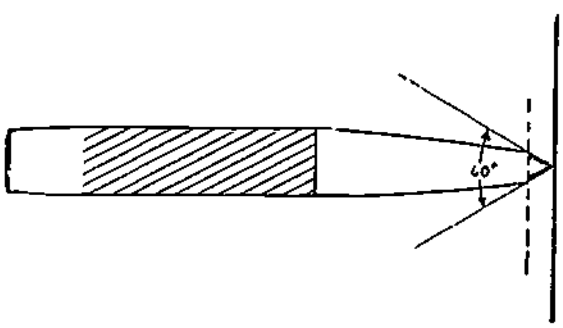


Figure 2-8. Prick Punch

Centre Punch The centre punch (Figure 2-9) is similar in design to the prick punch except that the tapered point is ground to 90°. This machine gives the capability of enlarging prick punch holes for drilling or machine punching. The centre punch is often made by the Boilermaker rather than purchased.

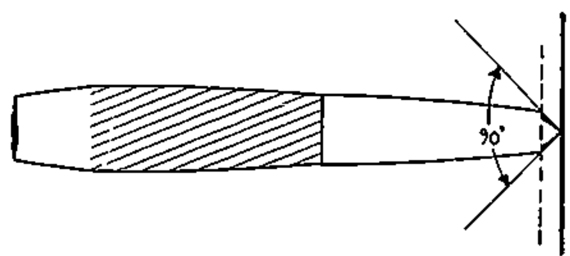


Figure 2-9. Centre Punch

Correct Use of Layout Punches

Precaution Since layout punches are made of hardened steel, they should not be used to try to mark hardened steel or alloys.

Maintenance Layout punches can be reground using the same procedures as recommended for grinding chisels. (See "Chisels.") Be sure to use a fine tool stone on the grinder and do not allow the layout punch to become too hot.

FILES

More than three thousand kinds, shapes and sizes of files are manufactured. This tremendous variety requires rigid specifications and control during production. Specialized files have been developed for filing of rough castings, die castings, stainless steel, aluminum, brass, lead, plastics, etc. Their specially designed teeth and in some cases extreme hardness and toughness will overcome the difficulties encountered with regular files.

Good files are made from high quality steel carefully formulated to provide the necessary properties required. Files have three distinguishing features:

1 Length — always measured exclusive of the tang
2 Kind or shape — flat, mill, half-round, etc.
3 Cut — character and relative degree of coarseness of the teeth.

TYPES OF FILES

Common types of files are shown in Figure 2-10.

CORRECT USE OF FILES

1 Always use a properly fitted handle when filing to prevent hand injury (Figure 2-11). A loose handle can slip off unexpectedly.
2. Use the right file for the job.
3. Hold the file correctly (Figure 2-11).
4 Maintain the hand in correct position.
5. Never use a file as a hammer or as a crow bar.

MAINTENANCE OF FILES

1. Clean the file as frequently as needed using a filecard or a brass file cleaner.
2 To remove soft metal particles, use a piece of wood and push across the file parallel with the teeth.
3 When filing soft metal, file a soapstone first to prevent lodging of metal pieces in the teeth (loading).
4. Keep files separate from other tools in the toolbox.

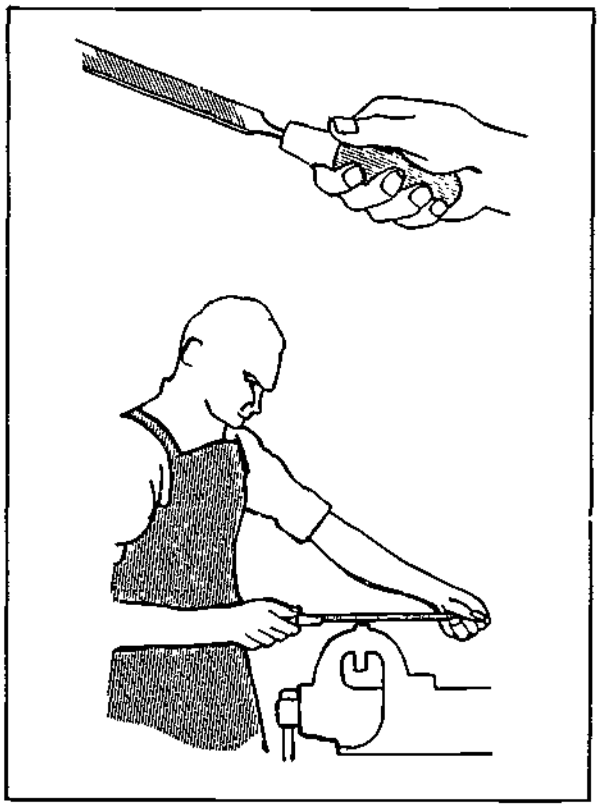


Figure 2-11. Using a File

CLASS	TRADE NAME	CUT on PITCH	SHAPE
SINGLE CUT	MILL FILE (SAW FILE)	COARSE BASTARD	Square, Pillar, Flat, Mill, Warding
DOUBLE CUT	MACHINIST WELDER	SECOND CUT SMOOTH	Threesquare, Taper, Cant Saw, Knife, Round, Pit Saw, Half Round, Cross Cut
CURVED TOOTH	METALWORKER WELDER	STANDARD FINE SMOOTH	Flat, Pillar, Half Round
SPECIAL PURPOSE FILES	METALWORKER WELDER	VARIES DEPENDING ON USE	Depends on Type of File

Figure 2-10. Types of Files

PLUMB BOBS

When a plumb bob is suspended from a cord or chalkline, it can: 1) align columns vertically; 2) centre penstock or pipe, 3) take horizontal measurements from a fixed point such as the centre line of a boiler or drum.

Plumb bobs (Figure 2-12) are quite light and are thus easily affected by air currents. For this reason they are sometimes suspended in a bucket of water or oil The cord may be shortened by tying a sheep shank in it.

Plumb bobs have a hardened steel point so that a reference point can be made by hanging the bob in its correct location and then carefully dropping it to make a mark

When constructing scroll casing or taking measurements from the centre line of a boiler steam drum, a heavy weight plumb bob is used, suspended from a stainless steel wire instead of chalkline or cord because of its weight. If a heavier weight bob is unavailable, a heavy piece of steel may be used, although it will be less accurate than a proper plumb bob.

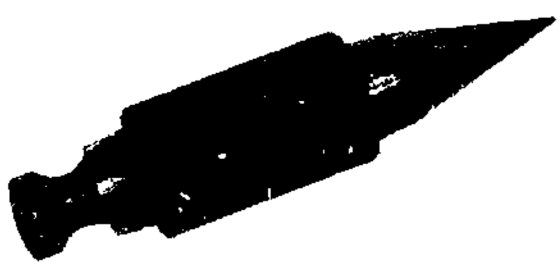


Figure 2-12. Typical Engineer's Plumb Bob

PLIERS

Slip Joint Pliers Slip joint pliers are the most common pliers used. The slip joint provides a wider opening of the jaws at the hinge for gripping material of larger diameter. Combination pliers are available in three sizes based on their overall length: 5", 6" and 10". Some combination pliers (Figure 2-13) are equipped with wire cutters, and better quality pliers are made of drop forged steel.

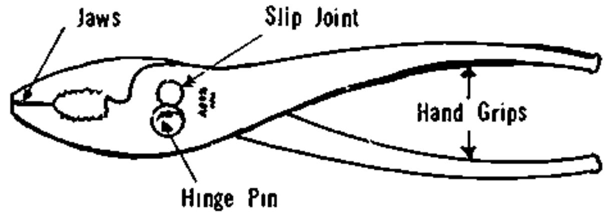


Figure 2-13. Combination Pliers

Water Pump Pliers (channel-lock pliers) Water pump pliers (Figure 2-14) were originally designed for tightening or removing water pump packing nuts whose varying sizes required an adjustable jaw hinge with seven different positions. The inner surface of the jaws has a series of coarse teeth formed by deep grooves for grasping cylindrical objects.

Figure 2-14. Water Pump Pliers

Side-Cutting Pliers (sidecutters) Side cutting pliers (Figure 2-15) are designed for holding, bending and cutting thin materials or small gauge wire. Various sizes are available, designated by their overall length. The jaws are hollowed out on one side just forward of the pivot point, while on the opposite side the jaws form the cutting edges.

Figure 2-15. Side-Cutting Pliers

WRENCHES

Certain general types of wrenches are used in almost all trades. It is important to recognize the required wrench by its proper name rather than its trade name to avoid confusion when ordering a wrench for a specific job.

Adjustable Wrenches Adjustable wrenches (Figure 2-16) are commonly available in sizes ranging from 4" to 15" in length, and adjustable to any bolt or nut size within their range. It is important to select a wrench size proportional to the diameter of the screw thread, since a large wrench adjusted to suit a small nut or bolt head can result in torque sufficient to strip the thread or snap the bolt under slight pressure.

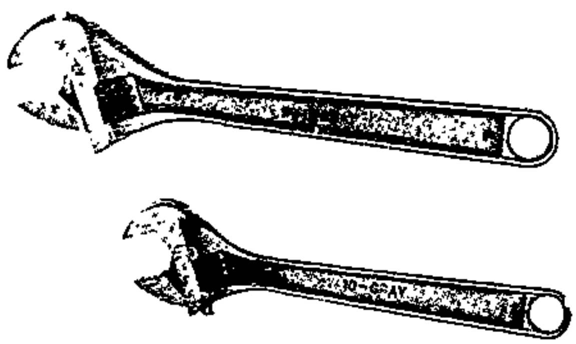


Figure 2-16. Adjustable Wrenches

Pipe Wrenches Pipe wrenches (Figure 2-17) are sized according to length and are adjustable to different pipe diameters. The jaws have teeth cut into them which bite into the pipe as leverage is applied. These wrenches are designed so that the grip of the jaws tightens as the leverage on the handle is increased. Pipe wrenches should not be used on thin wall tubing, on plated pipe or on any job where the high finish might be damaged

Figure 2-17. Pipe Wrench

Box and Open End Wrenches Box and open end wrenches are not adjustable (Figure 2-18 and 2-19). They are usually double-ended to accommodate two sizes of bolt heads. Sizes are given according to the dimensions of the nut or screw head measured across the flat, in fractions or millimetres.

Figure 2-18. Open End Wrench

Figure 2-19. Box End Wrench

VISE GRIPS

Vise grips could be classed as pliers or clamps (Figure 2-20). The knurled thumb screw at the back of the handle adjusts the jaw opening and the locking tension. The toggle type locking arrangement provides an adjustable clamp with powerful compound leverage. Some of the many uses for these tools are as adjustable pliers, as portable vises, as a portable toggle press, for pulling keys from shafts and for holding and twisting star drills.

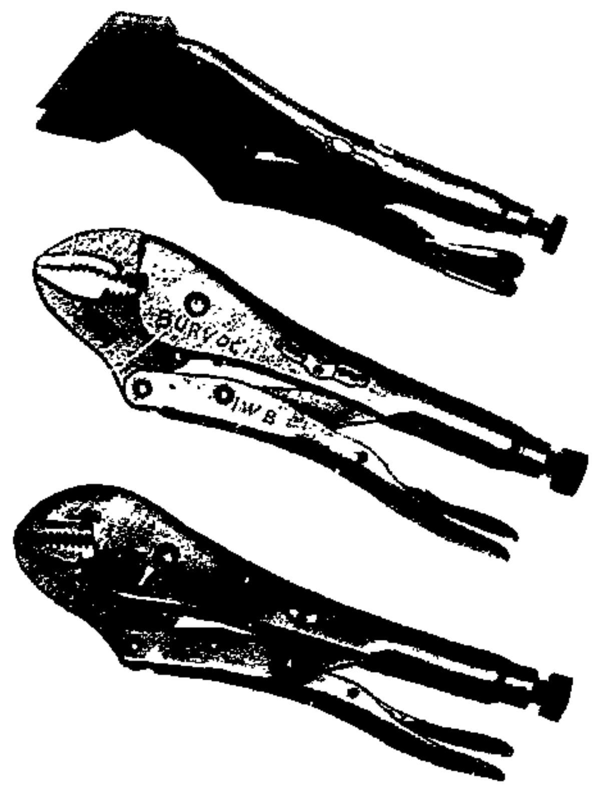


Figure 2-20. Three Types of Vise Grips

SCREWDRIVERS

Screwdrivers are available in a variety of types and sizes (Figure 2-21). The most common types used are Regular, Robertson and Phillips. Some principles to guide the selection of regular screwdrivers are illustrated in Figure 2-22.

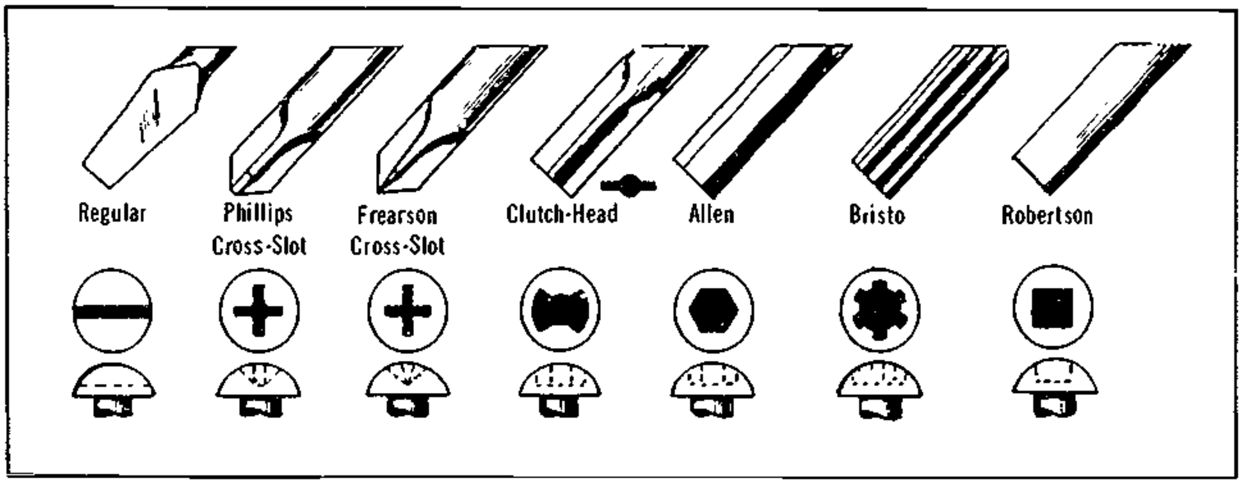


Figure 2-21. Standard Types of Screwdriver Tips and Screw Recesses

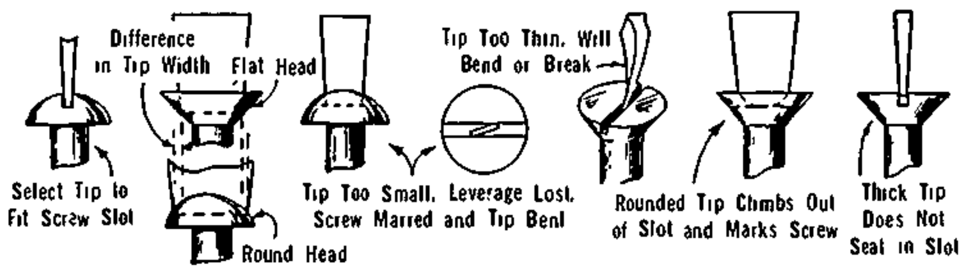


Figure 2-22. Principles for Selecting a Screwdriver

CHISELS

Chisels are made in a variety of sizes with different cutting edges and shapes. The selection of the right chisel is determined by the kind of material to be cut and the contour of the cut required.

The development of efficient air powered tools, such as the air grinder, chipping gun and disc grinder, has largely eliminated the use of chisels for metal cutting. Under some circumstances, however, a chisel may be used.

Flat Cold Chisel The flat cold chisel (Figure 2-23) is used to chip material from a flat surface to make a part smaller, shear sheet metal, cut off small rods and wire, split nuts and remove burning slag and weld spatter.

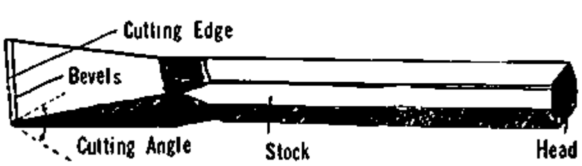


Figure 2-23. Flat Cold Chisel

Cape Chisel The cape chisel (Figure 2-24) is used to cut in grooves, slots and keyways due to its narrower cutting edge.

Figure 2-24. Cape Chisel

Round Nose Chisel The round nose chisel (Figure 2-25) is used to cut round grooves.

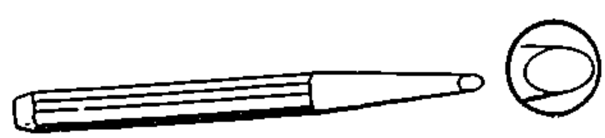


Figure 2-25. Round Nose Chisel

Diamond Point Chisel The diamond point chisel (Figure 2-26) is used to cut V-shaped grooves such as those in a boiler tube that is to be removed from a sheet It can also remove tack welds and chip metal out of square corners.

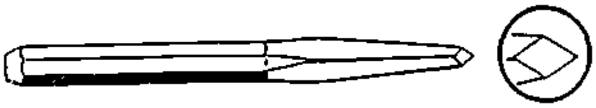


Figure 2-26. Diamond Point Chisel

MAINTENANCE OF CHISELS

When a chisel has become dull or mushroom-headed, it should be reground When grinding the tip of the chisel, hold it tightly against the wheel to prevent overheating. Dip the tip in water between passes. Be careful to grind as little as possible to restore the edge. A mushroomed head can be restored by revolving the chisel head against the grinding wheel.

HACK SAWS

The hack saw is used for cutting metal and other material such as hard plastics. Blades may be made of plain carbon steel or high speed steel, and blade construction may be "all-hard" or "flexible" "Flexible" means only the teeth have been hardened The number of teeth per inch for hacksaw blades varies from 14 to 32. Coarser teeth are better for making cuts in large pieces of cast iron or steel and heavy gauge sheet metal; finer teeth are for cutting thin-walled pipe or tubing, thin metal, and light angles.

The "set" of a blade refers to how much the teeth are set out from the sides of the blade. This "set" ensures that the width of the kerf or cut is a little greater than the thickness of the blade, providing clearance to prevent the blade from binding in the cut while sawing. Hack saw teeth may be set in three arrangements (Figure 2-27)

1 **Alternate set** Alternate teeth are bent slightly sideways in opposite directions
2 **Raker set** Every third tooth remains straight and the other two are set alternately
3 **Undulated set** Short sections of teeth are bent in opposite directions.

Most hack saws are made with an adjustable frame designed to accept blades 8", 10" or 12" in length. When fitting a blade to the frame (Figure 2-28) it is important that.

1 The teeth point in the same direction as the cutting stroke
2. It be adjusted to the proper tension using the wing nut.

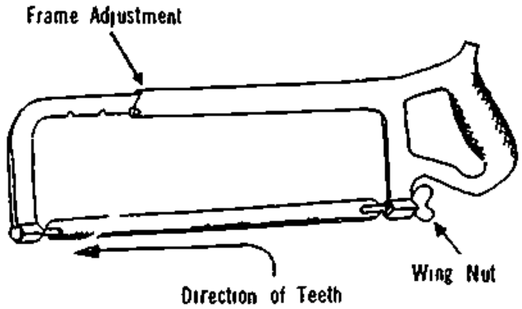


Figure 2-28. Fitting a Blade to the Frame

Some frames will allow the blade to be set at different angles (Figure 2-29).

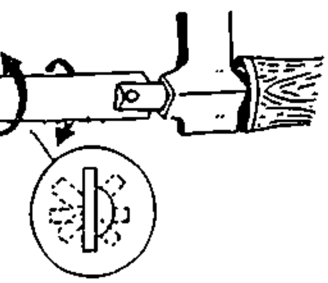


Figure 2-29. Blade Setting at an Angle

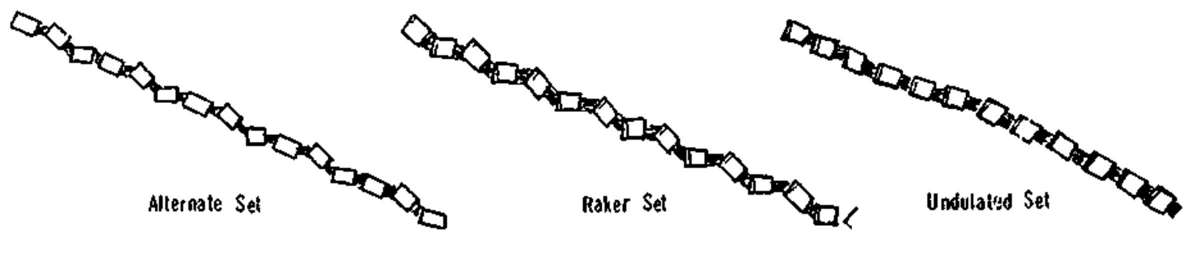


Figure 2-27. Different Types of Saw Sets

MEASURING TOOLS

Measuring tools are precision instruments, and it is very important to know how to use and maintain them. If not handled with care, even the best tools will become damaged and functionally unreliable even for rough jobs. Rules, calipers, tapes, micrometers, etc. should be properly stored in the toolbox, preferably boxed to prevent their coming into contact with other tools. A coat of light oil will help prevent rust.

STEEL TAPES

Steel tapes are available in a variety of lengths and widths, but the type most frequently used in construction work is 12' long and 3/4" wide with a concave blade to make it self-supporting over a limited distance.

The hook on the end of the tape is able to move on loose rivets to the extent of the hook's thickness so that the measurement is accurate whether the tape is hooked over the end of a work piece or positioned to make an inside measurement.

Uses of Steel Tapes

Measuring Length Use the hook on the end of the tape; it will slide out on the two rivets to give a true measurement (Figure 2-30).

Measuring Inside Length Most square tape cases are 2" long, so this 2" must be added to the length showing on the tape (Figure 2-31).

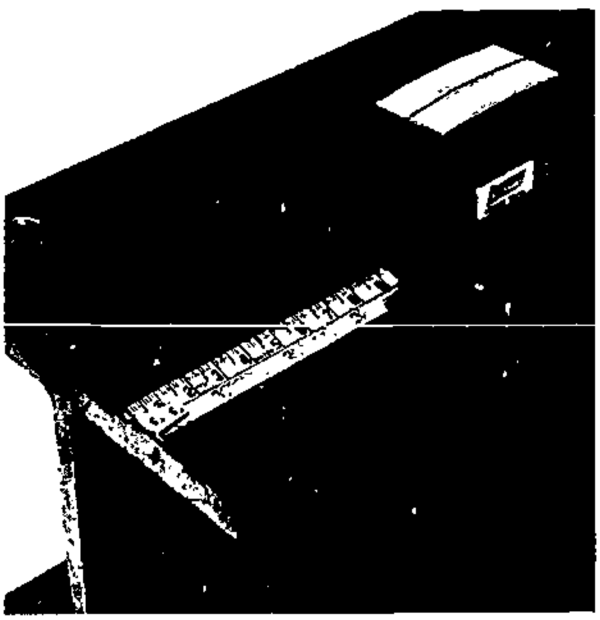


Figure 2-30. Measuring Length with a Tape

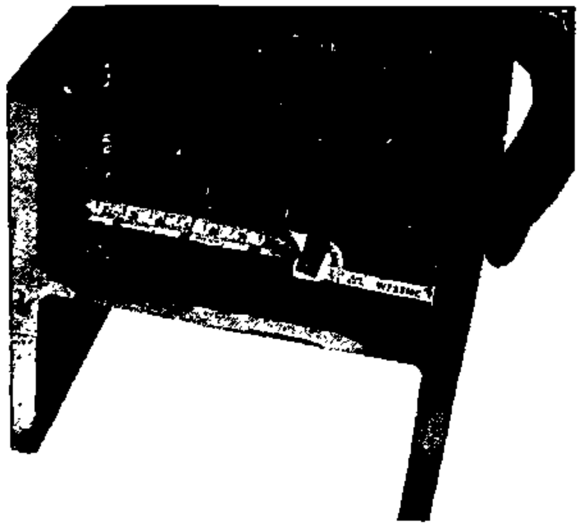


Figure 2-31. Measuring Inside Length with a Tape

The hook at the end of the tape slides back on the rivets to get a true measurement.

Marking Measurement with a Scriber The tape must be square with the work piece to get an accurate distance (Figure 2-32). If the rule were not square, the distance would be distorted.

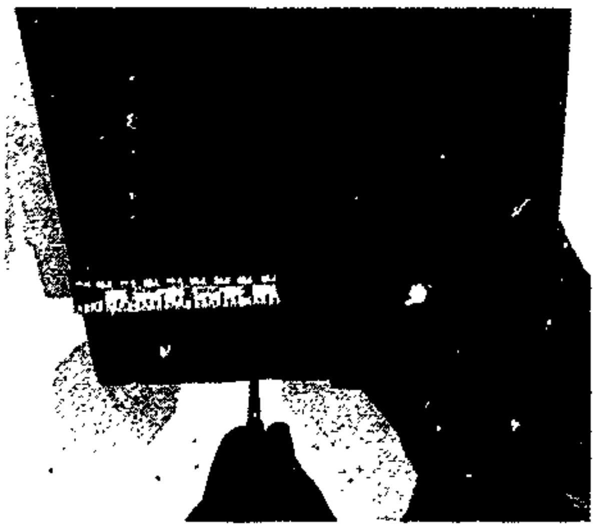


Figure 2-32. Marking Measurement with a Scriber

TWO FOOT FOLOING RULE

The two foot folding rule (Figure 2-33) is graduated in inches and 8ths of an inch on one edge and has corresponding circumference graduations on the other. The reverse side of the rule is marked in inches and 16th inches. It is

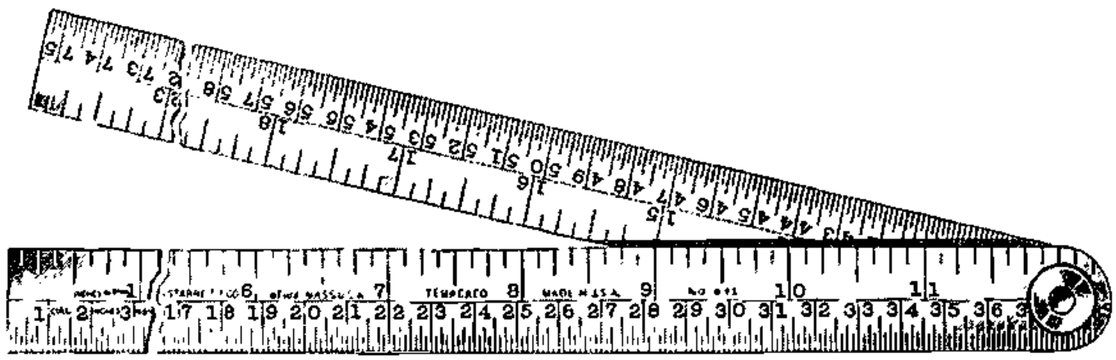


Figure 2-33. Two Foot Folding Rule

made of spring tempered steel and can be used as a straight edge or substitute for a level square to transfer angles. This rule is flexible enough to measure circumferences of large circles

Correct Use of Two Foot Folding Rule

1. Find the diameter of the work-piece using the inch edge.
2. Read the circumference of the corresponding circle from the point on the circumference scale opposite the length For example, it can be noted that a circle with a 7" diameter has a circumference of 22".

Note: When making measurements it may be desirable to use the one inch mark (or in the case of longer tapes, the one foot mark) as a starting point When this is done, double check to ensure the inch (or foot) is accounted for. Otherwise you could be an inch (or a foot) too short on the piece you are measuring, or an inch (or a foot) too long if you are transferring the measurement.

POCKET SLIDE CALIPER

The stainless steel pocket slide caliper on one side is graduated in 32nds of an inch and can be used to take both inside and outside measurements. The other side of the caliper is calibrated in 64ths of an inch and has a line on the body (marked "out") for outside reading and another line (marked "in") for inside readings (Figure 2-34). This type of caliper does not have a vernier scale and so will only measure to the nearest 64th of an inch. The inside measuring nibs on the jaws are rounded to permit an accurate reading in holes. The jaws and nibs are hardened and ground for accuracy. The locking clamp screw firmly locks the slide in any position in the body of the tool (Figure 2-35A. 35B).

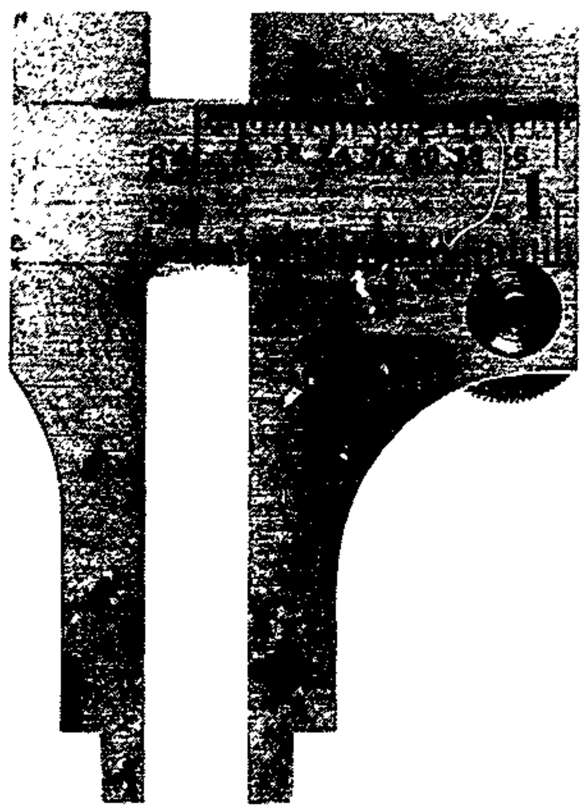


Figure 2-34. Pocket Slide Caliper

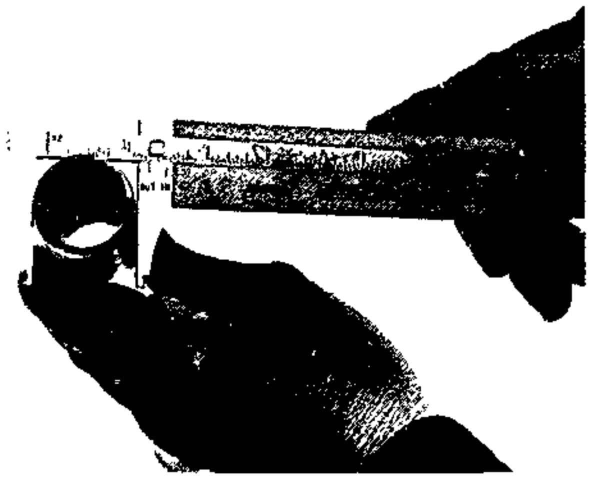


Figure 2-35A. Pocket Slide Caliper Locked Onto Work Piece

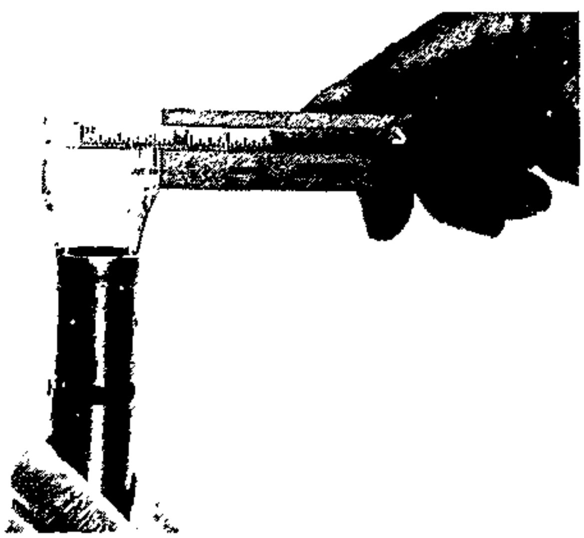


Figure 2-35B. Pocket Slide Caliper Locked Onto Work Piece

SPRING CALIPERS AND DIVIDERS

Spring calipers and dividers are made of high quality steel. The legs are made of flat stock, the fulcrum nut is hardened, and the large bearing surface on the legs helps prevent side deflection The bow spring is strong yet flexible. The adjusting nut may be solid or quick adjusting. Figures 2-36, 2-37 and 2-38 illustrate these tools. To transfer their measurements to inches, fractions or decimals requires a rule, micrometer or vernier calipers (see "Vernier Instruments" pp. 33)

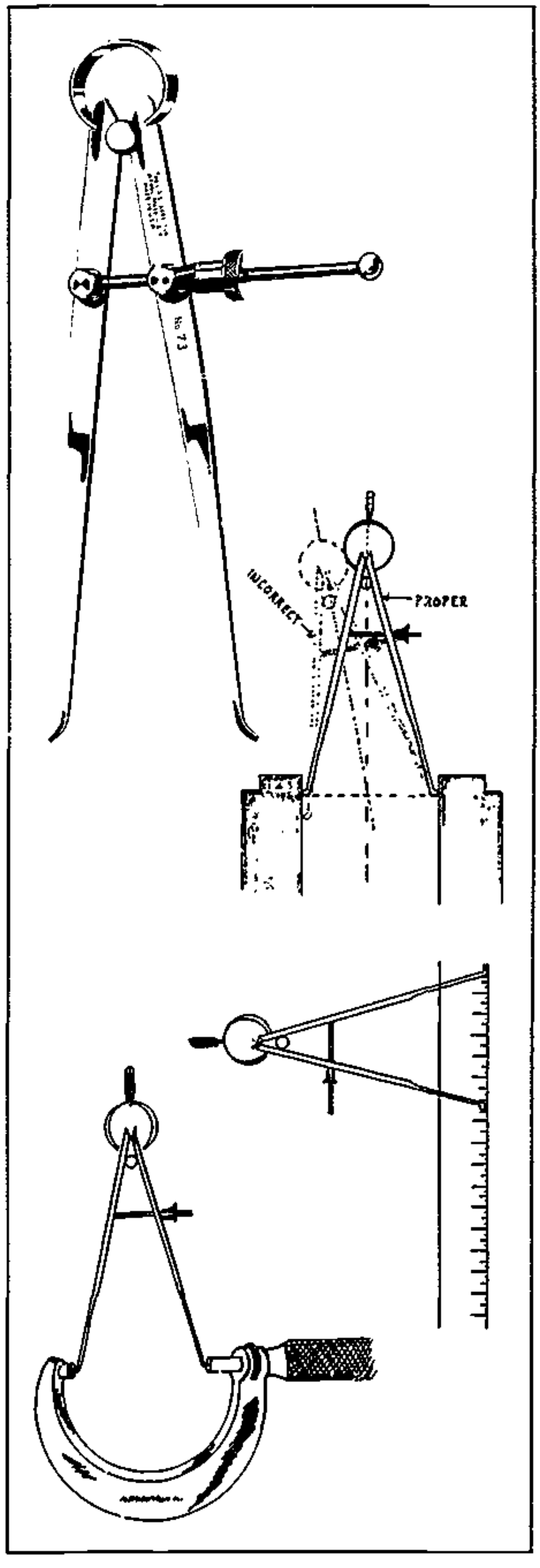


Figure 2-36. Spring Inside Calipers (3"-12")

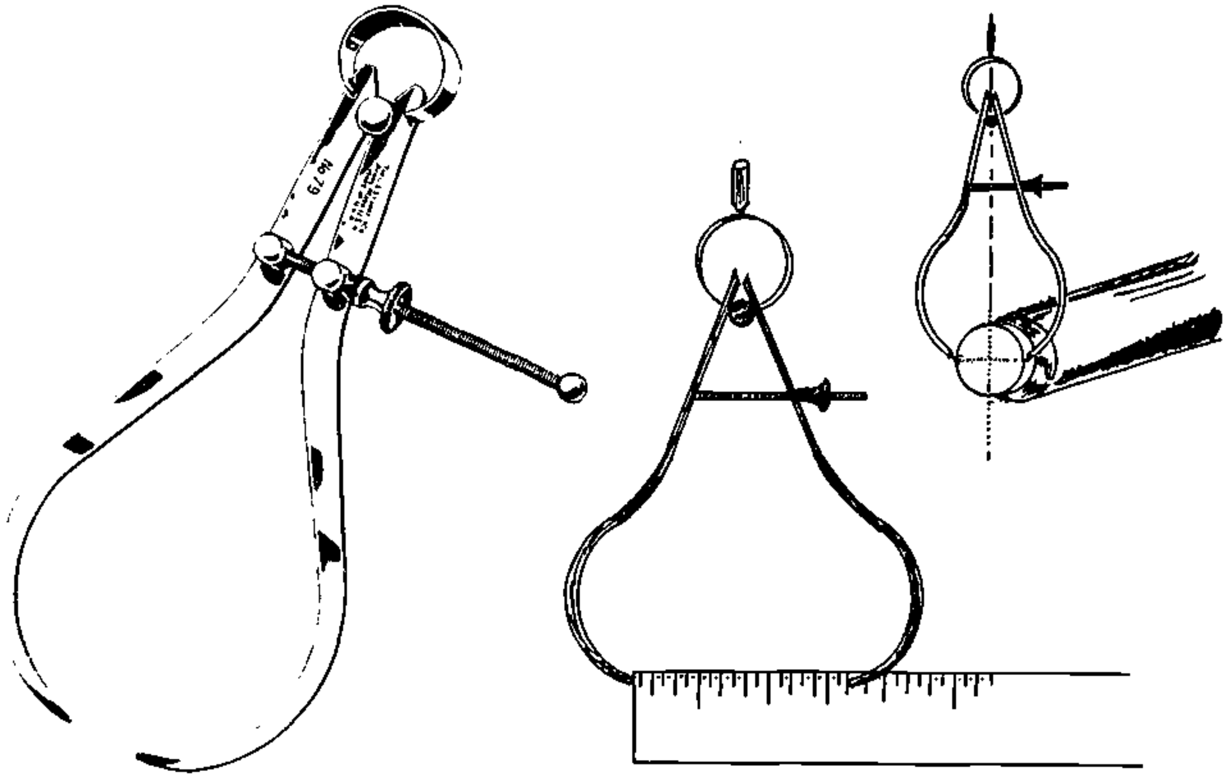


Figure 2-37. Spring Outside Calipers (3"-12")

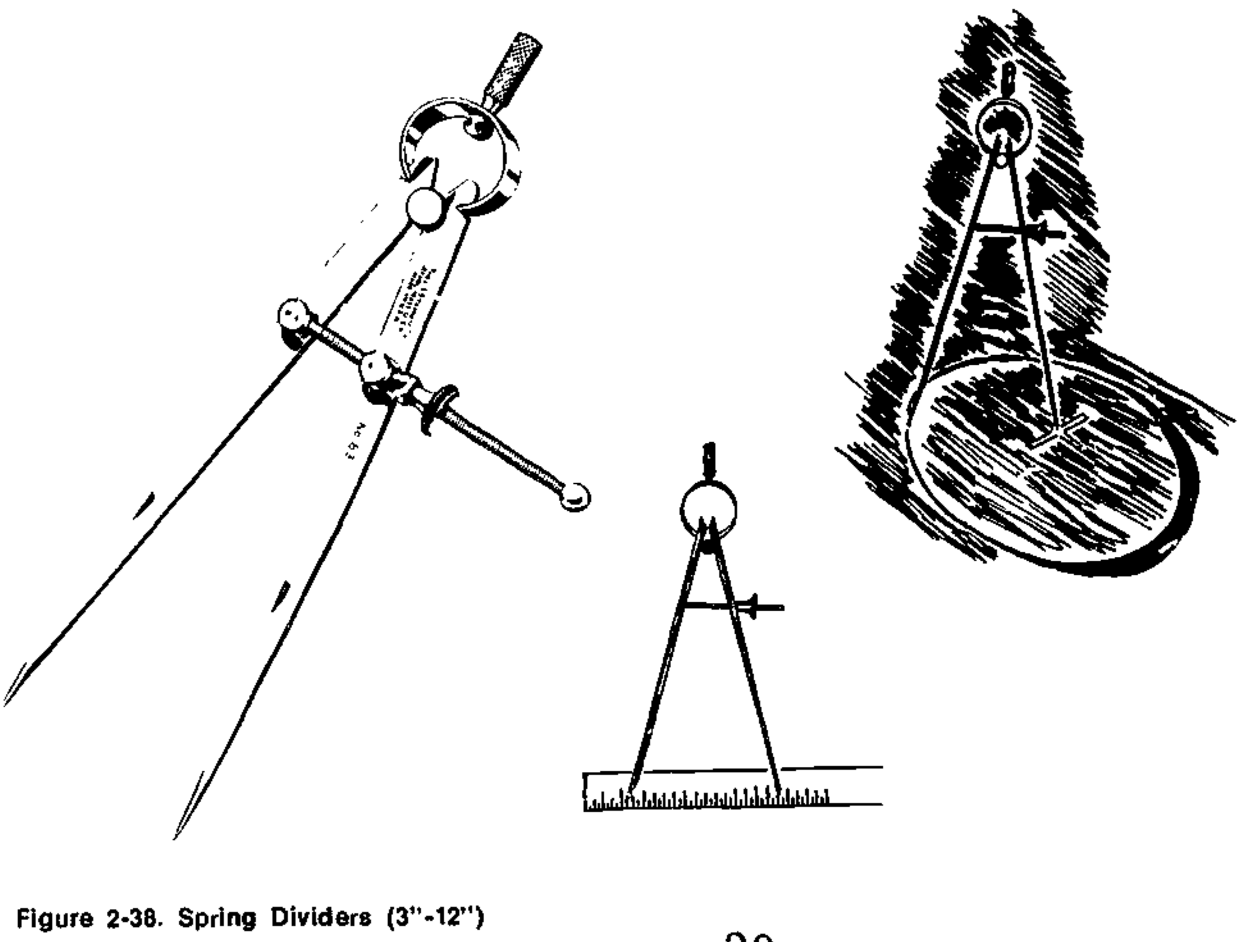


Figure 2-38. Spring Dividers (3"-12")

INSIDE AND OUTSIDE FIRM JOINT CALIPERS

Firm joint calipers are made of high quality tool steel with the ends hardened (Figures 2-39, 2-40) The tension on the joint is adjustable, and once the proper adjustments are made, the tension will not change as the legs are opened and closed The contact points are adjusted by "feel," and a rule or micrometer is used to measure the distance between points

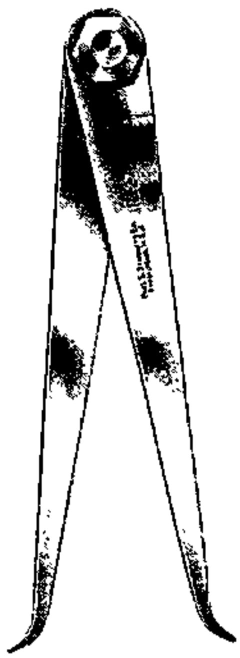
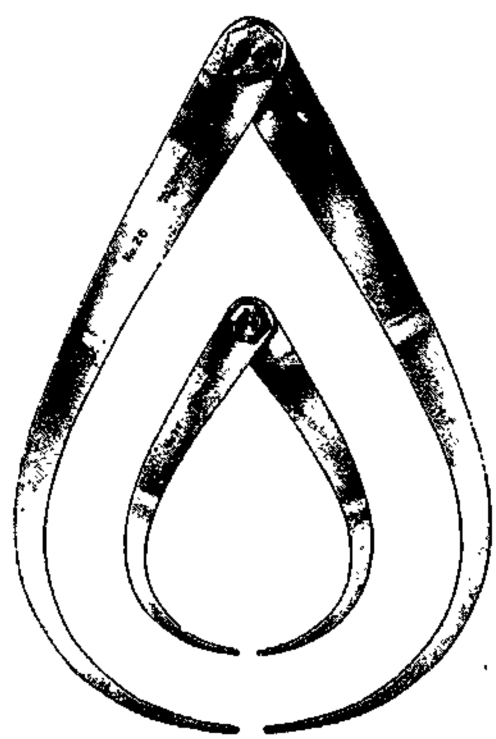


Figure 2-39. Inside Firm Joint Calipers



Figures 2-40. Outside Firm Joint Calipers (6"- 36")

SLIDING T-BEVEL

The sliding T-bevel is used for transferring angles and for testing constructed angles such as bevels. The T-bevel is made of wood, plastic or metal handles, with a slotted, bevelled blade (Figure 2-41). The angle can be adjusted by the wing screw on the handle. When not in use, align the blade into the handle and tighten.

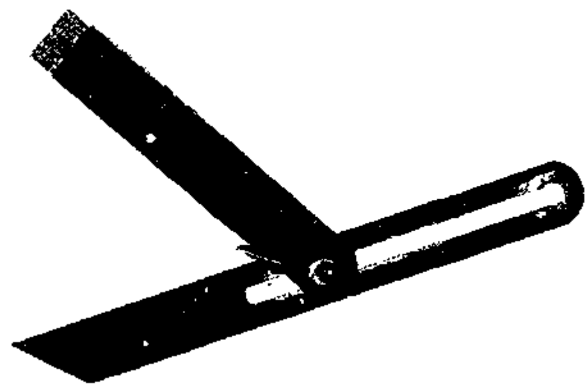


Figure 2-41. Sliding T-Bevel

DRILL POINT GAUGE

The drill point gauge (Figure 2-42) is used to check the accuracy of the drill point angle (always 59) and to determine the correct drill tip length to ensure clean cutting at maximum feed and speed. This tool consists of a 6" hook rule, divided into 1/8ths and 1/16ths and quick reading 32nds and 64ths. The adjustable sliding head can serve as a depth gauge, slide caliper or try square.

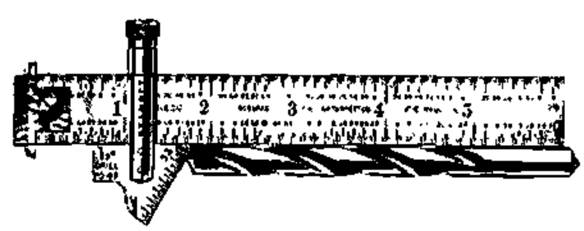


Figure 2-42. Drill Point Gauge

FRAMING SQUARE

The Carpenter's framing square (Figure 2-43) is used for measuring, as a straight edge, to check angles, for laying out 1/4 circumference marks on pipe and for many other functions. To discover the full range of uses for this versatile tool, books on the subject are available at most book stores

The square has two blades at right angles to one another The longer, wider arm is called the blade or body, and the shorter, narrower part is called the tongue (The Standard steel square (Figure 2-43) has a blade 24" long and a tongue 16 long) The outside corner where the two outside edges meet is called the heel

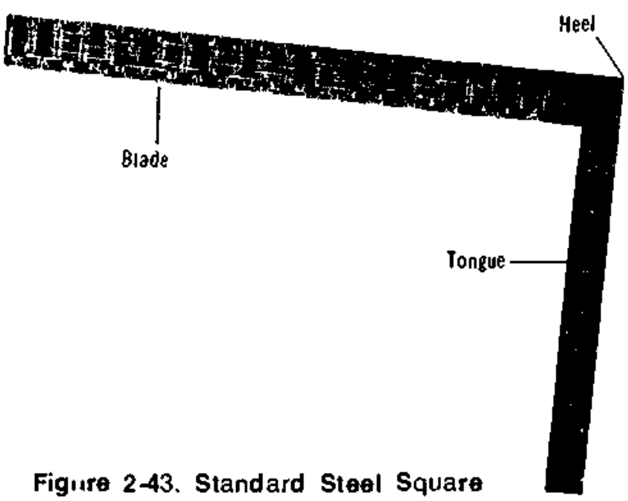


Figure 2-43. Standard Steel Square

Checking the Accuracy of the Square

The square must be accurate with respect to the required right angle between the blade and the tongue This accuracy must be checked before starting any precise layout. A piece of flat plate, a straight edge and a scriber are needed (Figure 2-44)

Step 1 Lay the straight edge on the plate, holding it firmly. Scribe a witness mark in case the straight edge is moved.

Step 2 Set the tongue of the square against the straight edge and scribe a line on the plate along the outside of the blade.

Step 3. Reverse the square on the straight edge and move the blade to the scribed line.

Step 4. If the square is true, the blade and the line will be perfectly aligned. If the line slopes away from the blade, the square is out-of-true.

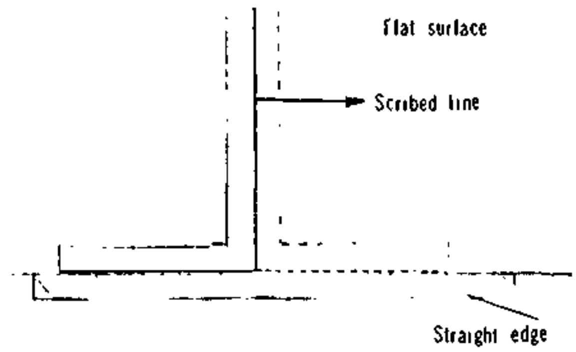


Figure 2-44. Checking the Accuracy of the Square

Correct Use of the Square

1 Never attempt to true up a square by striking the heel with a hammer.
2 Keep squares away from extreme heat or arc welding
3 Do not punch or drill a hole near the heel.

COMBINATION SQUARE

The Combination Square (Figure 2-45) consists of

1 The stock (square) head with one side at 90 and the other at 45
2 The protractor head
3. The centre head
4 The steel rule or blade that fits any of the three heads

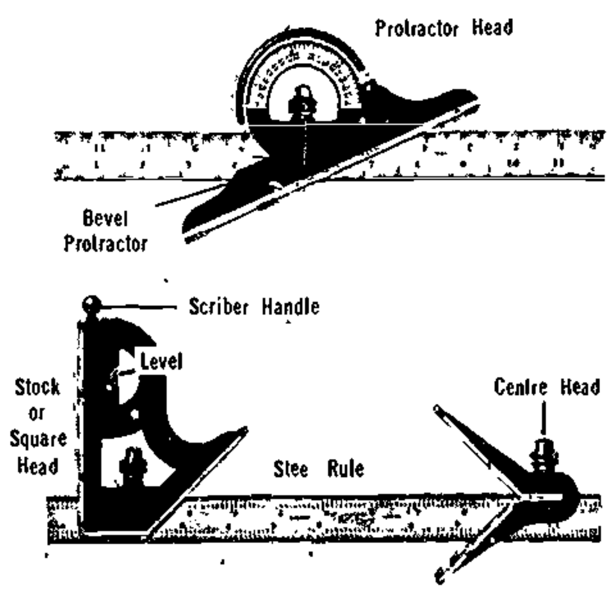


Figure 2-45. Combination Square Set

The protractor head is provided with a swivel or turret which is clamped to the steel rule. The revolving turret is graduated from 0° to 180° (on some models it is graduated from 0° to 90° in either direction). It can be adjusted to any angle and secured with a knurled nut. In conjunction with the steel rule, the combination square is used in layout for making and measuring angles (Figure 2-46).

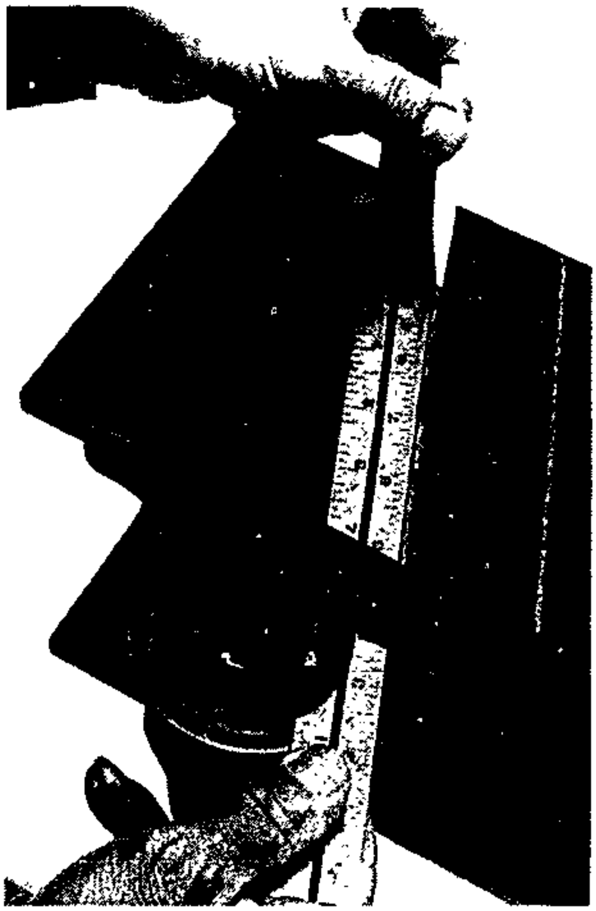


Figure 2-46. Making Angles with the Combination Square

Figure 2-47. Finding the Centre Point with a Combination Square

Figure 2-48. Checking 90° Angle

The centre head forms a centre square when clamped to the steel rule (Figure 2-47). Place the points of the centre head on the outer surface of a round object and scribe a line along the rule. Repeat this procedure at another position on the outer surface to find the centre point which is at the intersection of the two scribed lines.

The stock can be moved along the steel blade and clamped in any position. Its functions include:

1. A square for checking angles of 90° (Figure 2-48)
2. Scribing lines at right angles to a surface (Figure 2-49)
3. Marking or checking angles of 45° (Figure 2-50)
4. Depth gauge
5. Height gauge
6. Spirit level.

In addition, a scriber is held in the lower end by a friction bushing, and may be drawn out when needed.

Figure 2-49. Scribing a Line at Right Angles

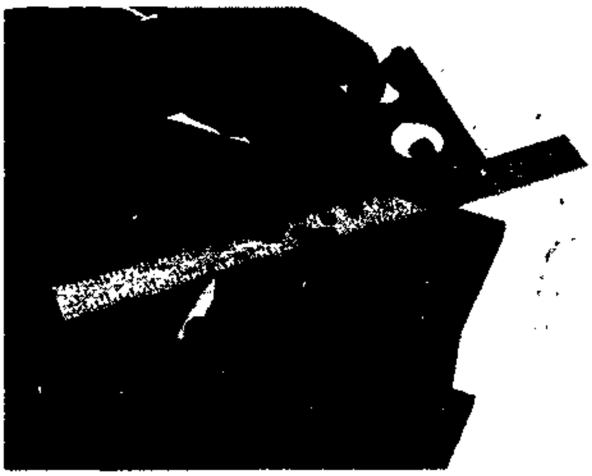


Figure 2-50. Scribing 45° Angle

RULE DEPTH GAUGE

The rule depth gauge (Figure 2-51) consists of a steel rule and a blade shaped to provide a straight edge at right angles to the rule. The blade can slide up or down the rule to permit measurement of the depth of holes and recesses. A knurled nut and friction spring

Figure 2-51. Rule Depth Gauge

assembly locks the blade into position on the rule. The rule is calibrated in 32nds and 64ths inches, but some models are graduated in 64ths and 100ths.

CENTRE FINDER WITH LEVEL AND CENTRE PUNCH MARKER

The centre finder (Figure 2-52) is designed to determine and mark the horizontal centre line on the outside surface of pipe or tube.

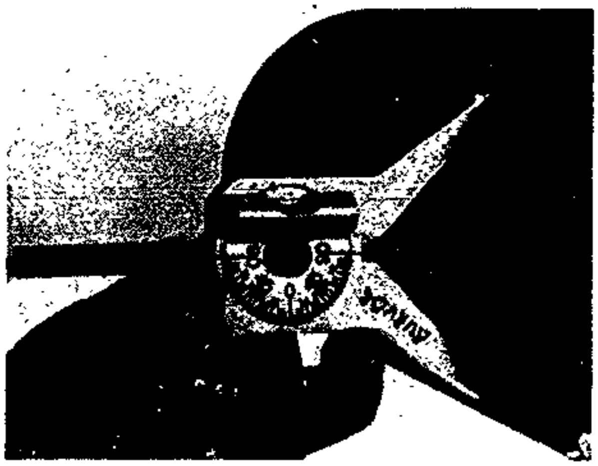


Figure 2-52. Centre Finder with Level and Centre Punch Marker

TWO FOOT LEVEL

The two foot level (Figure 2-53) contains two spirit levels: one for checking horizontal level and a plumb for checking vertical alignment. When structural shapes are not straight in long enough lengths to use the two foot level, the plumb bob or water level is prelerable.

To check the accuracy of a level, place it on a flat surface (if necessary shim up one end until the bubble is centred). Turn the level end for end (in the same position on the shims), and the bubble will be in the middle if the level is accurate. If the bubble is off centre, the level is not true. Sor·e levels can be adjusted to correct errors. The plumb is checked in the same manner against a vertical surface.

Figure 2-53. Two Foot Level

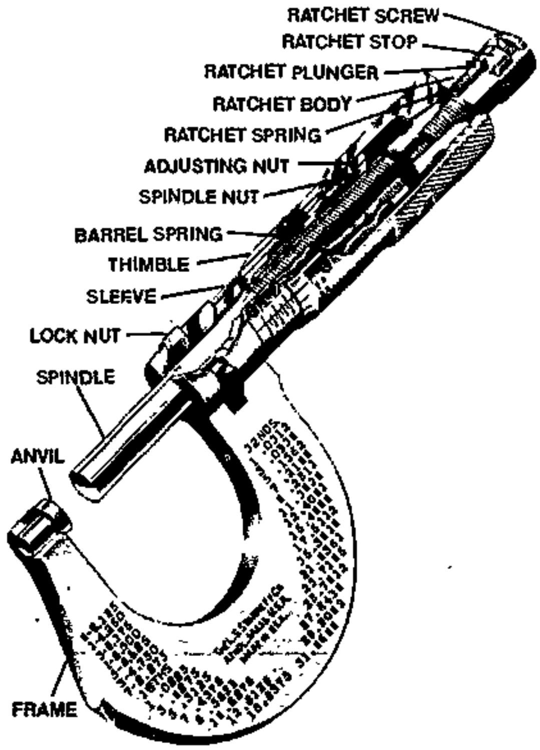


Figure 2-54. Outside Micrometer Caliper

MICROMETERS

Micrometers (derived from the Greek *micro*, meaning small) are used to gauge small or precise measurements. The outside micrometer caliper (Figure 2-54) frequently called a "mike" is used by the Boilermaker to check outside measurements such as tube sheet holes and the diameter of tubes, shafts, etc. where accuracy and precision are demanded.

The basis of the micrometer caliper is an accurate screw that can be revolved in a fixed nut to vary the opening between the two measuring faces, (the end of the spindle and the anvil). The screw has 40 threads per inch (40 TPI) so that one revolution of the thimble moves the spindle 1/40" or .025". These revolutions are plainly marked as graduations on the barrel. The frame end of the thimble is bevelled and graduated into 25 equally spaced divisions, each division being 1/25th of a revolution, representing 1/25th of .025" or one thousandth of an inch. (.001").

Maintenance of Micrometers

1. Never completely close when not in use.
2. Protect from dirt and grit at all times
3. Oil lightly before storing.
4. Store in a suitable case or a clean cloth slightly dampened with oil, separated from other tools.

Correct Use of Micrometers

1. Wipe clean before use.
2. Check zeroing before use.
3. Avoid excessive pressure on the spindle threads.
4. Ensure clamping ring is loose before readjusting.
5. Never twirl to open or close.
6. DO NOT DROP.

Reading the Micrometer

Reading a micrometer caliper involves a series of steps requiring mental addition:

Step 1. Read the highest numbered line seen on the barrel. Since each division represents .025. every fourth or numbered line represents .100" Thus:

1 = .100"

2 = .200"

3 = .300 ", etc.

Step 2. Count the number of **completely visible divisions** between the number read in Step 1 and the edge of the thimble. **Do not count any partial division that may** be showing. Each complete division equals 025".

Step 3 Read the number of the line on the edge of the thimble that coincides with the longitudinal line of the barrel. Each line represents 1/1000".

Step 4 Add the results of your readings from the Steps 1-3.

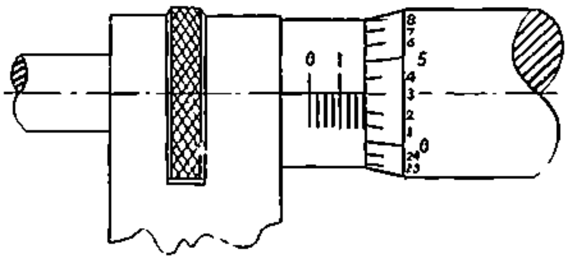


Figure 2-55. Micrometer

EXAMPLE:

Reading from the micrometer setting in Figure 2-55

The 1" line on sleeve is visible, representing...		= .100"
There are 3 additional lines visible, each representing .025"...	3 x .025	= .075"
Line "3" on the thimble coincides with the longitudinal line on the sleeve, each line representing .001"...	3 x .001"	= .003"
The micrometer reading is...		.178"

INSIDE MICROMETERS

Inside micrometers are available in sizes from 2" to 32", and are suppled in sets containing various ranges of length: 2"-8", 2"-12", 8"-32" and 2"-32". The desired range is set by assembling measuring rods and lapped gauges or spacing collars to the micrometer head (Figure 2-56).

Figure 2-56. Micrometer Head

Measuring rods have a shoulder against which the rods are set accurately and locked into position in the micrometer head. The "0" mark on the rod should be in line with the "0" mark on the end of the micrometer head (This is not required on the 2"-32" rod).

Tubular extention rods are available up to 107" capacity for large inside diameter measurements; however, the Boilermaker is primarily concerned with smaller sizes for measuring inside tube diameters and tube sheet holes. For very small tubing, an alternative device called the internal direct reading dial caliper is simpler to use and read (Figure 2-57).

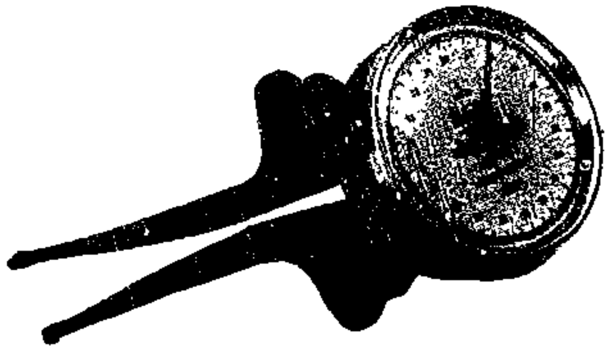


Figure 2-57. Internal Direct Reading Dial Caliper

Figure 2-58 shows the use of the micrometer in measuring the inside diameter of a large boiler tube.

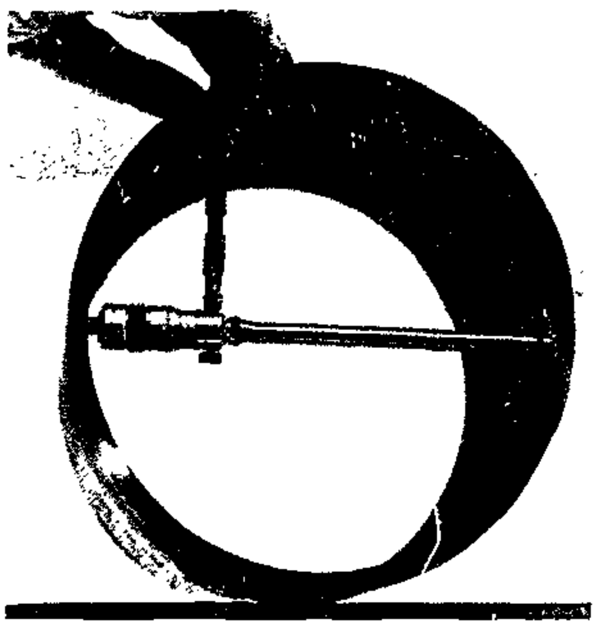


Figure 2-58. Micrometer Used to Measure Inside Diameter of Large Boiler Tube

MICROMETER DEPTH GAUGE

The micrometer depth gauge (Figure 2-59) can also be used to obtain distances from a plane surface to a projection This precision depth measurement tool is necessary for checking longitudinal expansion when rolling tubes. Since the movement of the screw is limited to 1", longer distances are obtained by using additional measuring rods. These are available in sets providing 0"-3". 0"-6" 0"-9" and 3"-9" ranges. This tool differs from most micrometers in that the graduations on the barrel are in reverse order Therefore. **the divisions to be counted are those covered by the thimble.**

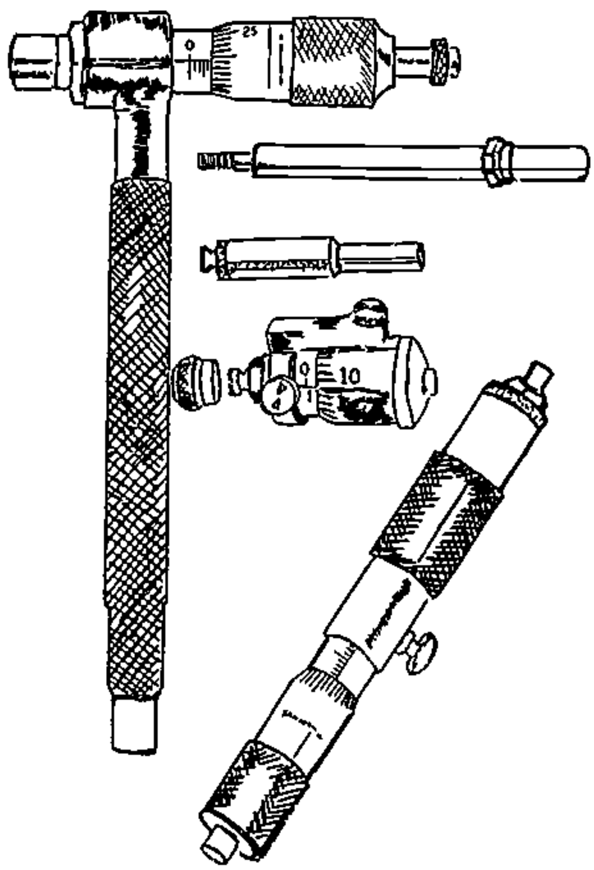


Figure 2-59. Micrometer Depth Gauge

VERNIER INSTRUMENTS

Vernier instruments (Figure 2-60) are measuring tools, such as calipers. depth gauges. height gauges and angular scales. which incorporate a vernier scale. a device capable of extending the accuracy of a measurement to a high degree of precision.

The principle of the vernier is based on the fact that a vernier scale has one less (usually) or one more (occasionally) divisions than the main beam. Thus a small difference is obtained that allows a much finer reading than normally obtained.

The basic measuring device consists of a Beam or Bar calibrated in inches Each inch is divided into tenths of an inch and numbered 1-9. Each tenth is sub-divided into 4. This means that each tenth = 9.100" and each sub-division = 0 100 ÷ 4 = 0 025".

The other part of the device is the vernier. usually with 25 divisions numbered 0 to 25. The length of the vernier is equal to 24 divisions on the Beam or Bar. Thus the length of these 25 divisions of the vernier is equal to 0.025 x 24 = 0.600. Calculating this we see that 0.600 ÷ 25 = 0.024 for one division on the vernier. The difference between one division on the Beam. and one division on the vernier is. therefore. 0.025 − 0.024 = 0.001.

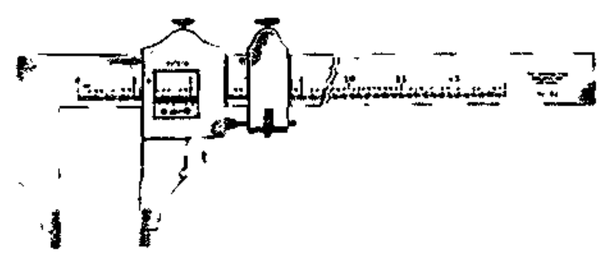


Figure 2-60. Vernier Instrument

Steps in Reading a Vernier Instrument (Linear)

Step 1. Count the number of inches and the number of tenths of inches plus the number of 40ths of inches **to the left of the 0 on the vernier.**

Step 2. Note carefully the line on the vernier **which is exactly opposite a line on the Beam.** This will give the number of thousandths of an inch.

Step 3. This figure must be added to the first part to have a complete reading.

EXAMPLE:

To read the vernier scale in Figure 2-61.

Read whole inches first	1.000
Read tenth divisions next	0.700
Read fortieth divisions next	0.000
Read vernier last	0.023
Reading is	1.723

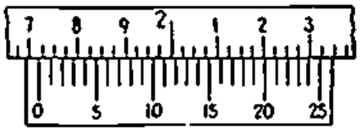


Figure 2-61. Vernier Scale

Figure 2-62 illustrates a typical vernier caliper for inside and outside measurements and incorporating a depth gauge.

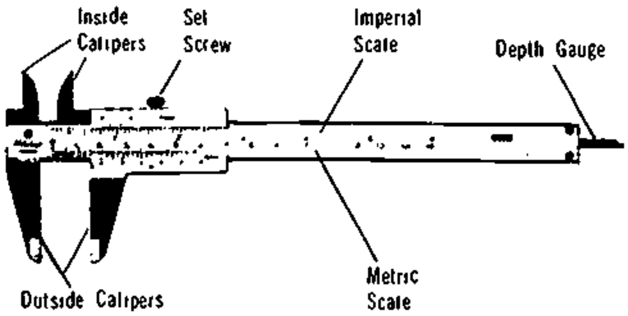


Figure 2-62. Typical Vernier Caliper

Angular Vernier Scales

Precise measurement of angles is possible with the angular vernier scale. This tool consists of:

1. A protractor or angular ring, divided into 360 (usually in four quadrants, each reading from 0° to 90°).
2. A vernier plate positioned under the angular ring, divided into 12 spaces extending over 23 spaces on the protractor dial. The difference between 1 vernier division and 23 protractor divisions is equal to 1/2 of a degree, or 5 minutes.

The dial is read in the same manner as other verniers except that it is read in angular degrees and units of 5 minutes.

Steps in Reading Angular Vernier Scales

Step 1. Read the number of degrees up to the "0" mark on the vernier scale.

Step 2. Read the number of minutes on the vernier scale where two lines coincide.

Example 1: (see Figure 2-63)

Protractor dial............................45°

Vernier dial...............................30'

Reading: 45°30'

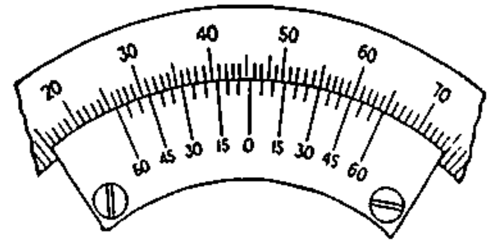


Figure 2-63. Angular Vernier Scale

Example 2: (see Figure 2-64)

Protractor dial............................80°

Vernier dial...............................5'

Reading: 80°5'

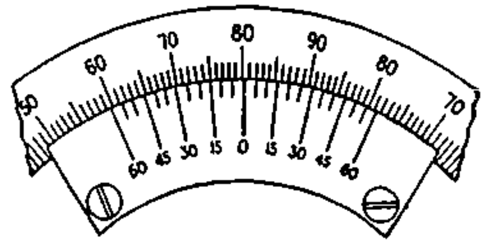


Figure 2-64. Angular Vernier Scale

SURFACE GAUGE

The surface gauge (Figure 2-65) is used for scribing lines at a given height from a face of the work or for making lines around several surfaces of the job. The gauge consists of a heavy

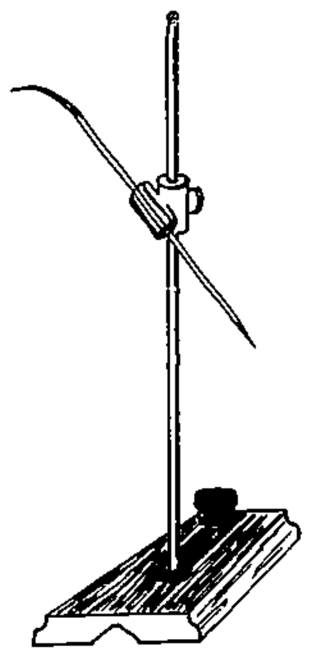


Figure 2-65. Surface Gauge

base and an upright pivoted spindle to which a scriber is attached by a clamp. The scriber can rotate through a complete revolution and be locked in any position.

By resting both the surface gauge and the work upon a plane surface, the point of the scriber can be set at a given height, either by using a scale or some other standard and drawing lines at this height on all faces of the work or on any number of pieces when duplicate parts are being made.

TRAMMEL POINTS

A set of trammel points (Figure 2-66) is a tool for laying-out circles or arcs. The two points are attached by knurled nuts to a suitable bar or beam. The distance between them may be adjusted to the required radius. Place one trammel point on the punched centre mark and scribe the circle or arc with the tip of the other trammel point.

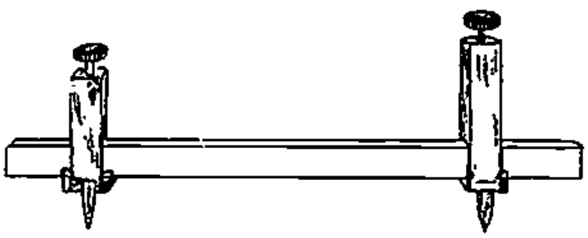


Figure 2-66. Trammel Points

TAPS

Taps (Figure 2-67) are used for cutting internal threads in metal, fibre or other materials, and are classified according to size (diameter) and the type of thread they cut. The most common are "National Fine" and "National Coarse," although designations such as "National Special," "National Extra Fine" and metric threads may be used.

Taps are divided into two main categories: standard hand taps having a diameter of 1/4" or

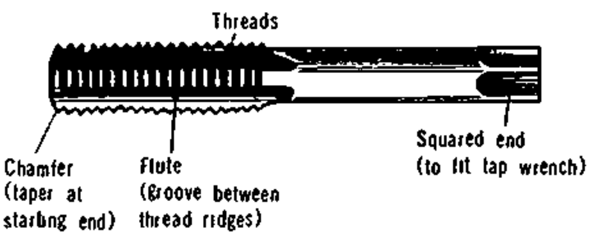


Figure 2-67. Tap

greater, and machine screw taps having a diameter of less than 1/4".

Standard hand tap sizes are identified by the actual outside diameter in inches as well as the thread type. For example, 5/8-18 identifes a tap having an outside diameter of 5/8 inches and a thread count of 18 per inch.

Machine screw tap sizes are identified by a number system ranging from #0 (smallest) to #14 (largest) and the thread type. For example 10-32 identifies a tap that will thread a hole for a size 10 screw with 32 threads per inch.

Each size of tap is provided in three forms: **taper, plug** and **bottoming** (Figure 2-68). These are used in sequence to tap a hole properly. The chamfer length is different in each form.

Tap wrenches are used to turn taps. Two types are shown in Figure 2-69. A set of taps and tap wrenches is illustrated in Figure 2-70.

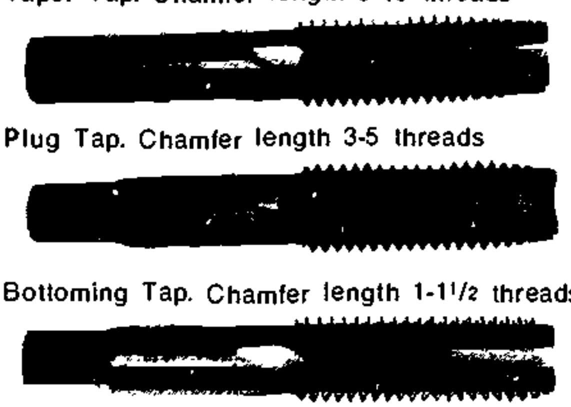


Figure 2-68. Taper, Plug, and Bottoming Taps

Procedure for Tapping

Step 1. Select the correct drill size for making the hole. Consult Tables 2-1 and 2-2 for standard hand taps, or use the following formula to calculate drill size:

$$\text{Drill size} = (\text{outside tap diameter}) \text{ minus } \left(\frac{1}{\text{number of threads per inch}} \right)$$

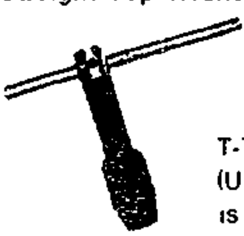
TABLE 2-1. TAP DRILL SIZES FOR STANDARD HAND TAP SCREWS/75% DEPTH OF THREAD

Tap Size	Threads per inch	Diameter Hole	Drill	Tap Size	Threads per inch	Diameter Hole	Drill
1/4	32	220	7/32	7/8	18	.821	53/64
1/4	28	.215	3	7/8	14	.805	13/16
1/4	27	214	3	7/8	12	.794	51/64
1/4	24	.209	4	7/8	9	.767	49/64
1/4	20	.201	7	15/16	12	.856	55/64
5/16	32	.282	9/32	15/16	9	.829	53/64
5/16	27	.276	J	1	27	.964	31/32
5/16	24	.272	I	1	14	.930	15/16
5/16	20	.264	17/64	1	12	.919	59/64
5/16	18	.258	F	1	8	.878	7/8
3/8	27	.339	R	1 1/16	8	.941	15/16
3/8	24	.334	Q	1 1/8	12	1.044	1 3/64
3/8	20	.326	21/64	1 1/8	7	.986	63/64
3/8	16	.314	5/16	1 3/16	7	1.048	1 3/64
7/16	27	401	Y	1 1/4	12	1.169	1 11/64
7/16	24	.397	X	1 1/4	7	1.111	1 7/64
7/16	20	.389	25/64	1 5/16	7	1.173	1 1/64
7/16	14	.368	U	1 3/8	12	1.294	1 19/64
1/2	27	.464	15/32	1 3/8	6	1.213	1 7/32
1/2	24	.460	29/64	1 1/2	12	1.419	1 27/64
1/2	20	.451	29/64	1 1/2	6	1.338	1 11/32
1/2	13	.425	27/64	1 5/8	5 1/2	1.448	1 29/64
1/2	12	.419	27/64	1 3/4	5	1.555	1 9/16
9/16	27	.526	17/32	1 7/8	5	1.680	1 11/16
9/16	18	.508	33/64	2	4 1/2	1.783	1 25/32
9/16	12	.481	31/64	2 1/8	4 1/2	1.909	1 29/32
5/8	27	.589	19/32	2 1/4	4 1/2	2.034	2 1/32
5/8	18	.571	37/64	2 3/8	4	2.131	2 1/8
5/8	12	.544	35/64	2 1/2	4	2.256	2 1/4
5/8	11	.536	17/32	2 5/8	4	2.381	2 5/8
11/16	16	.627	5/8	2 3/4	4	2.506	2 1/2
11/16	11	.599	19/32	2 7/8	3 1/2	2.597	2 19/32
3/4	27	.714	23/32	3	3 1/2	2.722	2 23/32
3/4	16	.689	11/16	3 1/8	3 1/2	2.847	2 27/32
3/4	12	.669	43/64	3 1/4	3 1/2	2.972	2 31/32
3/4	10	.653	21/32	3 3/8	3 1/4	3.075	3 1/16
13/16	12	.731	47/64	3 1/2	3 1/4	3.200	3 1/2
13/16	10	.715	23/32	3 5/8	3 1/4	3.325	3 5/16
7/8	27	.839	27/32	3 3/4	3	3.425	3 7/16
				4	3	3.675	3 11/16

TABLE 2-2. TAP DRILL SIZES FOR MACHINE SCREW THREADS/75% DEPTH OF THREAD

Tap Size	Threads per inch	Dia. Hole	Drill	Tap Size	Threads per inch	Dia. Hole	Drill
0	80	.048	3/64	7	36	.124	1/8
1	72	.060	53	7	32	.121	31
1	64	.058	53	7	30	.119	31
2	64	.071	50	8	36	.137	29
2	56	.069	50	8	32	.134	29
3	56	.082	45	8	30	.132	30
3	48	.079	47	9	32	.147	26
4	48	.092	42	9	30	.145	27
4	40	.088	43	9	24	.136	29
4	36	.085	44	10	32	.160	21
5	44	.103	37	10	30	.158	22
5	40	.101	38	10	28	.155	23
5	36	.098	40	10	24	.149	25
6	40	.114	33	12	28	.181	14
6	36	.111	34	12	24	.175	16
6	32	.108	36	14	24	.201	7
				14	20	.193	10

Straight Tap Wrench



T-Type Tap Wrench (Used where Space is Restricted)

Figure 2-69. Tap Wrenches

Example: Find the drill size for a 3/4-16 tap

Solution The tap diameter is 3/4 inch and it has 16 threads per inch. Therefore the drill size is 3/4" − 1/16" = 11/16"

Step 2 Secure the work piece so that it cannot move and cause the tap to break.

Step 3 Begin with a taper tap. Start the tap square with the work piece Check with a square at several points around the tap.

Step 4. Select a lubricant appropriate to the material being tapped:

MATERIAL	LUBRICANT
Mild and Medium Steel Tool Steel Cast Iron	Lard oil
Copper Aluminum	Soluble oil (usually 1 part oil to 40 parts water)
Brass and Bronze	Dry

Step 5. Once properly started, the tap does not require downward pressure. After each revolution, it is useful to reverse the turning for a part revolution to free the chips Repeat the turning and reversing, adding additional lubricant at intervals until the thread is well started. Reverse to remove the tap.

Step 6 Using a plug tap, repeat the procedure as above until the hole is completely tapped. (For tapping a blind hole, repeat the procedure with a bottoming tap to ensure finished threading to the bottom of the hole.)

Figure 2-70. Set of Taps

Step 7. Unscrew the tap and remove chips and burrs from the threaded hole.

Removing Broken Taps Special tools assist in removing taps, studs, bolts, screws or pipes that have broken off at or below the surface of a piece of work. The cause of a broken tap is generally a chip caught between the threading teeth and the side of the hole. If this chip can be loosened so it will drop in a flute, the broken part of the tap will come out easily. Broken taps may be removed using tap extractors (Figure 2-71) made of high quality steel designed to withstand shearing strain. They are supplied in sets that conform to standard tap sizes ranging from 1/8" to 1 1/2". Some extractors can be used on two or three sizes of taps.

The tap extractor consists of four parts: the holder, collar, sleeve and fingers. The holder is a solid, fluted core with a squared end to accommodate a tap wrench. The fingers, which fit into the flutes of the holder, are held together at the top by the collar. The collar and fingers are free to slide up and down the flutes of the holder as required. The sleeve can slide down over the fingers to provide rigid support for them when they are seated around the broken tap.

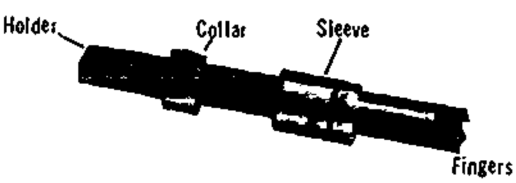


Figure 2-71. Tap Extractor

Procedure for Removing a Broken Tap

Step 1. Select the correct size and type of tap extractor. Ensure the number of fingers corresponds with the number of flutes in the broken tap. (Extractors are available with two, three or four fingers.)

Step 2. Remove all loose chips from the holes around the broken tap. If compressed air is used for this, WEAR SAFETY GOGGLES.

Step 3. Remove any sharp metal projections that could obstruct the tap extractor fingers from seating firmly around the tap.

Step 4. Secure the workpiece firmly, using a vise if appropriate.

Step 5. Place a few drops of cutting oil in the hole.

Step 6. If the tap is broken into two or more irregular pieces they sometimes act as locknuts against each other. Try to move the top piece slightly so this will not happen.

Step 7. Be careful not to damage the threads in the hole as this will make removing the broken tap more difficult.

Step 8. Adjust the extractor fingers so that they project beyond the holder. Slide them down into the flute of the broken tap as far as they will go without forcing.

Step 9. Push the holder down until it touches the broken tap. Slide the sleeve down until it touches the work piece. The fingers of the tap extractor must be supported over their entire length, either in the flutes of the holder or in the flutes of the broken tap. They may otherwise twist out of shape or break.

Step 10. Apply a tap wrench to the squared outer end and rotate forward and backward a few times to loosen. Once loosened, reverse rotation of the extractor will remove the tap.

Note: If the tap is wedged too tightly so that moderate pressure on the extractor fails to loosen it, it is advisable to try another method for removal since a tap extractor is a fragile tool.

Alternative Methods for Removing a Broken Tap

Working a Broken Tap Loose If a piece of the tap extends above the hole, grasp it firmly with a pair of pliers or vise grips and work it back and forth to loosen it (Figure 2-72)

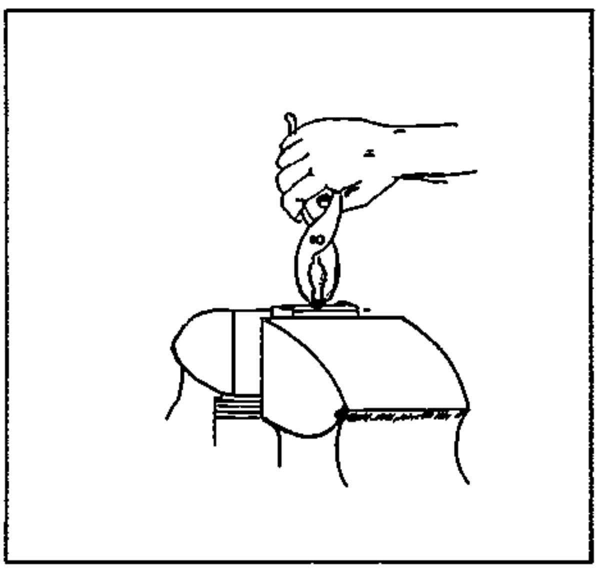


Figure 2-72.

Prick Punch and Hammer Method If the tap is broken off below the surface of the metal, it can sometimes be removed by using a prick punch and hammer. By rapping the punch at an angle that forces the tap to turn counter clockwise, it may loosen sufficiently to be removed (Figure 2-73).

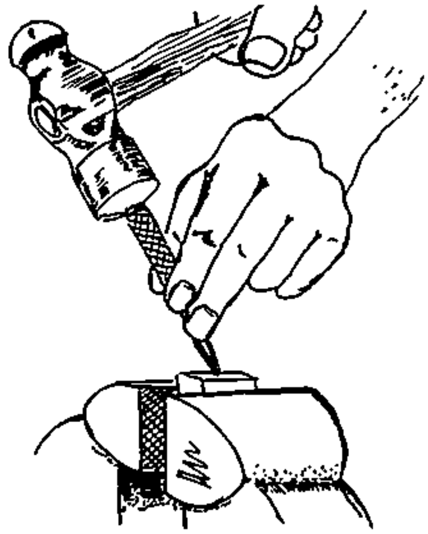


Figure 2-73.

Heat Softening Method Heat the stock with the broken tap to a cherry red colour and allow it to cool slowly. This will remove the hardness from the tap and it can be removed by one of the procedures for removing broken studs.

SCREW PITCH GAUGE

The Screw Pitch Gauge or Thread Gauge (Figure 2-74) is a useful tool for determining the pitch of an unknown thread It is designed with a strong steel case, having a number of folding leaves at both ends which can be matched with the thread on a screw or pipe. The correct pitch can be read directly from the leaf.

Figure 2-74. Screw Pitch Gauge

DIES

Dies are used for cutting external threads on rod, bolts or pipe. The principles for correctly using dies are similar to those that apply in tapping.

Dies are held in holders called diestocks which provide leverage for turning Diestocks may be straight or T-type Dies may be solid (able to thread only one size) or adjustable (adaptable to a range of sizes) and are made in a number of shapes — round. square. hexagon (Figure 2-75)

Procedure for Using a Die

Step 1 Hold the work piece firmly in a vise.

Step 2 Bevel the end of the rod or pipe slightly so the die can start easily.

Step 3 Place th starting side of the die squarely over the work

Step 4 Apply downward pressure and rotate the diestock clockwise until the threading begins.

Step 5 Apply an appropriate lubricant for the material being threaded as described in "Procedure for Tapping." pp. 35-38.

Step 6 Continue threading. applying the same forward and reverse turns used with taps If the chips are not freed in this way. the threading may be irregular and some threads may shear off

Step 7 Continue threading until the end of the work piece emerges from the outer face of the die Reverse the diestock to remove the die.

Step 8 Clear any chips or burrs from the finished threads.

DIE NUTS

Die nuts or rethreading dies (Figure 2-76) are used to reform rusty or bruised threads on bolts or rods. There are usually six cutting teeth on die nuts to aid in starting the thread repair. The procedure for repairing a thread is similar to making a new thread. Lubricant should be used. A wrench is used to turn the nut. Do not use a pipe wrench or any wrench with hardened teeth.

Figure 2-76. Solid Rethreading Dies

STUD AND SCREW EXTRACTORS

Removing broken sections of studs, screws or pipe is relatively straightforward unless the broken piece is rusted and tends to tear apart when forced to dislodge.

A stud or screw extractor (Figure 2-77) is a tapered tool with spiral ridges designed to bite and grip softer metal when pressure is applied in a counter clockwise direction. They are made of heat treated steel that withstands considerable torque strain.

Extractors are supplied in sets that will handle all sizes of bolts, cap screws and stud bolts.

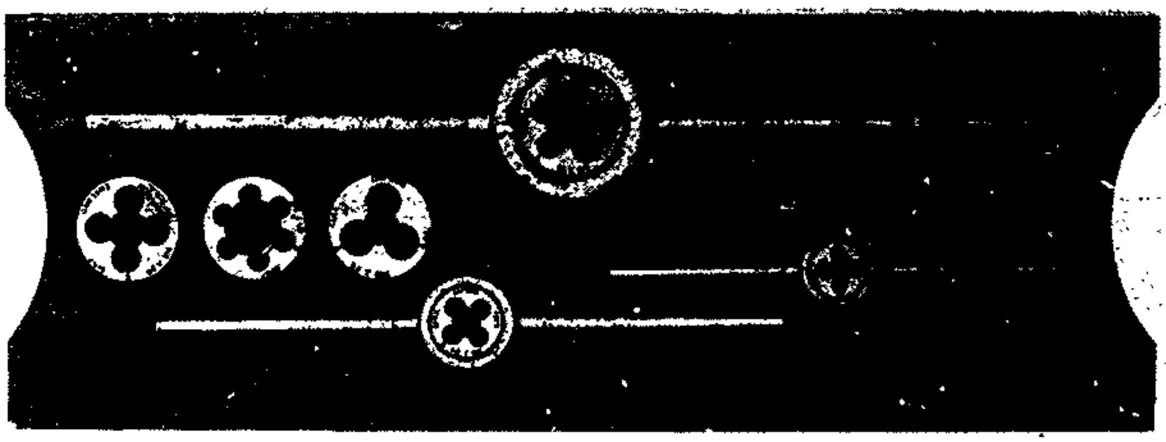


Figure 2-75. Set of Dies with Straight Diestocks

Each size is numbered and stamped showing the correct drill size to be used in conjunction with it

Figure 2-77. Stud or Screw Extractor

Procedure for Removing a Broken Stud or Screw

Step 1 Apply a penetrating oil to the broken stud or screw, allowing the oil to soak around the threads before attempting to remove the stud.

Step 2. Measure the size of the broken part and calculate the size of hole that can be made in the centre. Leave enough metal for the extractor to bite without expanding the remaining part

Step 3 Select the appropriate extractor. (The matching drill size is stamped on the extractor)

Step 4 Locate the centre of the broken part, mark with a prick punch, and drill a hole deep enough to permit the extractor to grip the sides evenly.

Step 5 Insert the extractor into the hole and turn it counter clockwise with a wrench under steady pressure until the broken part moves (Figure 2-78)

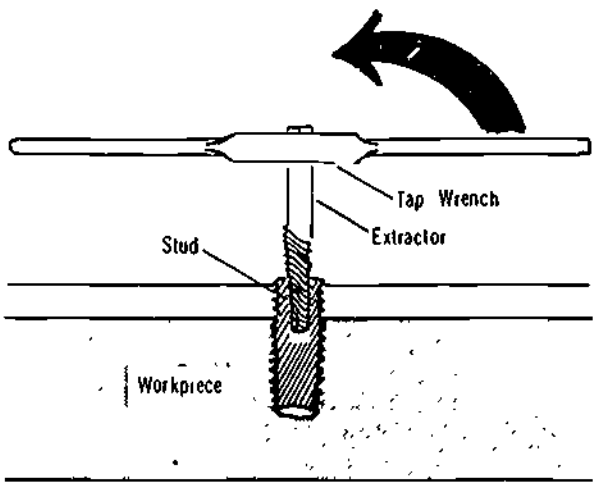


Figure 2-78. Removing a Broken Stud

PIPE EXTRACTORS

To remove broken pieces of pipe, a tool similar to the stud extractor has been designed. It has steeper angle spiral ridges, so that a shallow grip will be taken on the broken piece of pipe to prevent excessive bending pressure. Pipe extractors are available in sizes to accommodate most standard pipe sizes, and the squared end is large enough to accept a heavy duty wrench.

PIPE REAMERS

When pipe is cut with pipe cutters, a burr is forced up on the inside diameter of the pipe edge. If this is not removed before the pipe is installed, the capacity of the pipe will be reduced due to: unnecessary restriction of flow through the line, or drainage line solids and impurities hanging up on the burrs.

A pipe reamer is used to remove this burr. The operator must take care to ream only enough to restore the original inside diameter of the pipe. Excessive reaming will thin out the edge of the pipe causing it to collapse or tear open if it is to be threaded.

There are three types of reamers, fluted reamer, spiral reamer and brace reamer. **Fluted reamers** (Figure 2-79) are made in two sizes: 1) for pipe 1/8"-2" and 2) for pipe 1/4"-3". **Spiral reamers** (Figure 2-80) only ream pipe 1/8"-2". **Brace reamers** (Figure 2-81) are made in three sizes: 1) for pipe 1/8"-2", 2) for pipe 1/8"-1 1/4" and 3) for pipe 1/8"-2". Brace reamers are seldom used except for light work because they are hand driven with a brace.

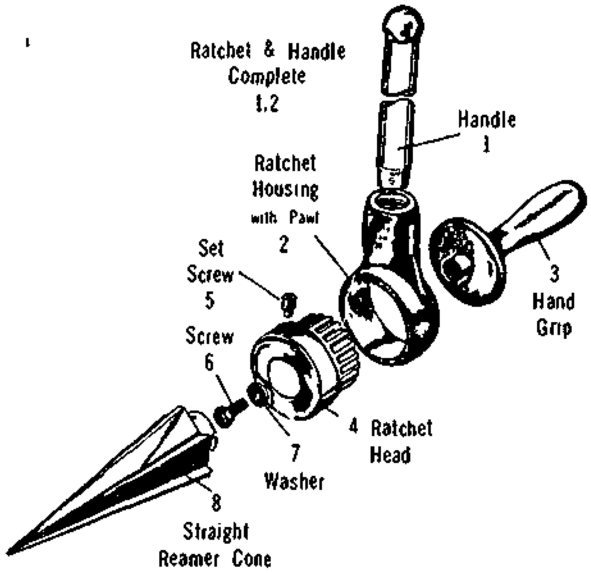


Figure 2-79. Rigid 21 Fluted Reamer

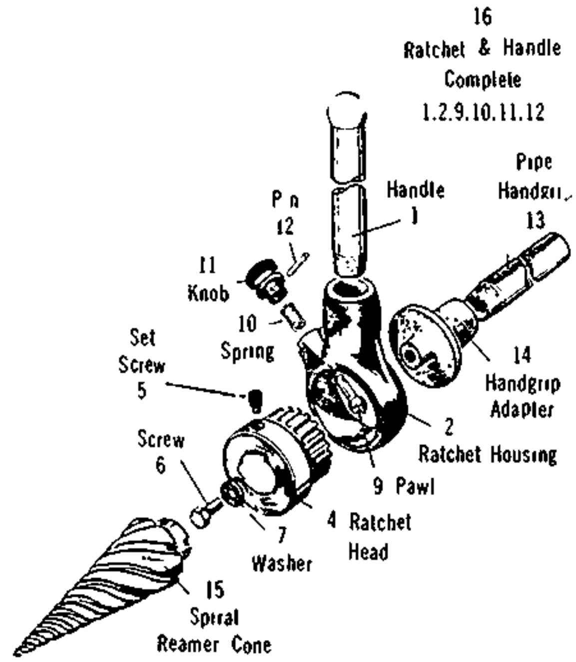
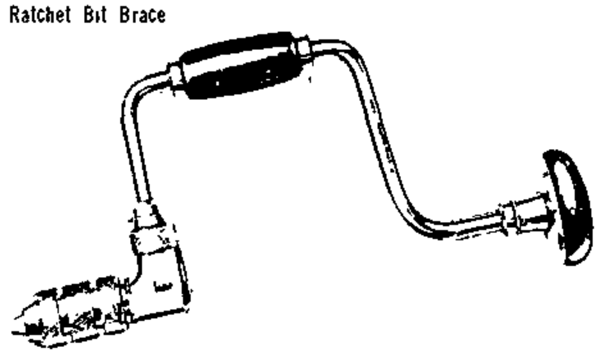


Figure 2-80. Spiral Reamer

Ratchet Bit Brace



Brace

Figure 2-81. Brace Reamer

Care of the Reamer When using a reamer, the operator should apply only enough pressure to cause the cutting edge to bite. Excessive pressure will cause the motor to bind.

A reamer is an expensive tool and the cones can be broken or dulled easily. When not in operation, the tool should be hung on an appropriate hanger mounted on or beside the work bench.

Maintenance of a reamer requires:

1. Keeping the tool clean.
2. Replacing the cone by removing set screw No. 5.
3. Tightening screw No. 6 if the handle is loose.
4. Ordering replacement parts by name.

LEVELS

The level consists of a telescopic line of sight of relatively high magnification (about 25 diameters) and a relatively sensitive spirit level whose bubble moves one graduation when the instrument is tipped about 20 seconds of arc. The spirit level is adjusted so that the line of sight is horizontal when the bubble is centred.

The telescope and level, with their supports, are mounted on a vertical spindle which fits in a vertical bearing in a levelling head. The levelling head is provided with levelling screws so that the bubble may be centred. An adjustment is provided so that the bubble centres when the vertical axis is vertical, to avoid undue levelling.

Two types of levels are used in Canada: the **Y level** and the **dumpy level**. The Y level can be adjusted by one man. The dumpy level requires the assistance of a rodman. The telescope tube of the Y level is supported in two Y supports. It may be rotated in these supports and changed end for end. The telescope tube of the dumpy level is rigidly attached to the vertical spindle. This eliminates a considerable number of parts. The two models of levels commonly used today are: the 4 Screw Type (Figure 2-82) and the 3 Screw Type (Figure 2-83).

Levelling The importance of elevations cannot be overstated. Gravity plays such an important part in every operation that except for a very few minor exceptions it must always be considered in design. In particular, any facility for moving materials or personnel must be held to carefully established grades. Floors must be kept level to avoid hazards, simplify plant revision, provide safe storage, etc. Monorails and gravity pipelines must be carefully graded. Boiler, tank and stack alignments can usually be established by using surveying levels.

The accuracy requirements for levelling are usually much higher than for horizontal measurement. Fortunately accuracy is easier to obtain. The spirit level is itself a very sensitive instrument, and because the line of sight is in-

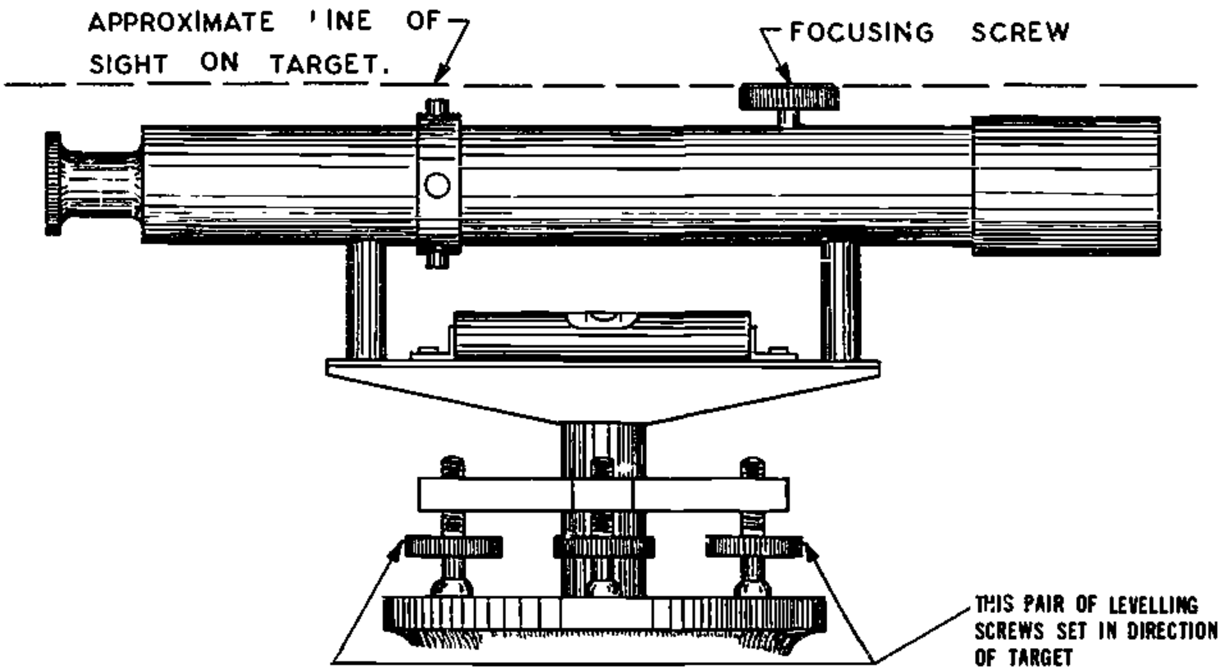


Figure 2-82. The 4 Screw Level

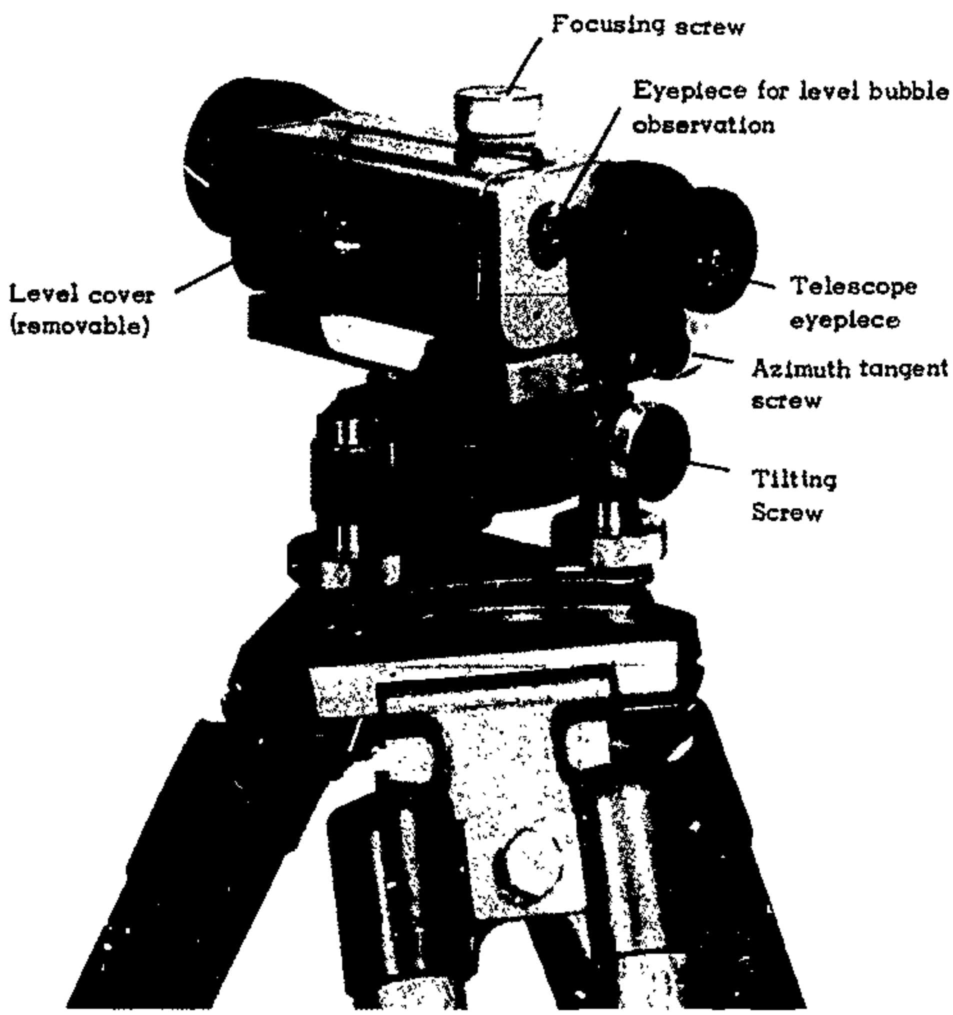


Figure 2-83. The 3 Screw Level

dependently made horizontal at each setup the accumulation of angular errors is prevented

Uses of the Level

1. To find the difference in elevation between two points that are below the line of sight of the telescope.
2. To find the difference in elevation between two points that are above the line of sight of the telescope.
3. To find the difference in elevation between two points, one below and one above the line of sight.
4. To find the difference in elevation between two points that cannot be seen from one setup of the instrument.

METHODS OF SETTING UP LEVELS

Adjusting the Foot-Screws on a Level with Four Screws See Figure 2-84.

Step 1 Ensure the legs are firmly placed

Step 2 Adjust the legs until the tripod head is approximately level.

Step 3 Adjust the foot-screws until they are all approximately at the same setting

Step 4 Loosen, slightly, two adjacent foot-screws.

Step 5 Set one pair of diagonally opposite foot-screws in line with the target.

Step 6. Turn the levelling plate until one bubble tube is parallel to the line of sight

Step 7 Use "thumb in and thumb out" method on the foot-screws (keeping them snug to the base) until the bubble is centred The bubble always moves in the same direction as the left thumb rotates the screw.

Step 8. Repeat Step on the opposite set of foot-screws to centre the other bubble.

Step 9 Turn the level plate 180 .

Step 10. Check the bubbles for centre.

Step 11. Adjust the foot-screw if required

Step 12. Check by turning the level plate 180 The bubble should remain on centre. Should the bubble show off centre after a re-check, the bubble tube requires adjustment.

Step 13. The bubble tube is adjusted as follows:

a) Turn the adjusting nut at end of the bubble tube — **one-eighth turn or less at a time until half the error is corrected.**

b) Centre the bubble by adjusting the foot-screws.

c) Turn the level plate 180 to check. Repeat a), b) and c), if necessary.

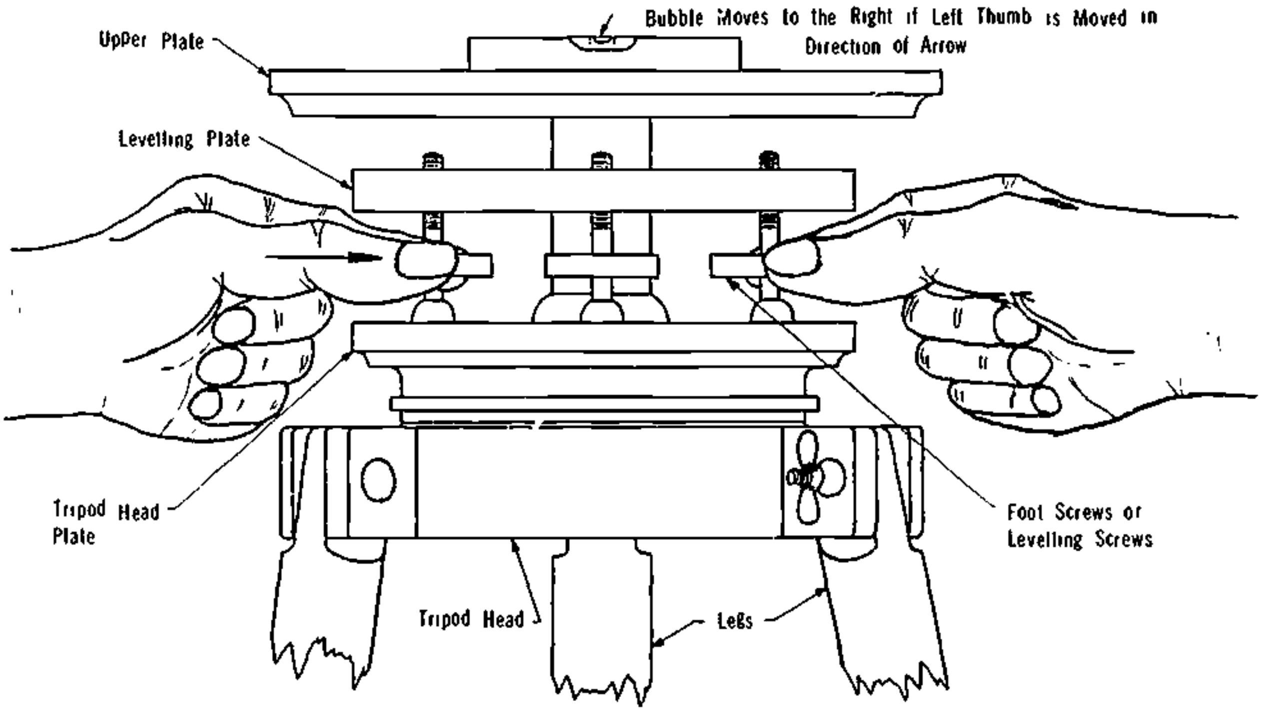


Figure 2-84. Adjusting Foot-Screws

Adjusting the Foot-Screws on a Three Screw Level See Figure 2-85

Step 1 Think of the three foot-screws as an equilateral triangle — A.B.C

Step 2 Turn the telescope until the bubble tube is parallel to foot-screws A.B.

Step 3 Use the left hand to adjust screw B until the bubble is centred.

Step 4 Turn the telescope until the bubble tube is parallel to foot-screws A.C.

Step 5 Adjust screw C until the bubble is centred

Step 6 When taking level reading, adjust either foot-screw B or C.

Step 7 Should the bubble show "out of adjustment" when checking, adjust half the error shown when it is reversed 180 by adjusting the screws at the end of the bubble tube. The other half is then adjusted by the foot-screw

Note: Many instruments are equipped with a "fish eye" for approximate level and also a tilting adjusting screw for speed in levelling the telescope for each sighting.

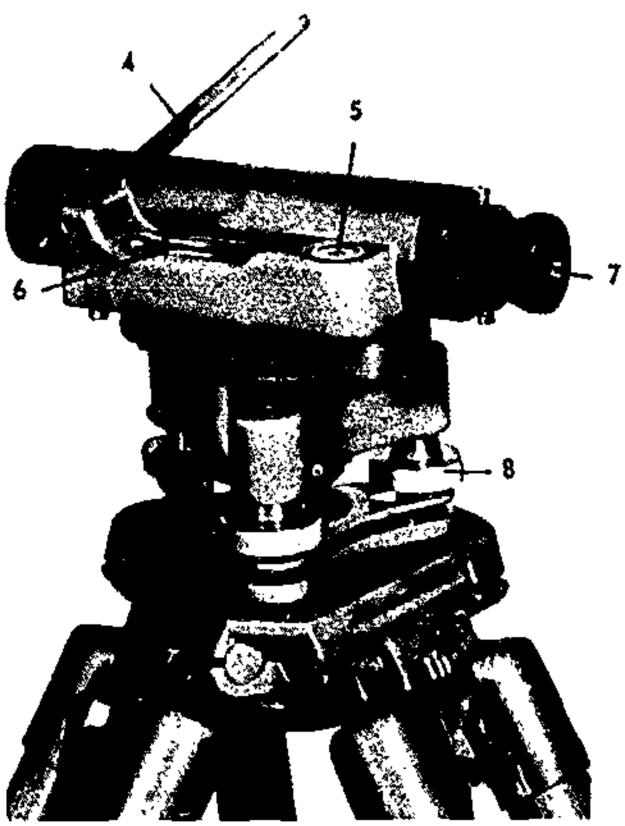


Figure 2-85. Small Builder's Level with Three Foot-Screws

Method of Focusing On a Target

Step 1. Aim in the general direction of the target by sighting along the top of the telescope.

Step 2 Turn the adjusting screw of the object lens to one extreme of travel

Step 3. Turn the screw carefully in the opposite direction until the target comes into sharp focus.

Step 4. Re-focus the object lens each time the target distance changes.

Step 5. To check the focus, move the eye up and down while sighting. If the crosshairs seem to move up and down slightly on the target, adjust the focus until they remain on target.

Glossary of Level Terms

Stadia Hairs — Two parallel hairs within the telescope.

A reading, taken on a rod and multiplied by 100 is equal to the distance from the instrument to the rod.

Station — A point at which a reading is required.

Sunshade — A shield to shade the objective lens from the sun.

Tangent Screw for Inner Circle (Vernier) — A screw used for fine adjustments onto a target.

Tangent Screw for Outer Circle (Degree) — A screw used when the upper clamp is tightened. and a small adjustment on the reading on the circle is required to line up with the target.

Tripod — The three-legged stand which supports the instrument.

Turning Point — A point on which a foresight has been taken and which is now to be used for a backsight.

Upper Clamp — A clamp on the upper horizontal circle (vernier).

Vernier	A scale on the instrument used to obtain a very accurate reading.
Vertical Circle	A vertical disc graduated in degrees. and used to measure angles in a vertical plane.
Vertical Clamp	A clamp used to lock the telescope at any angle in a vertical plane.
Vertical Tangent Screw (Vernier)	A screw used for fine adjustment when the telescope is clamped in position to read vertical angles.

POWER TOOLS

INTROOUCTION TO AIR (PNEUMATIC) TOOLS

Compressed air is the most desirable power source for Boilermaker tools. A number of advantages apply to pneumatic tools:

1. Speed control is variable from zero to maximum.
2. They can operate in contaminated areas, or outdoors in any weather.
3. Overloading will stall the motor without damaging it.
4. Maintenance costs are low.
5. They are not at risk of exploding in relineries, mines, etc.
6. They represent no electrical shock hazard.

One central air compressor usually supplies all the air required to operate the pneumatic tools on a jobsite, although widely scattered jobs may require several portable compressors powered by gasoline or diesel engines. Larger projects often use a stationary electric motor-driven compressor.

The size of the compressor is determined by:

1. The amount of air required in cubic feet
2. The capacity of the storage vessel
3. The size and length of lines to be used.

The required pressure also depends on length and size of air lines. Small lines because of their greater resistance may require higher initial pressure to offset the pressure drop.

Compressors may require an after-cooler device to remove heat from the air. A water separator in the system will discharge excess water automatically.

For maximum efficiency of air tools, the correct air pressure and hoses of correct capacity must be used. Therefore Y fittings on a hose should not be used when both lines will be in operation at the same time. Hypodermic gauges that can penetrate the hose may be used to check line pressure, particularly on torquing tools.

SAFE USE OF COMPRESSEO AIR

Air hoses should be blown out before use to remove dirt and moisture; however, **the hose must be held securely before the air is turned on.** A free hose under pressure whips uncontrollably posing an extreme danger to persons in the vicinity.

An air hose should never be pointed at anyone because particles fly out at dangerous speed. Internal hemmorage will result if compressed air enters the body.

In attaching an air hose to a power tool, ensure that the connection is tightened securely to prevent loosening and possible separation while the air is under pressure.

If possible, suspend the hose from above to avoid tangles, tripping, unnecessary wear or crushing from vehicles running over it. A loose hose can also be caught on passing vehicles, pulling the operator off his feet.

COMMON PNEUMATIC TOOLS

The most commonly used pneumatic tools include:

1. Tuggers and hoists
2. Chipping hammers, chisels and sealers.
3. Nibblers
4. Air grinders (pencil, disc and cup)
5. Riveting guns and equipment
6. Impact wrenches.

CARE OF PNEUMATIC TOOLS

1. Use an emulsifying oil, commonly called air oil.
2. Use a filter and an oiler on the air line ahead of the tool. (Emulsifying oil is commonly added to the main air supply by an automatic Line Oiler, but using air oilers on the line

ahead of the tool ensures that the moving parts of the tool will be adequately lubricated.)

3 Blow air lines before connecting the tool to clear the line of moisture, dirt or other foreign material.
4 Blow the water out of the compressor at start of shift.
5 Some air tools have a self-contained oiler which should be filled at the start of each shift.
6 To unfreeze an ice-blocked line up in cold weather, pour alcohol in the main line.
7 Handle tools with care and protect them from damage.

The oil deposits a low friction film between rubbing surfaces which serves to:

1. Assist in removing heat from localized areas
2. Flush dirt from the airstream
3. Provide a seal between low and high pressure pockets.

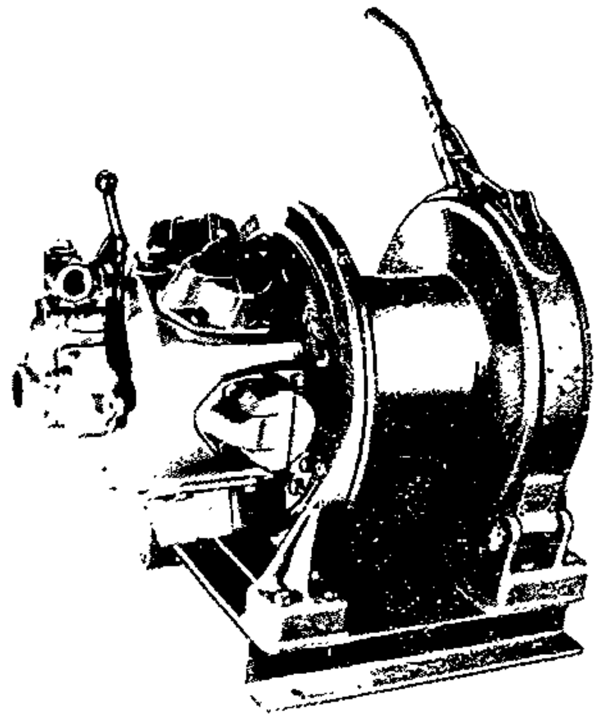


Figure 2-86. Air Tugger

AIR TUGGER

In all types of industry such as steel, processing, shipbuilding, petroleum, as well as in construction and maintenance projects, many lifting, hoisting and lugging jobs are done by hand or with special rigging. The air tugger (Figure 2-86) is a utility hoist for lifting or moving loads.

The tugger can be mounted in almost any position on walls, ceilings, columns or floors, and is portable from one job to another (Figure 2-87). It is equipped with a forward, reverse and neutral control, and a band-type brake capable of holding more than the rated capacity of the hoist.

The tugger's portability makes it very useful in construction work, and it is common to see six or eight tuggers on one jobsite. With snatch blocks (and reeving, if required), the boilermaker can raise, lower and move steel or components to any part of the job. Since snatch block or other tackle tends to put more angle than usual on the rope, reverse bends are often necessary. As a result, **the safety factor for air and electric tuggers is 7.**

Rated Capacities for Air Tuggers

1. Load capacity range: 750-7,000 pounds
2. Drum capacity range: 100-1,675 feet
3. Range of speed: 40-150 feet per minute.

CHIPPING HAMMERS AND CHISELS

Chipping hammers or guns (Figure 2-88) are versatile tools that provide sensitive impact control and require very little maintenance.

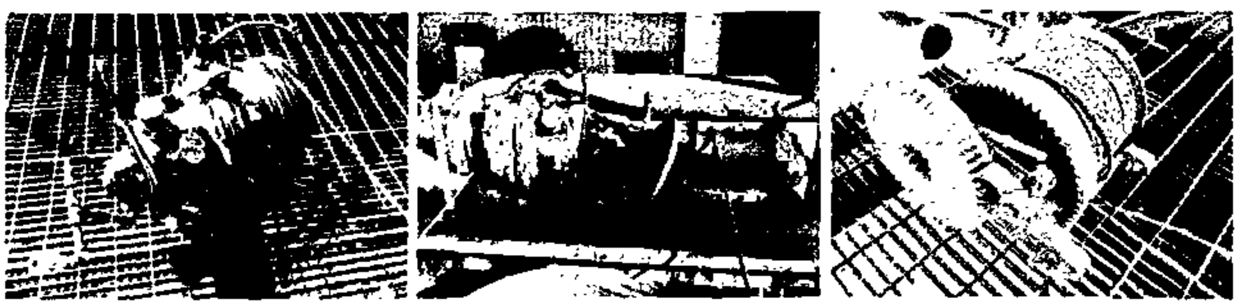


Figure 2-87. Air Tuggers on the Job

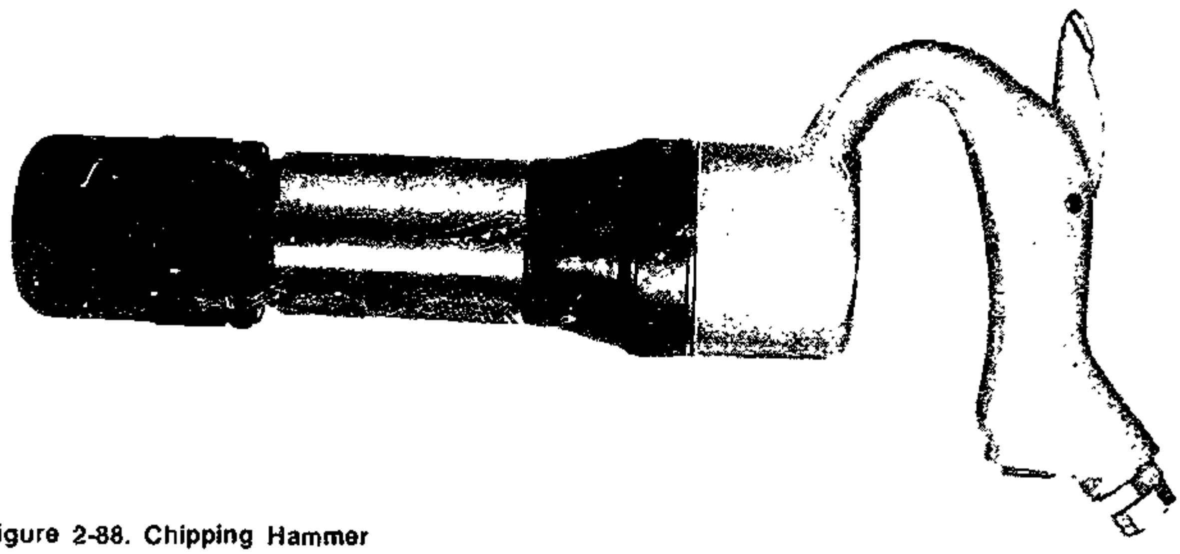


Figure 2-88. Chipping Hammer

Chipping hammers are used for.

1 Chipping welds off steel
2 Caulking riveted welds
3 Cutting out tubes
4 Scarfing and back gouging plate.

Tool shanks are available in different shapes (hexagonal, square, round) to fit most hand and boiler chisel-type tools (Figure 2-89). Chisels may also be purchased in blank form and forged for particular functions. Chipping hammers are available in a range of piston stroke lengths.

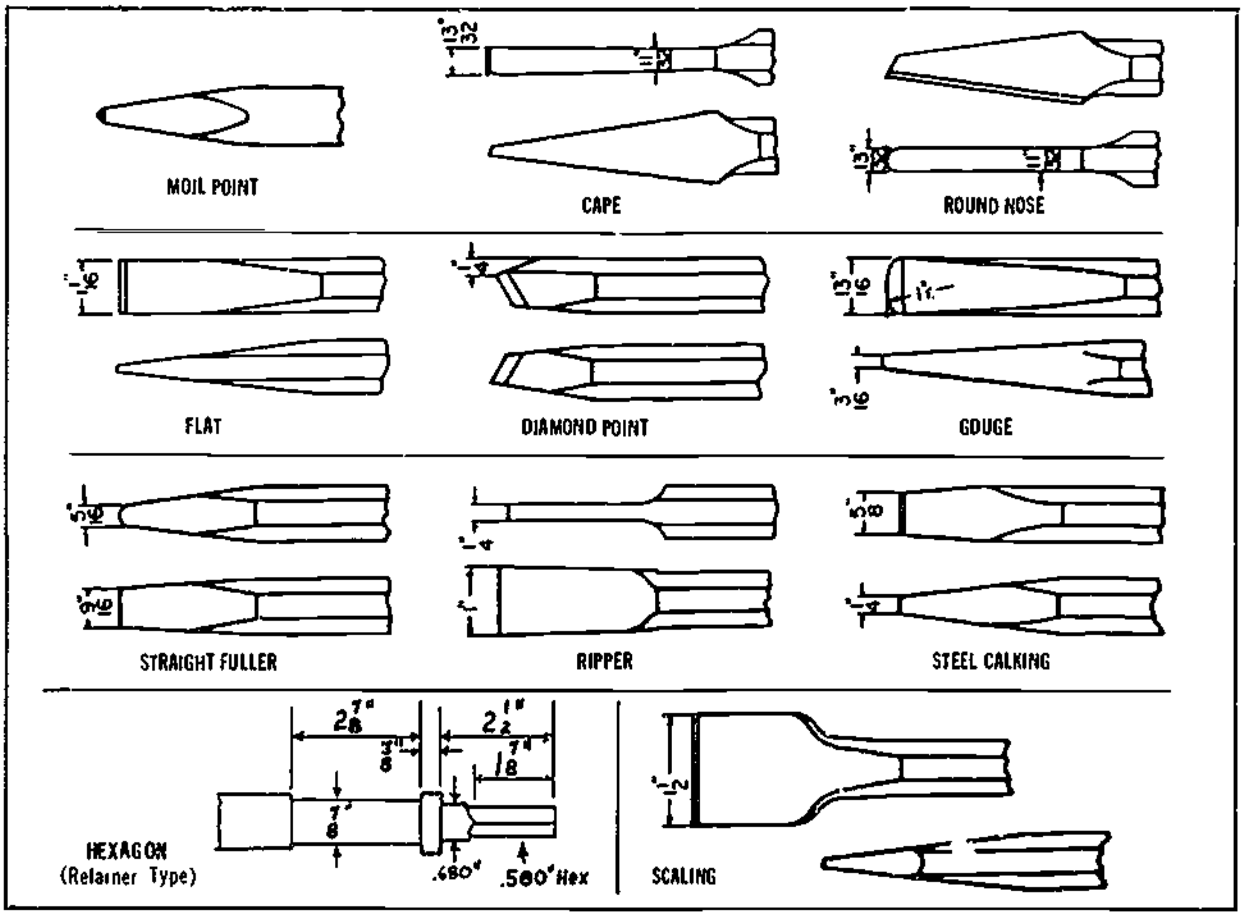


Figure 2-89. Chisel Types and Dimensions

AIR HAMMERS

The air hammer is a small but powerful multi-purpose tool whose retainer can accept a variety of working attachments for riveting, cutting, shearing, punching, driving and chiselling jobs

Figure 2-90 shows two models of air hammers. The difference in the retainers in each case determines which attachments can be accepted. The Beehive Retainer provides positive retention for rivet sets. The Quick Change Retainer provides for fast change of a variety of chisel-type attachments.

Figure 2-91 illustrates some of the common air hammer attachments.

AIR SCALERS

The air scaler (scaling gun or flash gun) is a lightweight, high speed tool designed for chipping, scaling, caulking, and removing rust, paint, scale, flux and weld spatter from all types of surfaces and shapes.

Figure 2-92 illustrates two types of air scalers

Some common attachments for air scalers are illustrated in Figure 2-93.

Some chisel attachments are available in which the blade is offset at an angle to permit access into awkward corners and positions.

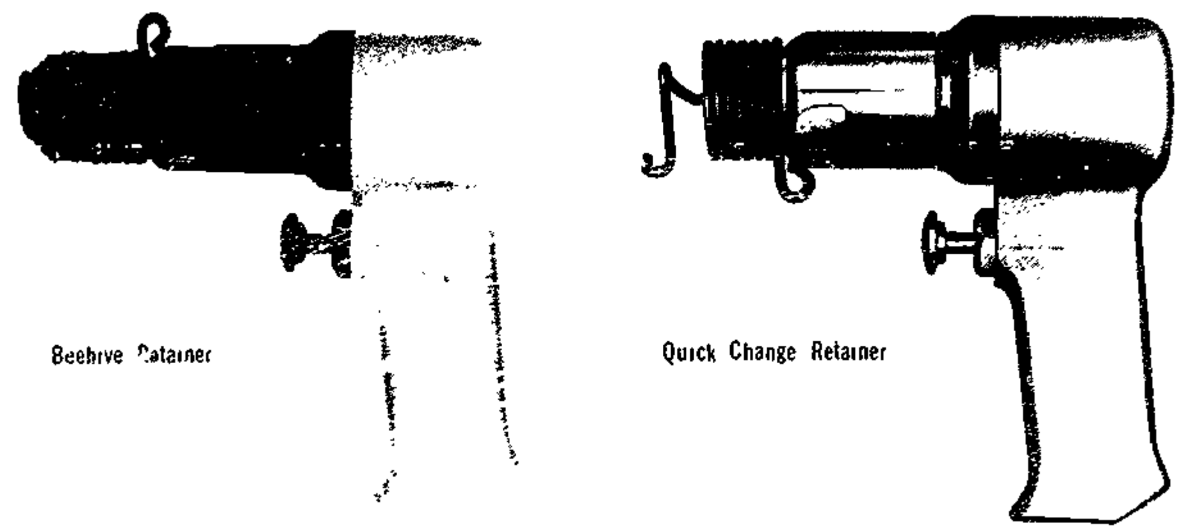


Figure 2-90 Air Hammers

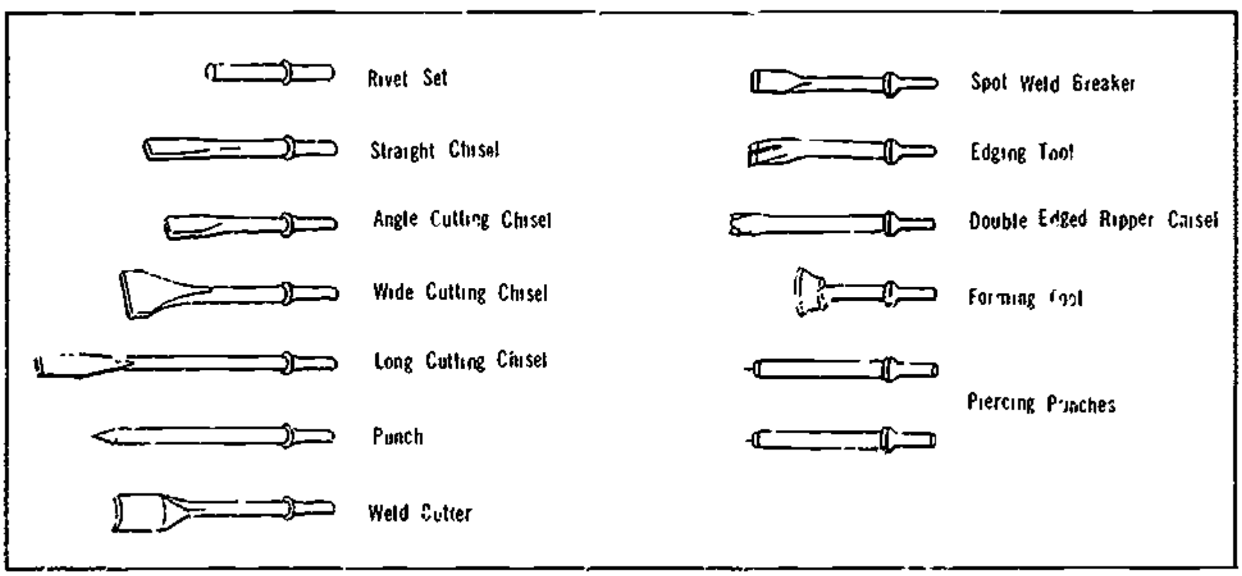


Figure 2-91. Common Air Hammer Attachments

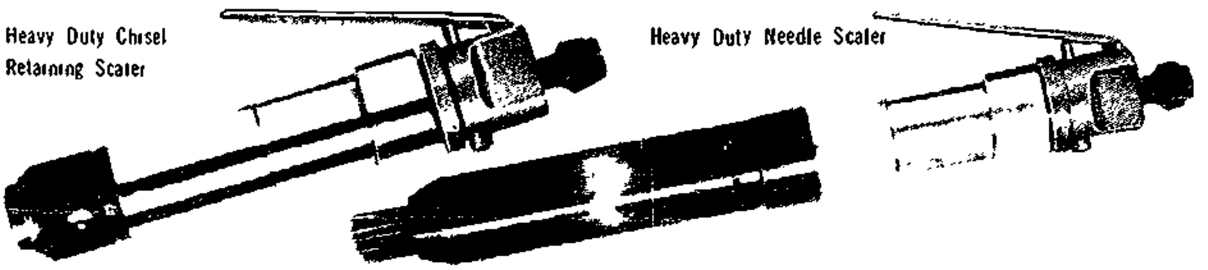


Figure 2-92. Air Scalers

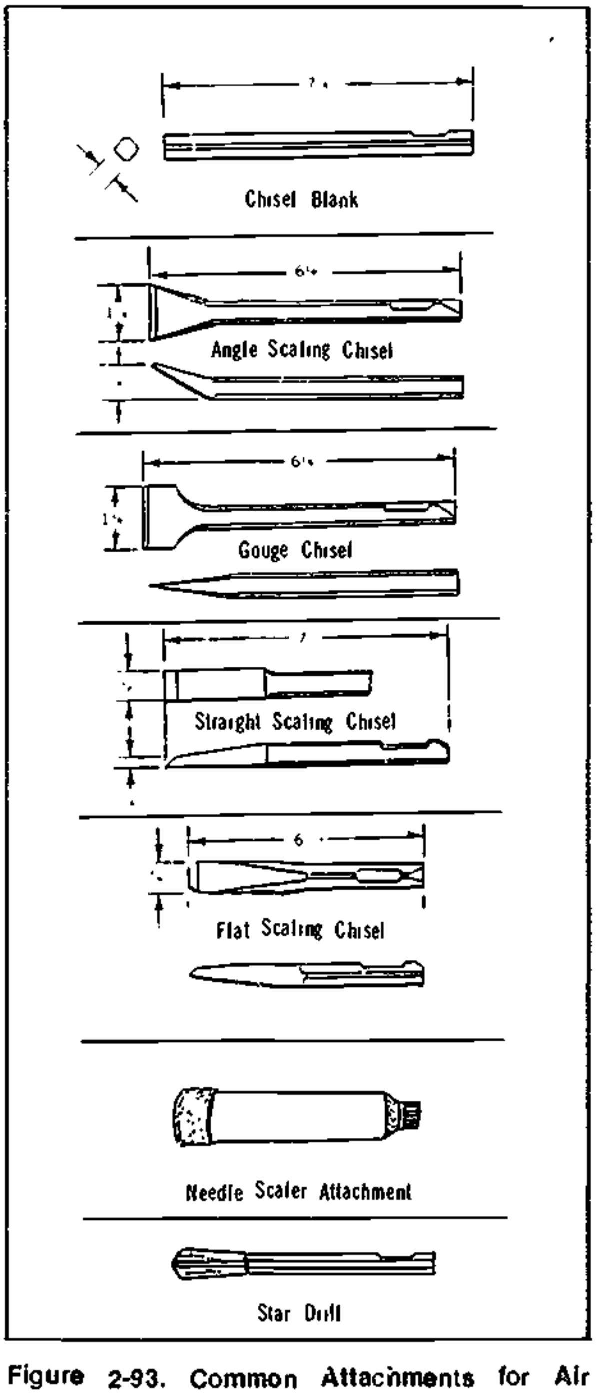


Figure 2-93. Common Attachments for Air Scalers

These tools are not intended to cut, and thus the chisels are sharpened to a dull edge so the tool will knock off slag and clean out corners without leaving a sharp undercut line. There is a tendency to get a light, peening effect which helps relieve stresses in the weld.

RIVET GUNS

The rivet gun (Figure 2-94) is a heavy-duty power tool used to drive rivets into steel. The gun has a plunger inside the barrel which strikes the rivet tool causing it to shape a head on the rivet. Since the plunger is free to come out, it should be removed from the gun when the tool is put aside as a precaution against loss or accidental discharge of the gun.

Rivet guns are manufactured in various sizes to handle different sizes of rivets. Larger model rivet guns are suited for general structural work, boilers, large steel vessels, ship decks and joints which must be steam- or water-tight.

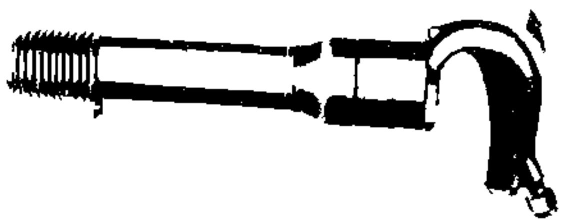


Figure 2-94- Rivet Gun

The Rivet Buster (Figure 2-95) is constructed similarly to the rivet gun except that the front end has been adapted for chisel-type attachments that remove rivet heads. This tool is a little larger and heavier than the rivet gun.

It should be noted that riveting is now less widely used in the Boilermaking Trade because welding and burning produce a cheaper and more efficient job.

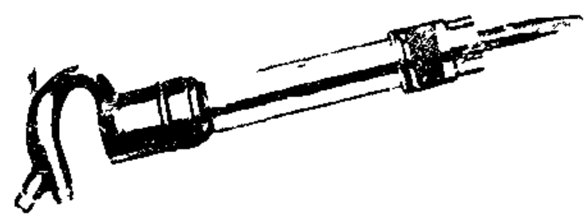


Figure 2-95. Rivet Buster

AIR GRINDERS

Two types of air grinders are used in construction: straight or horizontal grinders (pencil grinder), angle or vertical grinders (Figure 2-96). Table 2-3 compares the two types of grinders.

Stones and discs are supplied in various grits with different abrasive types and bonding materials. Specifications are indicated by the manufacturers' code numbers. Their catalogues recommend the proper stone or disc to provide fast cutting and the required finish on each type

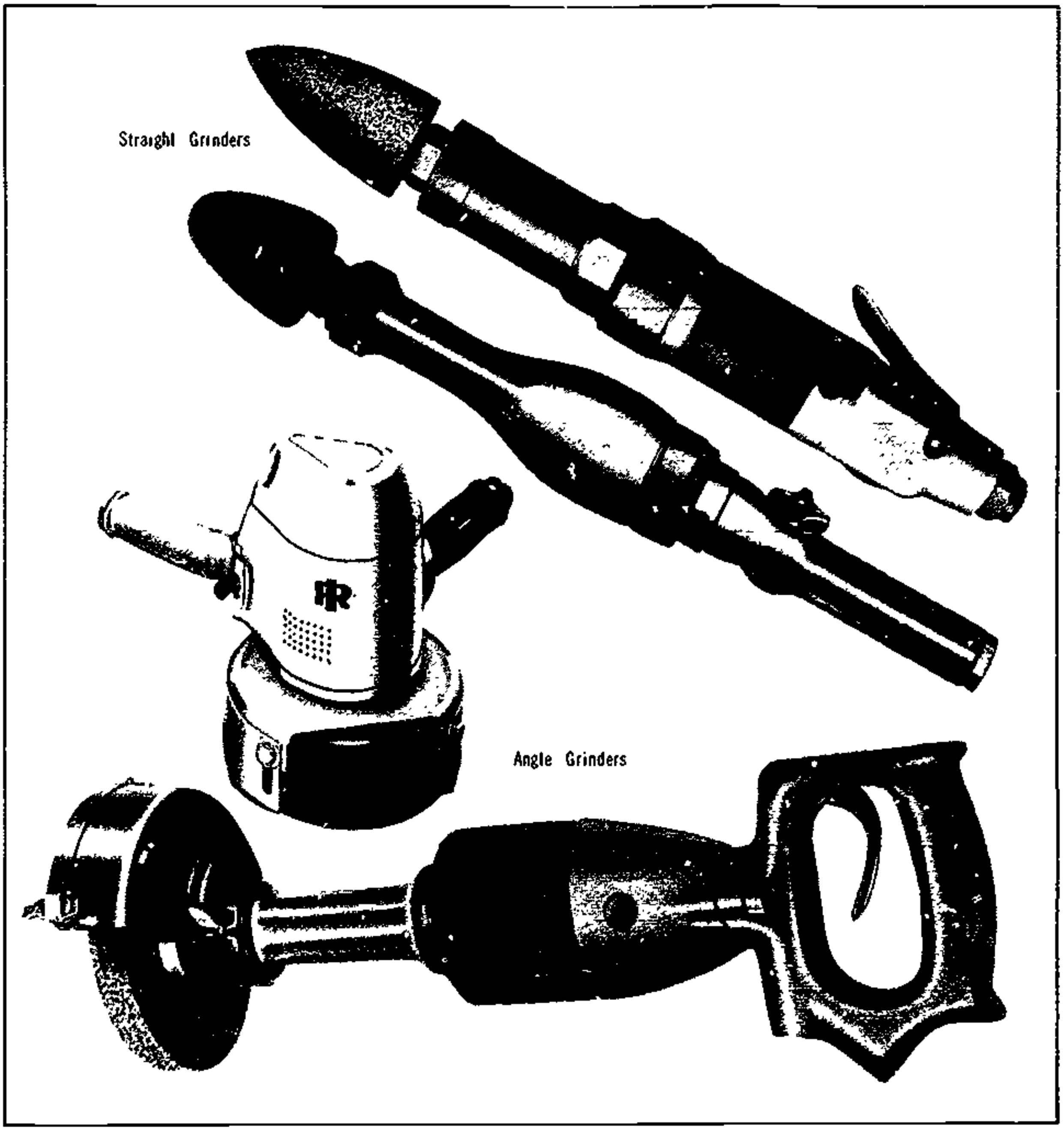


Figure 2-96. Types of Air Grinders

TABLE 2-3. COMPARISON OF STRAIGHT AND ANGLE GRINDERS

	Relationship to motor	Relationship to work	Grinding Attachments used	Speeds
Strai... Grinders	in line	horizontal	Stones 1/... (or more) wide 4 8" diameter	generally comparable
Angle Grinders	at 90	vertical	Sanding discs, Abrasive discs, Cup stones } various sizes	

of material Each stone or disc should specify the maximum safe grinding speed in revolutions per minute This speed must **never** be exceeded.

Note: Speeds described in revolutions per minute should not be confused with surface speed in feet per minute

Safe Grinding Wheel Speeds

It is good practice to operate a grinding wheel at or near the manufacturers' recommended speed. Table 2-4 specifies **safe grinding speeds** in **surface feet per minute** for specified tasks.

To work at a recommended speed in surface feet per minute using a grinder designated to operate at a specified number of revolutions per minute. **it is important to select a grinding wheel of the appropriate diameter.**

For example. a six inch diameter wheel at 4.456 revolutions per minute will travel 7.000 surface feet per minute. An eight inch diameter wheel at 3.342 revolutions per minute will maintain the same peripheral surface speed as the six inch wheel

TUBE TOOLS AND THEIR OPERATIONS

TUBE EXPANSION TOOLS

Tube installations are found in boilers. tubular air heaters. heat exchangers. evaporators and condensers. The tools described here are used in the operations required to fit tube ends into tube holes in a header. tube sheet or boiler drum producing a strong. stable. pressure tight joint using a cold-working process

The tools may be power- or hand-driven. Types of power assistance commonly used for these tools are:

1 Chipping gun
2 Air motor (for reaming operations) (Figure 2-97)
3 Torque motor (for tube expanding) (Figure 2-98)
4 Milling machine
5 Hydraulic tube puller
6. Electric drill.

TABLE 2-4. RECOMMENDED WHEEL SPEEDS IN SURFACE FEET PER MINUTE

Tool and cutter grinding	4.500-6.000
Cylindrical grinding	5.500-6.500
Internal grinding	2.000-6.000
Snagging. offhand grinding (vitrified wheels)	5.000-6.000
Snagging (rubber and resinoid wheels)	7.000-9.500
Surface grinding	4.000-6.000
Knife grinding	3.500-4.500
Hemming cylinders	2.100-5.500
Wet tool grinding	5.000-6.000
Cutting wheels	4.000-5.000
Cutting-off wheels (rubber. resinoid and shellac)	9.000-16.000

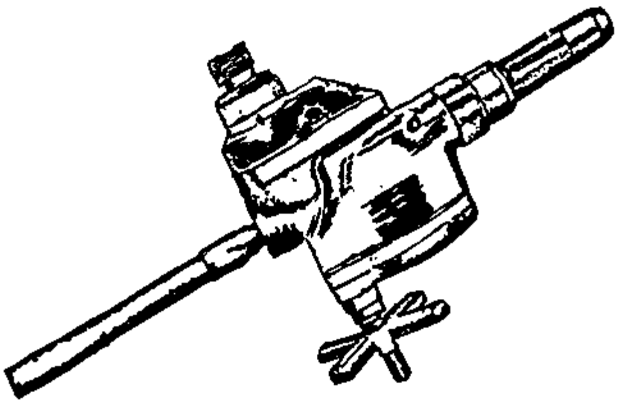


Figure 2-97. Air Motor

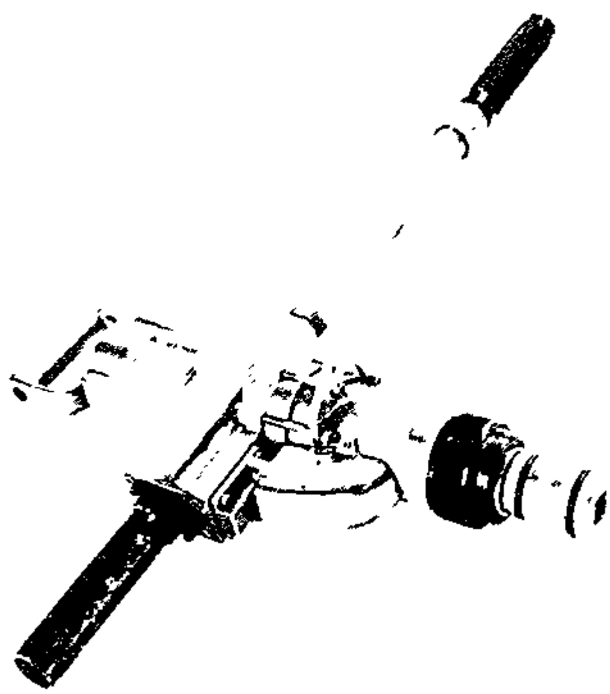


Figure 2-98. Torque Motor

The tools are required for:

1. Removing old tubes
2. Preparing tube holes in the tube sheet
3. Preparing new tubes
4. Rolling in new tubes
5. Dressing tube ends.

These operations are described in detail below.

REMOVING OLD TUBES

Large tubes are cut by burning or gouging, leaving stub ends in the sheet. Small tubes (up to 2½" O.D.) may be cut with a single turn tube cutter (Figure 2-99) turned with a wrench by hand or by an air motor.

Figure 2-99. Single Turn Tube Cutter

The collar of the cutter may be moved up or down the shaft to accommodate various thicknesses of tube sheet. When the tubes have been removed and only the stubs remain at the tube sheet, the stubs must be removed.

It is sometimes necessary to reduce the tube wall thickness of large tubing to weaken the rolled tube joint prior to collapsing or splitting the tube stub. The tube wall reducing tool (Figure 2-100) is powered by an air motor.

Figure 2-100. Tube Wall Reducing Tube

Collapsing and splitting tools (Figure 2-101) are driven under the edge of the tube stub to crimp the tube and weaken the rolled joint, and may also drive out the collapsed stub. These tools are powered by a chipping gun.

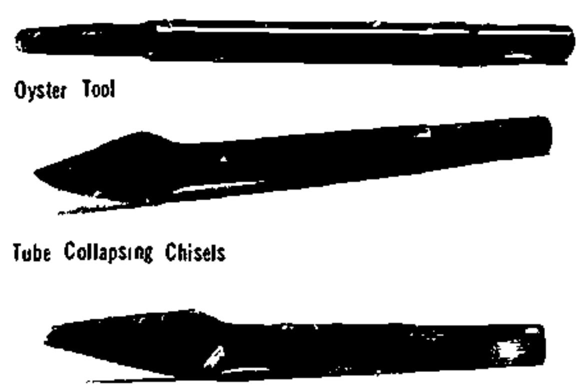


Figure 2-101. Tube Collapsing and Splitting Tools

The knock-out tool or tube drift (Figure 2-102) is used with a chipping gun to knock out collapsed tube stubs These tools are sized to specific tube diameters and thicknesses to avoid damage to the tube sheet

Figure 2-102. Knock-Out Tool

Small tube stubs are removed using an hydraulic tube puller (Figure 2-103) The hydraulic tube puller is specifically designed to speed condense, and heat exchanger tube pulling and to remove the danger of damaging the tube sheet holes Adaptable for use with either manual-or power-operated pumps, tube pullers can be used with a single unit for pulling from only one end, or used in pairs for pulling tubes from both ends simultaneously. Easier tube removal results from double end pulling because the tubes neck down and separate more easily from the tube sheet. In addition, a single power source can be utilized for double end pulling in one set-up. Figure 2-104 illustrates the parts of an hydraulic tube pulling system. Sets of spears and adapters are available.

Figure 2-103. Complete Airetool Hydraulic Tube Puller with Extension and Spear

PREPARING TUBE HOLES IN THE TUBE SHEET

To prepare the tube sheet for new tubing, inspect the holes for damage from chipping or gouging Make repairs as necessary by welding and grinding to the required tube hole size

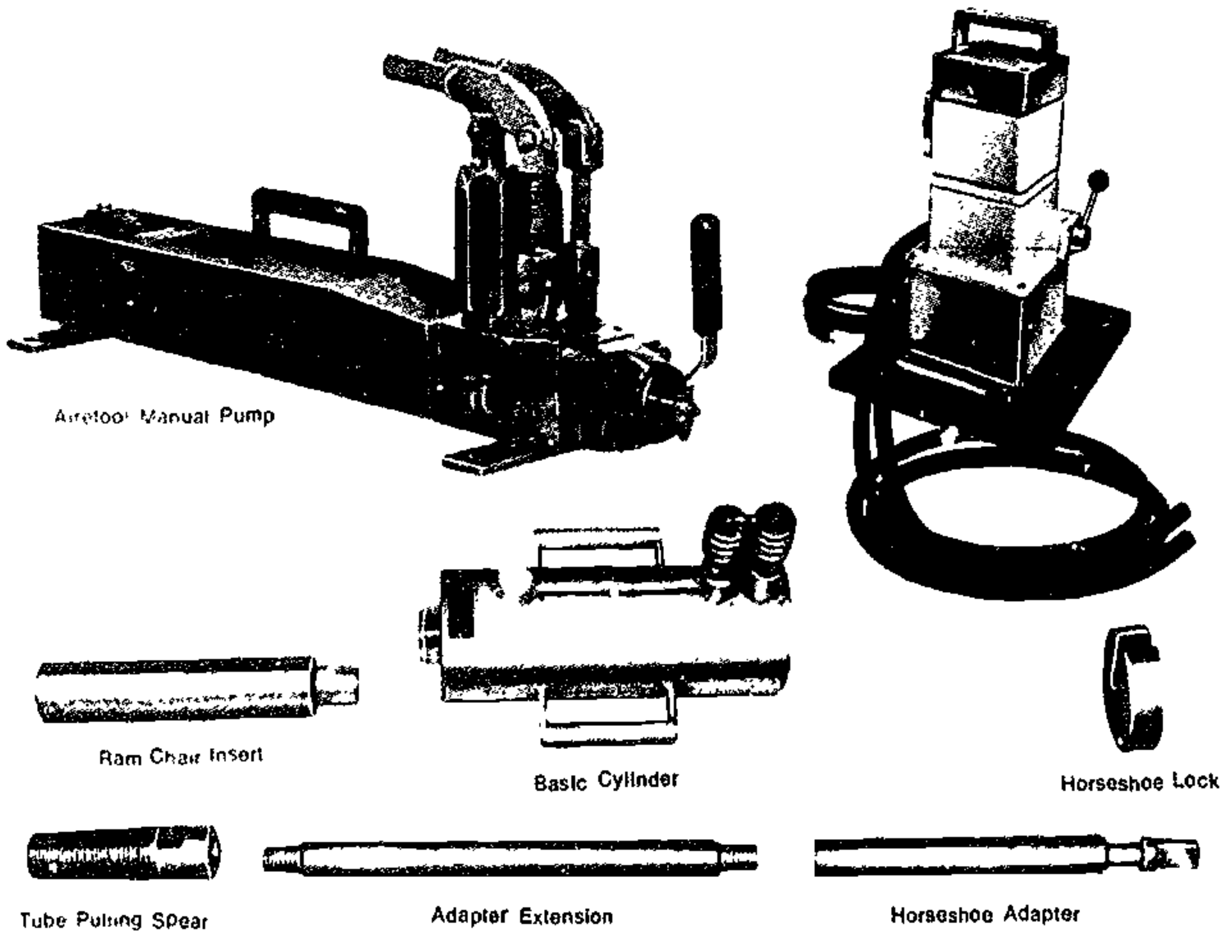


Figure 2-104. Hydraulic Tube Puller Parts

A tube reamer (Figure 2-105) powered by an air motor may be required to finish tube sheet holes to a specified size, or to remove scale, dust, dirt or burrs to prevent damage to new tube ends resulting in an incompetent joint

In some circumstances there may be a groove in the circumference of the tube sheet hole which locks the rolled tubes tightly in position. When tubes are pulled or driven out, metal is sometimes sheared off in the groove. It must be removed to permit a secure connection with the new tube. A grooving tool (Figure 2-106) powered by an air motor is used for this purpose.

PREPARING NEW TUBES

If the tubes need to be cut to length, an air-powered hack saw (Figure 2-107) is used A tightening device holds the machine at right angles to the work, assuring a square and accurate cut. To prepare the tubes for setting into the tube sheet, the terminal 4"-5" are buffed with a grinder and wire wheel to remove dirt and scale which could reduce the efficiency of the joint

ROLLING IN THE NEW TUBES

The new tube is placed into the tube sheet hole and must be expanded by a cold-working

Figure 2-105. Tube Reamer

Figure 2-106. Grooving Tool

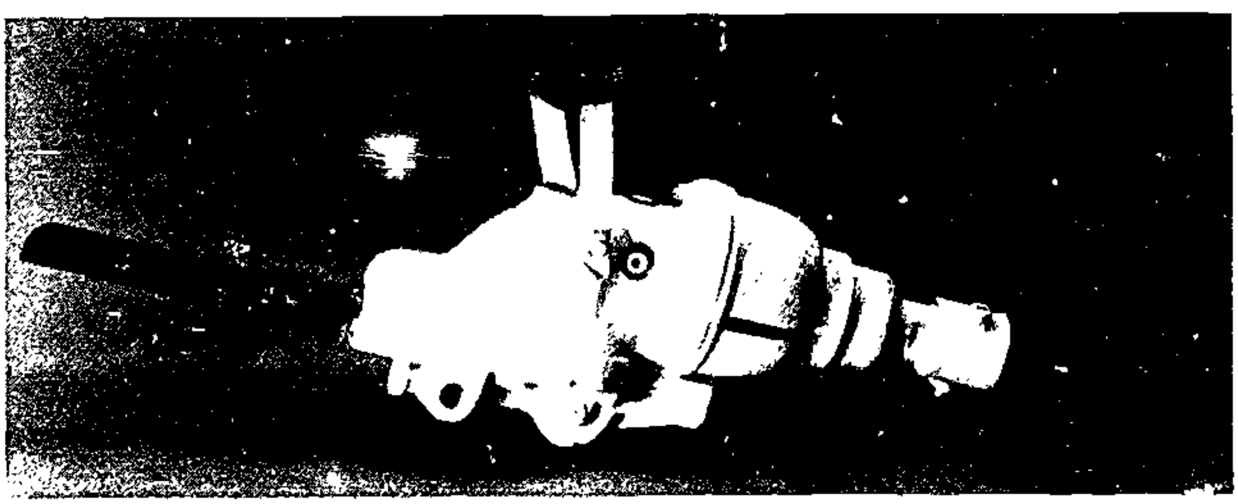


Figure 2-107. Air-Powered Hack Saw

process which forms a mechanically strong and leakproof joint with the tube sheet. If the tube sheet holes are grooved, the tube rolling operation squeezes tube metal into the grooves, resulting in a tightly bonded joint.

The tools described in Figures 2-108 to 2-113 are used with a torque motor (or hand driven) to expand a tube that has been positioned in a tube sheet hole

The Condenser roll (Figure 2-108) is adjustable as to depth of roll and where required may make several passes on thick tube sheets

Tube expanders are available in sizes ranging from $1/4$ O.D. to O.D., and for tube sheets up to $6^3/4$ thickness.

The tube expander is a self-feeding parallel rolling tool in which the tapered mandrel forces

Figure 2-108. Condenser Roll

Figure 2-111. Rectractor Rolls Used on Boiler Tubes, Usually for Deep Rolling in Heavy Tube Sheets

Figure 2-109. Adjustable Condenser Roll with Stopper Device Partly Extended

Figure 2-112. Combination Tube Rolling (Expanding) and Belling (Flaring) Tool

Figure 2-110. Adjustable Condenser Roll with Ball Bearing Stopper Roll

Figure 2-113. Combination Rolling and Belling Tool (Alternate View)

the rollers out as it moves forward This places gradually increasing pressure on the inside tube walls which in turn forces the outside tube walls against the tube sheet holes, producing a pressure tight joint An adjustable ball bearing thrust collar remains stationary when in contact with either the tube end or tube sheet. This eliminates tube end cutting, tube sheet shearing and frictional heat.

Tube expanders are precision tools and severe service is demanded of them. The following precautions should be taken:

1 Before using an expander, wash all parts thoroughly in clean solvent to remove all foreign material.
2 Lubricate the expander before use.
3 After each rolling operation, wash the expander and inspect it for scarred or chipped rolls or mandrels. Replace as required.
4 Store the tool in a container of light oil or wrap in an oil soaked cloth.

Where space is confined, as in a small header, it may be necessary to operate the tube rollers at an offset angle some distance away from the tube ends. Driving links (Figure 2-114) with universal joints may be used to connect the tube rollers to the power source.

In restricted spaces a bevel gear right angle drive (Figure 2-115) may be used to turn a rolling tool which is seated at 90° to the power source.

When a torque motor is inappropriate or unavailable tube rollers may be hand driven using a ratchet wrench (Figure 2-116)

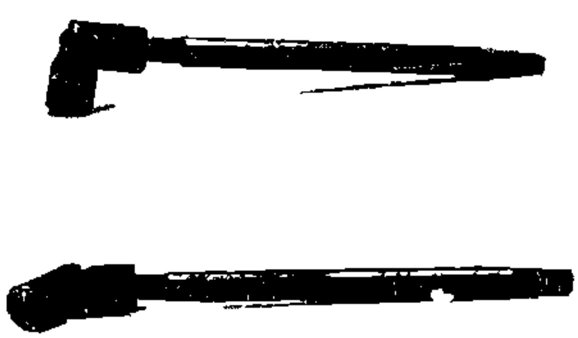


Figure 2-114. Driving Links

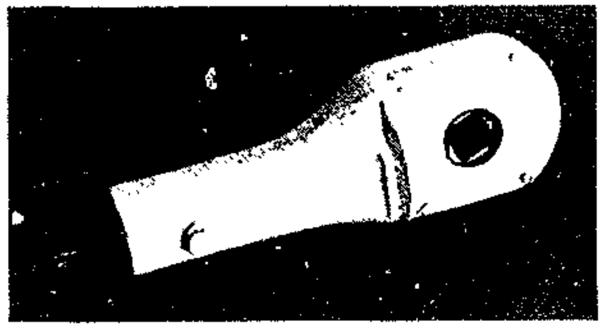


Figure 2-115. Bevel Gear

Figure 2-116. Ratchet Wrench

Under certain circumstances a tube sheet hole may have to be closed off rather than retubed Blind tube nipples (Figure 2-117) are used for this purpose, and are inserted into the hole and then expanded with tube rollers

Figure 2-117. Blind Tube Nipples

DRESSING TUBE ENDS

Tube ends that project beyond the face of the tube sheet may be finished in one of several ways flaring, facing, welding, beading The required finish is set out in the job specifications.

Flaring Tube Ends Flaring or belling or exposed tube ends is produced primarily by using a tube expander with belling rolls incorporated into the expander (Figure 2-112). Alternative flaring and belling tools (Figure 2-118) are powered by a chipped hammer.

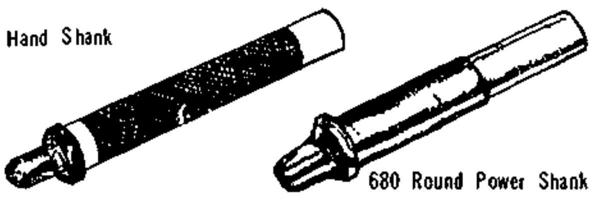


Figure 2-118. Flaring and Belling Tools

Facing Tube Ends Facing is a process of cutting off tube ends to required stock as specified. Tube end facers (Figure 2-119) are adjustable to varying lengths of stock and are supplied with extra sleeves to accommodate different sizes of tubes.

Figure 2-119. Tube End Facers

Welding Tube Ends When specifications require a bonded joint between tube ends and tube sheet holes, as in fire tube boilers, the method involves welding the tube ends to the tube sheet. The tubes are usually expanded both before and after the welding.

Beading Tube Ends Some specifications require the beading of tube ends. This may be accomplished with a power impact hammer and a beading tool.

A type of beading effect can be accomplished with a peening tool (Figure 2-120) and hammer in the absence of the power impact hammer. After beading or peening it is often necessary to repeat the tube rolling process.

TUBE MILLING PROCEDURE

It is sometimes necessary to cut and bevel sections of tube which are to be replaced so that the new sections may be competently welded to the old sections.

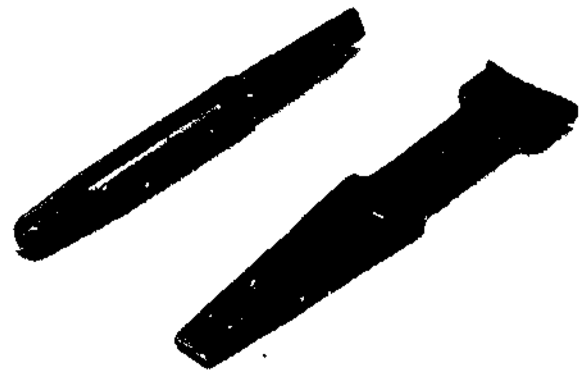


Figure 2-120. Peening Tools

A milling and scarling machine (Figure 2-121) encorporates its own air motor and has an expandable locking device that centres the cutting edges around the tube. The travel of the cutters is controlled by a hand crank. Different types of cutting edges are available for various facing and bevelling requirements.

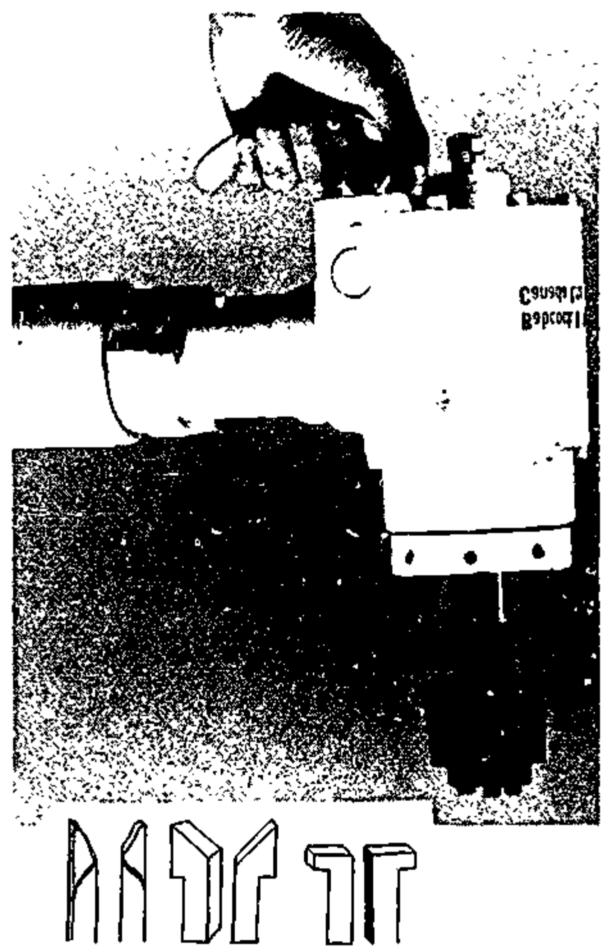


Figure 2-121. Milling and Scarfing Machine with Various Cutting Edges

ELECTRIC TOOLS

Most of the pneumatic tools described above are available as electric tools. In some areas where air is not supplied. electric tools are used: however. both types of power tools are available in many shops and construction sites. Electric tools are more portable than air tools because longer lengths of extension cord are easier to carry than the same length of air hose

PRECAUTIONS IN USING ELECTRIC TOOLS

1. Ensure that the tools are properly grounded.
2. Examine the cables to ensure they are in good condition.
3. Do not overload the machine. This can cause the motor to burn out.

Torque control on electric motors for tube rolling is provided by a meter that regulates the amperage used by the motor. This type of limiting switch may be found on other load-rated electrical equipment to protect it from burn out. Some tools have thermal overload controls that cut out when the temperature rises above the safety margin. If the electrical equipment is double insulated. the power cable may have only two controls on the plug.

ELECTROMAGNETIC DRILL PRESS

The electromagnetic portable drill press (Figure 2-122) enables an operator to carry out drilling. tapping and reaming in any horizontal. vertical or overhead position as long as the base is seated on a ferrous metal surface.

The base acts as a magnet when an electric current is connected and the magnetizing switches are in the "ON" position. The magnet's capacity is rated in terms of the drill point pressure that can be applied without weakening the magnetic seat. Drills up to 1¼" can be accommodated in the heavier models. Most drill presses have reversing motors. Cutting oils

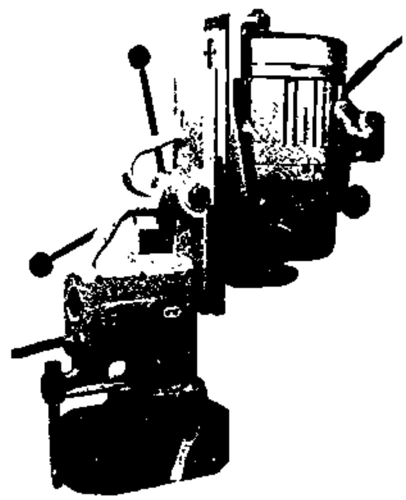


Figure 2-122. Electromagnetic Drill Press

and/or coolants should be used as recommended for the type of material being drilled.

Several factors influence the drill point pressure in actual operation:

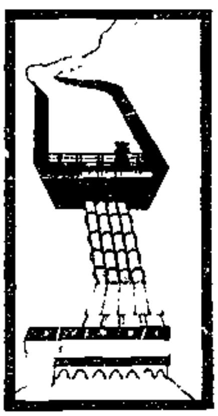
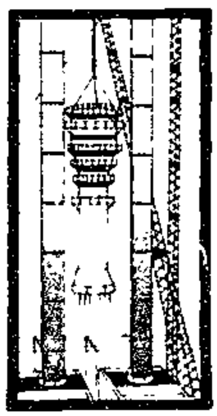
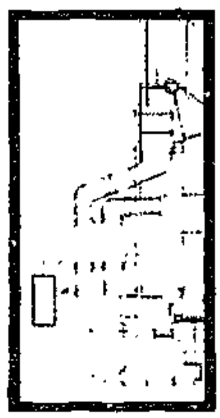
1. Drill speed
2. Hardness of the material being drilled
3. Sharpness of the drill
4. Drill point angle.

It is advisable to begin with a smaller drill to make a pilot hole before attaching the required drill This reduces the drill point pressure needed to complete the hole.

Drill sharpness and the drill point angle must be compatible with the material to be drilled.

Whenever the drill is attached in a vertical or overhead position. a safety chain must be used to secure the tool to a structural member in case of a power failure which would release the magnet and cause it to fall. When the drill is in operation. the operator must have no loose hair or loose or torn clothing that could be drawn into the drill bit and cause serious injury.

Chapter 3
MATHEMATICS

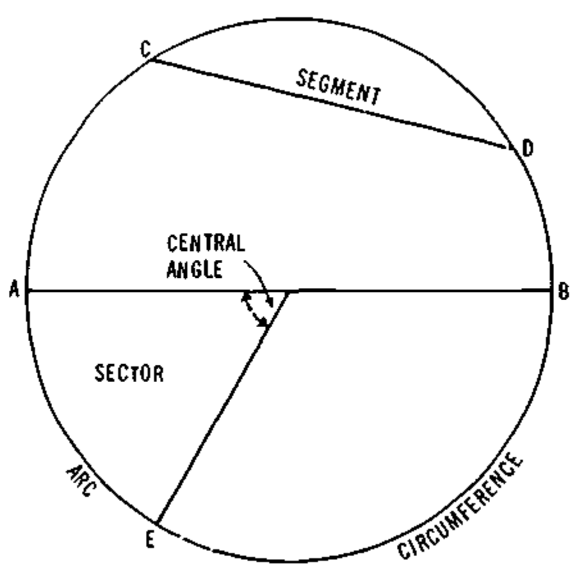
INTRODUCTION

Although the Construction Boilermaker usually erects fabricated sections, he is expected to have a baseline knowledge of mathematics related to the circle, square and triangle.

This chapter is not intended as a complete mathematics course It presents the basic facts of these common shapes so that the Boilermaker, whether journeyman or apprentice, will be able to establish unknowns merely by using common sense and a piece of soapstone, without requiring a calculator or slide rule.

THE PROPERTIES OF CIRCULAR SHAPES

One of the most common shapes encountered by a Boilermaker is the circle or portions of the circle The circular shape may be seen in tanks, penstocks, tubes, drums and headers, to name a few Figure 3-1 illustrates the parts of a circle.



1 The **circumference** is the perimeter of a circle
2 The **diameter** (line AOB) is a straight line drawn across the circle through the centre.
3. The **radius** (line OE) is the distance from the centre to any point on the circumference (or one half the diameter).
4 A **chord** (line CD) is the distance from one point on the circumference to another point on the circumference. The largest chord of any circle is the diameter.
5. The **arc** is any curved portion on the circumference.
6 A **sector** is an area subtended by two radii and an arc.
7. A **segment** is an area subtended by a chord and an arc.
8. The **central angle** (EOA) is subtended by two radii and an arc.

Any full circle contains 360°.
A semi-circle or half circle contains 180°.

CIRCUMFERENCE OF A CIRCLE

The circumference of a circle is almost exactly 3.1416 times the length of the diameter. Where reasonable accuracy will suffice, 3.14 is acceptable. In formulas, 3.14 is represented by the Greek letter π.

The relationship between the circumference and the diameter is expressed as follows:

$$\text{Circumference} = \pi \times \text{Diameter}$$
or
$$\text{Diameter} = \frac{\text{Circumference}}{\pi}$$

Example 1:

If the circumference of a tank is unknown and the diameter given is 25', the circumference would be:

$$C = \pi \times D$$
or
$$C = \pi D$$
$$C = 3.14 \times 25'$$
$$= 78.5'$$

Example 2:

If the inside circumference of a penstock is 62.80' and the inside diameter is needed in order to install spiders for rounding out the can, the solution would be:

$$\text{Diameter} = \frac{\text{Circumference}}{\pi}$$

$$D = \frac{C}{\pi}$$

$$D = \frac{62.80'}{3.14}$$

$$D = 20'$$

Example 3:

Another practical problem involving circumference and diameter occurs when fitting two cans of penstock that have a variance of 1" on the circumference. To spread the difference evenly about the seam, the fitter can calculate the "high-low" for the same as follows

Circumference of can #1	= 60'0"
Circumference of can #2	= 60'1"
Difference in circumference =	1"
Difference in diameter =	1"
	= 318" or 5/16"

To distribute the 5/16" evenly, divide by 2 to split the 5/16" on either side of the diameter:

$5/16 \div 2 = 5/32"$

AREA OF CIRCLE

To find the area of a circle, the formula is expressed as follows

$$\text{Area} = \pi \times (\text{Radius})^2$$

or

$$A = \pi R^2$$

Example:

To calculate the weight of the plate required for the floor of a tank whose diameter is 25', the first step would be to determine the area of the tank floor

Diameter = 25'
Radius = 12.5'
Area = πR^2
= 3.14 x (12.5' x 12.5')
= 3.14 x 156.25
= 490.625 sq. ft. of plate

Plates of 1/2" thickness weigh 20 lbs. per sq. ft. Thus the weight of the plate for the tank floor is determined by:

Area to be covered x weight of plate per sq. ft

490.625 x 20
= 981.25 lbs

A summary of the mathematics of a circle is given in Table 3-1.

THE SQUARE

A figure having 4 **equal** sides, containing 4 right angles (90° angles) is a square (Figure 3-2). The essential components of any square are

1. The side (AB)
2. The diagonal (AC)
3. The perimeter (total length of the 4 sides)
4. The area.

If any of the components of the square are known, the others can be calculated because the following constants apply:

1. The diagonal is 1.414 times longer than a side:
   $D = 1.414 \times S$
2. The side is 0.707 times the length of the diagonal:
   $S = 0.707 \times D$
3. The area of a square is equal to the side multiplied by the side:
   $A = S^2$
4. The area of a square is equal to one-half of the diagonal, squared:
   $A = (.5\ D)^2$

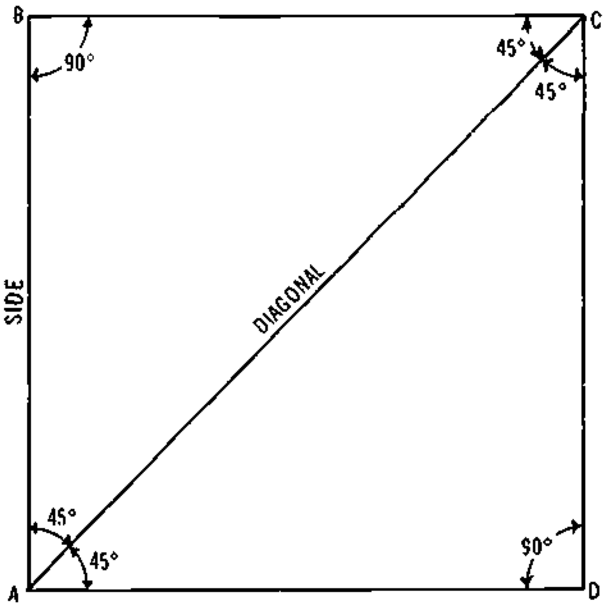
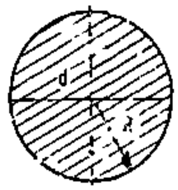
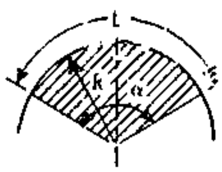
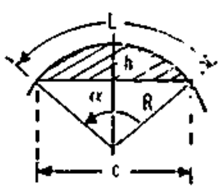
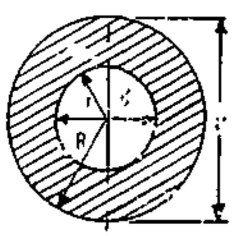
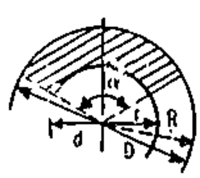
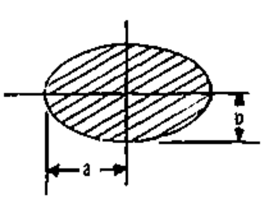


Figure 3-2. Square

TABLE 3-1. APPLICATION OF CIRCLE MATHEMATICS

PROPERTIES OF CIRCULAR SHAPES		EXAMPLES SHOWING USE OF FORMULAS
 CIRCLE	A = AREA C = CIRCUMFERENCE $A = \pi R^2 = 3.1416R^2 = .7854d^2$ $C = 2\pi R$ or πd $d = C \div 3.1416$	DIAMETER = $2\frac{3}{4}$ inches $A = 0.7854 \times 2.75^2 = 5.9396$ square inches $C = 2.75 \times 3.1416 = 8.6394$ inches
 CIRCLULAR SECTOR	A = AREA L = ARC α = ANGLE in ° $L = \dfrac{\alpha \times R \times 3.1416}{180}$ $A = \frac{1}{2}RL = .0087\alpha R^2$	$R = 1\frac{1}{2}$ inches, $\alpha = 60°$ $A = 0.008727 \times 60 \times 1.5 = 1.178$ sq inches $L = 0.01745 \times 1.5 \times 60 = 1.5705$ inches
 CIRCULAR SEGMENT	A = AREA L = ARC α = ANGLE in ° $c = 2\sqrt{h(2R - h)}$ $A = \frac{1}{2}[RL - c(R - h)]$ $L = 0.01745R\alpha°$ $h = R - \frac{1}{2}\sqrt{4R^2 - c^2}$	$R = 60$ inches $h = 8$ inches $c = 2\sqrt{8 \times (2 \times 60 - 8)}$ $= 2\sqrt{896} = 59.86$ inches If $c = 16$ inches $h = 6$ inches $R = \dfrac{16^2 + 4 \times 6^2}{8 \times 6} = \dfrac{256 + 144}{48} = 8.325$ inches
 CIRCULAR RING	A = AREA $A = \pi(R^2 - r^2)$ $= 3.1416(R + r)(R - r)$ $= 0.7854(D^2 - d^2)$ $= 0.7854(D + d)(D - d)$	OD = 12 inches ID = 8 inches $A = 0.7854(12^2 - 8^2)$ $= 0.7854(144 - 64)$ $= 0.7854 \times 80$ $= 62.83$ square inches
 CIRCULAR RING SECTOR	A = AREA α = ANGLE in ° $A = \dfrac{\alpha\pi}{360}(R^2 - r^2)$ $= .00218\alpha(D^2 - d^2)$	Outside R = 5 inches Inside r = 2 inches $\alpha = 72°$ $A = 0.00873\alpha(R^2 - r^2)$ $= 0.00873 \times 72 \times (5^2 - 2^2)$ $= 0.6286\ (25 - 4) = 13.2$ square inches
 ELLIPSE	A = AREA P = PERIMETER or circumference $A = \pi ab$ $P = \pi\sqrt{2(a^2 + b^2)}$	MAJOR AXIS = 8 in MINOR AXIS = 6 in $a = 4$ $b = 3$ $A = 3.1416 \times 4 \times 3 = 37.699$ square inches $P = 3.1416\sqrt{2(4^2 + 3^2)}$ $= 3.1416\sqrt{50} = 22\frac{1}{4}$ inches

Example 1:

If a square piece of plate is required to fit an opening whose diagonal is 3'. the fitter would lay out the sides of the square as follows:

$$D = 1.414 \times S$$
$$3' = 1.414S$$
$$S = \frac{3}{1.414}$$
$$S = 2.12' \text{ or } 2'\ 1\ 1/2''$$

Example 2:

If a fitter wants to ensure that a piece of plate whose sides measured 4' each is a true square. he could check the sides against the diagonal as follows:

$$S = 0.707 \times D$$
$$4' = 0.707D$$
$$D = \frac{4}{0.707}$$
$$D = 5.65' \text{ or } 5'\ 7\ 7/8''$$

If the diagonals measure 5' 7 7/8". the plate is a perfect square.

TRIANGLES

Triangles are 3 sided figures which enclose 3 angles. the sum of which is 180

Triangles may take various shapes. In the equilateral triangle. all 3 sides are equal. and all 3 angles are equal (Figure 3-3). In the isosceles triangle. 2 sides are equal. and the angles opposite these sides are equal (Figure 3-4). In the scalene triangle. no two sides are equal. and no two anlges are equal (Figure 3-5).

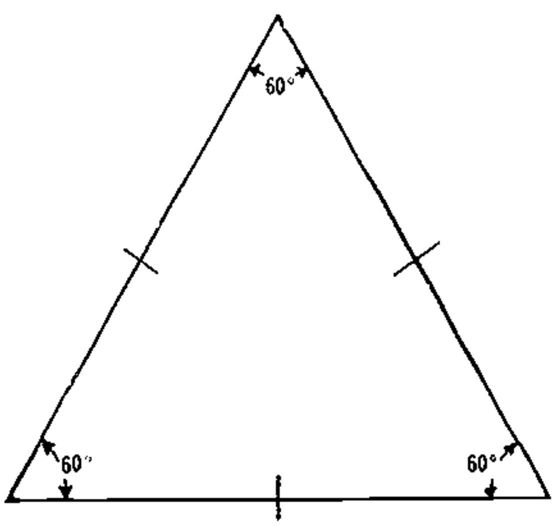


Figure 3-3. Equilateral Triangle

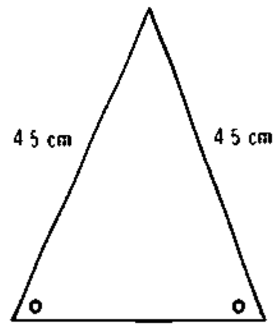


Figure 3-4. Isosceles Triangle

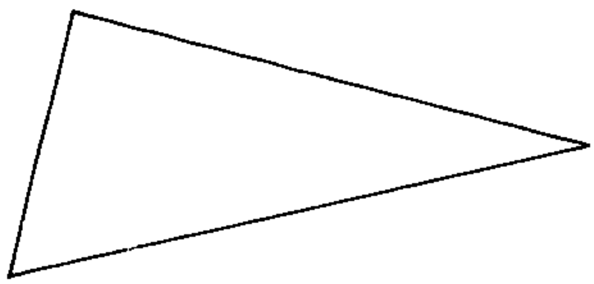


Figure 3-5. Scalene Triangle

In the right angle triangle (Figure 3-6). the sides may be of varying lengths. but one angle must be 90 . This triangle form has certain constant characteristics that make it the most useful to the Boilermaker in calculations and design.

The essential components of a right anlge triangle are

1. The 90 angle
2. The side (always the longest) opposite the right angle — called the hypotenuse (h)
3. The other two sides.
   — the shortest side (a)
   — The remaining side (b).

The value of the right angle triangle as a basis for calculations and design derives from the unique relationship between the hypotenuse and the other two sides. called the "Rule of Squares."

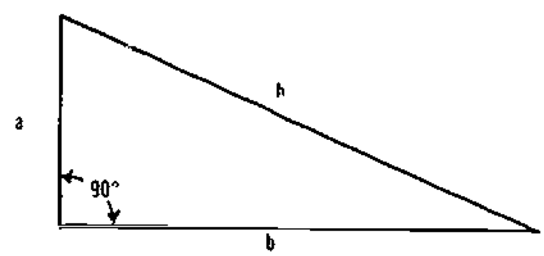


Figure 3-6. Right Angle Triangle

THE RULE OF SQUARES

This rule (also described as the Theorem of Pythagoras) states that the distance (h) squared is equal to the distance (a) squared plus the distance (b) squared

$h^2 = a^2 + b^2$

Many useful functions can be accomplished by applying this rule in a number of ways in the shop Before attempting to illustrate these, however the mathematical procedures of squaring numbers and finding the square root of numbers will be reviewed

SQUARES AND SQUARE ROOTS OF NUMBERS

Squaring a Number

$6^2 = 6 \times 6 = 36 \qquad \sqrt{36} = 6$

Square Root Sign

This statement illustrates the meaning of squaring a number and finding the square root of a number

6^2 (say 6 squared) — means 6 multiplied by itself $6 \times 6 = 36$ $10^2 = 10 \times 10 = 100$

Warning: 6^2 should not be confused with 6 twice or 6 times two. Squaring a number means only one thing — **Multiplying it by itself.**

Example:

$25.2^2 =$

```
  25 2 x 25 2
   25 2
    504
  1260
  504
  635 04
```

So $25.2^2 = 635.04$

Square Root

The square root of a number is found by the opposite process to that for squaring a number That is, the solution will be a number, which, when multiplied by itself, will be equal to the question

Examples:

$\sqrt{36} = 6 \ (6 \times 6 = 36)$

$\sqrt{64} = 8 \ (8 \times 8 = 64)$

Methods of Finding Square Root

1 Using mathematical tables of square roots
2 Using logarithms
3. Using a slide rule
4. The formal method of calculation

FORMAL METHOD OF CALCULATING SQUARE ROOT

Not all numbers will calculate their square root exactly, in which case a decision must be made concerning the number of decimal places required in the answer.

Example:

Find the square root of 77368.2907 correct to 2 decimal places.

There two phases to the task

1 Preparation
2 Calculation

Preparation:

1. Starting at the decimal, arrange the number into **groups of 2 figures** — to the left and to the right:

   $\sqrt{7\ 73\ 68\quad 29\ 07}$

2 Locate the decimal point on the answer line, **directly** above the decimal in the question

   $\sqrt{7\ 73\ 68\ .\ 29\ 07}$

3 Take the extreme left figure (or pair of figures) — in this case 7 What number squared is nearest to 7, but not more than 7?

   Answer 2, since $2^2 = 4$

   This chosen number 2 is the first figure in the answer

   The square of this number is subtracted from the 7

```
   2  .  .      .  .
 √ 7  73 68     29 07
   4
   3
```

   The problem is now ready for the calculation phase Repeated operations will each result in another figure in the answer — each one corresponding to a pair of figures in the question — and should be placed at each • marked above.

Calculation:

```
              2   7   8     1   5
            ------------------------
            7  73  68  .  29  07  00
       (B)  4
            ---
            373
  47        329      (C)   7 x 47     =      329
            ----
            4468
(D)--548    4384           8 x 548    =     4384
            ----
            8429
  5561      5561           1 x 5561   =     5561
            ------
            286807
  55625     278125         5 x 55625  =   278125
            ------
             868200
```

Notes

(A) 4 at the left side is obtained by **doubling** the answer figure A line should be drawn to the right of this 4 in anticipation of the next number being sought

(B) The next number is a trial number of 7 and is to be placed on the answer line, as well as to the right of the 4. The number selected as the trial number, when multiplied (as shown in (C)), results in a number less than the 373 (in this step) from which it is to be subtracted.

(C) Complete the operation of multiplying, entering and subtracting.

(D) Double the total on the answer line (27 x 2 = 54) and enter this product to the left of the next line of operation

(E) Repeat steps (B), (C), (D) In each case find a new trial divisor.

PRACTICAL APPLICATION OF THE RULE OF SQUARES

Demonstration

Figure 3-7 shows two examples of right-angle triangles.

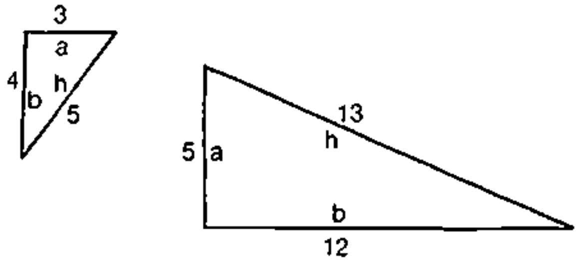
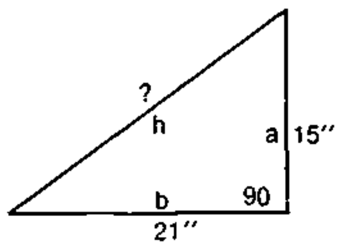


Figure 3-7. Right Angle Triangle

CHECK:	IF	$a^2 + b^2 = h^2$	
	THEN	$3^2 + 4^2 = 5^2$	
	AND	$9 + 16 = 25$	**TRUE**
	IF	$a^2 + b^2 = h^2$	
	THEN	$5^2 + 12^2 = 13^2$	
	AND	$25 + 144 = 169$	**TRUE**

Example 1:



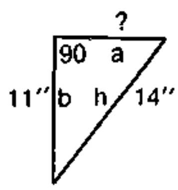
a = 15"
b = 21"
h = ?

Select this formula:

$$h = \sqrt{a^2 + b^2}$$

$$h = \sqrt{15^2 + 21^2}$$
$$= \sqrt{225 + 441}$$
$$= \sqrt{666.0} = 25.807'' \text{ or } 25\ 13/16''$$

Example 2:



a = ?
b = 11"
h = 14"

Use $a = \sqrt{h^2 - b^2}$

So: $a = \sqrt{14^2 - 11^2}$

$$\sqrt{196 - 121} = \sqrt{75}$$
$$= 8.66'' \text{ or } 8\ 21/32''$$

Use of the Rule of Squares to Check Angles

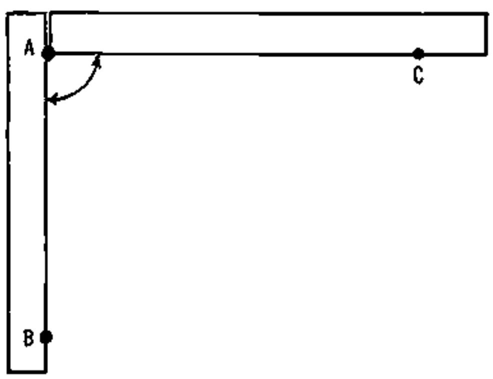
These properties of 90 triangles are sometimes used for making or checking 90 angles. without proper tools.

Dimensions of 3 triangles used for this purpose are

(1) 3. 4. 5
(2) 5. 12. 13
(3) 8. 15. 17

Example:

To check angle between the legs of this joint:



1 Measure from A—B. distance of 3′
2 Measure from A—C. distance of 4′
3 If distance B—C is **EXACTLY** 5′ then you have formed a good 90 joint. If B—C is less than 5′ — angle is less than 90 — if more than 5′ then angle is more than 90 .

THE MATHEMATICS OF VOLUME

The cubic content or capacity of a solid figure is called the **volume**. A **solid** has three dimensions: length. width and height.

COMMON TYPES OF SOLIDS

A **prism** is a solid figure with parallel edges and a uniform cross-section. Right prisms (Figure 3-8) have these edges perpendicular to the base.

A **cylinder** (Figure 3-9) is a Right Prism whose base is a circle.

The volume of any prism or cylinder is determined by multiplying the area of the base by the height.

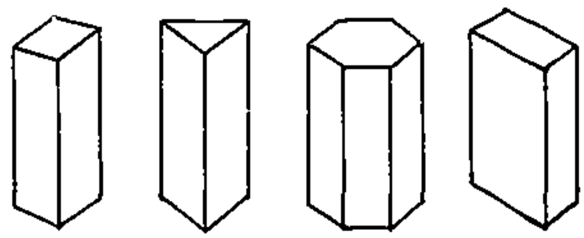


Figure 3-8. Right Prisms

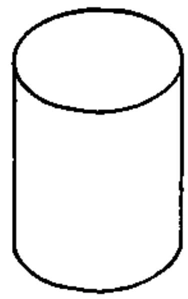


Figure 3-9. Cylinder

Volume = end area x height

End Area = $\frac{\text{volume}}{\text{height}}$

Example 1:

What is the volume of a pan roofed tank with a diameter of 100′ and a height of 40′?

Volume = end area x height
End Area = πR^2
= 3.14 x 50^2
= 7850 sq. ft.
Volume = 7850 sq. ft. x 40′
= 314.000 cu. ft.

Example 2:

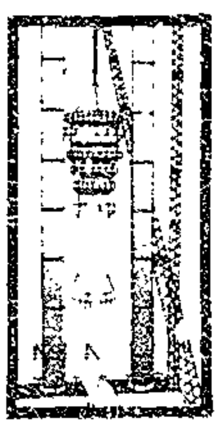
Find the diameter of an oil storage tank with a height restriction of 30′ and a capacity of 2100 cu. ft.

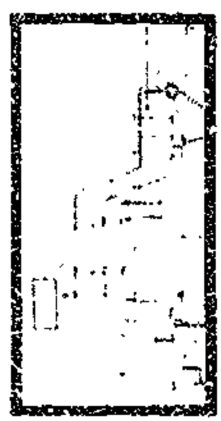
Area = $\frac{\text{volume}}{\text{height}} = \frac{2100 \text{ cu. ft.}}{30 \text{ ft.}}$
= 700 sq. ft.

Diameter = $2\sqrt{\frac{\text{area}}{\pi}}$
= $2\sqrt{\frac{700 \text{ sq. ft.}}{3.14}}$
= $2\sqrt{222.93}$
= 2 x 14.93
= 29.86 ft.

Tank diameter is 29 86 ft.

Chapter 4
MATERIALS, BLUEPRINT READING AND SKETCHING





MATERIAL: SHAPES AND SIZES

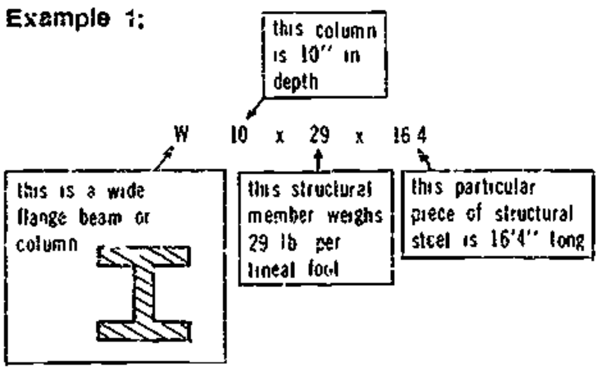
It is essential to have a full understanding of the designations and symbols that specify the shapes and sizes in which material is available. (Figures 4-1, 4-2 and 4-3 and Table 4-1). There is a prescribed sequence for representing the type, dimensions and weight of structural members.

Recently Boilermakers adopted a new system of symbols for structural shapes to conform with the Canadian and American Institutes of Steel Construction These new symbols are standard for the steel producing and fabricating industries and should be used in all references to shapes including ordering, cutting and fabricating.

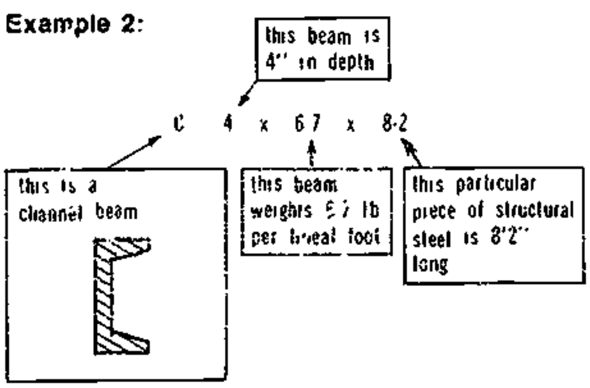
DESIGNATION FORMAT

For beams and channels, the letter(s) at the beginning represent the type of structural member (welded wide flange, standard beam, miscellaneous channel). The first number following the symbol indicates nominal depth of the item and the second number specifies weight per lineal foot A final number can be added to indicate overall length of a particular piece of material.

Example 1:

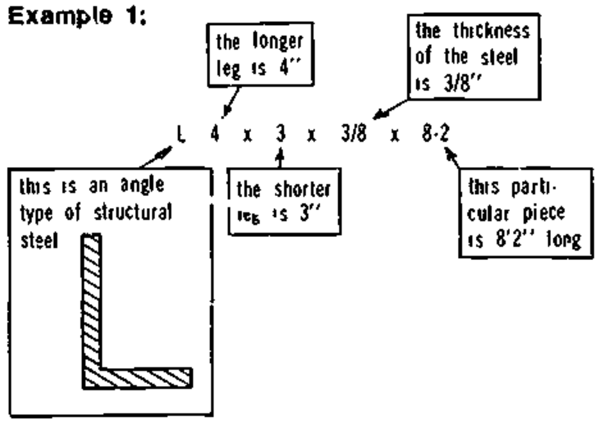


Example 2:



For angles, flat bar and plate, dimensions are always given in this order: symbol, width, thickness and length. Since angles have two width (legs), the longest is shown first in the case of unequal legs.

Example 1:



Example 2:

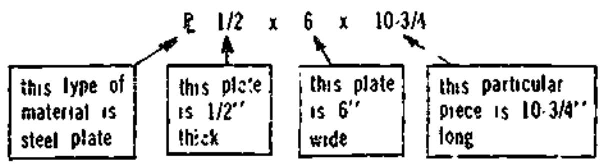


Table 4-2 shows the common structural members using the new designation (imperial measure), the new designation (metric), the type of shape represented and the old designation for reference only.

STANDARDS AND IDENTIFICATION

The Boilermaker must have a precise knowledge of steel and its specifications to appreciate the importance of having the right grade of material for each job. In North America a number of agencies determine material standards:

C.S.A.	— Canadian Standards Association
C.G.S.B.	— Canadian Government Specification Board
A.S.T.M.	— American Society for Testing Metals
A.N.S.	— American National Standards
S.S.P.C.	— Steel Structures Painting Council

TABLE 4-1. MATERIAL AND BLUEPRINT SYMBOLS AND ABBREVIATIONS

STRUCTURAL ABBREVIATIONS

AR PL	Abrasive Resistance PL (Plate)
Ls	Angles
CHK PL	Checker PL (Plate)
C H S	Circular Hollow Section
WWC	Columns (welded)
F B	Flat Bar
HP	Bearing (Loose Tolerances)
J B M	Junior Beam
L B M	Light Beam
PLs	Plates
WWR	Reduced Webs (Welded)
∅	Round Bar
S	Standard Beam
C	Standard Channel
WWS	Standard Webs (Welded)
$\boxed{\emptyset}$	Square Bar
T	Tee Bar (cut from W-I)
WWT	Thin Webs
W	Wide Flange

MISCELLANEOUS SYMBOLS & ABBREVIATIONS

ABT	about
@	at
ABUT	abutment
ADN	addition
ADJ	adjacent to
A I S C	American Institute of Steel Construction
A P I	American Petroleum Institute
APP	approved
APPROX	approximately
A S C E	American Society of Civil Engineers
ASSEM	assembly
A S M E	American Society of Mechanical Engineers
ASSOC	associates
A S T M	American Society for Testing Materials
AUX	auxiliary
A W G	American Wire gauge
A W S	American Welding Society
B B or B/B	back to back
B C	bolt circle
BEV	bevel
B E or B/E	both ends
B L	base line, building line or bend line
BLDG	building
BM	beam
B M	benchmark
B/M	bill of material
BOTT	bottom
B P	base plate
B/P	blueprint
BR	brace
BRKT	bracket
B.S.	both sides
C C	centre to centre
C G S B	Canadian Government Specification Board
C I S C	Canadian Institute of Steel Construction
CK. PL	checkered (floor) plate
CL	clearance
℄ or C/L	centre line
CM.	centimetre
COL.	column
CONN	connection
CONST	construction
C R.	cold rolled
C S.A.	Canadian Standards Association
CSK	countersunk
CU	cubic
C W.	complete with
C.W B	Canadian Welding Bureau
CYL	cylinder
DET	detail
DIA.	diameter
DIAG	diagonal
DIAPH	diaphragm
DIM.	dimension
◇S	direction mark
DIV	division
DO.	ditto (same)
DUP.	duplicate
DWG.	drawing

E	east
EA	each
E F	each face
E H	end hole
EL or ELEV	elevation
EQ	equal
EQUIP	equipment
EST	estimated
E.W	each way
EXP	expansion
EXT	exterior
FAB	fabricate
F B	flat bar
FDN.	foundation
F2/E	face 2 ends
F F	finished floor or surface
FIN	finished
FL	floor
FLG.	flange
F O B.	free on board
FR	frame
F S.	far side
FT.	feet
FTG	footing
FW	falsework
GA.	gauge
GAL.	galvanized
GDR or GIRD	girder
G.O L.) / G.O.S L.)	gauge outstanding leg
G O S	gauge outstanding side
GR	grade
HD	head
H.D.	heavy duty
HEX	hexagon
13/16 ⌀ (2cm ⌀)	-hole size (round)
13/16 ⧄ (2cm ⧄)	-hole size (square)
HOR.	horizontal
H.R	hot rolled
HT.	height
H T.	High tensile

I.D.	inside diameter
I F	inside face
IN	inches
INCL.	include/inclusive
INT.	interior
I/S	inside
J	joist
JR.	junior (lightweight beams or channels)
Kips.	kilo pounds
K.P.	kick plate
L	left
LAT.	lateral
L.B.	light beam
LBS.	pounds
LG.	long
L H.	left hand
Lin. ft.	linear feet
L O.	layout
L O.A.	length overall
LONG	Longitudinal
LT.	light
MACH.	machine
MATL.	material
MAX.	maximum
M B.	machine bolt
MIN.	minimum
MISC.	miscellaneous
MK.	mark
MM.	millimetre
M S.	mild steel
N.	North
N.A.	neutral axis
N.C.	national course
N F.	national fine or near face
N.L.	nosing line
NO.	number
NOM.	nominal
N.P.	no paint
N.P.T.	national pipe thread
N.S.	near side
N.T.S.	not to scale

(continued)

TABLE 4-1. MATERIAL AND BLUEPRINT SYMBOLS AND ABBREVIATIONS (continued)

O C or C/C	on centre
O D	outside diameter
O F	outside face
O O or O/O	out to out
OPG	opening
OPP	opposite
OPP H	opposite hand
ORN	ornamental
O/S	outside
O S L	outstanding leg
PAT	pattern
PCS	pieces
PL or Pl	plate
PROJ	project/projection
P S I	pounds per square inch
R	right/radius
RAD	radius
RD	round
R D	running dimension
REF	reference
REQ'D	required
REV or △1	revision
R F	ring fill
R H	right hand
RIV	rivet
RM	ream
R P	reference point
S	South
S A	submerged arc
S A E	Society of American Engineers
Sch	schedule
SEC. or SECT	section
S H S	submerge hollow section
SPA.	space
SPCS	spaces
SPEC. or SPECS	specifications
SPL	splice
Sq or SQ	square
SQ2/E	square 2 ends
S R	sag rod
S S P.C	Steel Structures Painting Council
St or STR	Straight
STD	standard
STIFF	stiffeners
STRUCT	structural
SUP'T.	support
SYM.	symmetrical
T	top
TEMP.	template/temperature
THD.	thread
THK	thick
TOL	tolerance
TD	tread
T W.	tack weld
TYP	typical
U/N	unless noted
VERT	vertical
W	west
W D	working drawing
W L	working line
W P	work point/wear plate
WT	weight

Symbols and abbreviations for structural shapes are given in Figure 4-1. Figure 4-2 shows the components of structural shapes, and Figure 4-3, structural members.

GRADES FOR STRUCTURAL STEEL, BOLTS, AND ELECTRODES

Below is a representative sampling of some steel products used in Boilermaking, indicating the standardizing agency and grade [illegible] with an accompanying description of the product

Structural Steel

CSA G40.8 Structural Steels with improved resistance to Brittle Fracture

CSA G40.11 High Strength Low-Alloy Atmospheric Corrosion Resisting Steel

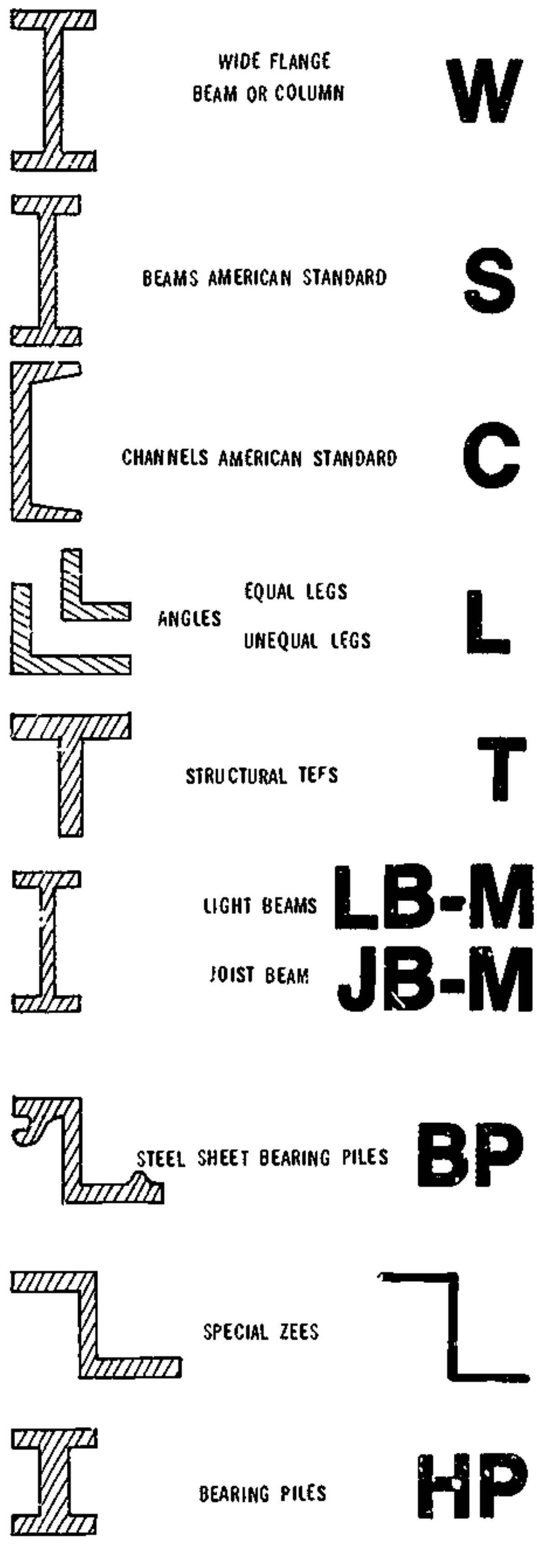


Figure 4-1. Symbols and Abbreviations for Structural Shapes

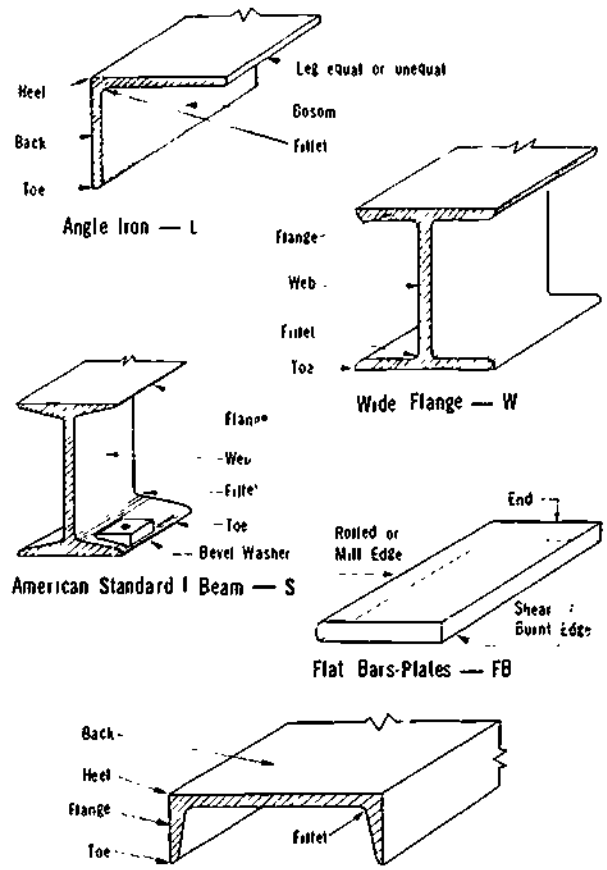


Figure 4-2. Components of Structural Beams, Bars, Plates, Angles and Channel Shapes

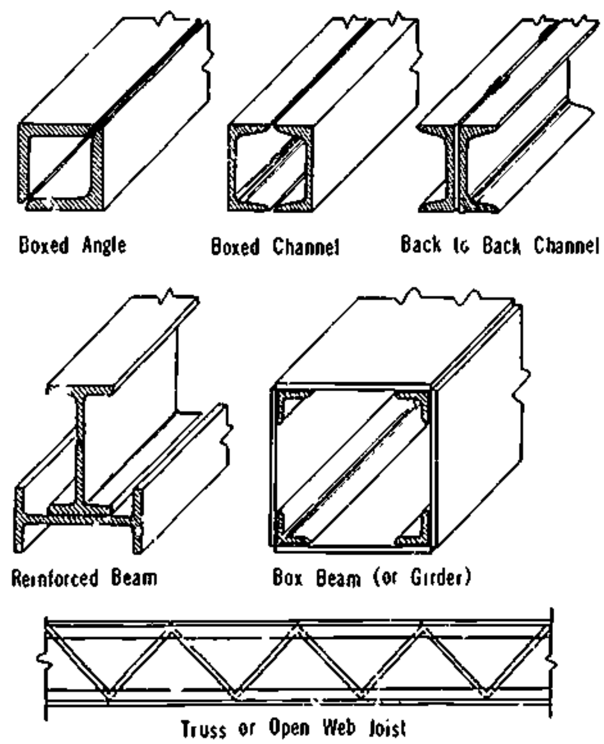


Figure 4-3. Structural Members

TABLE 4-2. COMMON STRUCTURAL MEMBERS

NEW DESIGNATION (IMPERIAL)	DESIGNATION (METRIC)	TYPE OF SHAPE	OLD DESIGNATION
W 24 x 76	W 61 cm x 34 5 kg	W shape — Wide Flange	24 WF 76
W 14 x 26	W 35 5 cm x 11 9 kg	W shape	14 B 26
S 24 x 100	S 61 cm x 45 36 kg	S shape — American STD Beam	24 I 100
M 8 x 18 5	M 20 cm x 8.39 kg	M shape — Miscellaneous	8 M 18 5
M 10 x 9	M 25 cm x 4 kg	M shape	10 Jr 9 0
M 8 x 34 3	M 20 cm x 15.6 kg	M shape	8 x 8 M 34.3
C 12 x 20.7	C 30.5 cm x 9 4 kg	American Standard Channel	12 c 20 7
MC 12 x 45	MC 30.5 cm x 20 4 kg	Miscellaneous Channel	12 x 4 C 45.0
MC 12 x 10 6	MC 30.5 cm x 4.8 kg	Miscellaneous Channel	12 JR C 10.6
HP 14 x 73	HP 35.5 cm x 33 kg	HP Shape (Bearing Pile)	14 BP 73
L 6 x 6 x 3/4	L 15.2 x 15.2 x 1.9 cm	Equal leg angle	L 6 x 6 x 3/4
L 6 x 4 x 5/8	L 15.2 x 10.2 x 1 6 cm	Unequal leg angle	L 6 x 4 x 5/8
WT 12 x 38	WT 30 5 cm x 17.24 kg	Structural Tee cut from W Shape	ST 12 WF 38
WT 7 x 13	WT 17.8 cm x 6 kg	Structural Tee cut from W Shape	ST 7 B 13
ST 12 x 50	ST 30.5 cm x 22.7 kg	Structural Tee cut from S Shape	ST 12 I 50
MT 4 x 9 25	MT 10.2 cm x 4 2 kg	Structural Tee cut from M Shape	ST 4 M 9.25
MT 5 x 4 5	MT 12 7 cm x 2 kg	Structural Tee cut from M Shape	ST 5 JR 4.5
MT 4 x 17 5	MT 10.2 cm x 8 kg	Structural Tee cut from M Shape	ST 4 M 17.5
WW 30 x 198	WW 75 cm x 90 kg	Welded Wide Flange	30 WWF 198
WWT 15 x 99	WWT 37.5 cm x 45 kg	Tee cut from Welded Wide Flange	ST 15 WWF 99
℞ 1/2 x 18	℞ 1.2 x 45.7 cm	Plate	℞ 18 x 1/2
BAR 1 Sq ◫	BAR 2 54 cm Sq. ◫	Square Bar	BAR 1 SQ.
BAR 1 Hex.	BAR 2.54 cm Hex.	Hexagon (Cold Rolled)	BAR 1 Hex.
BAR 1 1/4 RD	BAR ∅ 3.2 cm	Round Bar	BAR 1 1/4 RD.
BAR 2 1/2 x 1/2 F.B	BAR 6.3 x 1.2 cm	Flat Bar	Flats 2 1/2 x 1/2

TABLE 4-3. HOT ROLLED STRUCTURAL STEEL

NEW DESIGNATION (IMPERIAL)	NEW DESIGNATION (METRIC)	TYPE OF SHAPE	OLD DESIGNATION
Pipe 4 STD	PIPE 10.15 cm	Pipe Standard	Pipe 4 STD
Pipe 4 x -Strong	PIPE 10.15 cm x -Strong	Pipe 4 Extra Strong	Pipe 4 x -Strong
Pipe 4 xx -Strong	PIPE 10.15 cm xx -Strong	Pipe 4 Double Extra Strong	Pipe 4 xx -Strong
HSS 4 x 4 x .375 x 16.8	HSS 10.15 x 10.15 x 1 cm x 7.6 kg	Hollow Structural Tubing: SQ	Tube 4 x 4 x .375
HSS 5 x 3 x .375 x 16.8	HSS 12 7 x 7.6 x 1 cm x 7.6 kg	Hollow Structural Tubing: Rectangular	Tube 5 x 3 x .375
HSS 3 1/2 OD x .25 x 8.68	HSS 8.9 OD x .6 x 4 kg	Hollow Structural Tubing: Circular	Tube 3 1/2 OD x .25

CSA G40.12 General Purpose structural steel controlled chemistry provides good weldability in all thicknesses
Note: No Cold Water Quenching when Flame straightening or shrinking procedure is applied.

CSA G40.13 Structural Steel Welded Shapes

CSA G40.16 Hot-Formed Welded or Seamless Hollow Structural Sections

CSA G40.17 Cold-Formed Welded or Seamless Hollow Structural Sections

ASTM A36 Structural Steel

ASTM A242 High Strength Low-Alloy Structural Steel

ASTM A440 High Strength Structural Steel

ASTM A441 High Strength Low-Alloy Structural Manganese Vanadium Steel

ASTM A514 High-Yield Strength. Quenched and Tempered Alloy-Steel Plate. Suitable for Welding

Bolts

ASTM A307 Low-Carbon Steel (commonly called Mild Steel Bolts)

ASTM A325 High Strength Steel Bolts for Structural Steel. Joints including suitable Nuts and Plain Hardened Washers

ASTM A490 Quenched and Tempered alloy. Steel Bolts — Nut and Washers for Structural Steel Joints

Welding Electrodes

CSA W48.1 Mild Steel Covered Arc-Welding Electrodes

CSA W48.3 Low-Alloy Steel Arc-Welding Electrodes

CSA W48.4 Solid Mild Steel Electrodes for Gas Metal-Arc Welding

CSA W48.5 Mild Steel Electrodes for Flux Cored Arc Welding

CSA W48.6 Bare Mild Steel Electrodes and Fluxes for Submerged Arc Welding
Note: Further information on Standard and Identification is covered under Quality Control

BLUEPRINT READING

The unique advantage of drawings is that they promote visualizing objects. To visualize an object is to "see" a complete mental picture of it: what it is, how it goes together and all details connected with it.

Drawings are valuable only so far as the tradesman takes a cautious and precise approach to interpreting them. He can take nothing for granted and must be certain of all details before proceeding with the work. Errors are more likely to occur on simple jobs because a more complicated detail forces closer attention to what is required. Always study a drawing carefully. Even an experienced engineer would not glance at a drawing and start to work from it.

TITLE BLOCK

The first element to examine in a drawing is the title block (Figure 4-4). This is normally placed in the bottom right hand corner on all finished drawings. It contains a number of important items of preliminary information concerning the project including:

Page Number On the drawings in the Boilermaking trade the page number of a blueprint is sometimes preceded by an E. as E1, E2, etc. In this case the E stands for erection print. On drawings not preceded by E, it will usually be a detail or miscellaneous iron print.

Division Number This usually indicates a part of a large job. Because there is a need for a workable system to maintain fabrication, shipping and erection schedules on large jobs, they are broken down into parts and given a division connotation. Division is usually abbreviated as Div-3 or Div-6, etc.

Scale The scale will be indicated as 1/4"-1"-0" or simply 1/4". In any case the scale will always use one foot as the reference, unless otherwise noted.

Unit or Structure This is usually indicated by large letters and will describe the kind of unit to be erected such as, Plant, Office, Bridge, Addition, Steel Mill, etc.

Job Number or Order Number Most fabricators and erectors use these as a kind of shorthand to identify a certain job or order.

Customer or Owner

Architect

Draftsman This is indicated by the draftsman's initials.

REVISIONS	MADE BY	CHK'D BY	DATE	ZONE	REVISION LETTER
DEMISTER LOCN ADDED ADDED in h 2 4 PIPE FOR 8' ONLY	CAH	Jml	oct 23'72		B
APPROVAL REVISIONS DETAIL "C" REV.	LA	Jml	AUG 3/72		A

DOMINION BRIDGE COMPANY LIMITED — Vancouver, B.C.

DRAWN LA JULY 14/72	PROPRIETOR IMPERIAL OIL LTD.	CONTRACT No. P1420
CHECKED Jim Bu/7/72	PURCHASER FISH ENGINEERING & CONST.	
SQUAD 270 WB	DESCRIPTION 120"I/D × 30'-0 SEAM TO SEAM	DRAWING No.
MAT'L ON LOOSE BILL No. /a	SWAN HILLS INLET SEPARATOR-ITEM# V1402 GENERAL ARRANGEMENT AND DETAILS	1

Figure 4-4. Sample Title Block

Revisions Most drawings are revised before fabrication or erection, some as many as six times before final approval. Usually the date of revision is listed along with the draftsman's initial.

Specifications For every unit or structure, the architect draws up a list of specifications that all contractors must follow. The specifications describe minimum standards for materials and labour. Sometimes they will specify the type of material to be used and some of these "specs" might appear in the title block, for example, bolt sizes, type of paint, type of weld, boiler code, pressures, etc.

Number of Prints Issued

Project Some people refer to a job as a project; however, it is inappropriate to define a simple job involving one small unit as a project. Technically the term "project" is used to define a large job with at least one large unit.

TYPES OF DRAWINGS

ISOMETRIC DRAWING

An object can be represented in several different ways. Pictorial drawings show an object as it appears to the eye with all three dimensions included in the one view. Two types of pictorial drawings are in common use, **ISOMETRIC** (Figure 4-5) AND **OBLIQUE**. These are fully described in the section on "Sketching," pp. 90-94.

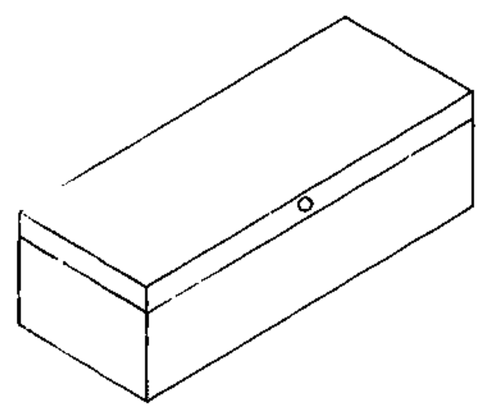


Figure 4-5. Isometric Drawing

ORTHOGRAPHIC DRAWING

The most functional type of drawing for communicating exact specifications and instructions for fabrication and erection is the **orthographic** drawing. This type of drawing is able to represent the exact shape of an object with its three dimensions (length, height and width) on a two dimensional sheet of paper. This multiview system shows all views (projections) separately the front elevation, the side elevation and the plan view (top view). Figure 4-6 is an orthographic drawing of the same object shown previously as an isometric drawing (Figure 4-5).

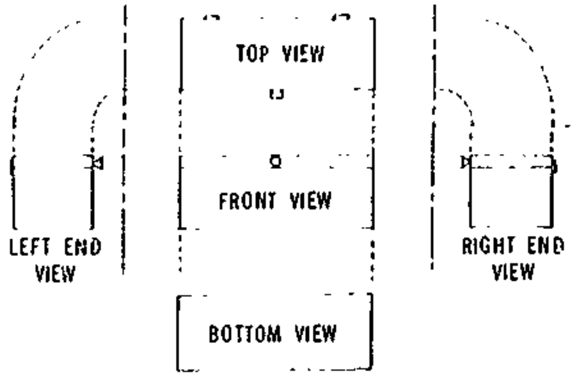


Figure 4-6. Orthographic Projection Drawing

AUXILIARY VIEWS

Lines and conventional forms are used to make orthographic drawings of odd-shaped objects that cannot be shown clearly by means of conventional views, for example, objects with inclined surfaces. To present the true shapes of these surfaces accurately, special views known as auxiliary views are required. The principle of auxiliary views is shown in Figure 4-7. Figure 4-8 illustrates three types of auxiliary views. Further auxiliary views are given in Figures 4-9 to 4-11.

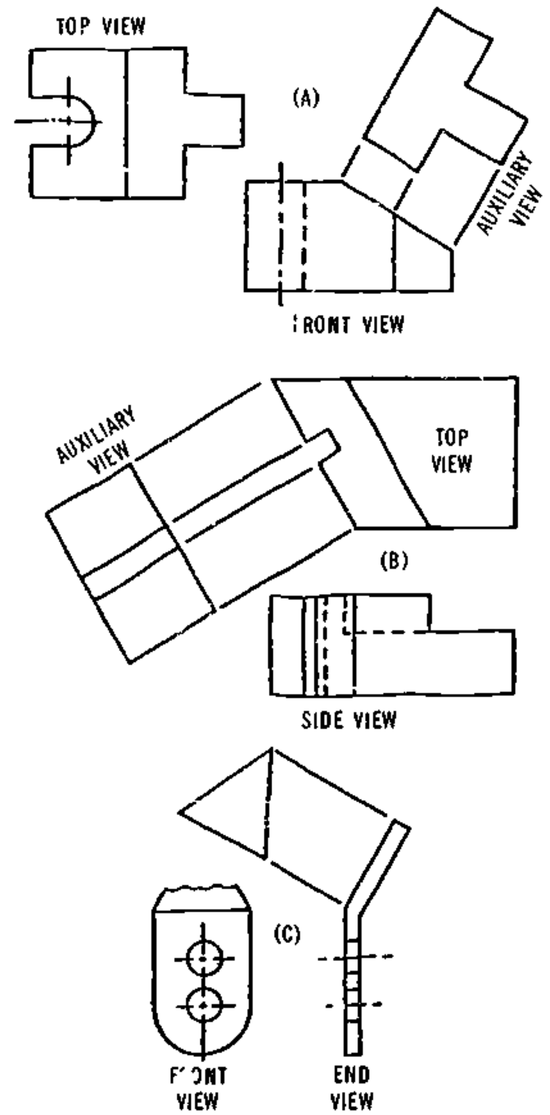


Figure 4-8. Three Types of Auxiliary Views

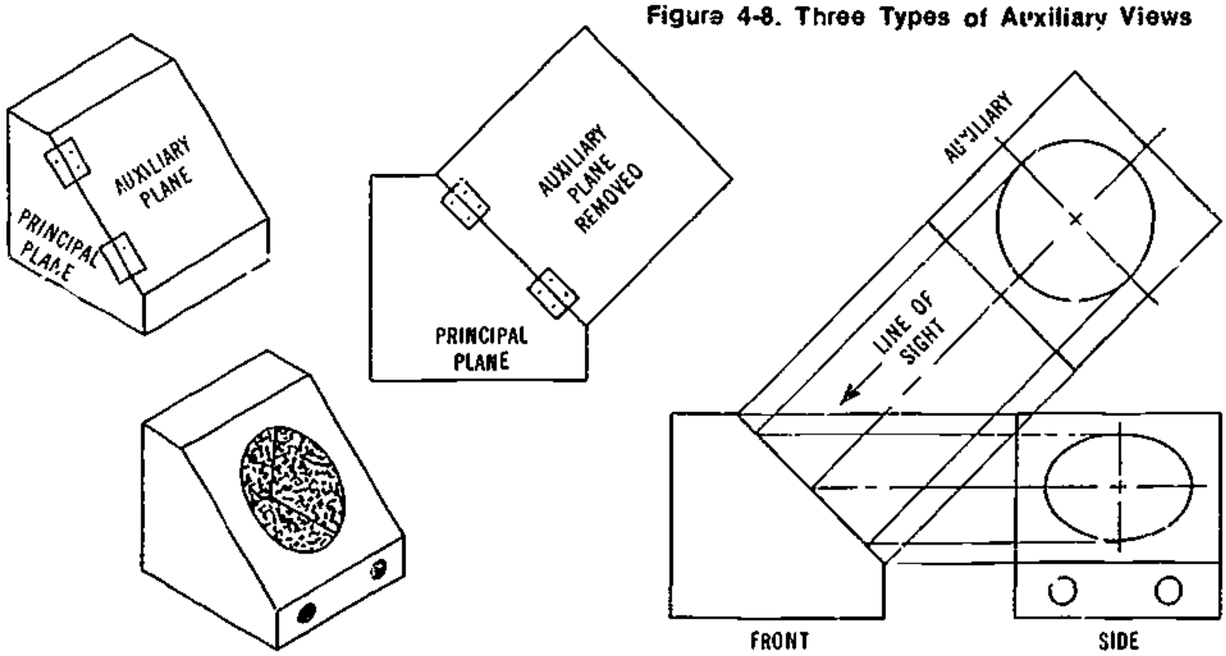


Figure 4-7. Auxiliary View Drawing

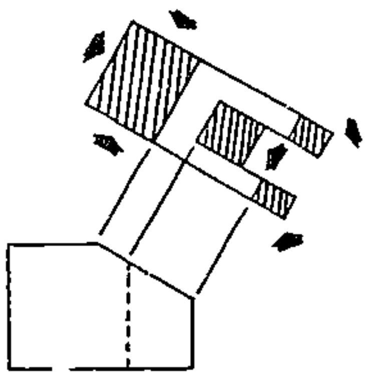


Figure 4-9. An Auxiliary View Includes Only the Outline of the Slanted Part

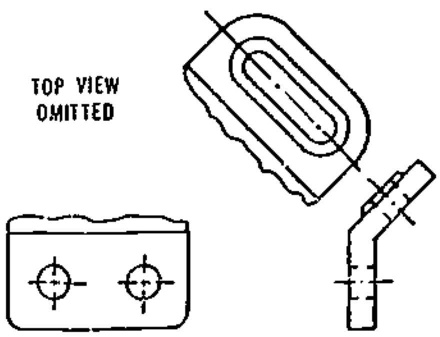


Figure 4-10. Auxiliary Sometimes Eliminates the Need for a Principal View

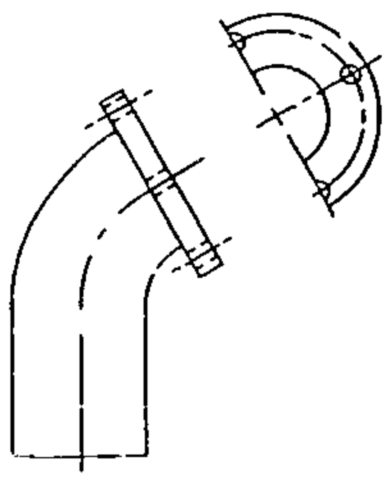


Figure 4-11. How a Symmetrical Auxiliary View Is Shown

SECTIONAL VIEWS

When the fabricator or erector must know what the inside or hidden part of an object or structure looks like, sectional views are drawn which provide all the necessary information without cluttering the principal view with numerous hidden lines. The sectional view assumes that a section of the object has been cut off by an imaginary plane and removed (Figure 4-12).

The large arrowheads in Figure 4-13 point to the direction of sight in which the object is viewed after the cut has been made. Capital letters are placed either before or behind the arrowheads. A notation is also used under the sectional view, e.g., section A-A or SECT. A-A.

Figure 4-14 illustrates different types of sectional views.

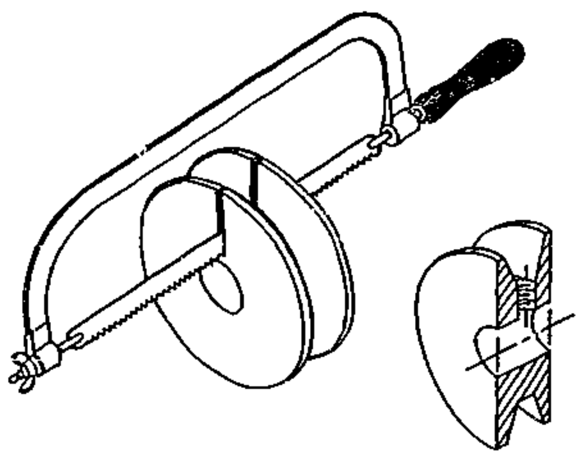


Figure 4-12. Obtaining a Sectional View

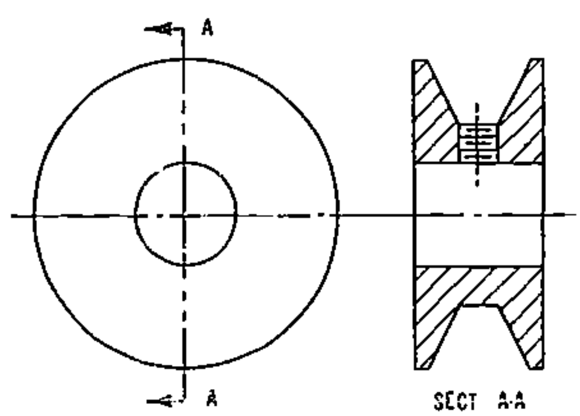


Figure 4-13. How Sectional Views are Represented

EXPLODED DRAWING

Sometimes it is necessary to know what is inside an object and how the interior parts are assembled. For this purpose the exploded drawing is used. This drawing shows all of the components pictorially in an arrangement illustrating the relationships between them (Figure 4-15)

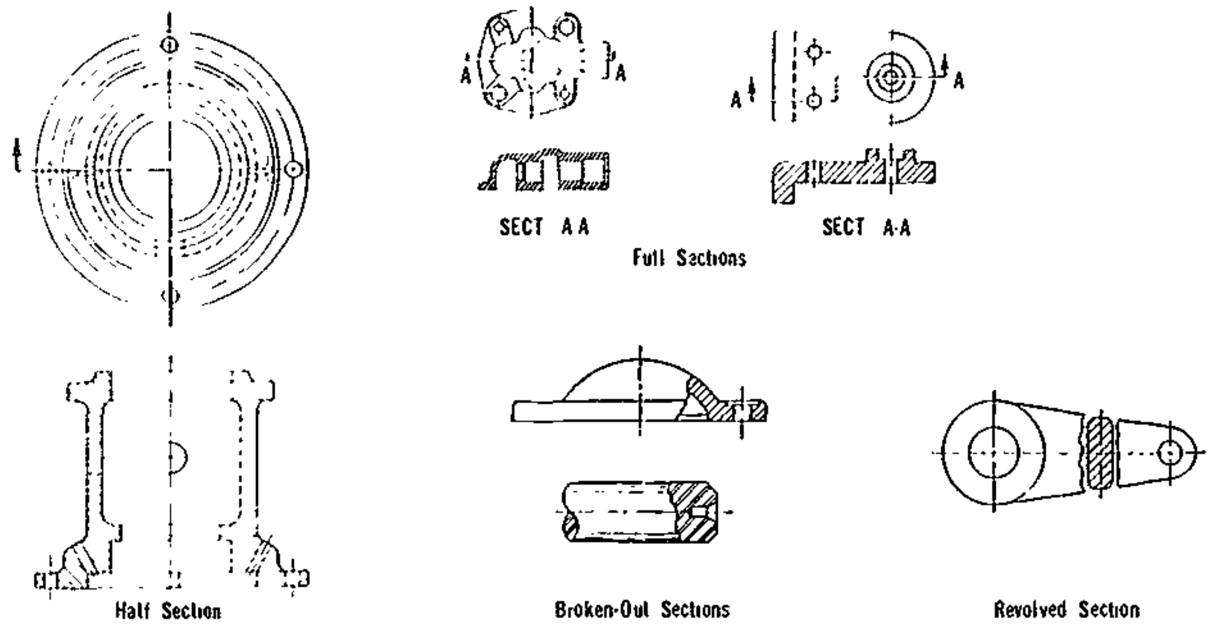


Figure 4-14. Various Types of Sectional Views

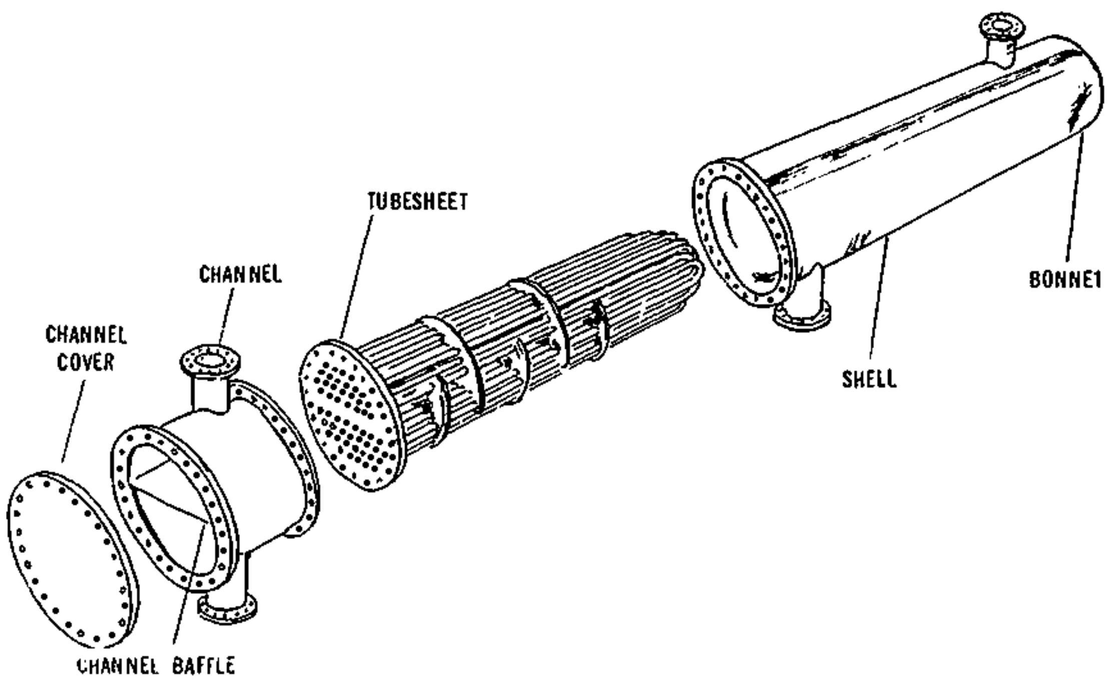


Figure 4-15. Exploded Drawing of a Heat Exchanger

THE LANGUAGE OF DRAWINGS

There are four basic components in a drawing or print:

1. Lines
2. Dimensions
3. Abbreviations and symbols
4. Notes.

LINES

Lines show the shape of an object. Many different lines are used on a print and each has a specific meaning. The types and meanings of drafting lines on structural drawings are described in Figure 4-25 (see page 87)

Circles on a drawing may show centre lines as well as diameter measurements. If centre lines are drawn, the short dash of each will intersect at the centre of the circle and the diameter is indicated outside the circle (Figure 4-16).

A circle without centre lines will have the diameter measurement inside the circle (Figure 4-17).

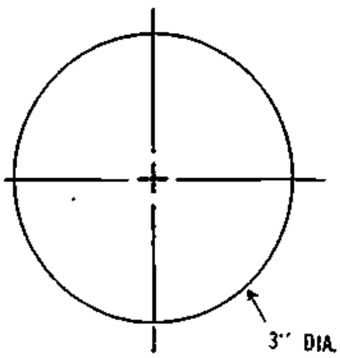


Figure 4-16.

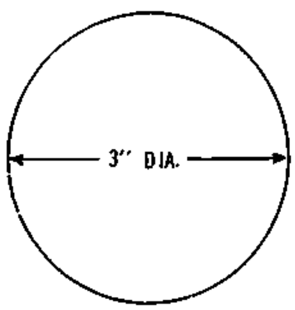


Figure 4-17.

The radius of an arc is specified in Figure 4-18.

The size of an angle is indicated with dimension lines inside or outside the angle depending upon the constraints of space as shown in Figure 4-19.

Arrows on drawings always have a slender, solid head for precision (Figure 4-20).

Figure 4-18.

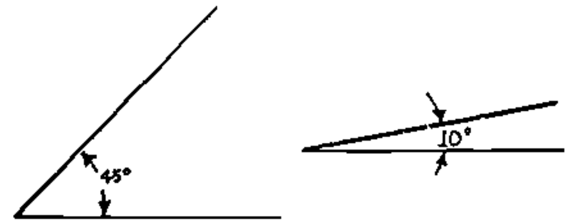


Figure 4-19.

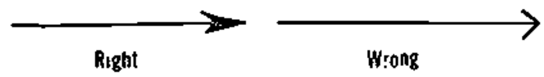


Figure 4-20.

Figure 4-21 illustrates conventional forms for representing structural members using combinations of lines on a drawing.

A structural drawing showing the use of lines and conventional forms is illustrated in Figure 4-22.

DIMENSIONS

The exact finished size of the object is specified by the dimensions. Extreme care must be taken in reading dimensions.

ABBREVIATIONS AND SYMBOLS

Many forms of abbreviations and symbols are used by the draftsman to minimize crowding and confusion on drawings. Figure 4-21 shows the way in which some structural members may be represented on a print.

NOTES

Notes are special instructions that cannot be communicated by means of the lines, dimensions or symbols on the drawing. They may appear anywhere on the drawing(s), grouped as a list or scattered in locations where they apply. Notes can be divided into two main categories:

1. Shop Notes — instructions or specifications to be followed by the shop when fabricating members or units. Figure 4-23 shows a list of Shop Notes
2. Erection Notes — are special instructions that apply to the erecting procedure. Figure 4-24 shows an example of Erection Notes.

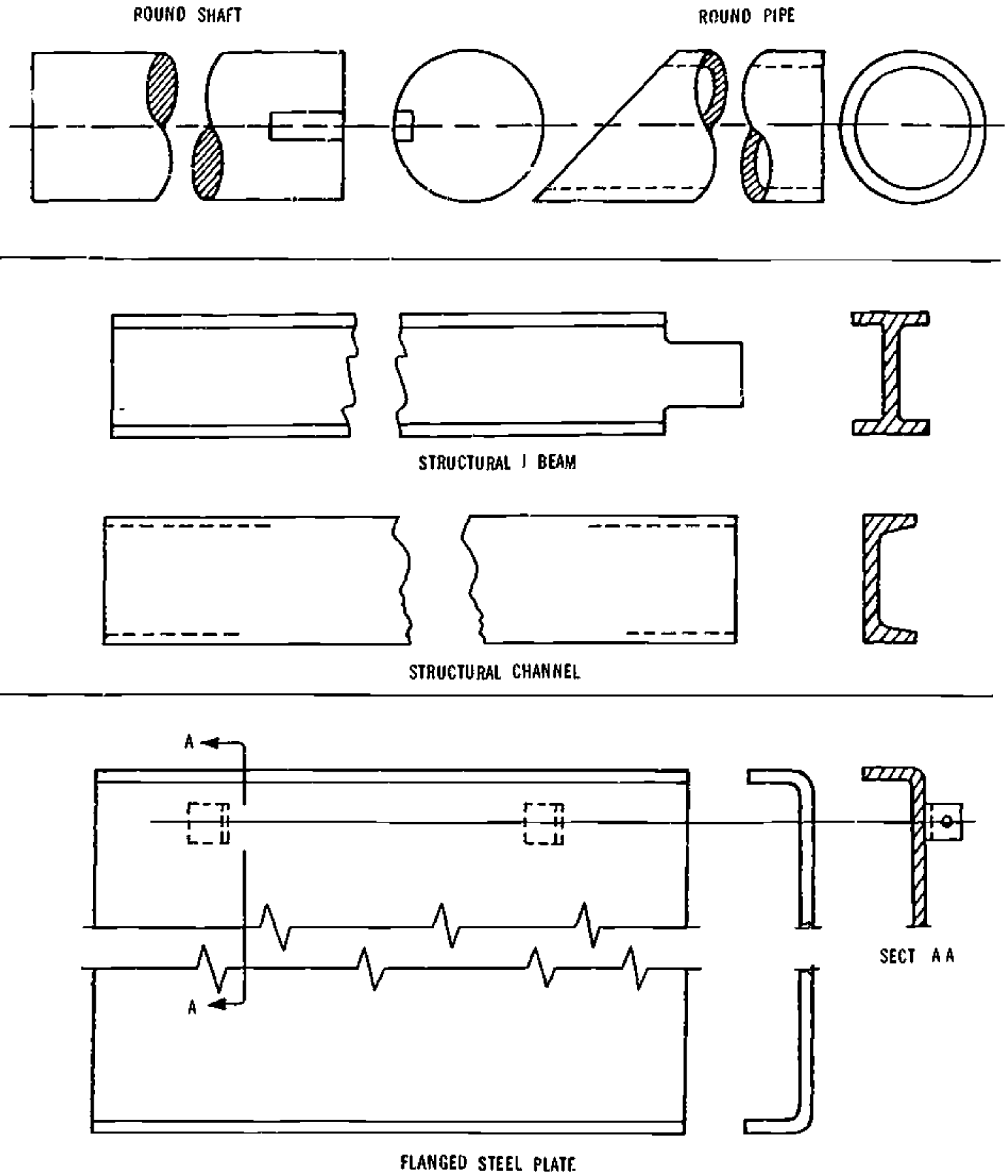


Figure 4-21. Conventional Forms for Representing Structural Members on a Drawing

HOW TO USE ORTHOGRAPHIC DRAWINGS

The orthographic projection technique is used in the following types of drawings:

1. General Arrangement Drawing
2. Shop or Fabrication Drawing
3. Detail Drawing
4. Miscellaneous Drawing
5. Working Drawing
6. Erection Drawing.

The General Arrangement drawing is the master plan that describes the construction of the entire building or structure including the masonry, steel, ventilation system and other aspects. In-

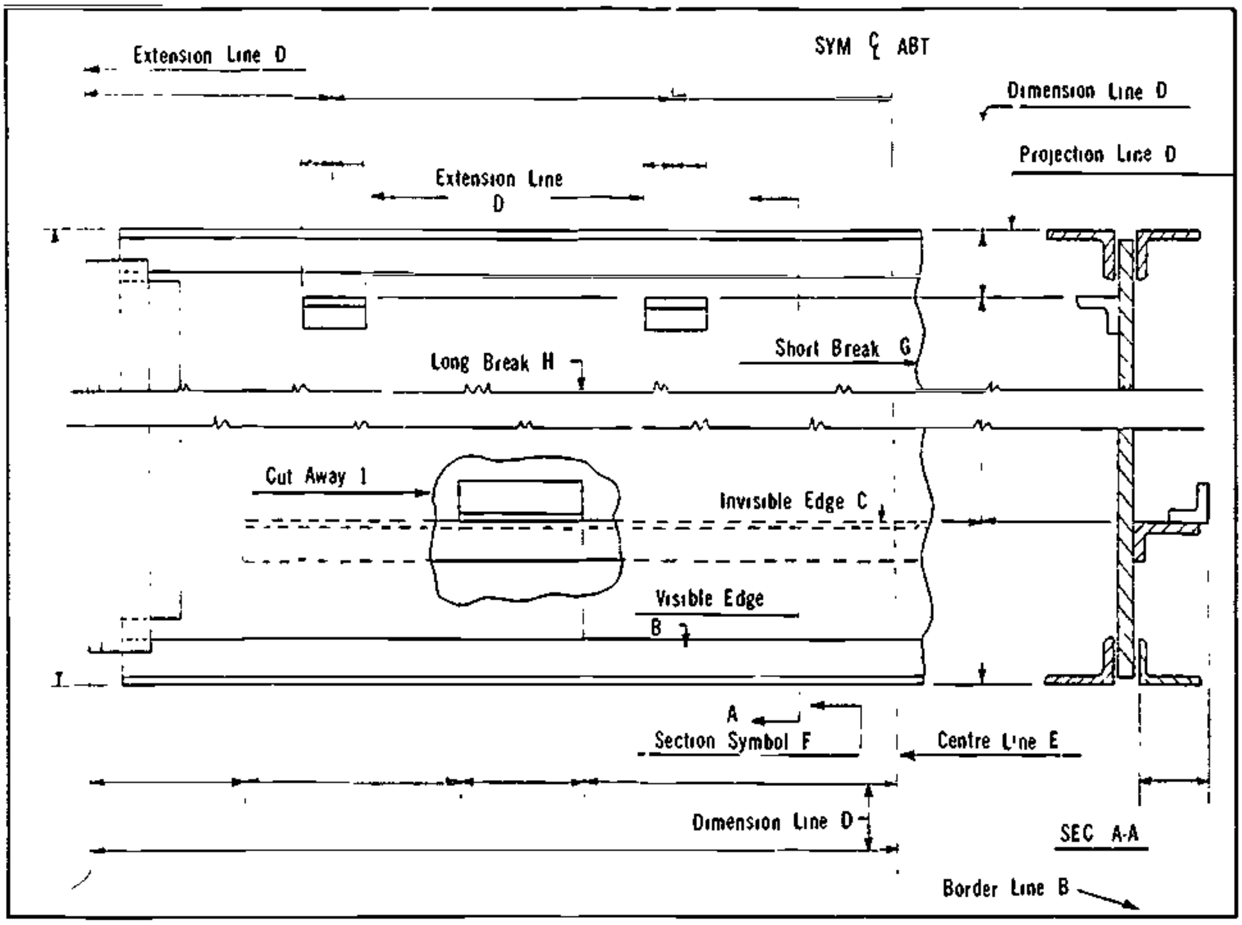


Figure 4-22. Use of Conventional Lines on a Structural Drawing

NOTES

1. ALL BOLT HOLES TO STRADDLE CENTRE LINES OF VESSEL.
2. ALL NOZZLE REINFORCING PADS TO HAVE 1/4 NPT TELL-TALE HOLE ON MEAN PAD CIRCUMFERENCE AND GIRTH LINE OF VESSEL.
3. INSIDE EDGES OF NOZZLES TO BE ROUNDED WITH 1/8 RADIUS.
4. ALL TAIL DIMENSIONS ARE FROM REFERENCE LINE.

PUNCH MARK I/S & O/S 3" FROM SEAM LINE

Figure 4-23. List of Shop Notes

GENERAL NOTES:

- SHRINKAGE ALLOWANCE, EQUAL TO GAP, ADDED TO SHELL PL LENGTHS

FOUNDATION - BY OTHERS
ERECTION - BY CHICAGO BRIDGE & IRON COMPANY
SERVICE - PUMP OUT TANK
CAPACITY - 80,000 GALLONS
SPECIFICATION - API 650 & CUST
STEEL - PLATES A283-C STRUCTURAL A36
INSPECTION - MILL - CTR'S
- SHOP - YES BY CUST
- FIELD - YES BY CUST
CLEANING - SEE P SHEETS
PAINTING - YES, SEE P SHEETS
FITTINGS - TO BE LOCATED AS SHOWN OR TO SUIT CUSTOMER IN FIELD EDGES OF ADJACENT REINFORCING PLATES MUST BE AT LEAST 6" APART NOZZLE BOLT HOLES TO STRADDLE VERTICAL AND RADIAL CENTERLINES
CORROSION ALLOWANCE - SHELL & ROOF 1/16" BOTTOM 1/32"

Figure 4-24. Sample Erection Notes

structions for all trades are taken from this master blueprint by transferring the information to their own drawings. Wherever possible, individual trade drawings eliminate all but those parts of a structure that are necessary for the fabrication and erection of their own work. Accordingly, this section presents only that in-

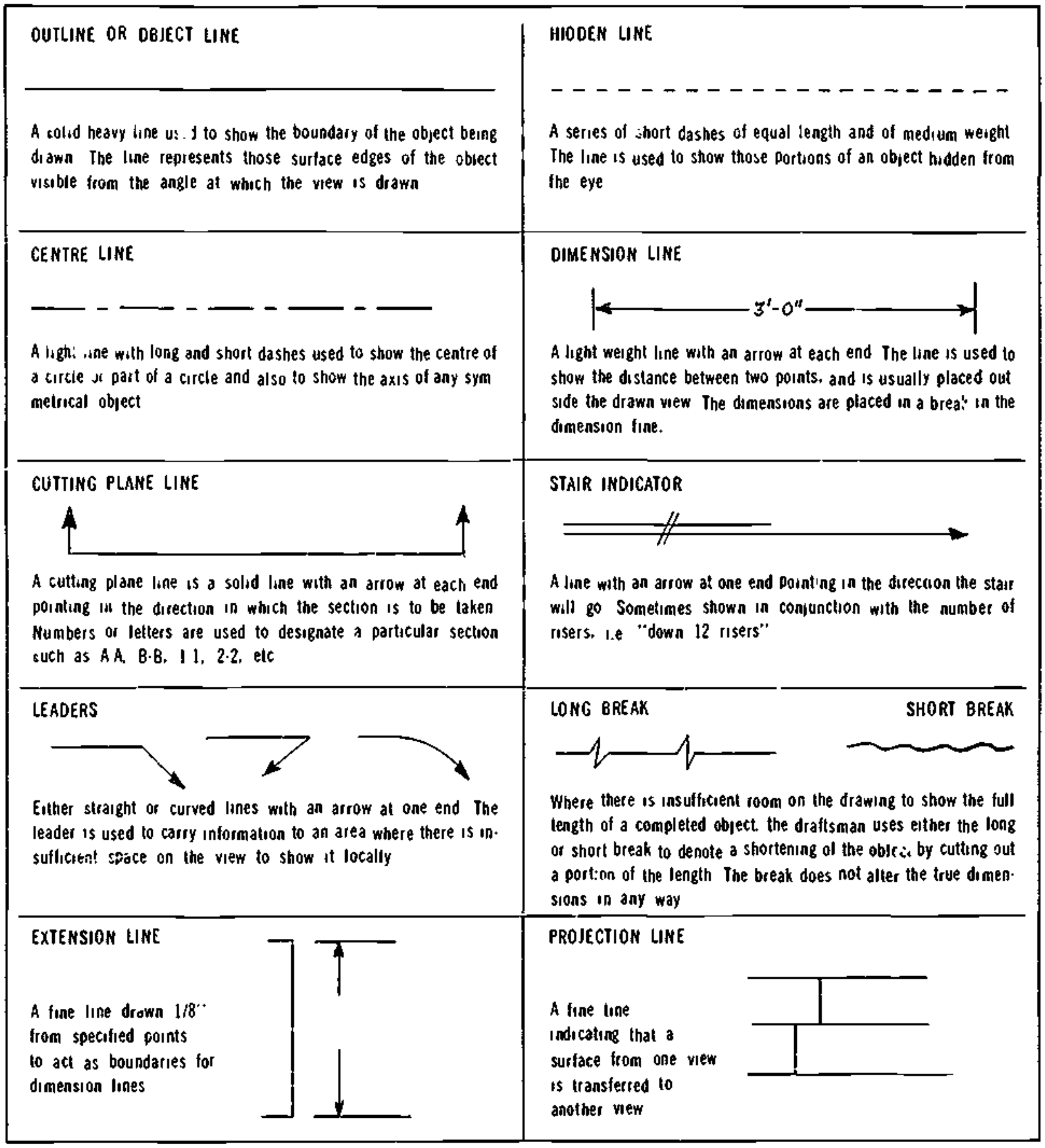


Figure 4-25. Lines Used on Structural Drawings

formation relevant to Boilermaking functions. Increased skill in reading the General Arrangement drawing, however, will produce a clearer understanding of the drawings and functions of other trades.

From the General Arrangement drawing, the engineering and drafting office prepares Detail drawings or sketches that contain all the calculations and instructions Boilermakers need for fabrication and erection.

HOW TO ORIENT YOURSELF TO THE DRAWING

Elevations The orthographic drawing presents three principal projections: front elevation, side elevation and plan view (top view). The term elevation implies that something has height, whether from the ground to the first floor or from sea level to a reference point.

Location A sectional elevation is established by drawing a cutting plane line on the plan view to indicate the point from which the elevation is taken A direction is often used to identify the elevation. e g . north elevation. west elevation. etc

Height Once a known point in the height of a structure is established. al. other heights can be shown in relation to it. Since the only constant known point is the level of the sea. we call that zero. Any elevation above this point is given a plus value and anything below a minus value. Using surveying instruments when a structure is first started. a **datum point** is established (datum is sometimes referred to as a reference point. working point or monument). This is usually located and marked on an object that is not likely to move or be moved such as a concrete pedestal.

Figure 4-26 illustrates how to calculate elevation points.

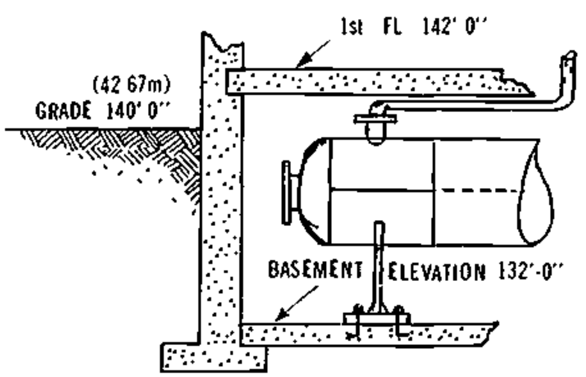


Figure 4-26. Calculation of Elevation Points

If a structure is to be built on a location that is 140'-0'' above sea level. the elevation of the top of the ground will be 140'-0''. Providing the grade remains the same (140'-0'') and the first floor of the building is to be 2'-0'' above the grade. the first floor elevation will be 140'-0''+ 2'-0'' = <u>142'-0''</u>. On the same building if the basement floor is to be 10'-0'' below the first floor. the elevation will be 142'-0'' - 10'-0'' = <u>132'-0''</u>.

Construction methods have become so complex that **bench marks** must be used to ensure that all structures are located at the proper level. Bench marks are fixed points of known elevation established at intervals by an engineer to provide permanent points of reference. In a building. bench marks are usually established on columns or walls or both at the height of 4' from finished floor. By using these. the Boilermaker can locate and establish the height of tanks. evaporators. etc. when the centre of the steam drum is not used as the elevation point. When erecting storage tanks the Boilermaker's print will show either the bottom or top of the base as the point from which all elevations are taken.

Direction Marks Compass direction is usually indicated by a large arrow. as shown in Figure 4-27.

It most always indicates one direction only. NORTH. This is very important to the erector.

It has happened on rare occasions that a building has been erected backwards.

Sections A key is sometimes used to link sections to the appropriate detail drawings. replacing the conventional cutting plane lines (see Figure 4-25 "Lines Used on Structural Drawings") on the erection drawing. as Figure 4-27 illustrates.

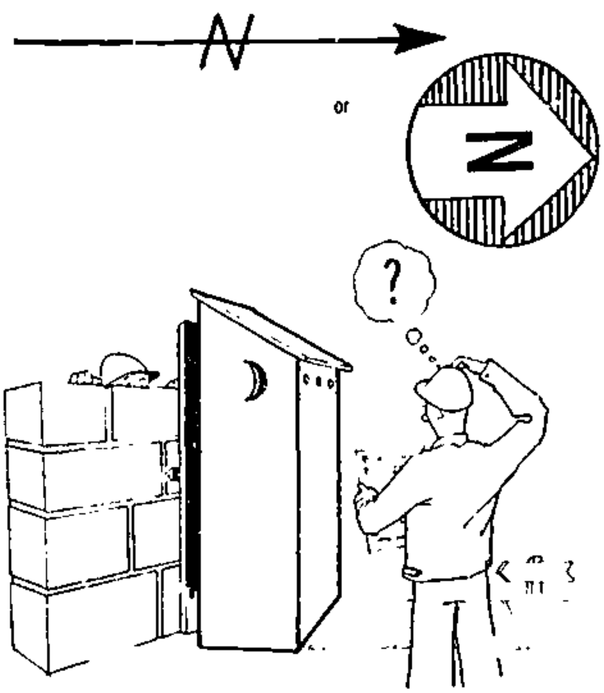


Figure 4-27. Compass Direction

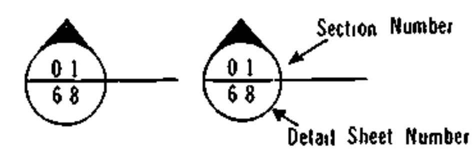


Figure 4-28. Key Used to Link Sections

On the detail sheet itself, the identifying symbol in Figure 4-29 would be used as a title.

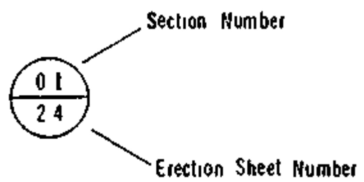


Figure 4-29. Key Used as Identifying Symbol

Details The location of details is emphasized on the drawing (Figure 4-30).

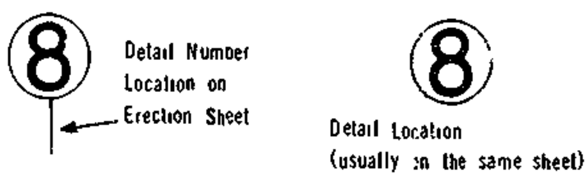


Figure 4-30. Detail Location

ROLE OF DETAIL DRAWINGS

A detail drawing expands one small section of a project represented on the general arrangement drawing to clarify the detail for fabrication or for identification of parts.

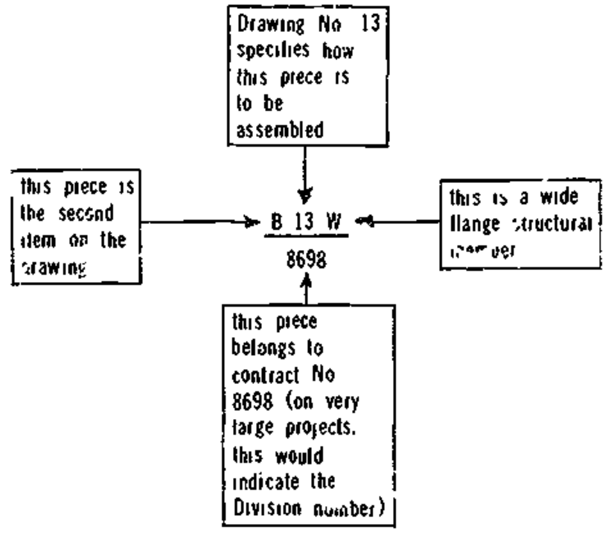
For the fabricator, it provides an accurate picture of the section including the individual components, all features, holes, cut outs, attachments and fastening arrangements that are not readily recognizable on the master drawing.

For the erector, the detail drawing provides **mark numbers** which identify structural members as an aid in assembling them. The mark number should be painted or stamped on the left end of the member just as it appears on the drawing. Where structural members have no directional marks (e.g., N) the mark number's position on the erection drawing should correspond with the location of the mark number on the erected member.

Although identifying marks may vary according to individual company standards, the customary method of marking is as follows:

Mark Number
Job Number

Example:



The Bill of Material (Figure 4-31) is a list containing all the material to fabricate the members laid out on that particular drawing. Placed at the bottom or right side of the drawing, this list is usually for the use of the fabricator or shop. It sometimes aids the erector in the field where pieces of loose stock are shipped out to be fabricated and erected.

Detail drawings also include welding symbols that designate location and types of welds required. These symbols and their meanings are described in the chapter on Welding

SUMMARY OF BLUEPRINT READING

There are four important elements to know and understand to read blueprints:

1. All structural shapes and materials
2. All drafting lines
3. Abbreviations and symbols
4. Ultimately, to visualize the unit.

There are four important steps to follow when you receive a drawing:

Step 1. Read the title block.
 Who is the customer?
 Where is the project to be located?
 What are you going to be working on?

Step 2. What are the notes and specifications shown?
 i.e., grade of material, hole sizes, types of bolts, special handling notes, grade of paint, revisions.

S O ______ ITEM 36 OD X 10-0 ______ W S ______

300# W.P. HORIZ. SEPARATOR

PART NO	[illegible]	[illegible]	DESCRIPTION		MAT
REQ# 33546	2		HEAD 36"OD × 3/8" MIN 2:1SE 2"SF		A-515-70
	1		PL 96" × 3/8" × 111 7/8" LG (ROLL TO 36" OD)		A-515-70
	1		PL 24" × 3/8" × 111 7/8" LG (ROLL TO 36" OD)		A-515-70
	2		1 1/4" × 5/16" OVAL BU BAR × 9'-7" LG		C S.
	2		PL 4 1/2" × 1/2" × 31/2" LG		A-283-C
	2		PL 29 15/16" × 1/4" × 38 1/2" LG (FLG 2 SIDES)		A-283-C
	2		PL 11 3/4" × 1/4" × 24 11/16" LG (CUTS 2 PC'S EA)		A-283-C
09-CIJ-314	1		NAME PL BRK'T		C S.
09-CS-1301	1		NAME PL		ST./STL.
	2		6"-300# USAS RF WN FLG W/ XHY WALL BORE		A-181-I
	1		6"-XHY SML'S PIPE × 9 1/8" LG (BOE)		A-53-B
	1		BAR 1" × 1/4" × 5" LG		C.S.
	1		6" XHY SML'S PIPE × 3 7/8" LG (BOE)		A-53-B

Figure 4-31. Sample Bill of Material

Step 3 How are you going to proceed?

Step 4 Mark the detail with a coloured pencil or that item might be overlook. A number of examples of beams and other connections are detailed.

Caution: Do not assume or guess about anything — if you are uncertain, ask your foreman or superintendent.

SKETCHING

Engineering or draftsman s drawings must meet ri ·d requirements in terms of precision, scale an ompleteness. Sketches, c ı the other hand, can communicate adequately without mathematical precision To produce an adequate sketch, it is only necessary to visualize the object or idea and to free hand draw that mental picture well enough so someone else can visualize it.

A Boilermaker should develop skill in making sketches because a number of circumstances occur in which sketching ability is needed. For example:

1. If the design of a piece of equipment is modified or revised after fabrication and delivery to the jobsite, a sketch of the revised component will guide fabricating the new part.
2. Some parts of an item or project may have been overlooked or drawn incorrectly on the drafting prints A sketch may be necessary to redesign or correct these parts.
3. If final adjustments on a project alter the physical shape and measurement of some parts so that adjoining parts must be redesigned, sketches will ensure that appropriate modifications are made By applying these basic principles, free-hand sketching is not difficult

Paper for Sketching Use squared or cross-section paper.

Maintain Correct Proporitons This is achieved by estimating the actual dimensions — sketches are not made to scale.

Sketching Figures Geometric constructions, squares, rectangulars, circles, angles. Curves are always sketched. Follow these procedures:

Step 1. Space off the squares on your paper.

Step 2. Draw light lines to outline object.

Step 3. Free-hand curves.

Step 4. Darken the lines to complete your sketch.

A few basic rules apply to the two main types of pictorial sketching: Isometric and Oblique.

ISOMETRIC SKETCHING

In making an isometric sketch, proper proportion is ensured if all vertical and horizontal lines are drawn in carefully estimated scale. Vertical lines are shown vertical, while horizontal lines are drawn 30° with the true horizontal. To draw a one-inch cube, start with a light horizontal reference line, a vertical line and two lines 30° to the horizontal, intersecting with the vertical line as shown in Figure 4-32.

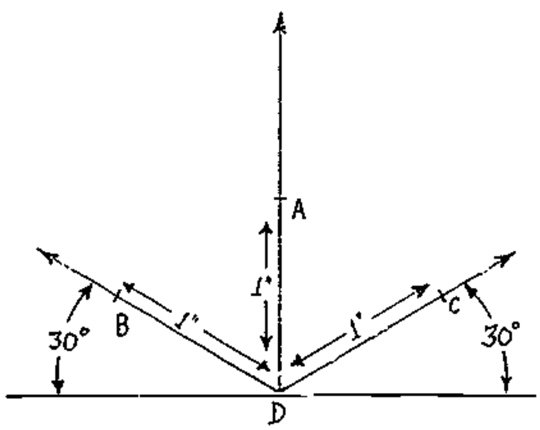


Figure 4-32. Axes for Isometric Sketch of a One-Inch Cube

These are the isometric axes. Measure the height of the cube on the vertical; the length of the front view on the line extending to the left; and the length of the side view, on the line extending to the right. In Figure 4-32, all lines would be 1" (labeled A, B, C) from point D.

To make the rear corners of the cube draw 1" vertical lines from points B and C. Next, draw line AE, parallel to line BD from point A; and lines AF parallel to line DC from point A. Parallel lines are lines that are always the same distance apart, and never meet or cross each other. (Figure 4-33).

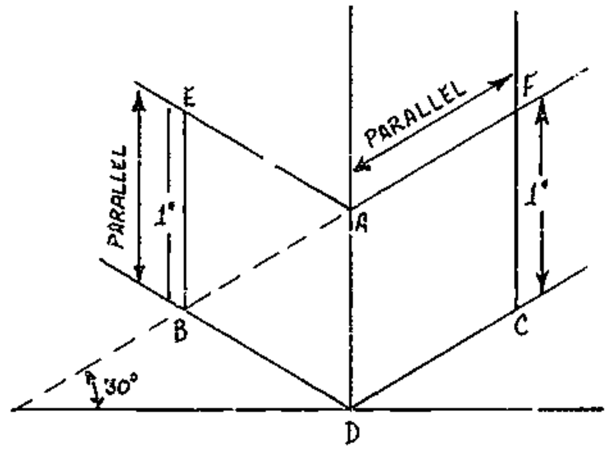


Figure 4-33. Parallel Lines for Isometric Sketch of a One-inch Cube

Draw in vertical lines from B and C; and draw parallel lines to BD and DC from point A, forming AE and AF. Note that if lines EA and AF were extended they also would be at 30° angles to the horizontal.

To complete the cube, draw a line parallel to line AF from point E, and a line parallel to line AE from point F. The point where they cross is labelled point G (Figure 4-34). Darken in the main lines of the object; then erase the extra lines you used drawing the cube.

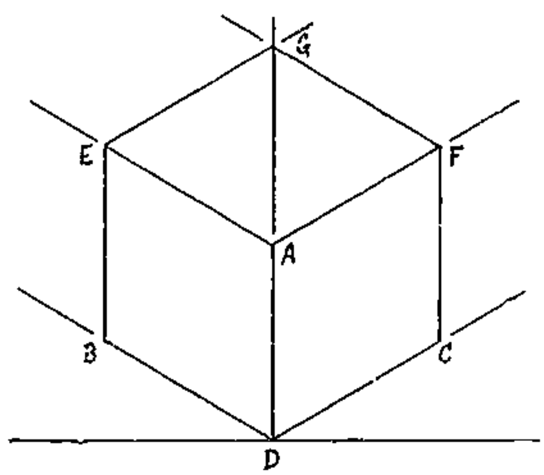


Figure 4-34. Isometric Sketch of a One-Inch Cube

SUMMARY

With a sketch you can do these steps free-hand, and lines are not shown to 1/16 of an inch. Remember that all vertcial lines are shown vertical, and all lines representing horizontal lines are at 30 angles to the true horizontal.

ORTHOGRAPHIC VIEWS

When it comes to more complex objects you can combine what you know about drawing a cube, with what you know about orthographic views. Look at the object in Figure 4-35 drawing and its orthographic views.

To draw this object as an isometric sketch, start out as in the one-inch cube by drawing the isometric axes. Next measure off the principal measurements and draw the additional vertical and 30° lines. Remember that the side on the left of the vertical axes represents the front view, so measure off the length of the front view in the orthographic sketch, and draw one of the vertical lines at that point (Figure 4-36).

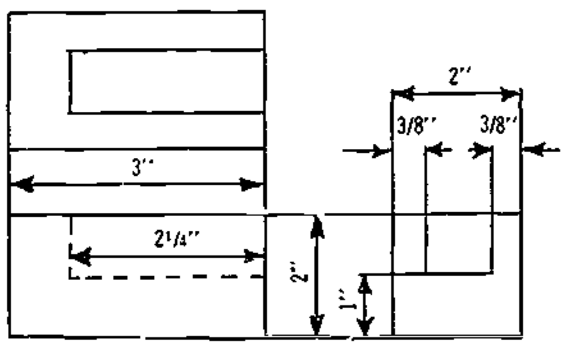


Figure 4-35. Object with Orthographic Views

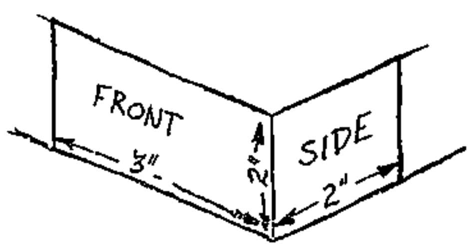


Figure 4-36. Front View of Orthographic Sketch

Next draw the remaining lines to complete the general rectangular shape (Figure 4-37).

Erase any unnecessary lines. Lightly sketch in the lines from the orthographic views on the appropriate faces of the isometric box. Note that the feature shown as hidden lines on the orthographic front view can be partially seen when the object is oriented for the isometric drawing. This appears as the vertical and horizontal line

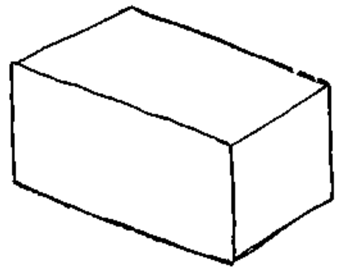


Figure 4-37. General Rectangular Shape

showing the corners of the cut-out in Figure 4-38. Since hidden lines are not usually shown on isometric drawings unless they add to the clarity of the drawing, the rest of the details are omitted.

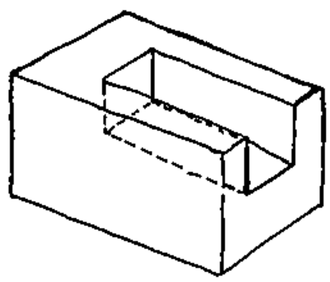


Figure 4-38. Vertical and Horizontal Lines Showing Cut-Out

OBLIQUE SKETCHING

In an **oblique sketch** the front view, or face of the object is shown in its actual proportion, as if it were the front view of an orthographic sketch. To sketch an object using this method, start with the front view on a horizontal. Next, sketch in the sides at an angle of 30° to the horizontal (Figure 4-39).

Remember that although the front view is shown in its true size and shape, the receding sides may be scaled at less than their actual length. They are often drawn about 3/4 of their scale length.

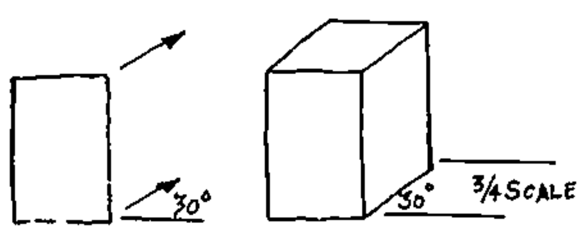


Figure 4-39. Front View with Angles 30° to Horizontal

Avoid distortion in oblique sketches by placing surfaces with long dimensions in front (Figure 4-40).

A Cabinet Sketch (Figure 4-41) is a type of oblique sketching showing the sides of an object at one-half their actual scale length, using 30 and 45 angles. The front view, however, is drawn as for a regular oblique sketch.

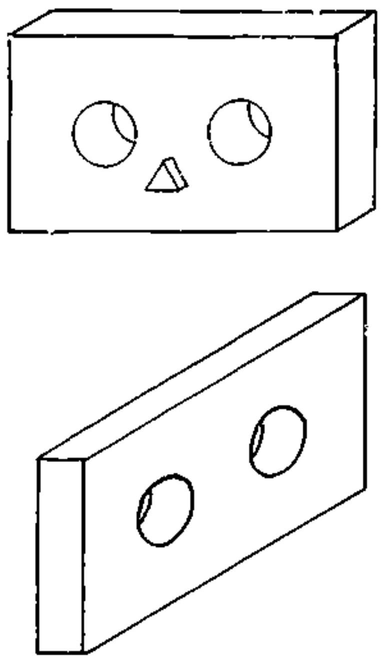


Figure 4-40. Avoiding Distortion in Oblique Sketching

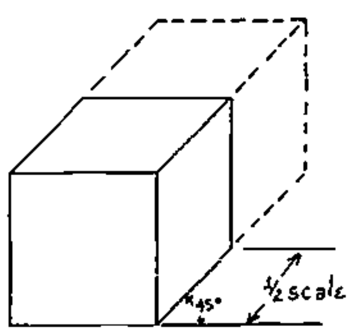


Figure 4-41. Cabinet Drawing of a Cube

A Cavalier Sketch (Figure 4-42) always shows the oblique sides at 45° angles, and at their actual scale length. Again, the front view is drawn in its true shape, as in an orthographic view.

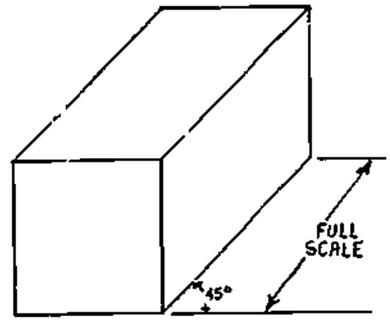


Figure 4-20. Cavalier Drawing of a Rectangular Prism

AN EXAMPLE OF A BOILERMAKER SKETCHING TASK

As seen in Figure 4-43, the machinery with its exposed pulleys represents a safety hazard and a guard for the moving parts must be designed.

The guard could not be designed until the mechanism was in operation at which time the finally adjusted position of the pulleys could be determined. This requires a "take-up" allowance of 4"

The guard must satisfy the following criteria:

1. All moving parts must be covered
2. The guard must be clear of the moving parts, but situated close enough to prevent debris from entering it and obstructing the mechanism
3. The guard should be removable to provide access for maintenance.

To illustrate the proposed guard in relation to the machine, it is first necessary to sketch the machine. Figure 4-44 shows that the sketch of the guard involves transferring dimensions from the machine with an allowance for clearance. Instructions for attaching the guard are noted on the sketch so that fabrication could be done either by the Boilermaker or by contracting to a fabricating shop.

This example only illustrates the principle of sketching and involves very simple criteria for the part being designed. It does point out the advantages of communicating ideas by drawings to assure clarity and accuracy.

Skill in sketching improves with practice. For more complicated drawings, the principles of orthographic drawings should be applied, showing each projection as required. For complicated

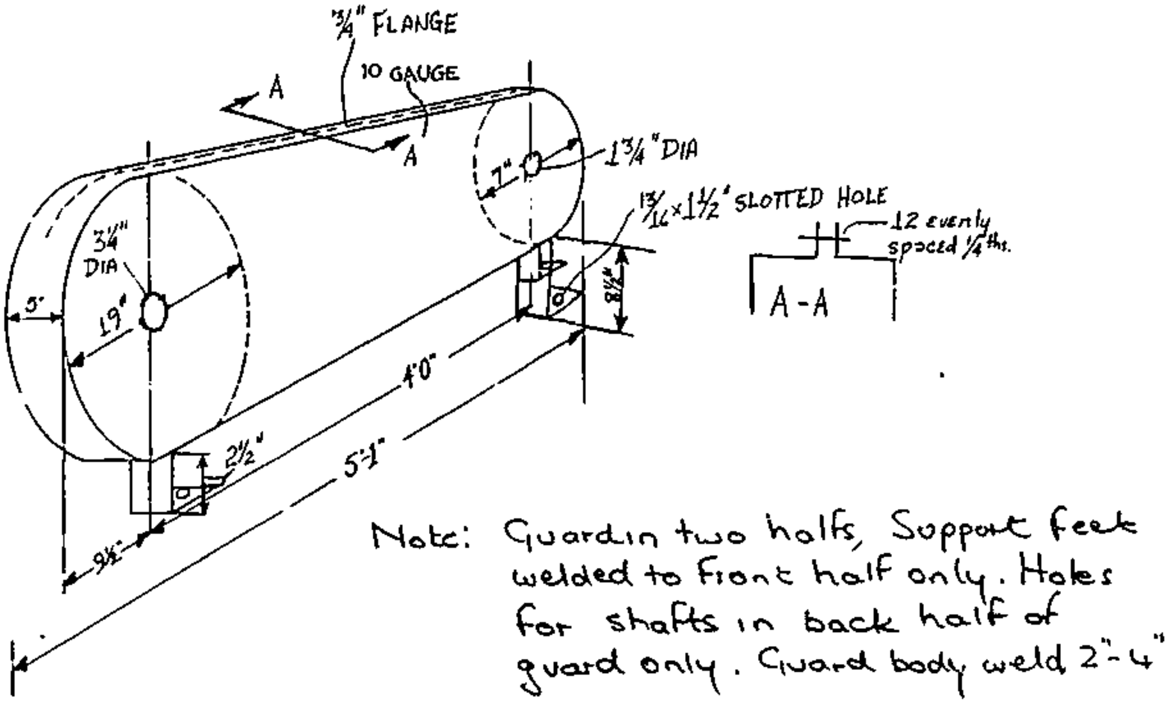


Figure 4-43. Sketch of Machine with Exposed Pulleys

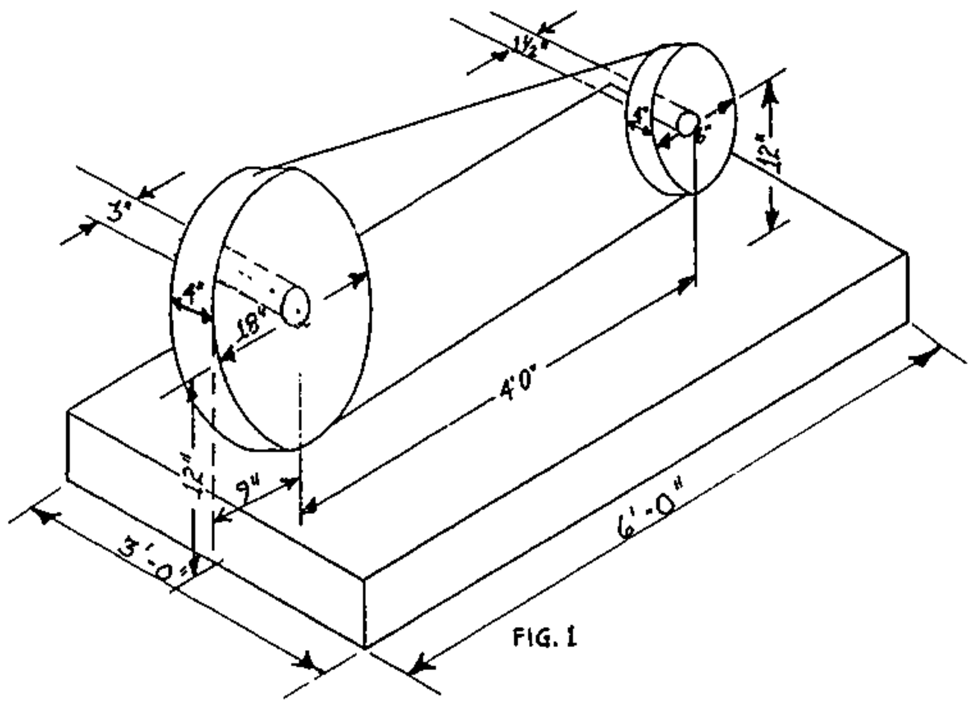
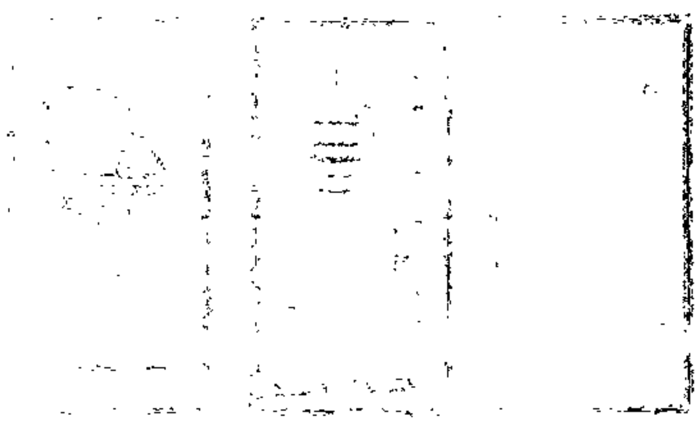


Figure 4-44. Sketch of Machine Showing Transferred Dimensions

objects or ideas, professional help with the sketch reduces the opportunity for error or misinterpretation. As a general rule, the isometric sketch is the most functional method of free hand drawing and should be used wherever possible.



INTRODUCTION

In a boilershop, layout involves:

1. Determining from blueprints, drawings or sketches, the true size and shape of the plates, bars, etc. to be used in constructing a unit.
2. Transferring these shapes to templates representing the dimensions for shaping and cutting the material. (Where the shapes are simple, they may be directly transferred from the drawings to the material.)

Most drawings or sketches of the various units made in a boilershop show only the dimensions of the completed unit, with the plates, angles, etc bent or rolled to the required shapes From these dimensions, the layout man must find the exact size and shape of every piece of material when laid out on the flat. After cutting and shaping with these lines as a guide, the piece will be exactly the required size and shape, and will accurately fit in its designated place.

To master these techniques, the layout man must have:

1. A knowledge of plane geometry and geometric illustrations dealing with the development of different surfaces.
2. An understanding of how specific materials will react when bent, flanged, rolled, etc. In some instances, the metal will "draw out" or stretch, producing a gain in length, while in others it will shrink and lose in length. When laying out, this gain or loss in size must be taken into account. In some cases the allowances are set out as rules: in others it is necessary to make judgments based on experience.

CLASSES OF SURFACES

In general there are four classes of surfaces the layout man must be capable of developing for boiler work:

1. Plane
2. Cylindrical or parallel
3. Conical or radial
4. Irregular curved surfaces.

A plane surface is a flat surface, where all lines lie in the same plane.

A cylindrical surface is generated by a straight line moving "parallel" to itself in a curved path. The most common form of the cylinder is that in which the path is a circle. Cylindrical surfaces are laid out by a method using parallel lines.

A conical surface is generated by moving a line from one fixed point. Conical surfaces are developed by a method similar to that for forming cylindrical surfaces. A cross section of the cone is divided into a number of equal parts, and the lines are drawn on the surface of the cone from these points to the vertex.

All surfaces that do not fall into the above categories may be considered **irregular curved surfaces** and are developed by special methods.

GEOMETRIC ILLUSTRATIONS

The discussions and illustrations that follow define the geometric terms and symbols that occur frequently in this subject area.

TERMS AND SYMBOLS

Line — assumed to mean a "straight line" with a constant direction

Angle — formed when two lines intersect; point of intersection is the vertex.

Right Angle — two lines meeting so as to form four equal angles; each part is a right angle (90° angle).

Acute Angle — any angle less than 90° angle.

Obtuse Angle — any angle greater than 90° angle.

Plane — a flat surface, real or imaginary, of fixed size and shape or unlimited in size.

The position of a plane on a drawing is established by:

Locating three points other than a line — Figure 5-1 (a).

Locating two intersecting lines — Figure 5-1 (b).

Locating two parallel lines — Figure 5-1 (c).

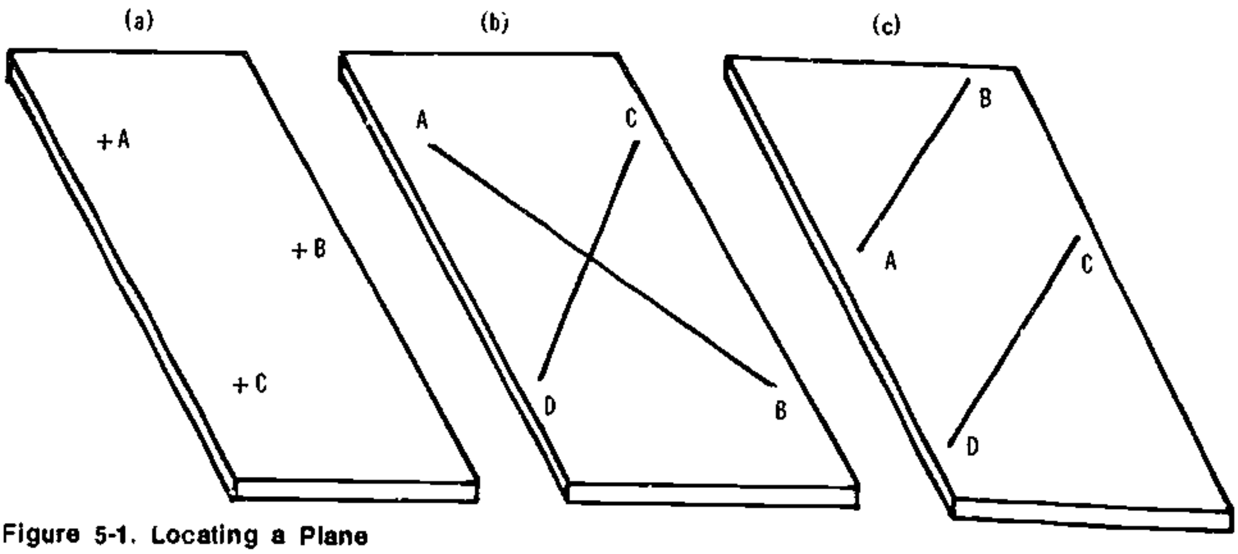


Figure 5-1. Locating a Plane

Plane Figure — a plane of fixed size and shape. Plane figures are composed of **three or more sides** and are classified as: **triangles**, **quadrilaterals** or **polygons**.

Triangle — a plane having three sides. The sum of the angles of any triangle is always 180°.

Right Triangle — contains one angle of 90° and two acute angles sum of 90°.

Quadrilateral — any plane figure having four sides that are (1) square, (2) rectangle, (3) rhombus, (4) rhomboid, (5) trapezoid, (6) trapezium. (See Figure 5-2.)

Polygon — a plane of many angles and many sides When all sides are equal and all enclosed angles are equal the polygon is called a "Regular Polygon."

Regular Polygons (Figure 5-3) are differentiated as: (1) Pentagon
(2) Hexagon (3) Heptagon
(4) Octagon (5) Nonagon

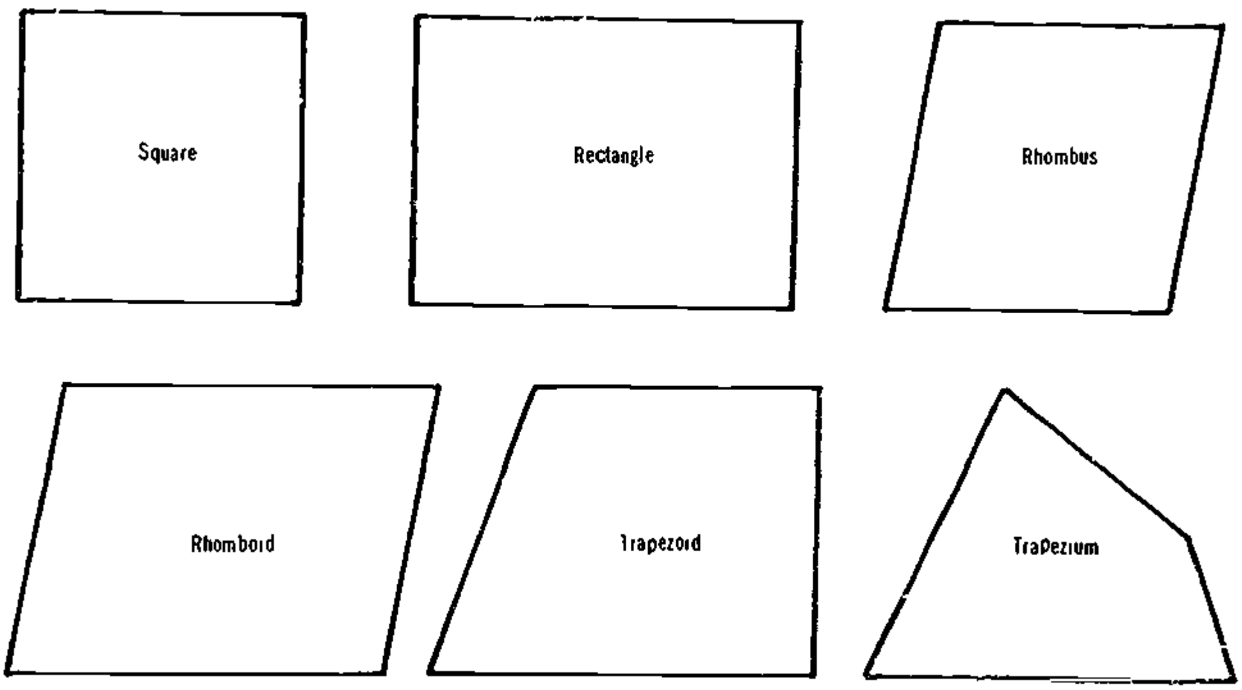


Figure 5-2. Quadrilateral Figures

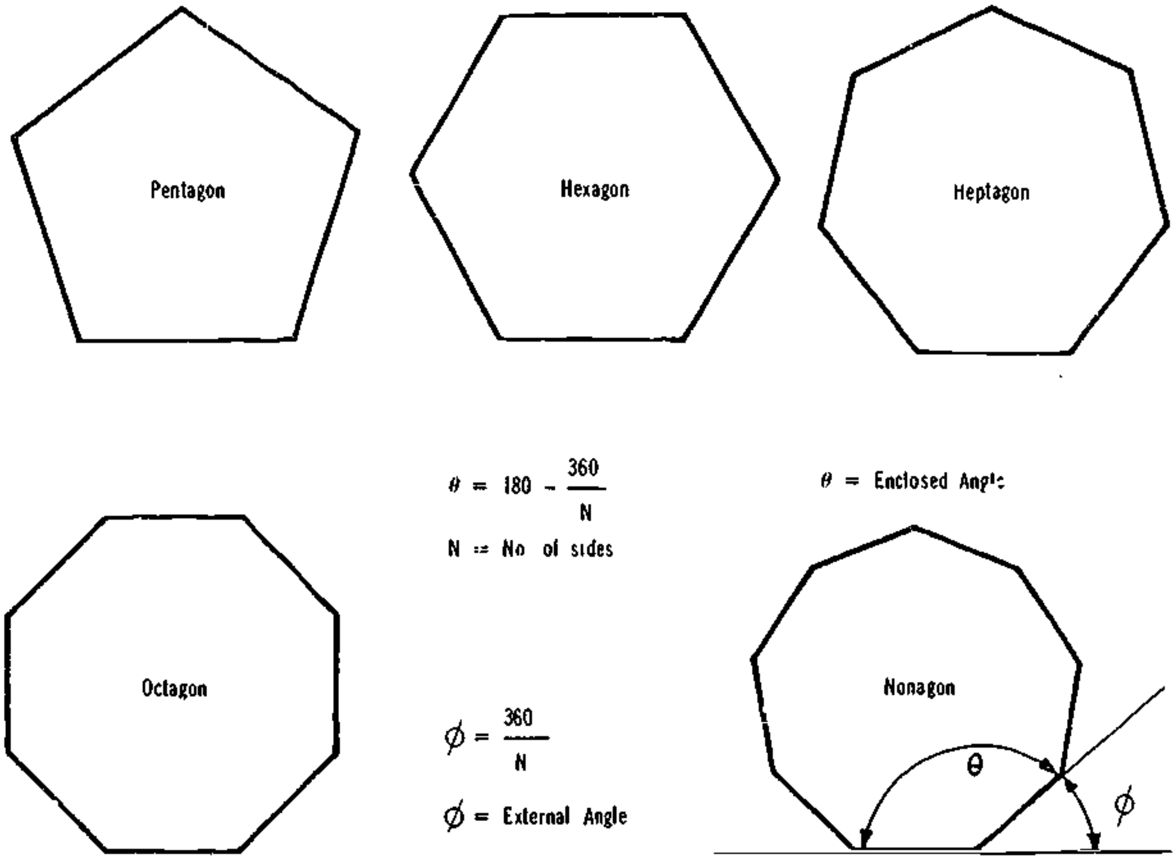


Figure 5-3. Regular Polygons

Circle — a plane figure enclosed by a curved line. All points on the curve are equidistant from a single point within the circle; this point is called the centre.

Ellipse — a plane figure enclosed by a curved line, having a major and a minor diameter perpendicular to each other, and crossing at a centre.

Oval — a plane figure having circular ends each having different radii and connected by straight lines at point of tangent (Figure 5-4).

Oblong — a plane figure with circular ends with the same radii, connected by straight lines at a point of tangent (Figure 5-5).

Prism — a geometric solid whose ends or bases are identical plane figures (Figure 5-6).

Cube — a right square prism with six faces which are all the same sized squares (Figure 5-7).

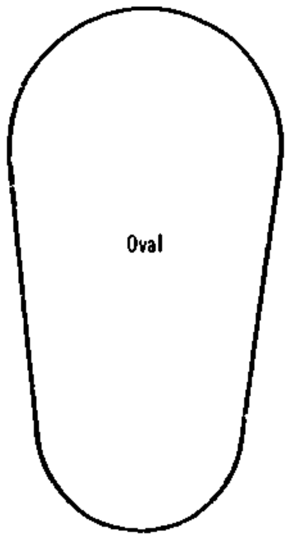


Figure 5-4. Oval

Cylinder — right circular cylinder is a prism of infinite sides whose bases are circles. Cylinders can be circular, elliptical, oval or oblong, depending upon the true shape of the right section. (Figure 5-8a). A cylinder is

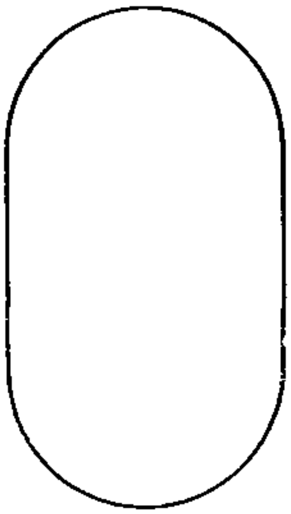


Figure 5-5. Oblong

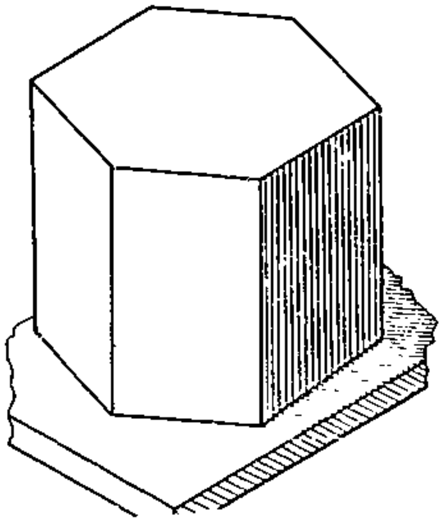


Figure 5-6. Prism

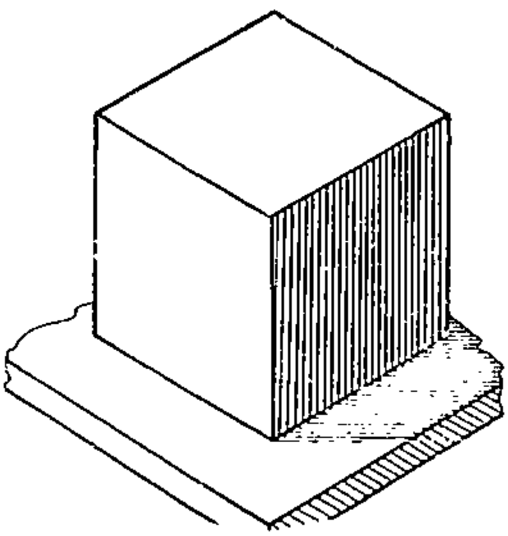
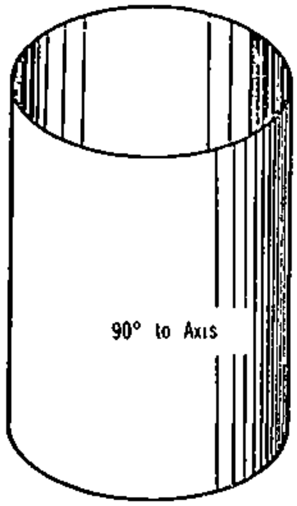
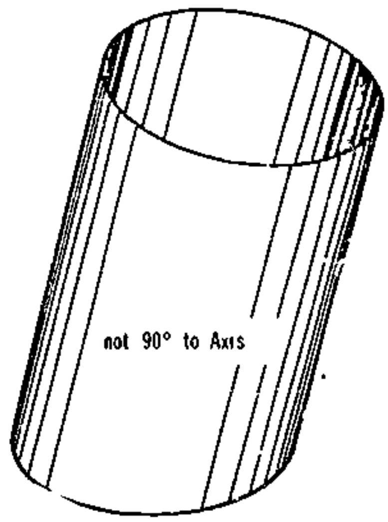


Figure 5-7. Cube



A



B

Figure 5-8. Right and Oblique Cylinder

oblique when not 90° to its axis (Figure 5-8b).

Pyramid — a geometric solid with triangular sides meeting at a common point called the apex (Figure 5-9).

Cone — a cone is a right cone if the base is perpendicular to the axis, and oblique if the base is not perpendicular to the axis. Cone bases are usually circular or elliptical (Figure 5-10).

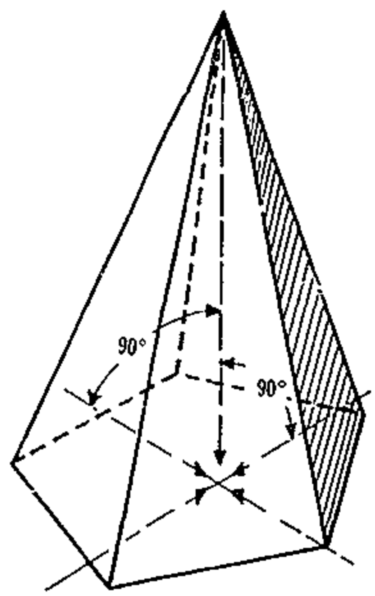


Figure 5-9. Pyramid

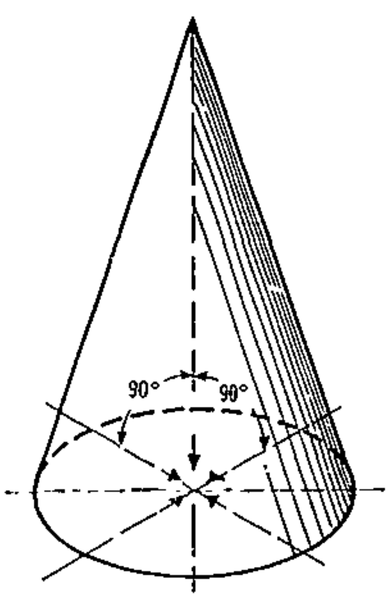


Figure 5-10. Cone

BASIC GEOMETRIC TECHNIQUES

Find the centre of a line or arc

Draw equal arcs from points A and B (using a radius greater than 1/2 AB) to intersect at C and D (Figure 5-11). Draw a perpendicular that joins C and D to locate centre E.

Divide a line into 5 equal parts

(This method may be used for any number of parts).

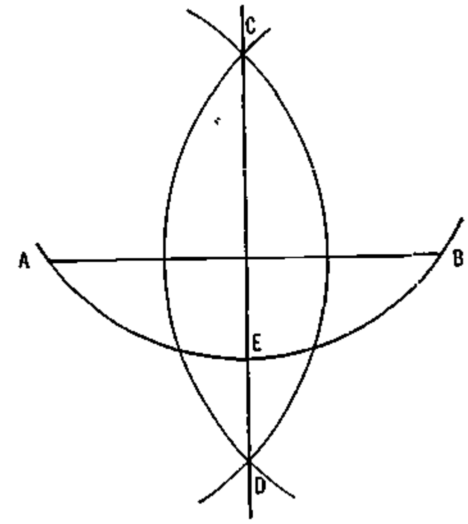


Figure 5-11. Finding the Centre of a Line or Arc.

Draw AC at a convenient angle to AB (Figure 5-12); the length of AC in this case should be a multiple of 5 (inches, or feet). Set divider points at a distance R (1/5 of AC) and mark divisions S, T, U and V on AC. Join BC and describe lines SZ, TY, UX and VW parallel to BC.

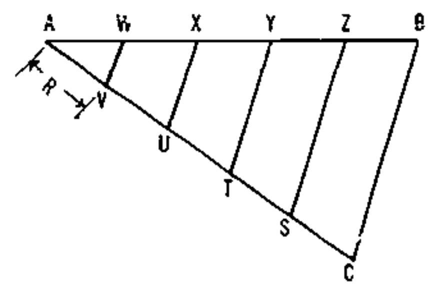


Figure 5-12. Dividing a Line into Equal Parts.

Bisect an angle Given the angle, strike an arc from centre C using any convenient radius to locate A and B (Figure 5-13). Draw equal arcs from A and B to locate D. Join CD to bisect the angle.

Transfer an angle Draw A'C' in the new location (Figure 5-14). From centre A, draw an arc BD. From centre A' strike an equivalent arc to locate D'. Using radius DB, and centre D' make an arc to locate B'. Join A' to B'.

Erect a perpendicular Using point O and a convenient radius, locate X and Y (Figure 5-15). Using a radius greater than XO, and centres at X and Y, describe arcs which intersect to locate C. Join CO.

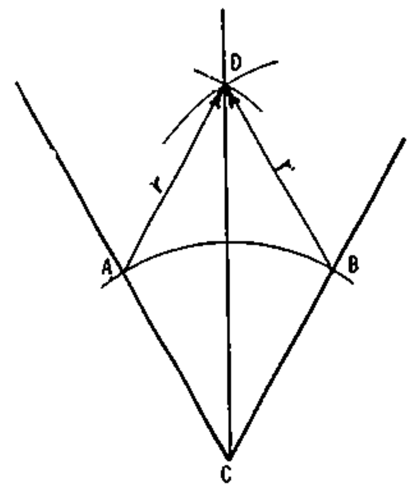


Figure 5-13. Bisecting an Angle

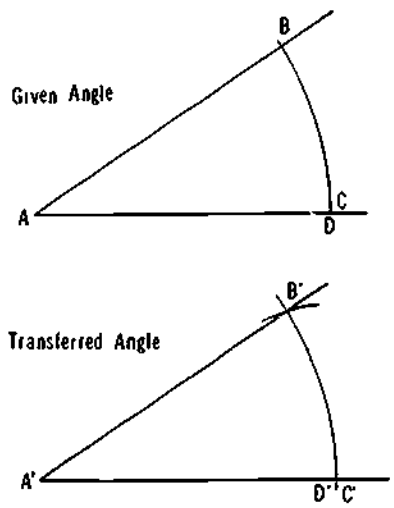


Figure 5-14. Transferring an Angle

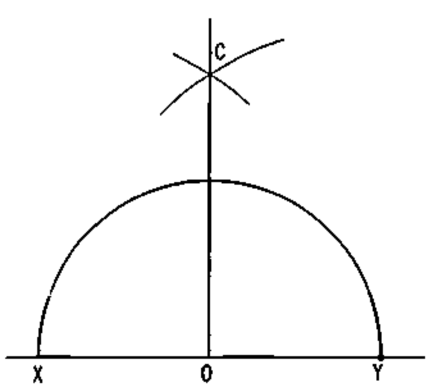


Figure 5-15. Erecting a Perpendicular

Construct parallel lines at a given distance Given line AB and r the required distance, from any two points on AB as centres, and radius r, describe arcs (Figure 5-16). Draw line CD tangential to both arcs.

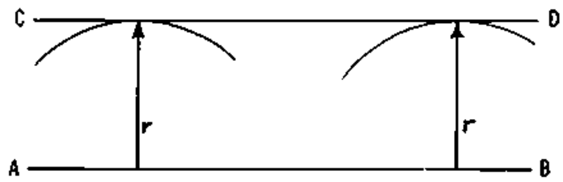


Figure 5-16. Constructing Parallel Lines

Divide a circle into 12 equal parts Locate the centre of the circle (Figure 5-17). First draw a chord x-x' and bisect it. Extend the bisector to intersect the circumference at A and B. Bisect AB and extend the bisector to intersect the circumference at C and D. Using radius OB and centres A, B, C and D, describe arcs intersecting the circumference; the resulting divisions are each equal to 1/12 of the circumference. (Outer circle illustrates that each division is equal).

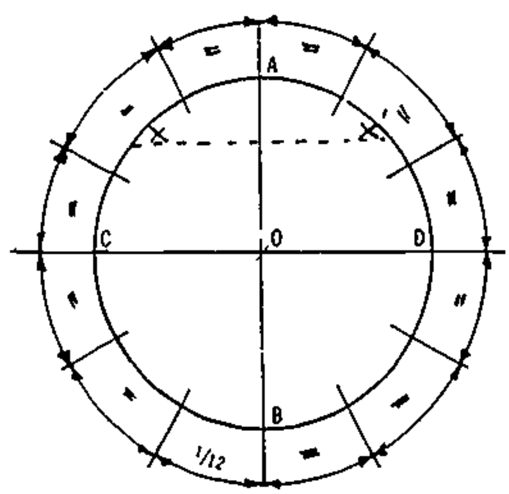


Figure 5-17. Dividing a Circle into 12 Equal Parts

Divide a circle into 16 equal parts Locate the centre of the circle (Figure 5-18), O, and draw the diameters as described in the technique for dividing a circle into 12 equal parts. Bisect angles ADD, DOB, BDC and AOC as described in the technique for bisecting an angle to locate points E, F, G and H. Bisect angles ADE, EOD, DOF, FDB, GOB, GOC, HOC and HOA. The resulting divisions are each equal to 1/16 of the circumference. (Outer circle illustrates that each division is equal).

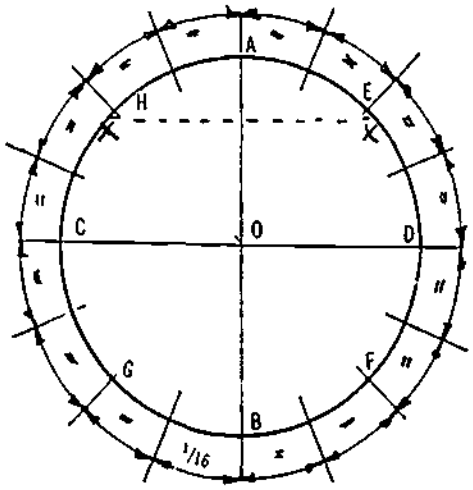


Figure 5-18. Dividing a Circle into 16 Equal Parts.

Construct an ellipse

Set out the major and minor axis, bisecting each other at E. (Figure 5-19).

On a straight edge, set off FG equal to CE, and FH equal to BE.

By keeping point G always on line AB and point H always on line CD, point F will trace a true ellipse as the straight edge is moved.

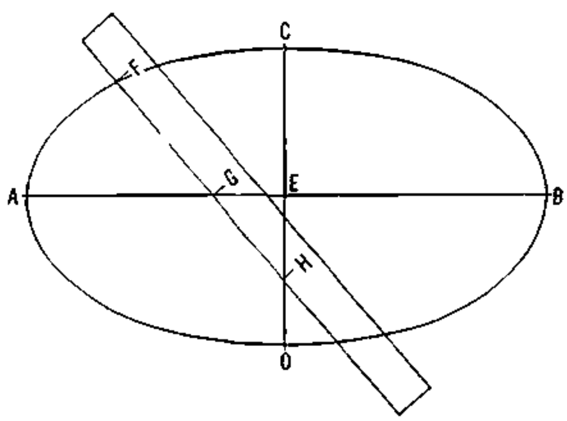


Figure 5-19. Constructing an Ellipse

PRACTICAL APPLICATION

A cutaway section of a reactor building is shown in Figure 5-20 to illustrate the many complicated pipes, hoppers, chutes and vessels that represent a large part of the Boilermaking trade. These components must be laid out, cut and fabricated, assembled and installed to precise dimensions. The following sections introduce techniques for laying out these shapes

The complexity of plate development procedures precludes detailed treatment in this manual. Only basic principles, accepted conventions and illustrations of procedures are included. These should, however, be sufficient to guide a tradesman who has some experience in the field.

PARALLEL LINE DEVELOPMENT (BASIC LAYOUT)

A geometric object of such a shape that straight lines are drawn on its surface parallel to its axis is called a parallel form The lines are termed elements of the object. Examples of parallel forms are cylinders, tanks, chutes and hoppers.

To develop a template for a steel object, the surfaces of the object must be:

1. rolled out (or stretched out) in the case of cylindrical shapes (Figure 5-21).
2. Unfolded in the case of square bends (Figure 5-22).

These procedures reveal the exact size and true shape of the material required.

The following steps must be taken before beginning any layout:

Step 1. Study the drawing or sketch

Step 2. Check type and grade of steel

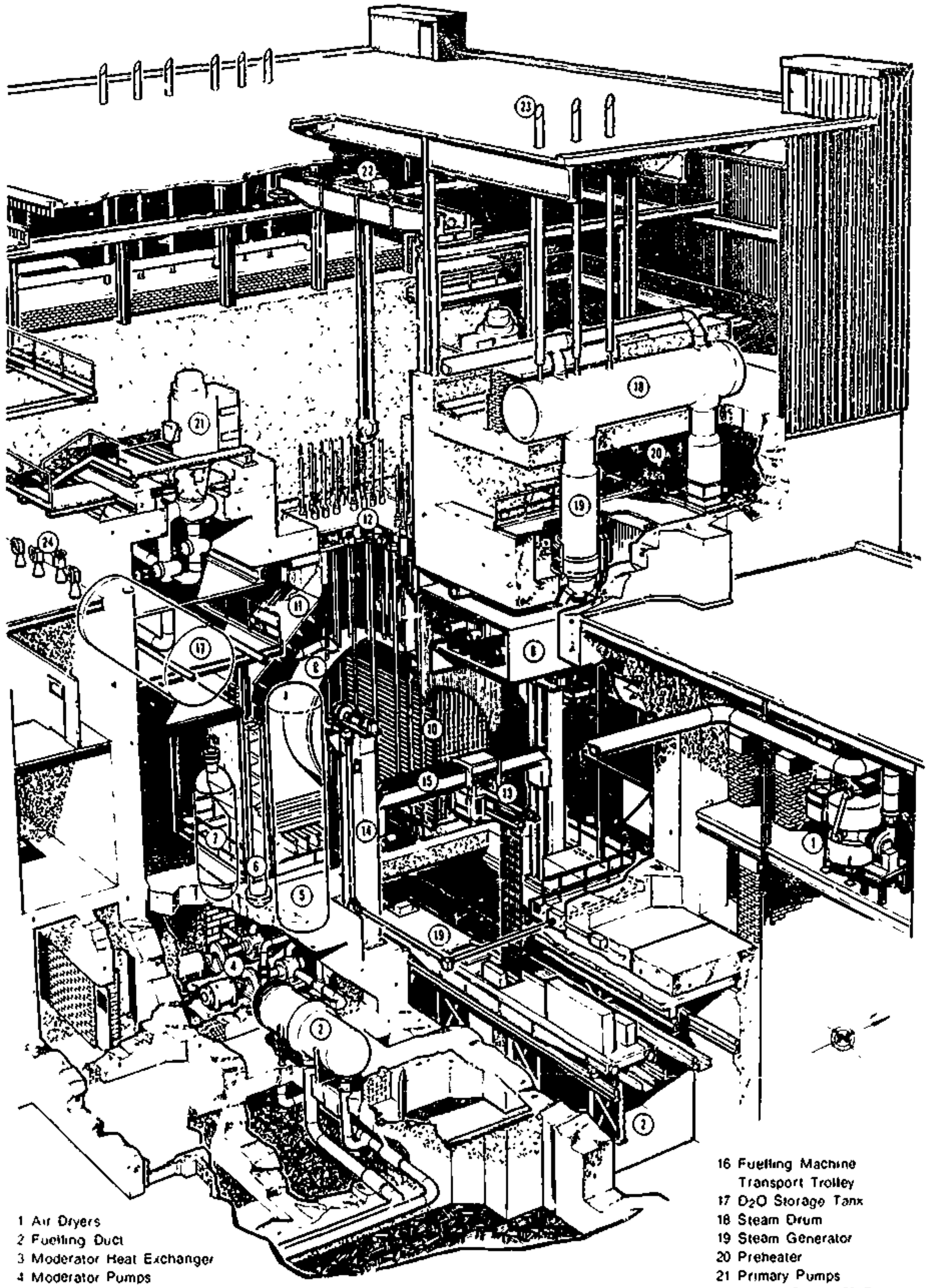
Step 3. Check size and thickness of material

Step 4. Check dimensions. Are inside or outside dimensions specified?

Step 5. Calculate for mean and true lengths.

ABBREVIATIONS AND SYMBOLS FOR PLATE DEVELOPMENT

The layout man uses specific symbols and abbreviations on the material being fabricated to communicate explanations and intentions to his fellow tradesmen. Most of the common terms used by the layout man are set out in Table 5-1. Figure 5-23 illustrates how these symbols and abbreviations are used.



1 Air Dryers
2 Fuelling Duct
3 Moderator Heat Exchanger
4 Moderator Pumps
5 Pressurizer
6 Bleed Cooler
7 Bleed Condenser
8 Feeder Cabinet
9 Calandria
10 End Fittings
11 Shield Tank
12 Reactivity Mechanism
13 Fuelling Machine Head
14 Fuelling Machine Bridge Column
15 Fuelling Machine Bridge
16 Fuelling Machine Transport Trolley
17 D_2O Storage Tank
18 Steam Drum
19 Steam Generator
20 Preheater
21 Primary Pumps
22 Bridge Crane (75 Ton)
23 Safety Blow-off Valves
24 Primary System Valve Operators

Figure 5-20. Cutaway View of Reactor Building

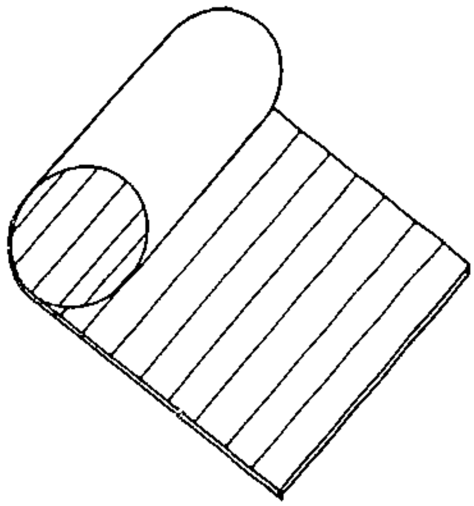


Figure 5-21. Stretchout of Cylinder

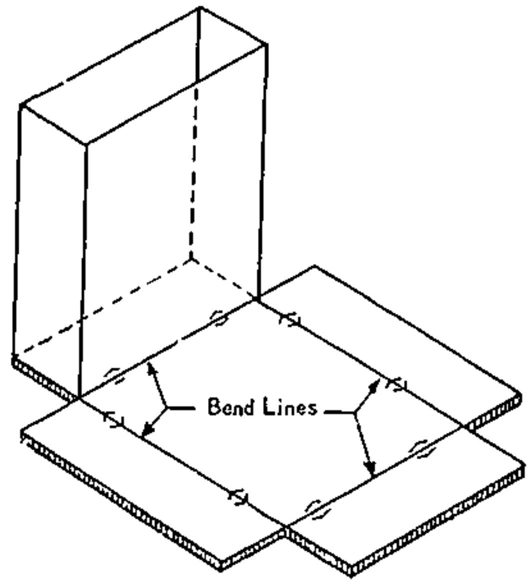


Figure 5-22. Unfolding of Square Bends

PLATE DEVELOPMENT

The simplest form of plate development is bending or flanging of plate. The following considerations are involved in forming plate:

1. Plate thickness
2. Type and quality of material, e.g., mild steel, abrasion resistance, Corten, Stainless, G40.12, G40.8, aluminum, etc.
3. Direction of the grain of the material
4. Process to be used, i.e., cold or hot forming
5. Equipment available.

EXAMPLE OF PLATE SINGLE BEND

When forming steel, a bend allowance must allow for compression of the material on the inside of the bend and stretching of the material on the outside (Figure 5-24). The line midway between the inside and outside margins is called the neutral axis (or the mean of the bend). All dimensions are calculated along the neutral axis.

TABLE 5-1. ABBREVIATIONS AND SYMBOLS FOR DEVELOPING PLATE

PL	PLATE	℄	CENTRE LINE
W.L.	WORK LINE	Sec.	SECTION
W.P	WORK POINT	Elev.	ELEVATION
B L	BEND LINE	Dev.L.	DEVELOPED LENGTH
In S.	INSIDE	T.L.	TRUE LENGTH
O.S.	OUTSIDE	Ref.L.	REFERENCE LINE
O.D	OUTSIDE DIAMETER	Cir.	CIRCUMFERENCE
I.D.	INSIDE DIAMETER	Dia.	DIAMETER
Bev	BEVEL	M.Dia.	MEAN DIAMETER
Temp.	TEMPLATE	Rad.	RADIUS
—◇—◇—	BEND SYMBOL	M.Rad.	MEAN RADIUS
SQ (Sq.)	SQUARE		

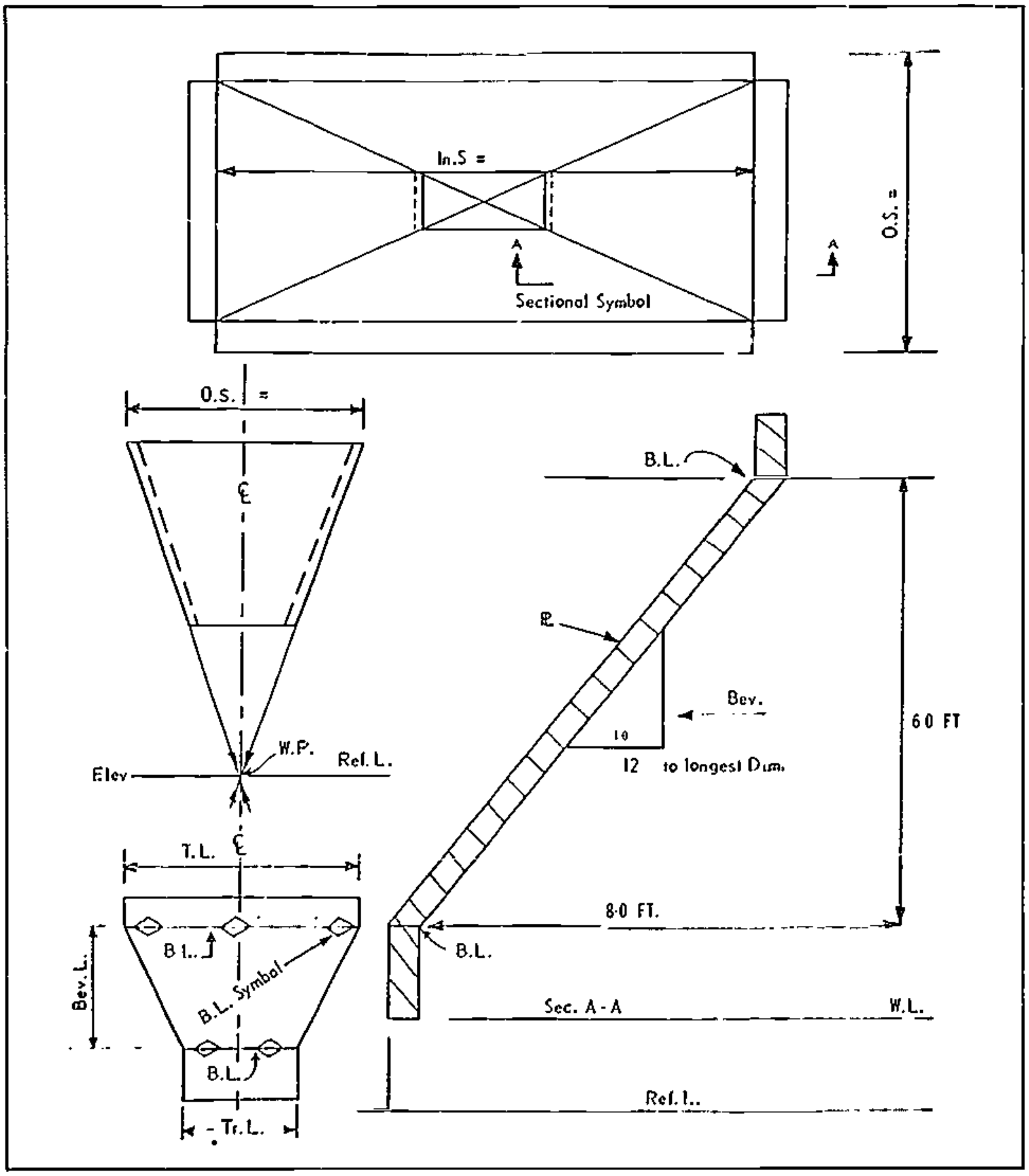


Figure 5-23. Sample Use of Abbreviations and Symbols for Developing Plate

The layout of a plate corner is shown in Figure 5-25. The length of material required to form a bend can be calculated from the following information provided on the drawing:

1. Material thickness
2. Flange length
3. Inside radius.

Using the specifications set out in Figure 5-25, the required length of the material is calculated as follows:

Specifications

Material thickness	=	3/8"
Flange length	=	3"
Inside radius	=	3/8"

Note: Unless otherwise specified, the inside radius is equal to the plate thickness.

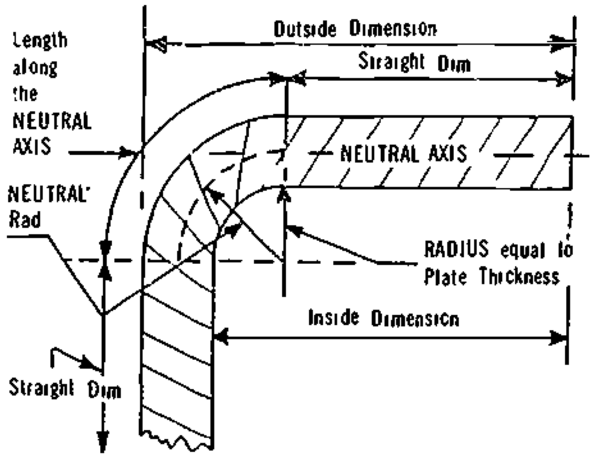


Figure 5-24. Calculating Bend Allowance

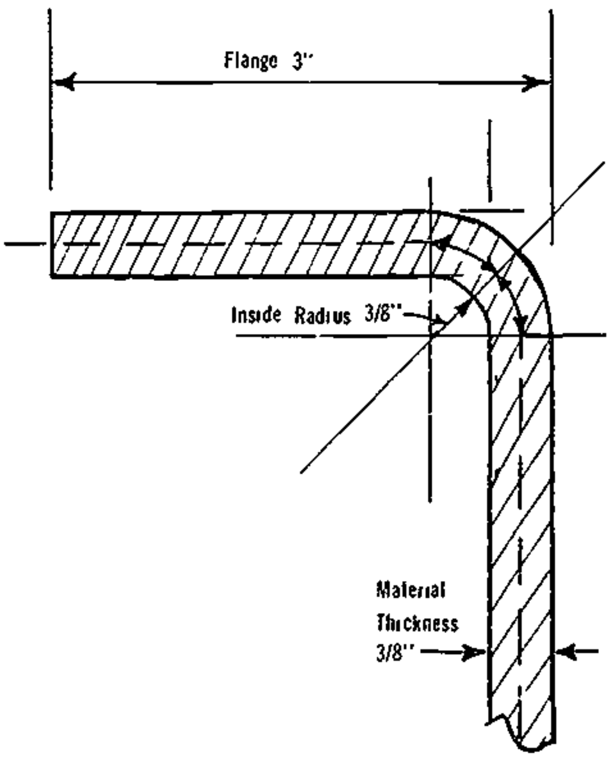


Figure 5-25. Layout of a Plate Corner

Length of straight section

Subtract inside radius plus plate thickness from flange length:

$3' - (3/8 + 3/8) = 2^1/_4$

Arc length

Arc length from the centre of the bend is seen to equal 1/8 of a circle with a radius of $^9/_{16}$.

(Since arc length is measured on the neutral axis, add the inside radius + 1/2 plate thickness to determine Mean radius.)

$3/8 + 3/16 = 9/16"$

Mean diameter $= 9/16 \times 2 = 1^1/_8$

Based on the formula for calculating circumference of a circle ($C = \pi \times D$), the length of this arc will be:

$$\frac{\pi \times D}{8} = \frac{3.1416 \times 1\ 1/8}{8} = 7/16"$$

Therefore the distance from the centre of the bend to the end of the plate is:

$2\ 1/4 + 7/16 = 2\ 11/16"$

EXAMPLE OF PLATE MULTIPLE BENDS

Figure 5-26 shows the profile of a series of bends fabricated from 3/8" plate. To calculate the length of the plate required, apply the principles from the preceding example.

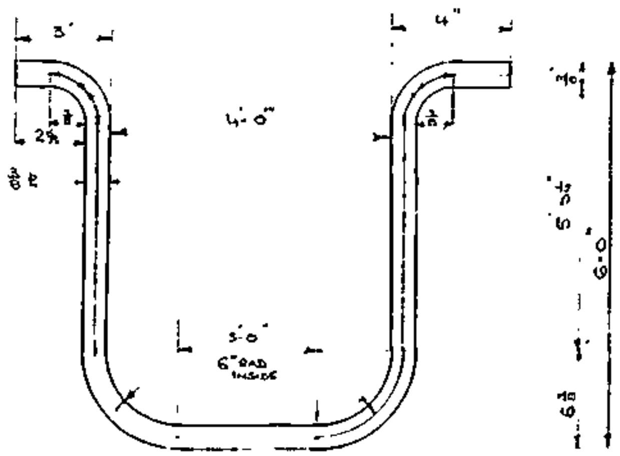


Figure 5-26. Profile of Series of Bends

Step 1. Calculate the true length of the 3" flange, i.e., from the plate edge to the centre of the bend:

$3 - (3/8 + 3/8) = 2\ 1/4"$ (straight section)

$$\frac{\pi \times \text{mean diameter}}{8}$$

$$= \frac{3.1416 \times 1\ 1/8}{8} = 7/16"$$ (arc length)

$2\ 1/4 + 7/16 = 2\ 11/16"$

Step 2. Calculate the true length of the section between the centre of the first radius and the end of the first straight section:

5 - 5 1/4 - 3/8 = 5 - 4 7/8
Add arc length 7/16":
5 - 4 7/8 + 7/16 + 5 - 5 5/16

Step 3 Calculate the length of the material in the 6" radius corner (1/4 of a circle):

Mean radius is 6 + 3/16 = 6 3/16

$$\frac{\pi \times \text{mean diameter}}{4} = \frac{3.1416 \times 1 - 0\ 3/8}{4}$$

= 9 23/32"

Step 4. Note the length of the material between the radii:
= 3 - 0

Step 5 Repeat Step 3:
= 9 23/32

Step 6. Repeat Step 2.
= 5 - 5 5/16

Step 7 Calculation of this section is similar to Step 1. however the flange length is 4" instead of 3" which adds 1" to the length of the opposite flange:

2 11/16 + 1 = 3 11/16

Step 8. Total all component measurements.

```
    2 11/16
5 - 5  5/16
    9 23/32
3 - 0
    9 23/32
5 - 5  5/16
    3 11/16
-----------
16 - 0 7/16
```

The plate required for the development is 16'-0 7/16".

The plate may be laid out as shown in Figure 5-27.

It is usually advantageous to work from the centre towards the ends and this should be achieved as indicated in Figure 5-27. Note the abbreviations and instructions given on the layout.

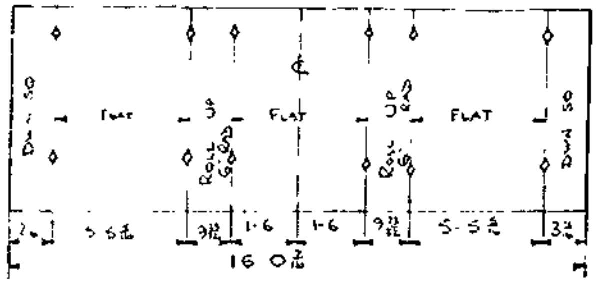


Figure 5-17. Layout of Plate

The importance of accuracy in calculating dimensions for forming is illustrated in Figure 5-28. In this case the plate lengths must be calculated precisely so the holes can be laid out and drilled prior to bending This avoids extra handling and expensive clamping procedures in the drill press.

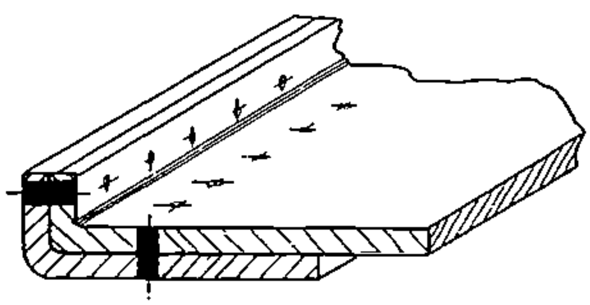


Figure 5-28.

PARALLEL LINE DEVELOPMENT

In its basic form Parallel Line Development is the simplest layout technique for developing the surfaces of prisms, cylinders and solids that retain a constant cross-section dimension throughout their lengths.

The following layouts are described to illustrate surface development using this method:

- Two piece 45° elbow
- Four piece 90° elbow
- Five piece 80° elbow
- 90° tee pipe
- 90° tee with small branch
- Tee offset
- Oblique tee at 45°, unequal diameters.

TWO PIECE 45° ELBOW

To develop the pattern, draw the elevation (profile) of the elbow full size, using the neutral diameter of the elbow (Figure 5-29).

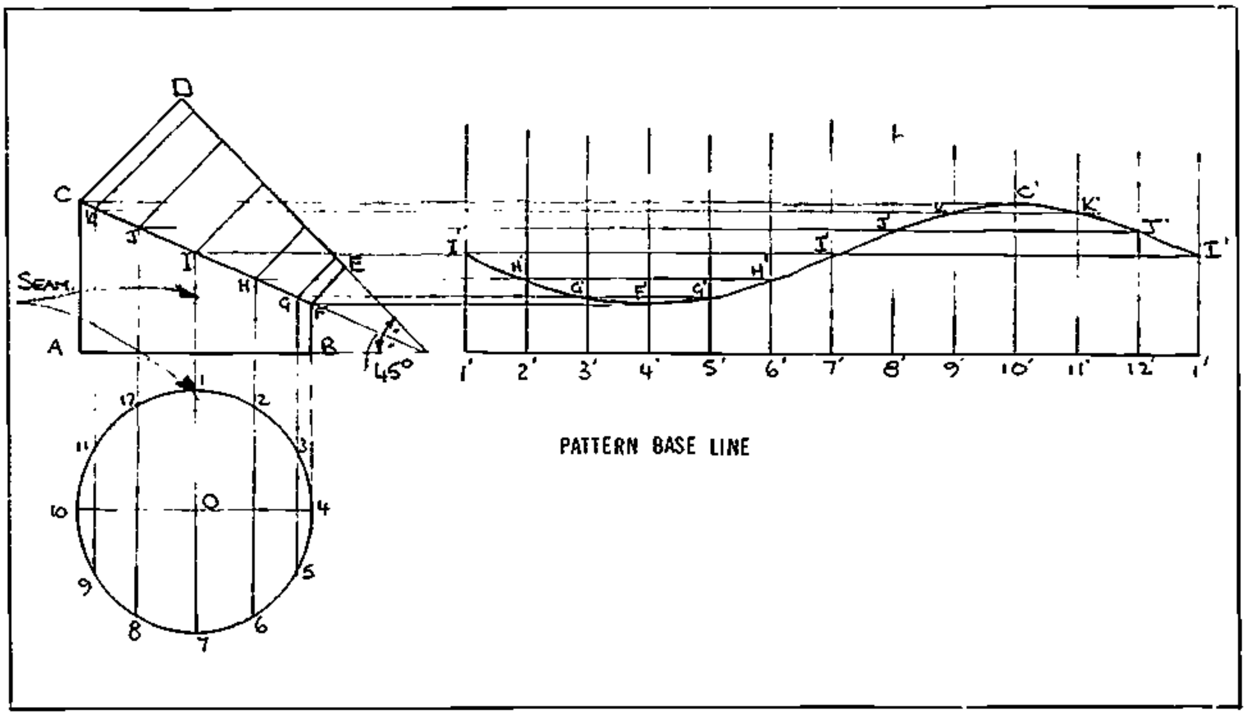


Figure 5-29. Two Piece 45° Elbow

Step 1. Locate the centre of line AB and project a perpendicular line downward.

Step 2. Draw a line parallel to AB, cutting the perpendicular line at O. With centre O and radius 1/2 AB, describe the circle as shown in Figure 5-29.

Step 3. Divide the circle into 12 equal parts and number the divisions from 1 to 12.

Step 4. Project lines 1 through 12 from the circle through base line AB to the metre line CF. The projected lines must be square to 10-4 and AB and parallel to the sides of the elbow.

Step 5. To layout the pattern fro the elbow, extend line AB in the elevation to a sufficient length to contain 12 divisions of the circle. Calculate the circumference of the elbow ($\pi \times D$) **using the neutral diameter.** This length will be the length of the pattern base line.

Step 6. Divide the pattern base line into 12 equal divisions matching arcs 1-2 through 12-1. A close approximation can be obtained by transferring the lengths from the circle to the pattern base line. Number the divisions as shown in Figure 5-29.

Step 7. Square lines from each division point on the base line upwards. Square lines F, G, H, I, J, K, C extending them across and parallel to the pattern base line.

Step 8. A decision must now be made to identify the seam locations on the elbows. In Figure 5-29, the seam will be on element line I-1. The key points of the pattern occur where the projected lines from the elevation cut the vertical lines from the pattern base line. By referencing from the circle to the elevation, the intersecting points can be identified as follows:

Since points 1 and 7 in the circle coincide with I in the elevation, therefore:

1 and 7 intersect at I
2 and 6 intersect at H'
5 and 3 intersect at G'.

Step 9. On large developments it may be more convenient to transfer the heights in the elevation to the pattern by trammels or by measurement. To complete the pattern connect the key intersecting points, and the resulting shape will be the stretchout pattern for one piece of the elbow.

Four Piece 90° Elbow To develop the pattern, draw the elevation full size using the neutral diameter of the elbow, and construct a 1/2 plan on the base line as shown in Figure 5-30.

Step 1. Using principles applied in the previous layout, divide the 1/2 plan into 6 equal parts and project the points through the base line to the mitre line. Note that the elbow is constructed from 2 full sections and 2 half sections.

Step 2. To lay out the pattern, draw the pattern base line 0-0 equal in length to the calculated circumference of the elbow. Divide the base line into 12 equal divisions and number as illustrated in Figure 5-30. Square the lines upward from the pattern base line.

Step 3. Transfer the points from the mitre line on the elevation to the projections from the pattern base line. Trace a line joining the points where the transferred heights from the elevation cut the corresponding numbered verticals from the pattern base line.

Five Piece 80° Elbow The principles applied in the two previous examples form the basis for developing this pattern as shown in the layout in Figure 5-31. In calculating the circumference of the elbow to establish the length of the pattern base line, the neutral diameter must be used. The two end sections are half sections of the main elbow patterns. The position of the seam line is a design specification and may vary from the joint line shown in Figure 5-31.

90° TEE EQUAL PIPES

Step 1. Draw the side elevation as shown in A in Figure 5-32.

Step 2. Draw the end elevation as shown in B.

Step 3. From the vertical pipe in A, describe a semi-circle and divide it into 6 equal parts, numbering the points 0 to 6.

Step 4. From the vertical pipe in B, describe a semi-circle, dividing and numbering to correspond with A as shown.

Step 5. Project lines downward from the points on both semi-circles.

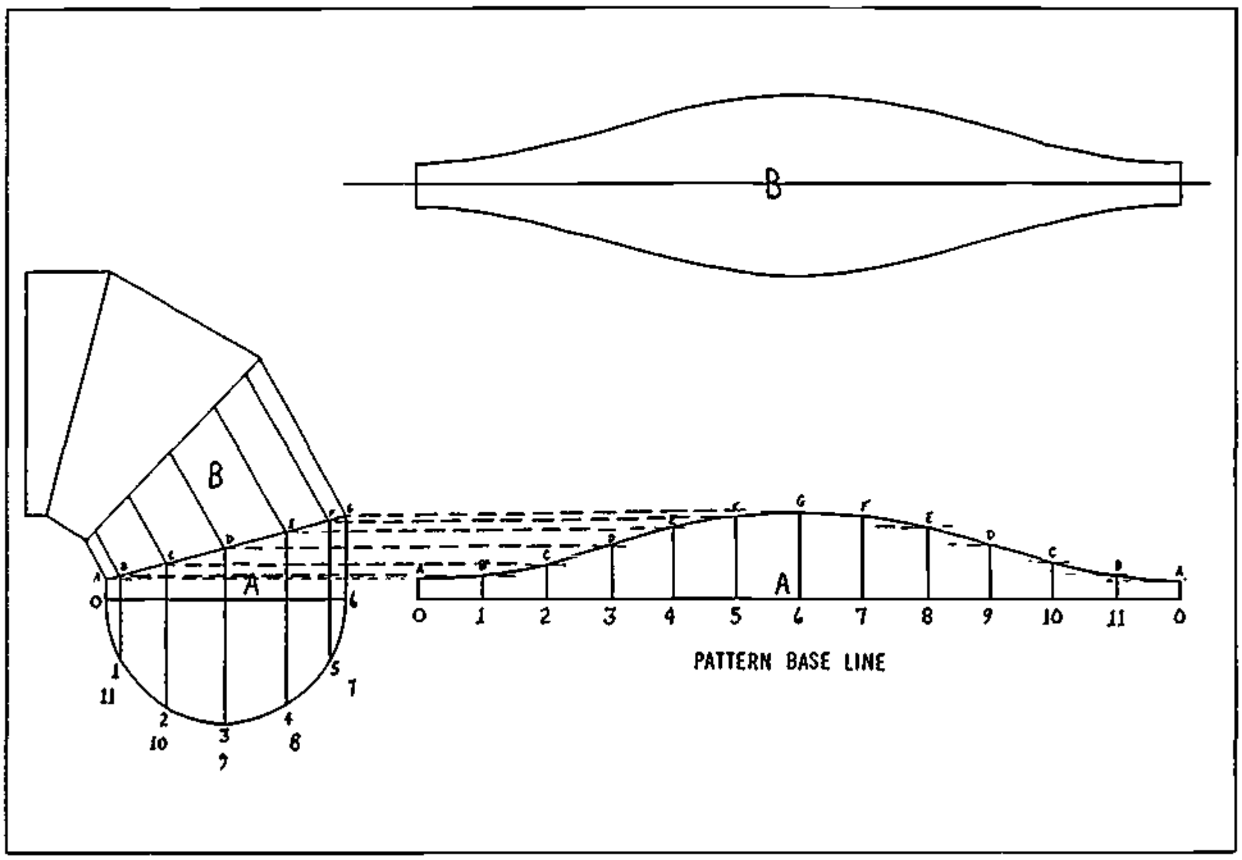


Figure 5-30. Four Piece 90° Elbow

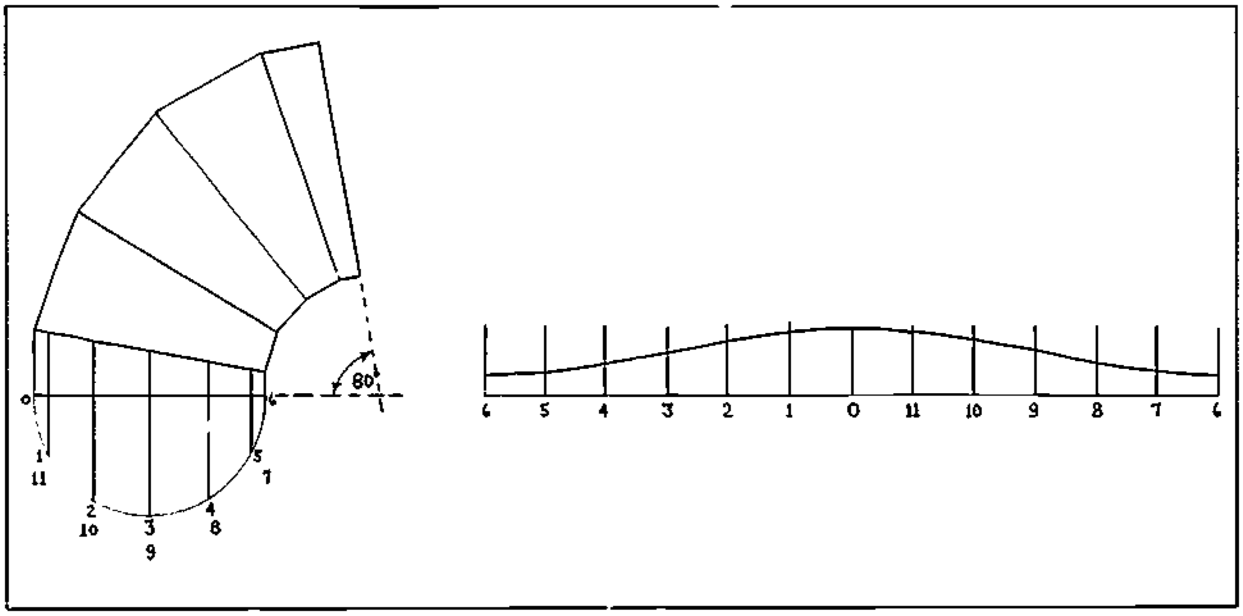


Figure 5-31. Five Piece 80° Elbow

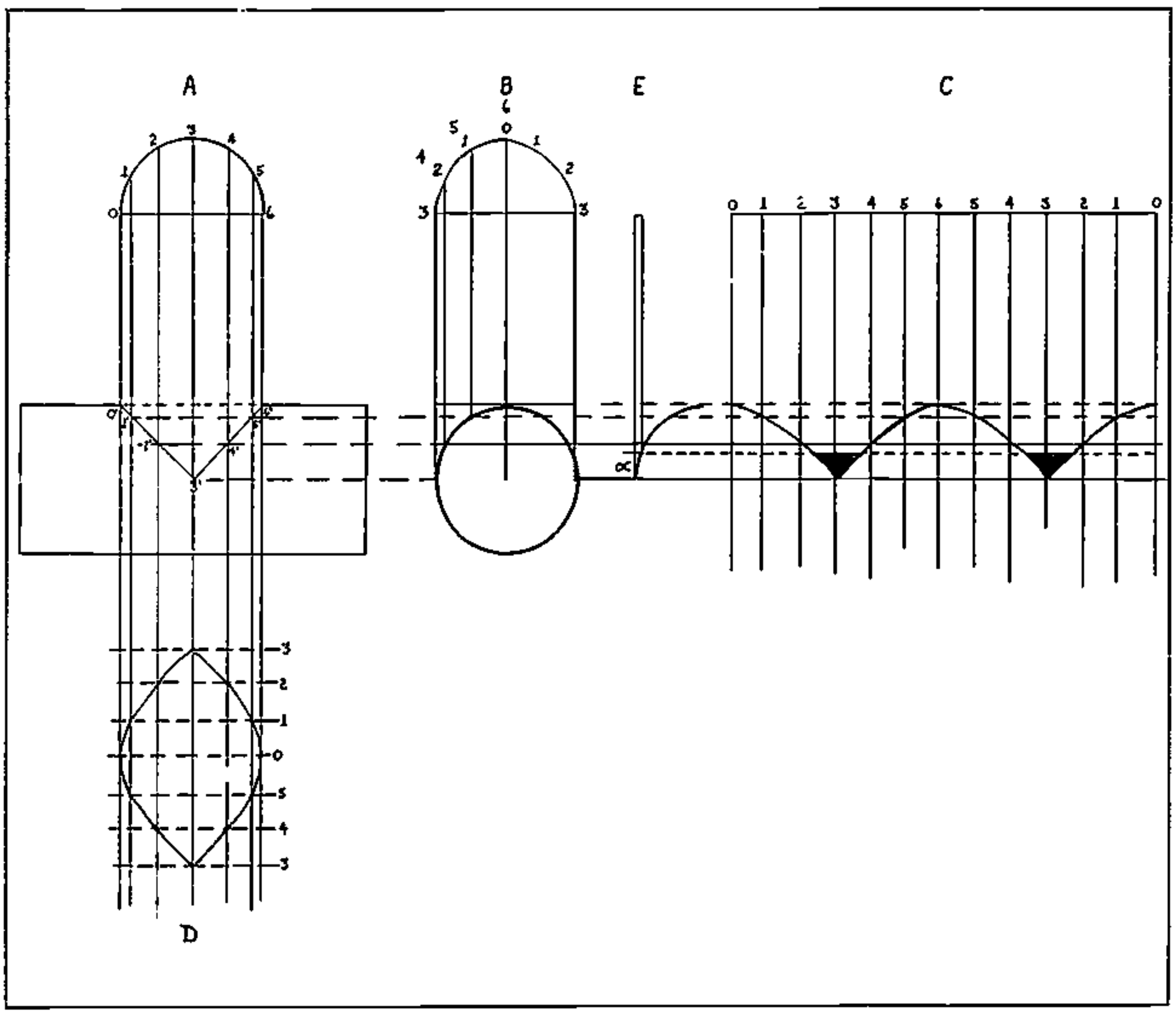


Figure 5-32. 90° Tee Equal Pipes

Step 6 Square lines from the elements in the end elevation to cut the vertical lines in the side elevation Where the corresponding numbered lines intersect, join the points tc locate the mitre line 0', 1', 2', 3', 4', 5', 6'.

Step 7 Calculate the circumference of the cylinder and draw the pattern base line 0-0 equal to the circumference. Divide the pattern base line into 12 equal parts and project and transfer the lengths from elevation A to the pattern. Through the points of intersection in the pattern, draw an even curve to form the shape of the vertical pipe required to fit the mitre line on the horizontal pipe.

Step 8 To develop the hole in the horizontal pipe, project the vertical lines in elevation A downwards. Locate a centre line at 90° to the lines, and mark off distances 0-1, 1-2, 2-3, 0-5, 5-4, 4-3, from elevation B. Square lines from the division points across the vertical projections and describe a curve joining the corresponding intersection points. The resulting hole contour is a true stretchout shape of the hole in the horizontal pipe.

An additional end evelvation "E" in Figure 5-32 illustrates a significant layout consideration when fabricating intersecting pipes. The thickness of the pipe must be taken into account and bevelled as required. In this example, the distance α which is shaded represents the length of the bevel.

It is often practical to use the inside wall length of the pipe as the longest element line to minimize costly fit-up time. In the exercise just described, however, the true length element line was used.

90° TEE WITH A SMALL BRANCH

To develop the patterns for this layout (Figure 5-33), follow the same procedures described in the previous exercise.

Step 1. Locate the mitre line 1', 2', 3', 4', 5', 6', on the side elevation.

Step 2. Describe the stretchout shape for the small pipe on the pattern as shown in C.

Step 3. Develop the stretchout shape for the hole in the large pipe as shown in D.

Step 4. Determine the amount of bevel required from the elevation in E, if the pattern is drawn from the outside pipe length.

In the previous exercise for equal branches, the seam in the stretchout was located on the shortest side; however, remember the seam is a design specification and can be located on any of the element lines. In the layout in Figure 5-33, the seam is located on the longest side.

The shaded portion in C extending from elevation E indicates the option of using the length of the pipe at the inside wall as the longest element line.

90° Tee, Off Centre, Unequal Pipes In this exercise (Figure 5-34) some variations from the basic layout principles described previously are involved. It is very important to number the division points on the semi-circle in the end elevation carefully in order to distinguish the references from each side of the centre line. Thus, in locating the mitre lines on the side elevation A, the visible mitre line derives from correlating points 1, 2, 3, 4, 5, 6 on A with points 1, 2, 3, 4, 5, 6 on B. The non-visible mitre line derives from correlating points 1, 2, 3, 4, 5, 6 on A with points 1', 2', 3', 4', 5', 6' on B.

Step 1. Carefully transfer this numbering system to the divisions on the pattern base line in the stretchout to ensure corresponding points are identified for describing the layout for the small pipe.

Step 2. To lay out the hole in the main pipe, project the lines from elevation A downward and square a line across at a convenient location.

Step 3 Transfer distances, a, b, c, d, e, f from elevation B and square lines across the projected lines as shown in D.

Step 4 Assign corresponding numbers from B to the squared lines and identify correlated intersection points to describe the shape of the hole in the stretchout.

OBLIQUE TEE AT 45°, UNEQUAL DIAMETER PIPES

This project applies some additional variations of principles described in previous exercises.

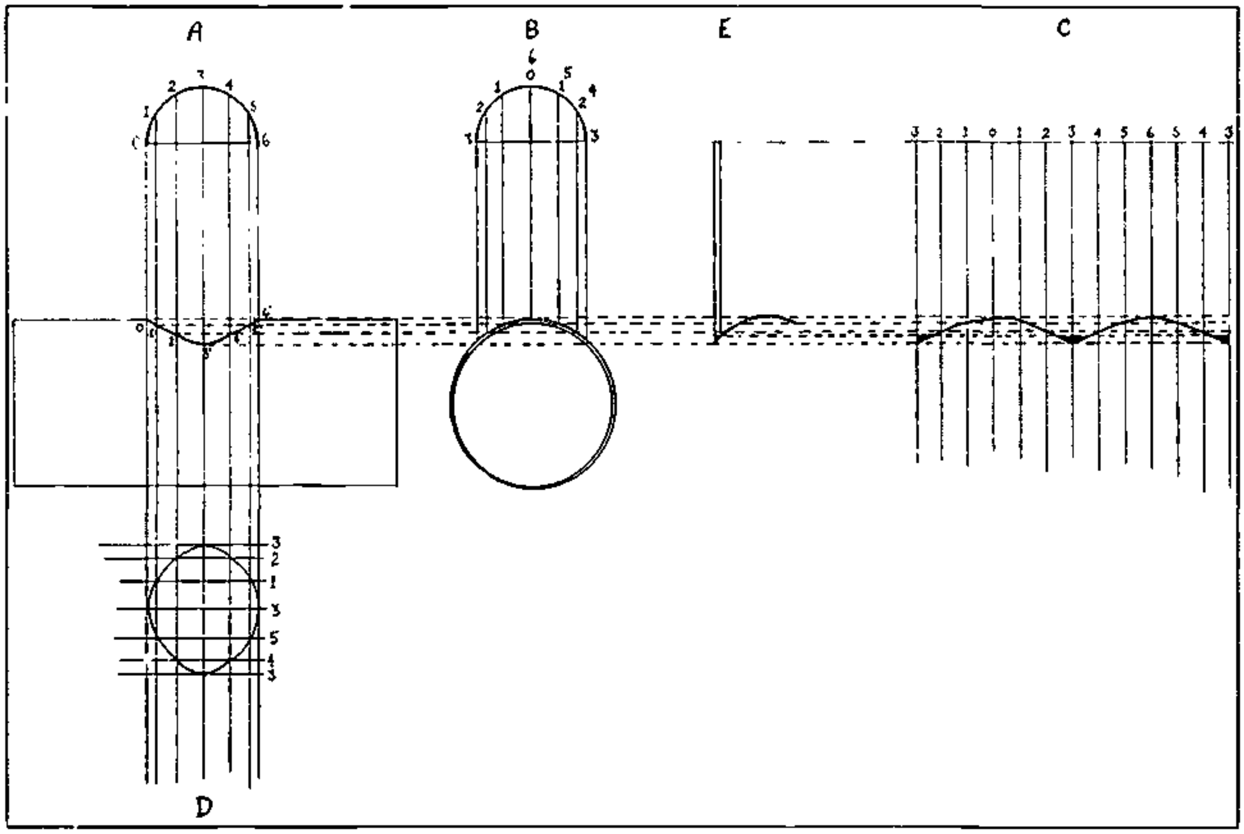


Figure 5-33. 90° Tee with a Small Branch

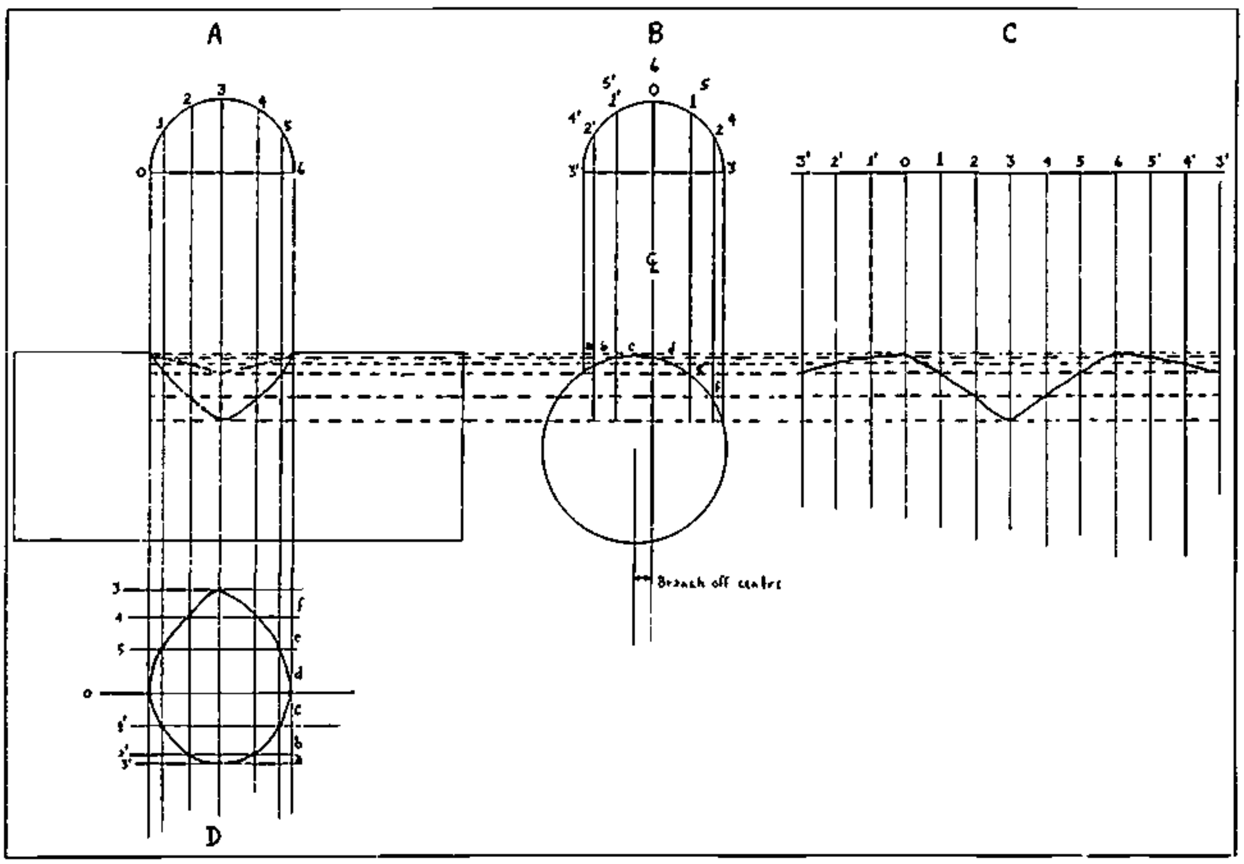


Figure 5-34. 90° Tee, Off Centre, Unequal Pipes

Step 1 To develop the pattern in Figure 5-35, draw side elevation A and end elevation B In a true end elevation, the top of the branch pipe would be shown as an ellipse. This representation, however, does not assist in the pattern development and is therefore shown as a straight line 3-9.

Step 2 Describe semi-circles on each of the branch pipes, divide and number as in Figure 5-35. Project the lines downward in each case parallel to the pipe wall.

Step 3 From elevation B, project lines from intersecting points 3, 24-4, 1-5, 6-0, x 11-7, 10-8, and 9 across to elevation A. Where the projected lines cut the corresponding lines in A, the points can be numbered and joined to locate the mitre line.

Step 4. Calculate the circumference of the branch pipe using the mean diameter (πD) and establish a pattern base line equal in length to the circumference, as an extension of line x'y. Divide the pattern base line into 12 equal parts and number as shown. In elevation B, locate the centre line of the cylinder and transfer the arc lengths from x to the nearest element lines, 7 and 11, to the pattern base line. Project lines from all points at 90° to the base line.

Step 5. Project and transfer the points on the mitre line from elevation A across to the pattern development. Note that each point on the joint curve in the pattern is assigned a number corresponding to the mitre line when the pattern is completed as in C.

Step 6. Indicate on the pattern which way the material is to be formed. This is extremely important. The labels "Roll Up" or "Roll Down" prevent the error of positioning the branch off-centre on the wrong side of the cylinder.

Step 7 To lay out the hole in the cylinder, calculate the cylinder circumference using the mean diameter (π D'). Transfer the required length of the cylinder from elevation A and the calculated circumference to the cylinder layout D.

Step 8 Project the points 0-11 from the mitre line in elevation A to cylinder layout D.

Step 9 Using the stretched out circumference line as a work line, step off the arc lengths from elevation B, x-0, 0-1, 1-2, 2-3, 3-4, 4-5, 5-6, 6-x, x-7, 7-8, 8-9, 9-10, 10-11, 11-x, and square across. The points of intersection should be sufficient to draw the contour of the hole.

RADIAL LINE (CONE) DEVELOPMENT

RADIAL FORMS

This section describes development methods for objects having straight lines (elements) radiating from an apex, commonly called radial shapes. Cones and pyramids, or portions of them, are examples of radial forms. In the Boilermaker trade, these shapes are used for hoppers, separators, funnels and large storage silos.

When a cone is unrolled (stretched out) on a flat plane (Figure 5-36) the apex of the cone remains fixed, and the form unrolls in a circular path about that point as a centre.

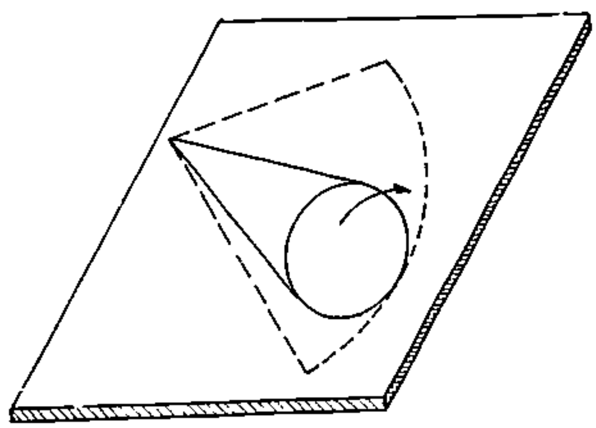


Figure 5-36. Cone Stretched Out on a Flat Plane

When the surfaces of a pyramid are unfolded (stretched out), the same relationship between the apex and the sides applies as for the cone (Figure 5-37).

The required specifications for developing templates for radial forms are:

1. The true lengths of the elements
2. The circumference or perimeter of the base
3. The necessary views
4. The stretchout.

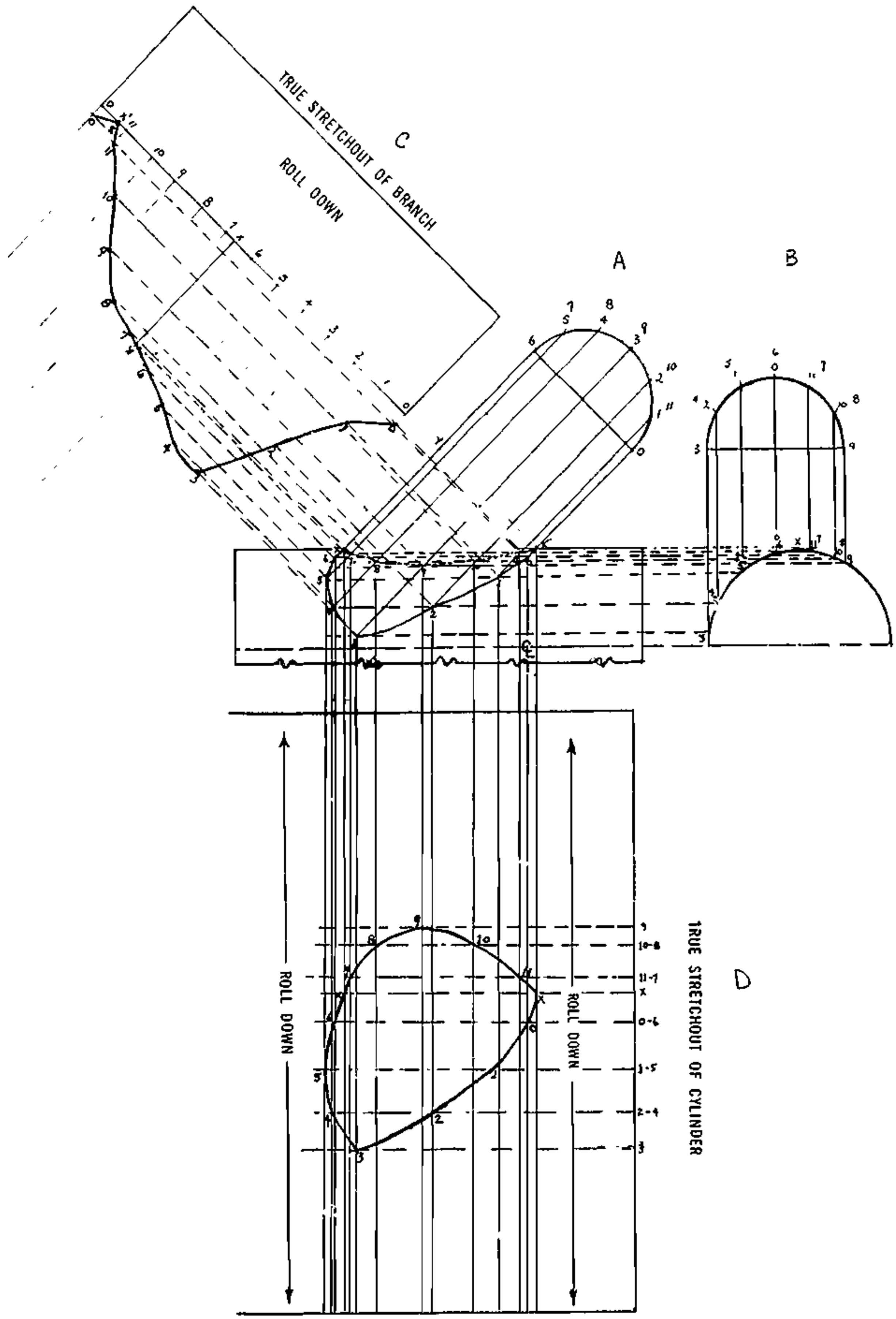


Figure 5-35. Oblique Tee at 45°, Unequal Diameter Pipes

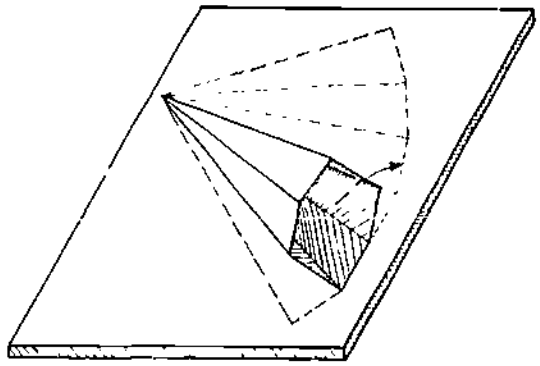


Figure 5-37. Pyramid Stretched Out on a Flat Plane

CONE PATTERNS

In developing a pattern or stretchout, the following factors are important:

1 Dimensions:
   a. Outside diameter
   b. Plate thickness
   c. Total height (base to apex).

2 Template may represent a half pattern only, for ease of handling in rolls or press.

3 Brake line and bend sets must be established and marked on the pattern.

4 True lengths for the slant height (radius) and arc length must be determined:
   a. For small cones, full size cone dimensions can be drawn or laid down OR
   b. For large conical sections, or where more accuracy is required, a mathematical solution for true lengths can be obtained from the dimensions using "Smoley's Tables" and a calculator.

Required Views The right circular cone as a geometric shape is completely described when elevation (front) and plan (top) views are shown (Figure 5-38). Dimensions for height and diameter are set out on the elevation. The plan view shows the circumference.

CONE PATTERN DEVELOPMENT

To develop the cone shown in Figure 5-39, follow these steps:

Step 1. Lay out the cone full size.

Step 2. Bisect the base line of the cone and connect the mid point of the base line to the apex of the cone.

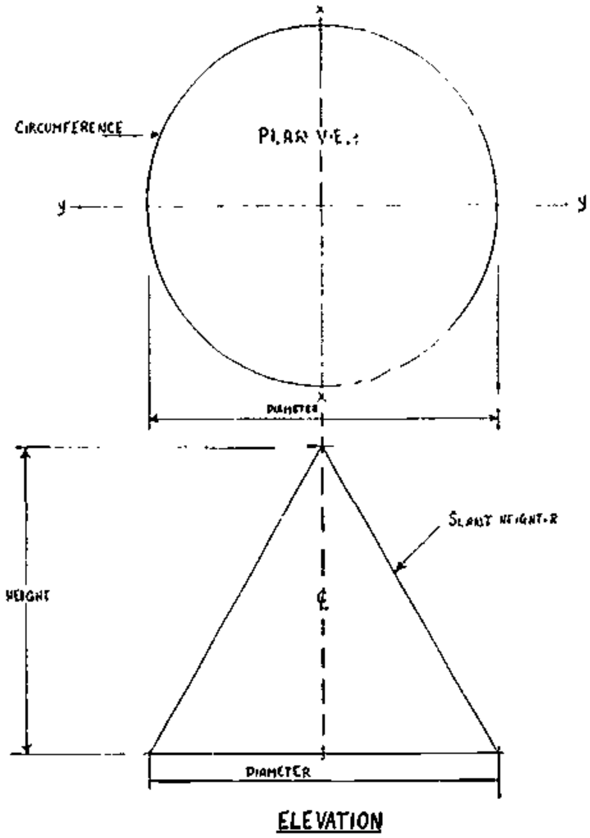


Figure 5-38. Description of Right Circular Cone

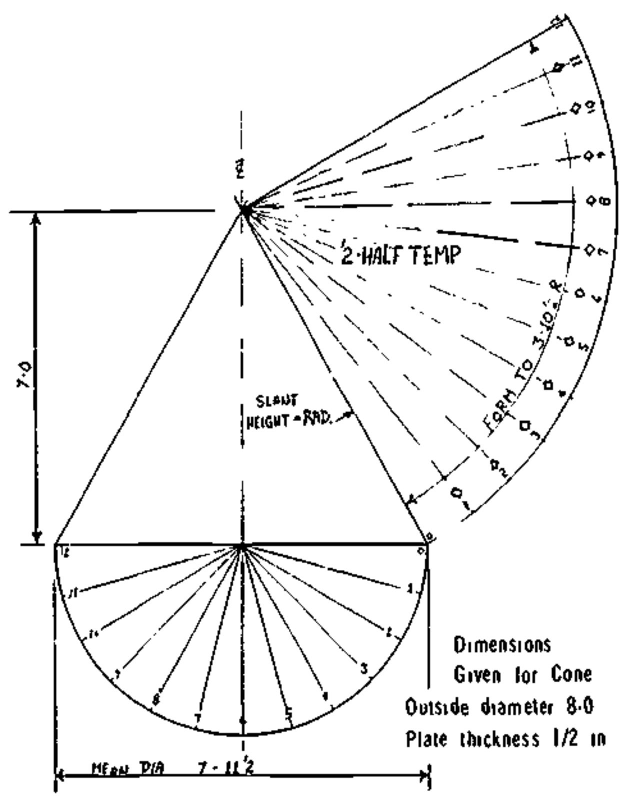


Figure 5-39. Pattern Development of a Cone

Step 3 Describe a semi-circle on the base line with radius equal to 1/2 the base. This constitutes a 1/2 plan of the cone

Step 4. Divide the semi-circle into 12 equal divisions and number as shown

Step 5. Join each division point on the semi-circle to the midpoint of the cone base line.

Step 6. With radius equal to the slant height of the cone in the elevation (this is a true length) and the apex as centre, describe an arc.

Step 7 Calculate the circumference of the cone using mean diameter:

Diameter = 8-0

Plate thickness = 7-11 1/2

Circumference = π × 7-11 1/2
= 3.1416 × 7-11 1/2
= 300.02
= 25-0

Step 8. Using a Boilermaker's wheel or by carefully extending a measuring tape around the constructed arc, measure 1/2 the circumference and join the resulting point to the apex.

Step 9. Divide the arc into 12 equal divisions and number as shown in Figure 5-39.

Step 10 Connect each division point to the apex. These lines will be bend lines if the cone is to be formed in a brake, or guide lines if the cone is to be rolled.

DEVELOPMENT OF CONE BY MATHEMATICAL SOLUTION

The required dimensions are set out in Figure 5-40.

Mean diameter = 8-0 - 1/2 = 7-11½ or 7.9583 ft

Slant height or R $= \sqrt{7^2 + 3.9792^2}$
$=$ 8-0 5/8 - 1/16 = 8-0 9/16 or 8.0469 ft.

Enclosed ϕ to Start the Development of the Cone

$$\phi = \frac{180 \times \text{Diameter}}{\text{Radius}} = \frac{180 \times 7.9583}{8.0469} = \frac{178.018}{2}$$

= 89.009 or 89 (1/2 **Template**)

$$\text{Half Circle} = \frac{7.9583 \times \pi}{2} = \frac{7.9583 \times 3.1416}{2}$$

= 12.5 ft. or 12-6

$$\text{Chord} = 2\left(R \text{ Sin } \frac{A}{2}\right) = 2\,(8.0469 \times \text{Sin } 44.5^\circ)$$

= 2(8.0469 × 7.0091)

= 11.28 ft. or 11-3⅜

Check for ϕ 89° from Table of Bevels

90 - 89 = 1° = 7/32 - 12 is the Bevel

In 8-0 = 8 x .21875 = 1.75 in. or 1¾ in 8 ft.

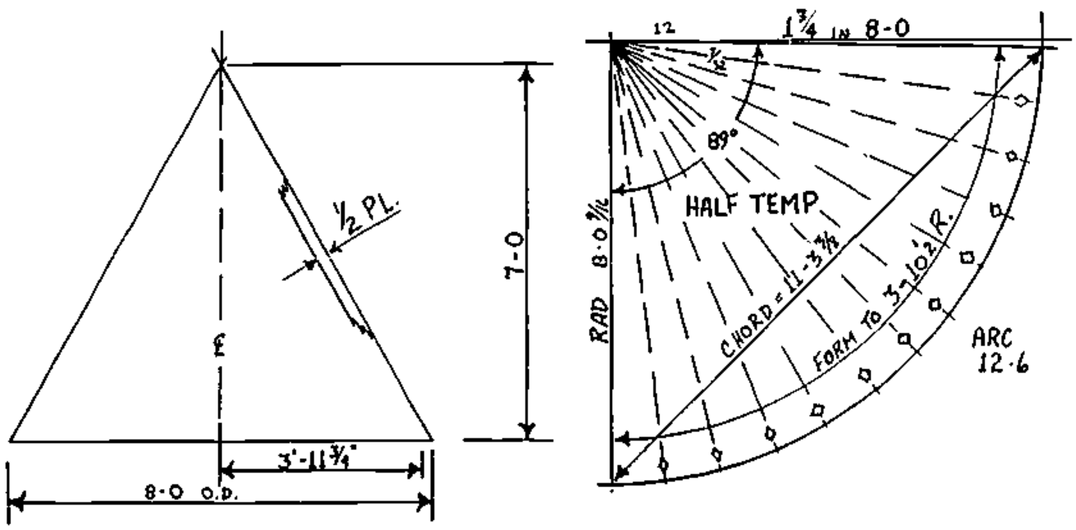


Figure 5-40. Dimensions of a Sample Cone

Check Ø and Chord Using Segmental Functions Smoley's Tables

Given Arc = 12-6 Log = 1.09691
Radius = 8-0 $^{9}/_{16}$ Log = .90563

Ø Log = Log A - Log R
= 1.09691 - .90563
= 19128
= 89

Chord Log = Log C + Log R
= 14669 + 90563
= 1 05232
= 11-3 $^{3}/_{8}$

RIGHT CONE WITH OBLIQUE CUT

Step 1 To develop the pattern (Figure 5-41) for the oblique-cut cone, KABL, lay out the elevation and extend lines AK and BL to intersect at X.

Step 2 On the base of the cone, draw a semicircle that represents half of the perimeter of the base. Divide the semicircle into 6 equal parts and letter A, B, C, D, E, F, G.

Step 3 Erect perpendiculars from these points to cut the cone base AB at g, f, e, d, c, and connect these points to apex X. Number the points at which these lines intersect the angle of cut as 1, 2, 3, 4, 5. To obtain the true lengths of these points from the apex, project them horizontally to line XL.

Step 4. With centre X' and radius XB, describe the arc BB' equal in length to the calculated circumference of the cone. Connect points B and B' to X. These lines represent the selected seam line in the layout, chosen because it will require the shortest weld. Divide the arc into 12 equal parts and label the division points as shown in Figure 5-41. Join these points to X'. Point A is the centre line of the pattern.

Step 5. From X in the elevation, transfer the lengths XL, X5', X4', X3', X2', X1' and XK to the corresponding line on the cone pattern. Connect the points to form the true joint line.

Step 6 To connect the branch to the cone at the intersecting line KL, refer to "Parallel Line Development — Two Piece 45° Elbow. See p. 108.

RIGHT CONE WITH ON-CENTRE BRANCH AT 90°

There are several methods of developing the pattern for a branch that intersects a cone. The

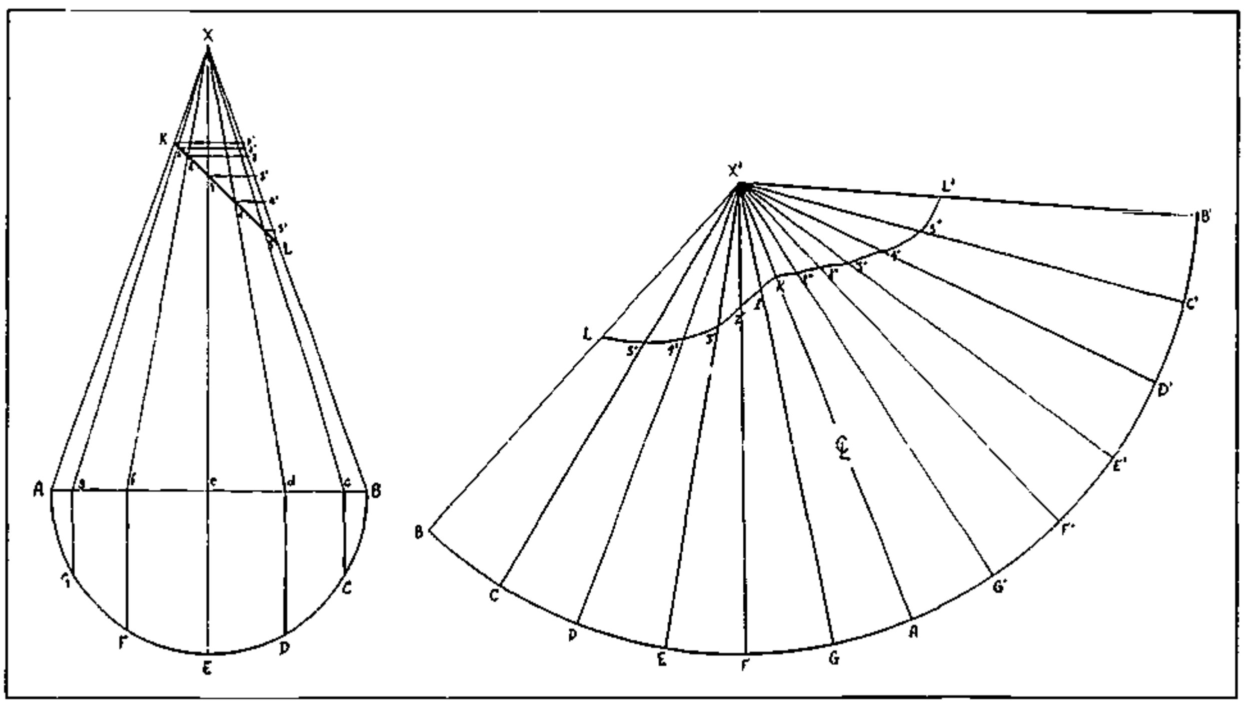


Figure 5-41. Right Cone with Oblique Cut

following method has limited application, but is relatively simple

Step 1 Lay out the elevation as shown in Figure 5-42 and draw a semi-circle on the end of the branch cylinder

Step 2 Divide the semi-circle into 4 equal parts and number as indicated. (**Note:** This varies from previous developments where 6 divisions were used) Project points 2, 3 and 4 horizontally to the centre line of the cone and number 2', 3' and 4'.

Step 3 With centres 2', 3' and 4', and radii 2'a 3'b, and 4'c, describe arcs ad, be, cf

Step 4 With centres 2", 3" and 4", and lengths 2"2, 3"3 and 4"4, describe arcs to cut line 1 - S at points t, 5 and u as shown in Figure 5-42. Project these points horizontally to the cone centre line Where the projected lines cut arcs ad, be and cf, erect verticals upwards to intersect lines 2"2', 3"3', and 4"4' Where point d cuts line 2"2' identifies a true point on the mitre line between the branch and the cone. Similarly, where point e cuts 3"3' and f cuts 4"4' represent additional points on the mitre line. Connect the points to describe the mitre line

Step 5 To develop the pattern for the branch cylinder, calculate the circumference of the cylinder and mark off this length on a line extending from the end of the branch. Divide this pattern base line into 8 equal parts and number as shown in Figure 5-42 In this case, line 5 was selected the seam line.

Step 6. Transfer the lengths from the established mitre line in the elevation to the pattern and join the corresponding intersecting points.

Step 7. To lay out the contour of the hole in the cone, describe an arc using centre A and radius equal to the slant height of the cone and having a length equal to the calculated circumference of the cone. Locate the centre line AX.

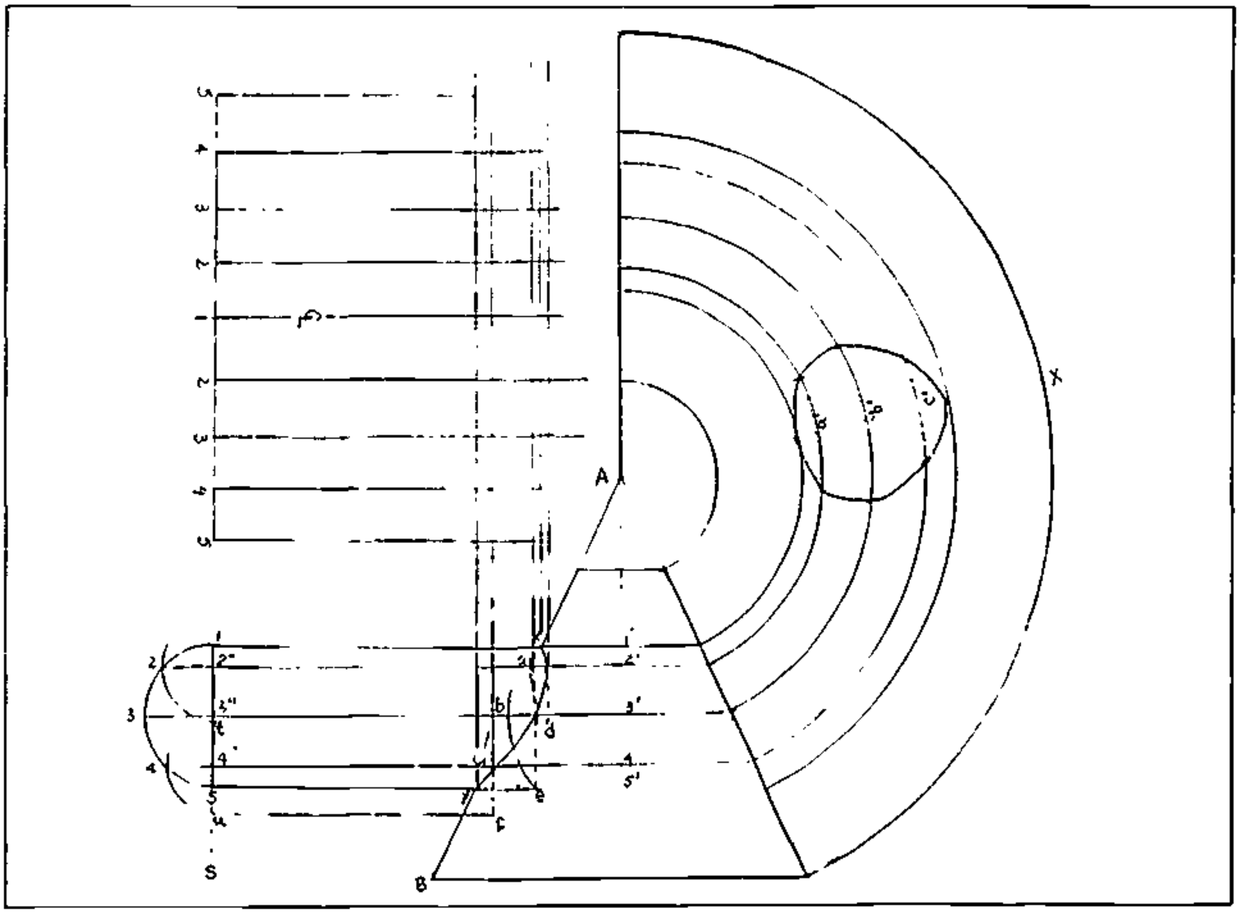


Figure 5-42. Right Cone with On-Centre Branch at 90°

Step 8. With centre A and lengths Ax, Aa, Ab, Ac and Ay, describe arcs in the conical pattern as shown. With centres at a′, b′ and c′, and lengths equal to the arc lengths ad, be and cf respectively, mark off the distances on the corresponding arcs to establish points on the contour of the hole Join the points to form the pattern.

TRIANGULATION

The single most important element of triangulation is finding the true length. The method is simple, yet in the more complicated layouts it can be difficult to establish what is in fact the true length.

The procedure for developing a pattern using the triangulation method involves these steps

Step 1. Establish the plan and elevation views

Step 2 Develop a system of numbering and lettering

Step 3. Establish reference lines

Step 4 Calculate and establish true lengths

Step 5. Mark the template

Step 6. Note bend lines, direction of bend and degree of bend.

The principle of establishing a true length is that a plan length placed at a right angle to its true vertical height will produce a diagonal equal to its true length. For example, Figure 5-43 shows three views of a wide flange strut.

If the plan length L were placed against the true vertical height H, the true length X of the strut would be established. This can be checked by comparing the true length in the elevation view with the length of X. The principle still applies if the strut is offset as in Figure 5-44. By placing the plan length L against the true vertical height H (projected from the front elevation), the true length X will be established.

To illustrate surface development using the triangulation method these layouts are described:

1. Square to Square Transition
2. Square to Round Transition
3. Rectangle to Round, Offset Both Ways.

SQUARE TO SQUARE TRANSITION

To develop the pattern for a square to square transition, draw the elevation and plan views as shown in Figure 5-45. Note in the plan view that triangles have been constructed by joining the following points:

N to E	D to K
E to M	K to C
M to D	C to J

The centre line DL has also been drawn

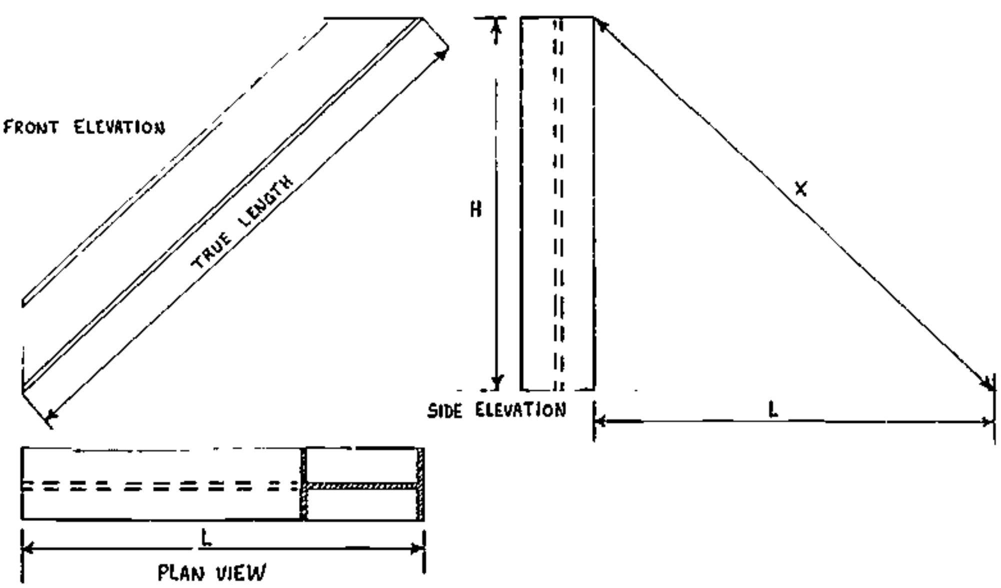


Figure 5-43. Three Views of a Flange Strut

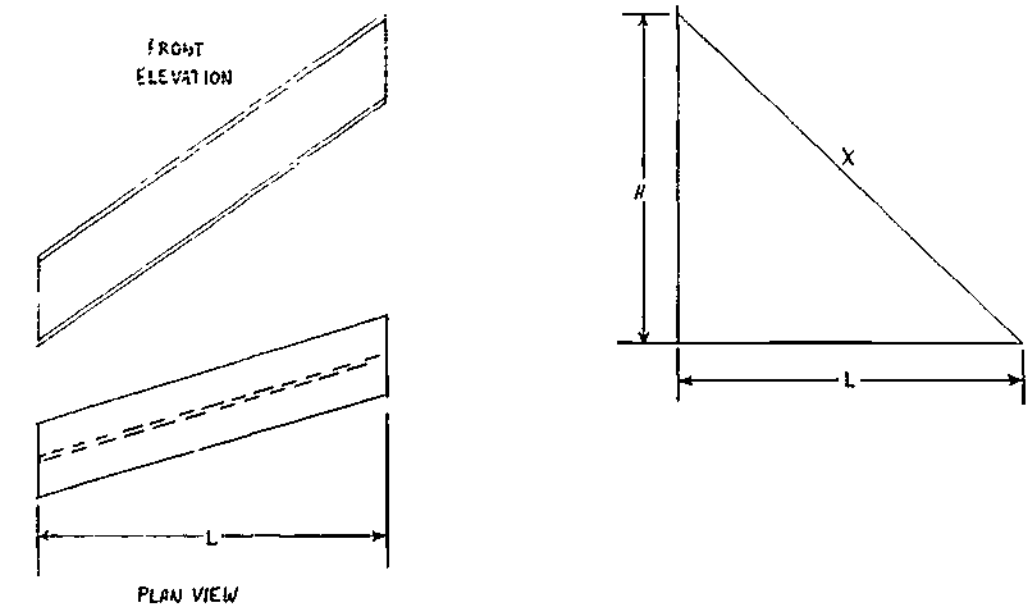


Figure 5-44. Offset Flange Strut

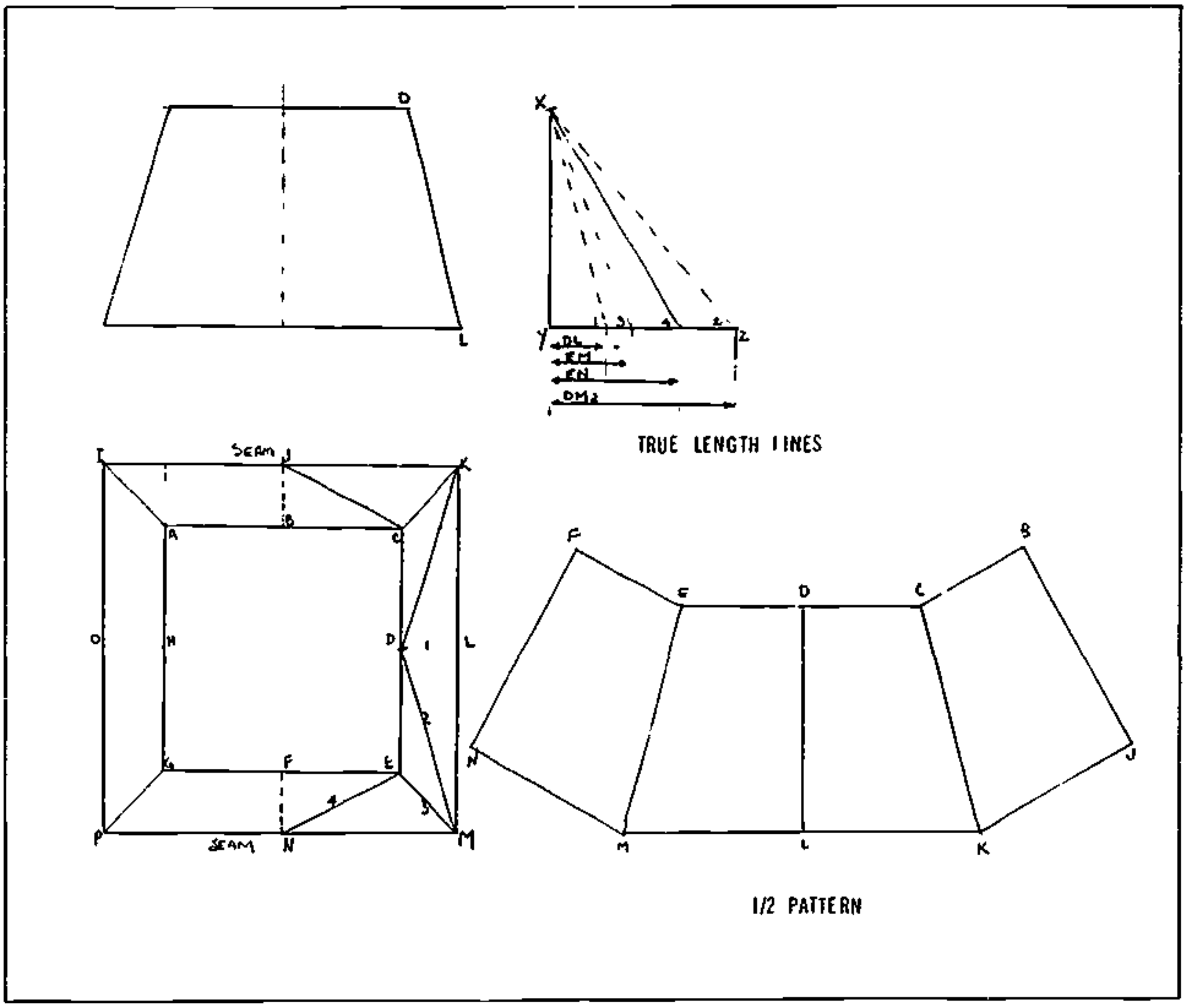


Figure 5-45. Square to Square Transition

Step 1 To determine true lengths, draw the right angle XYZ with XY equal to the vertical height of the transition (transferred from the elevation view). On line YZ step off plan lengths DL, EM, EN and DM. As the transition is symmetrical about the centre lines, the triangles in the other 3/4 of the drawing will be equal to the arcs constructed. Connect the points on line YZ to apex X. These lines represent true lengths of plan view dimensions.

Step 2 To develop the pattern, draw line MK equal to MK in the plan view, and from centre L erect a perpendicular equal to DL in the elevation view which is a true length. Check this length by transferring length X1 from the true length triangle, since X1 is the developed length of plan length DL.

Step 3 To locate points E and C on the pattern, describe arcs from centres M and K and length X3. With centre D and length DE or DC from the plan view (equal lengths), draw arcs to cut at C and E. Join E and C through D. Line EDC should be parallel to MK.

Step 4 To establish points N and J, scribe arcs from centres M and K with length MN to KJ (equal). With centres E and C and length X4, scribe arcs to cut at N and J. Join MN and KJ.

Step 5 To locate points F and B, describe arcs from centres N and J with true length DL from the elevation view (equal to FN). With centres E and C and true length EF (or BC) from the plan view, draw arcs to cut at F and B. Connect C and J to B, and E and N to F. Check to make sure that angles BJK and MNF are 90 angles

The developed plate is 1/2 of the pattern

SQUARE TO ROUND TRANSITION

In the square to square transition above, the conventional method of numbering and lettering to establish true lengths and indicate the triangles was amended to set out the principles more clearly. In the square to round pattern development, the conventional method is applied, and the procedure must be followed closely since the numbering and lettering are extremely important in more complex layouts.

Step 1. Draw the front elevation as shown in Figure 5-46. Since the transition is symmetrical, a full plan view is not required. In fact, a 1/4 plan would be sufficient; however, a 1/2 plan view is used to illustrate the numbering and lettering sequence. The semi-circle in the 1/2 plan is divided into 12 equal parts and the division points labelled and connected to C and E.

Step 2. To develop the true length lines, construct the true length triangle XCA with XC equal to the vertical height of the transition in the elevation view. From the 1/2 plan view, transfer the plan lengths CA, C1, C2, C3, C4, C5 and C6 to the base of the right angle triangle and connect the points to apex X.

Step 3. To develop the pattern, draw base line E'D'C' equal in length to EDC in the plan view. From D erect a perpendicular D6 equal to the true length AB in the front elevation. This true length corresponds to lines AB, D6 and FG in the plan view.

Step 4. Transfer arc length 6-5 from the plan view to the pattern and step off from 6 (this length is constant for the entire pattern).

Step 5. From the true length triangle, transfer the length X5 to the pattern by scribing arcs from centres E' and C' to in- at 7 and 5. (This length equals the true length of lines C5 and E7 in the plan.)

Step 6. Scribe arcs from 7 and 5 equal to the arcs in the 1/2 plan view. With centres E' and C' and length X4 from the true length triangle, draw arcs to intersect at 8 and 4.

Step 7. Continue the procedure as established, using true length lines to correspond with the plan view, to locate points 9, 3, 10, 2, 11, 1, G and A.

Step 8 To locate points F and B, use centres E' and C' with length CB or EF from the plan view and scribe arcs. With centres G and A and pattern length D6 (previously stated as equal to true lengths AB and FG), draw arcs to intersect at F and B.

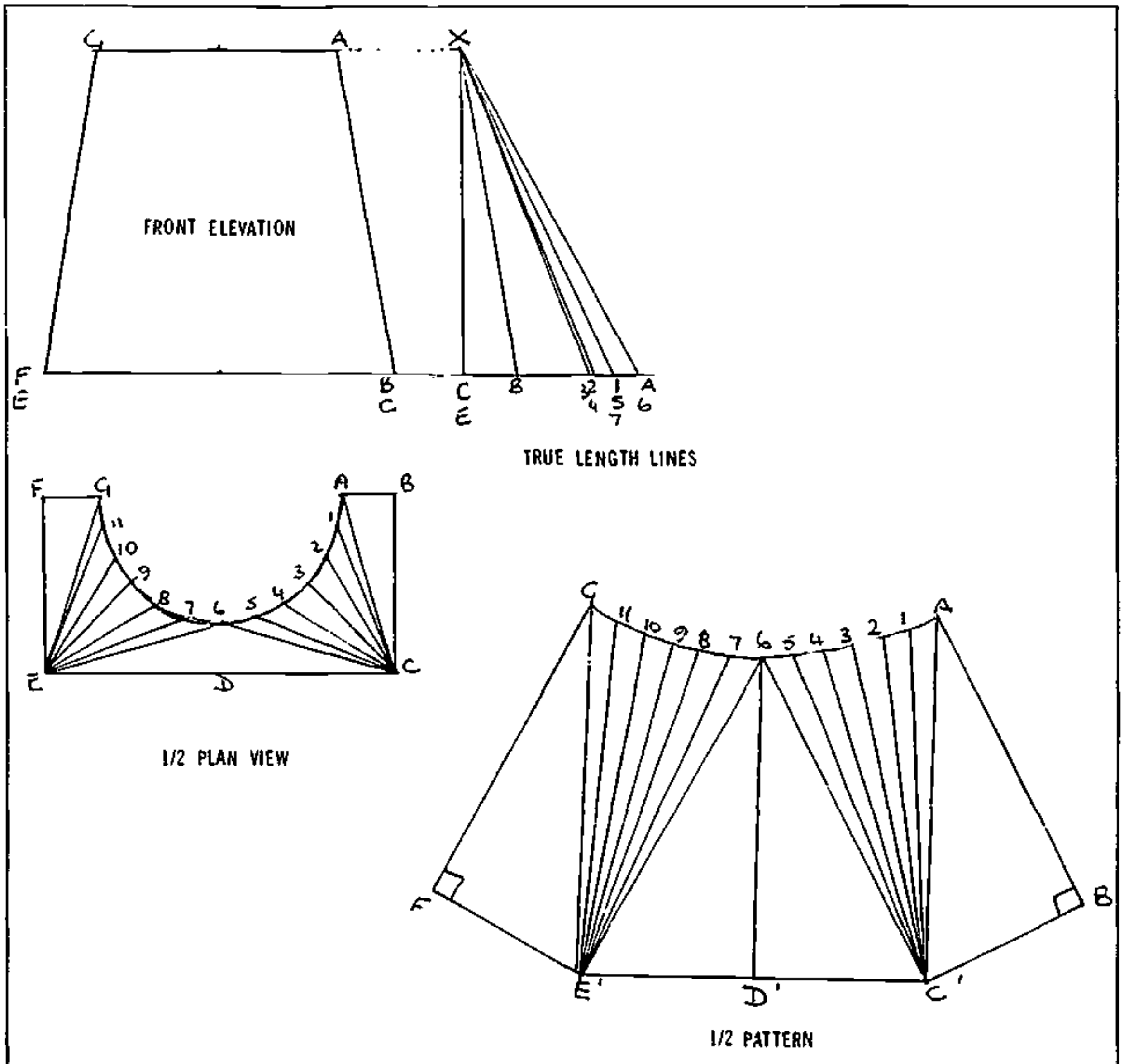


Figure 5-46. Square to Round Transition

Step 9. Connect all points as shown in the pattern. Verify that angles GFE and ABC are 90 since the seams in the plan meet at that angle.

RECTANGLE TO ROUND, OFFSET BOTH WAYS

Since this unit is not symmetrical about either axis, two separate and distinct half patterns must be developed from four different true length triangles. The principles established in the preceding exercises are applied; however, the complexity of this problem requires that the steps in the procedure be followed precisely.

Step 1. Draw the elevation and plan views as shown in Figure 5-47.

Step 2. Divide the round opening in the plan view into 12 equal parts and number the division points 1-12.

Step 3. Join the division points to the corners of the rectangle as follows:

Points 1, 2, 3, 4 to A
Points 4, 5, 6, 7 to B
Points 1, 12, 11, 10 to D
Points 10, 9, 8, 7, to C

Step 4. To establish seams, join E to 1 and F to 7 on the plan view. On one of the true

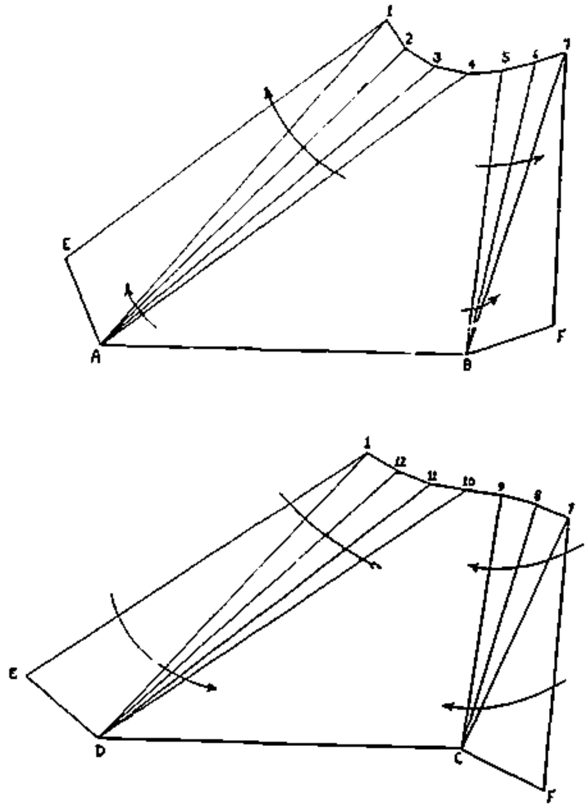


Figure 5-47. Rectangle to Round, Offset Both Ways

length triangles, step off E1 and F7 on the base line, and connect the points to the apex.

Step 5. To develop true lengths for the first half pattern, two true length triangles are required: the first will determine true lengths about point A. See Figure 5-48.

a. Construct a right angle triangle WA4 as shown. (The base A4 is taken from A-4 in the plan view, and the height WA is equal to the true vertical height from the elevation view.)

b. Step off lengths A1, A2 and A3 on the base line, and connect these points to apex W.

c. Construct a second right angle triangle XB7 to determine true lengths about point B. (B7 is taken from the plan view, and XB is equal to the true vertical height as in the first triangle.)

d. Step off lengths B4, B5 and B6 on the base line, and connect these points to apex X.

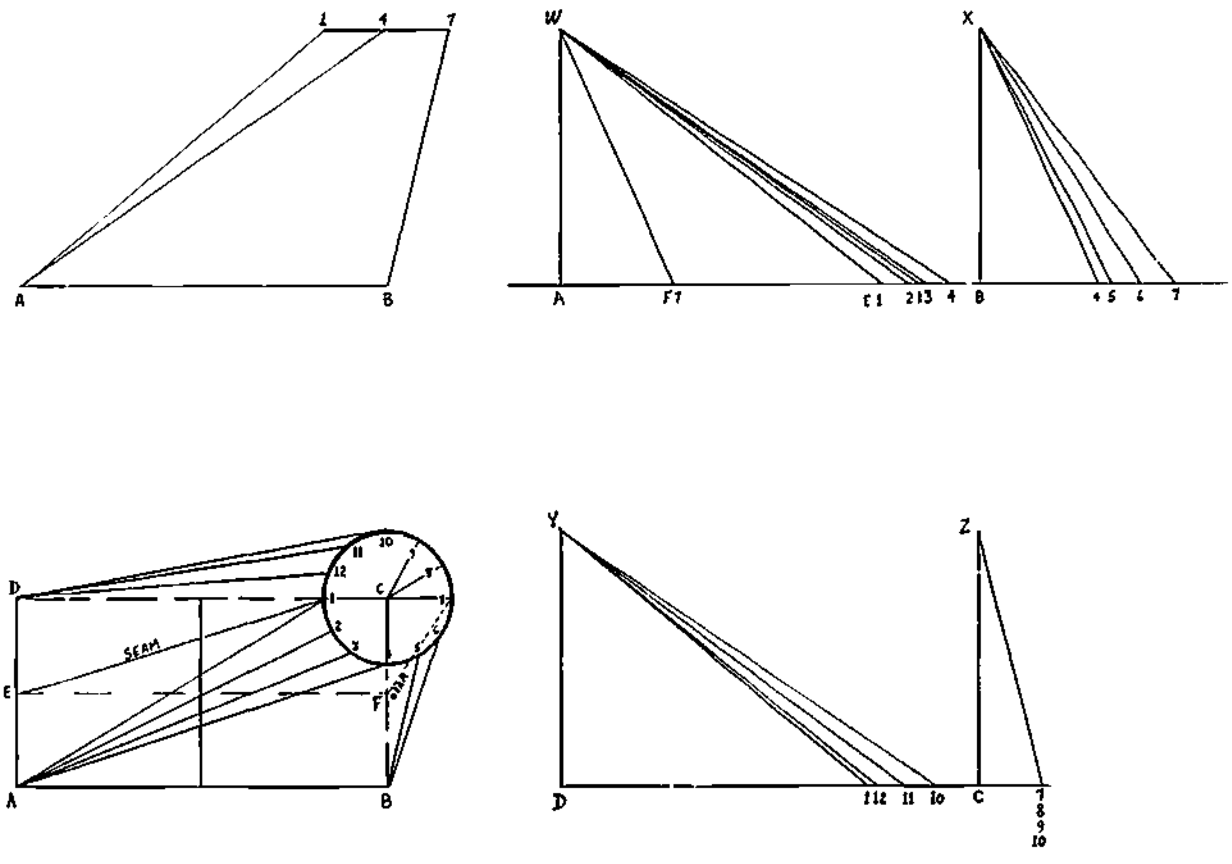


Figure 5-48. Rectangle to Round, Offset Both Ways (True Length Development)

Step 6 To develop true lengths for the second half pattern, construct two additional true length triangles in the same manner:

a. Construct a right angle triangle YD10 to determine true lengths about point D. Step off lengths D1, D12 and D11 on the base line and join these points to apex Y.

b Construct a final right angle triangle ZC7. Note that distances C8, C9, C10 and C7 are equal, since in this unit each is a radius of the circle in the plan view.

Step 7 To develop the first half pattern 1-E-A-B-F-7, draw a base line AB equal to true length AB in the plan view.

a. To locate point 4 as the centre of the curve in this half pattern, scribe an arc from point A and length W4. With centre B and length X4, scribe an arc to cut at point 4.

b With centre 4 and arc length 3-4 (from the plan view), scribe an arc; with centre A and length W3, scribe an arc to cut at 3.

c. Continuing this procedure, locate points 2 and 1 on the curve. Join 1, 2, 3 and 4 to A to establish bend lines for the transition.

d. With centre 4 and length 4-5, scribe an arc, with centre B and length X5, scribe an arc to cut at 5.

e Continuing this procedure, locate points 6 and 7 on the curve. Join 4, 5, 6 and 7 to B to establish bend lines.

f. To locate point E, scribe an arc from centre 1 and length WE1; with centre A and true length AE from the plan view, scribe an arc to cut at E.

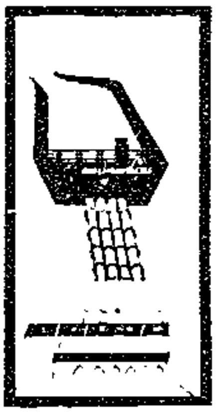
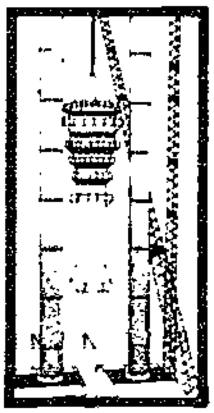
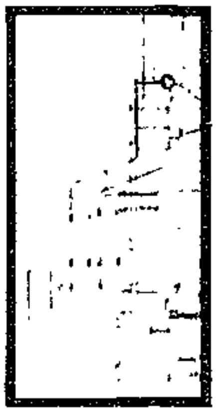
g To locate point F, scribe an arc from centre 7 and length WF7; with centre B and true length BF from the plan view, scribe an arc to cut at F.

h. Join 1-E-A-B-F-7-6-5-4-3-2-1 to complete the first half pattern.

Step 8. Using the same procedure, develop the second half pattern from the remaining true length triangles, drawing base line DC and establishing point 10 on the curve initially. Join the established points to complete the pattern.

Note: The direction of the arrows over the bend lines dictates the side from which the pattern will be shaped.

Chapter 6
BOILERSHOP FABRICATION

INTRODUCTION

Fabrication means the construction or manufacture of parts, and the operations include layout, cutting, forming, assembling, joining and inspection. Layout, cutting, joining and inspection are described in some detail in other chapters of this manual, they are illustrated here only to provide context. The emphasis in this chapter is on forming and assembling.

The principal machines used in fabricating are cranes, press brakes, plate rolls, pipe bending equipment, plate shears, structural shears (cropping shears), welding machines, burning equipment, hole punching and drilling machines as well as a wide variety of jigs and fixtures used to clamp or position parts to be welded

In forming metals the key considerations are:

1 Type of material being formed
2 Thickness of the material being formed
3 Direction of the forming operation

The type of material often dictates the forming process, for example·

1 When forming low carbon alloy steels (T.1, Corten, etc), working the material hot can be extremely detrimental in terms of changing the material's mechanical properties
2 Copper can be over-worked, causing it to work harden and become relatively brittle.
3 High zinc alloys should not be worked in cold temperatures as they may become brittle and crack during the forming operation.

The machine operator may have little control over selecting the forming process; however, he should not arbitrarily change the process without considering the many factors involved

The thickness of the material has great significance for the layout man and the machine operator. The important of working to the mean or neutral diameter is emphasized in the chapter on layout. The following example will illustrate this important point.

WORKING TO THE MEAN

Consider a vessel that will contain a round baffle on the inside with an inside diameter of 54". The shell material is 3/8" thick. Circumference calculations using the formula, $C = \pi D$, result in a flat length of 169 5/9" However, once the plate has been rolled, the vessel's inside diameter will not be 54" but 53 5/8" The reason for this discrepancy can be explained as follows

The length of a piece of plate is only constant for both sides as long as it is flat As soon as it is rolled, its length (or the circumference of the arc or circle it describes) becomes longer on the outside and shorter on the inside (Figure 6-1). The only portion of the plate that retains the original length is the middle of the plate thickness, referred to as the "mean" or "neutral" length or circumference. In the above case, the inside diameter of the rolled plate reflects the shortening of the inside circumference resulting from rolling.

The actual discrepancy between the mean diameter and the outside diameter is 3/8" (from 54" to 54 3/8") (Figure 6-2) which is equal to 1 time the plate thickness. Similarly, the actual discrepancy between the mean diameter and the inside diameter is 3/8" (from 54" to 53 5/8") (Figure 6-2).

To obtain the required inside diameter of 54", calculate the circumference using 54 3/8" as the diameter. This results in a flat length of 170 13/16" which will produce the required 54" inside diameter when rolled (Figure 6-3).

Conversely, when the outside diameter is the critical dimension (54" in this case), calculate the flat length of plate required by using 53 5/8" as the diameter. (Figure 6-4). The necessary flat length is 168 15/32".

From these examples, a rule of thumb can be developed to ensure precise finished dimensions for rolled plate:

For exact O.D., subtract 1 plate thickness from the specified diameter and calculate the required flat length as:

$$C = \pi (D - 1 \text{ p Thickness})$$

For exact I.D., add 1 plate thickness to the specified diameter and calculate the required flat length as:

$$C = \pi (D + 1 \text{ P Thickness})$$

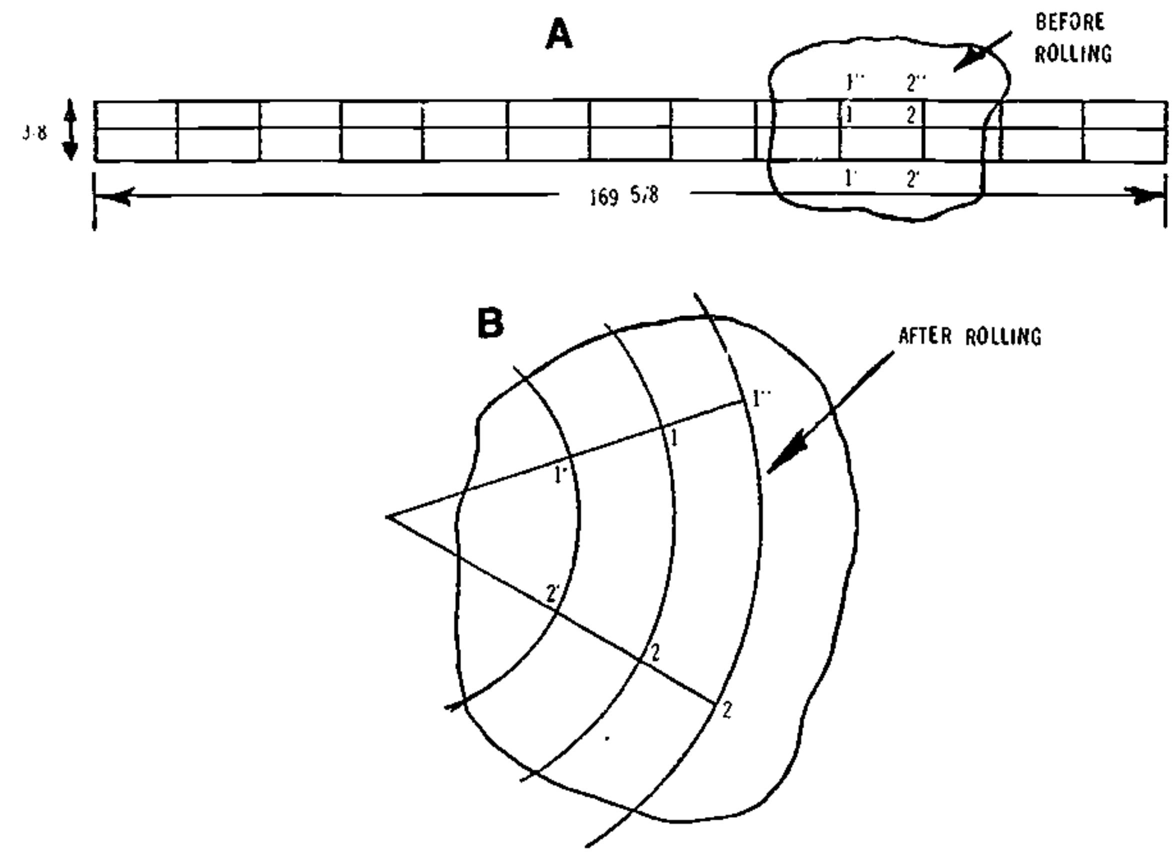


Figure 6-1. Length of Plate Before and After Rolling

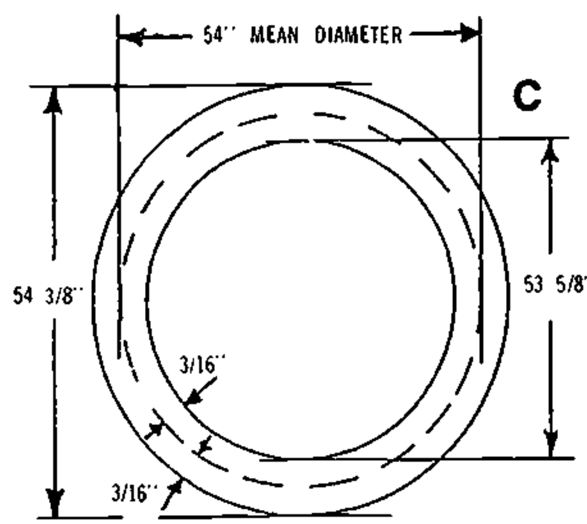


Figure 6-2. Discrepancies Between Mean Diameter and Inside and Outside Diameters

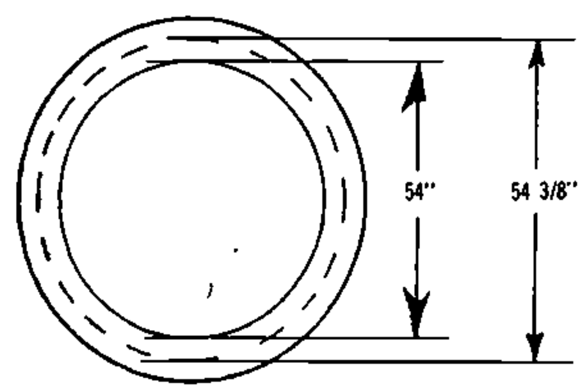


Figure 6-3. Getting the Correct Inside Diameter

GRAIN DIRECTION

A further critical consideration in forming metals is grain direction of the material. The grain direction in rolled steels and other sheet metals runs parallel to the edges of the sheet and strip as they are received from the mill. This feature of metal has the following implications:

Bending Whenever possible, material should be bent **across the grain**. Bending with the grain may cause the material to fracture, and, as thicker materials are used, the problem is more severe. Where bends are required that are parallel to the grain, increase the radius of the bend to the maximum allowable within design and cost considerations.

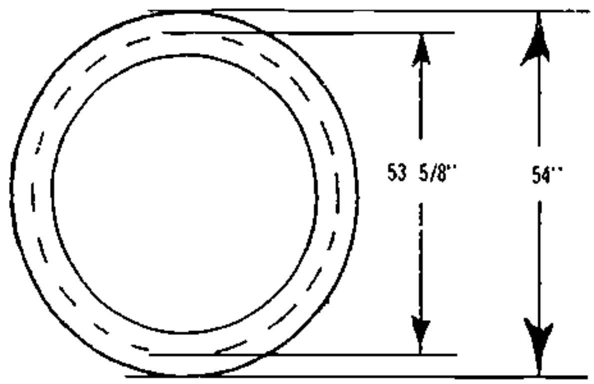


Figure 6-4. Getting the Correct Outside Diameter

Rolling Rolling should be performed in the direction of the grain. However, if it is necessary to roll across the grain, the pressure should be applied gradually to permit realignment of the granular structure so as to prevent severe stress and possible fracture of the material. On thick material, or when the radius is tight, or both, the material should be formed with the grain.

FORMING CONSIDERATIONS

The direction of forming is also important in terms of whether the part is to be left handed or right handed. In Figure 6-5 the influence of forming is shown in the case of a simple bracket to be formed by bending the plate at 90° on the centre line The bracket as shown at A and B in Figure 6-5 indicates the results of bending up and be ·· :ng down for the same item. Note that A and B are not interchangeable.

The amount of "spring back" in forming operations is influenced by the following factors.

1 Type of material
2. Thickness of material
3. Grain structure of the material.

In normal operations in a fabrication shop, the desired angle and radius are usually exceeded in the forming since the material will tend to "spring back" when the force is removed from the forming medium. The amount of "spring back" varies with different materials and sometimes with similar materials from different suppliers.

Since experience is the most important criterion when determining the degree of "spring back," test bends should be made whenever possible prior to forming. In the case of multiple bends check the first bend and, if necessary, make allowance on subsequent bends.

Information for the forming procedure is marked on the plates. As Figure 6-6 in A shows, the marking of a hopper plate for bending with instructions "bend up," "bend down" (sometimes marked "up sq.," "down sq.," "up to set" and "down to set") is made with a paint stick or wax crayon The bend mark symbol is marked on the bend. The marking medium is often determined by the finishing material to be used, e.g., wax crayon may be detrimental to a subsequent painted finish, and centre punched lines can cause problems if the finished product is to be lined with corrosive-protective rubber, ebonite, or other substances.

FORMING PROCEDURES FOR CONES

The marking lines and forming procedure for rolling conical work are shown in Figure 6-6 at B. The lines radiate from the apex of the cone; pressure is exerted from the top roll, and the plate is rolled over each line half way to the next line. Repeat this procedure on each bend line with equal rolling and pressure applied to each line Repeat the process several times until the correct contour is obtained. In the absence of plate rolls or rolls of sufficient size and capacity, the operation can be performed in the press brake. In this procedure, it is necessary to avoid flats between the bend lines by: 1) incorporating more bend lines and 2) reducing the angle of each bend.

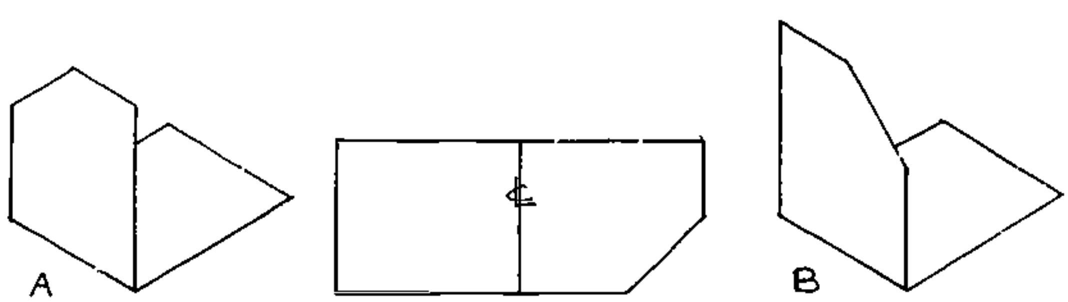


Figure 6-5. Influence of Form on a Sample Bracket

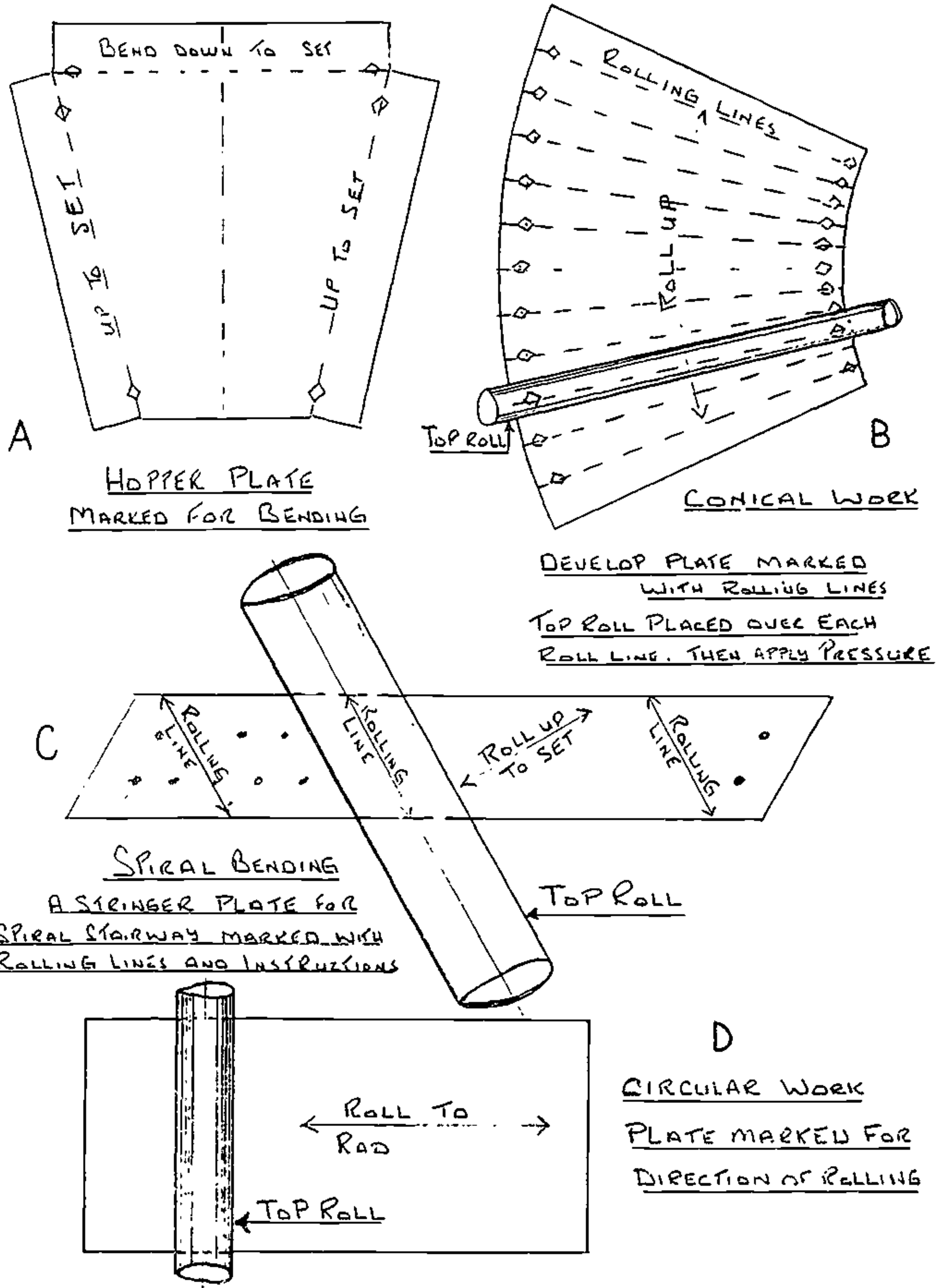


Figure 6-6. Sample Marking Lines and Forming Procedures

Figure 6-6 at C shows a stringer plate for a spiral staircase. The plate is marked with rolling lines to indicate the direction of rolling and to specify the correct hand. The angle of the stringer to the tank is also indicated to provide a check on the amount of radius or set. Owing to the relatively short length of plate rolls and the acute angle at which stringer plates may have to be placed in the rolls, it may be necessary to roll the plate at two or even three settings to obtain the finished contour. The machine operator must be particularly diligent in setting the top roll accurately to obtain the correct spiral bend.

For conventional circular rolling of plates (D in Figure 6-6), the direction of rolling is indicated by marking with arrow pointers and proper instructions. If the plate has special welding preparations at the seam, indicate this clearly as it will determine the decision to roll up or roll down. Similarly, the requirement for mitring or pre-drilling the plate may influence the forming direction.

The ends of cylinders should be pre-formed to the correct radius prior to rolling to avoid flats at the seams. This can be accomplished by setting the ends on the press brake or on a pinch type set of plate rolls, if available.

BASIC RULES FOR FABRICATION

During fabrication, several basic rules should be followed:

1. Before assembly, check individual units for part number, size and straightness. Material fitted into a unit by force using jacks or dogs and wedges is the cause of built-in stresses that may cause premature failure in service or failure during further fitting operations. Oversize material may force parts together causing stresses or may make the finished unit exceed the customer's size tolerances. Undersize material will create gaps between mating parts, resulting in more welding, more distortion and, therefore, more stress. Oversize and undersize result in a less than perfect assembly, adding to the cost of each item.
2. Check material prior to assembly for correct edge preparation, and, if possible, perform machine operations such as drilling, punching, machining, etc. before assembly. For example, it is easier to drill and machine a flange before rather than after assembly. Note, however, that design tolerances may dictate the procedure.
3. During assembly, tack welding is a convenient method of maintaining alignment of component parts. Determine the size, number and length of tack welds by the thickness and shape of the parts to be welded. They must be strong enough to restrain the parts during assembly, and must not break as a result of the strains exerted during moving or when expansion and contraction take place during welding. A tack weld is generally about twice as long as the thickness of the parts to be welded. As tack welds may form part of the finished welded joint, they should have good fusion, penetration and a good surface contour.

PRESS BRAKES

Press brakes are either hydraulic or mechanical

The hydraulic press brake is particularly suitable for plate bending and short run applications of the type usually found in a boilershop Most brakes have interchangeable dies.

The selection of the press brake as a forming medium is determined by the length of the work, the radius or sharpness of the bend and the thickness of the material. The operator must exercise care in following the forming instructions, in aligning the work and in selecting the correct die for the press brake. Figure 6-7 shows a selection of common dies used for material up to 1" thickness. Dies for forming plate greater than 1" thickness are available and are supplied with brakes of sufficient rated capacity.

Note in Figure 6-7 that the included angle for both male and female dies allows for overbending of metal to compensate for springback. Angles from very shallow to 90° are formed by adjusting the press brake ram.

"R" equals the radius of nose of male die and should not be confused with radius of angle formed by die.

PIPE AND TUBE BENDING

Pipe and tube bending are important skills in boilermaking, primarily in shop layout and forming functions, but also in certain field operations.

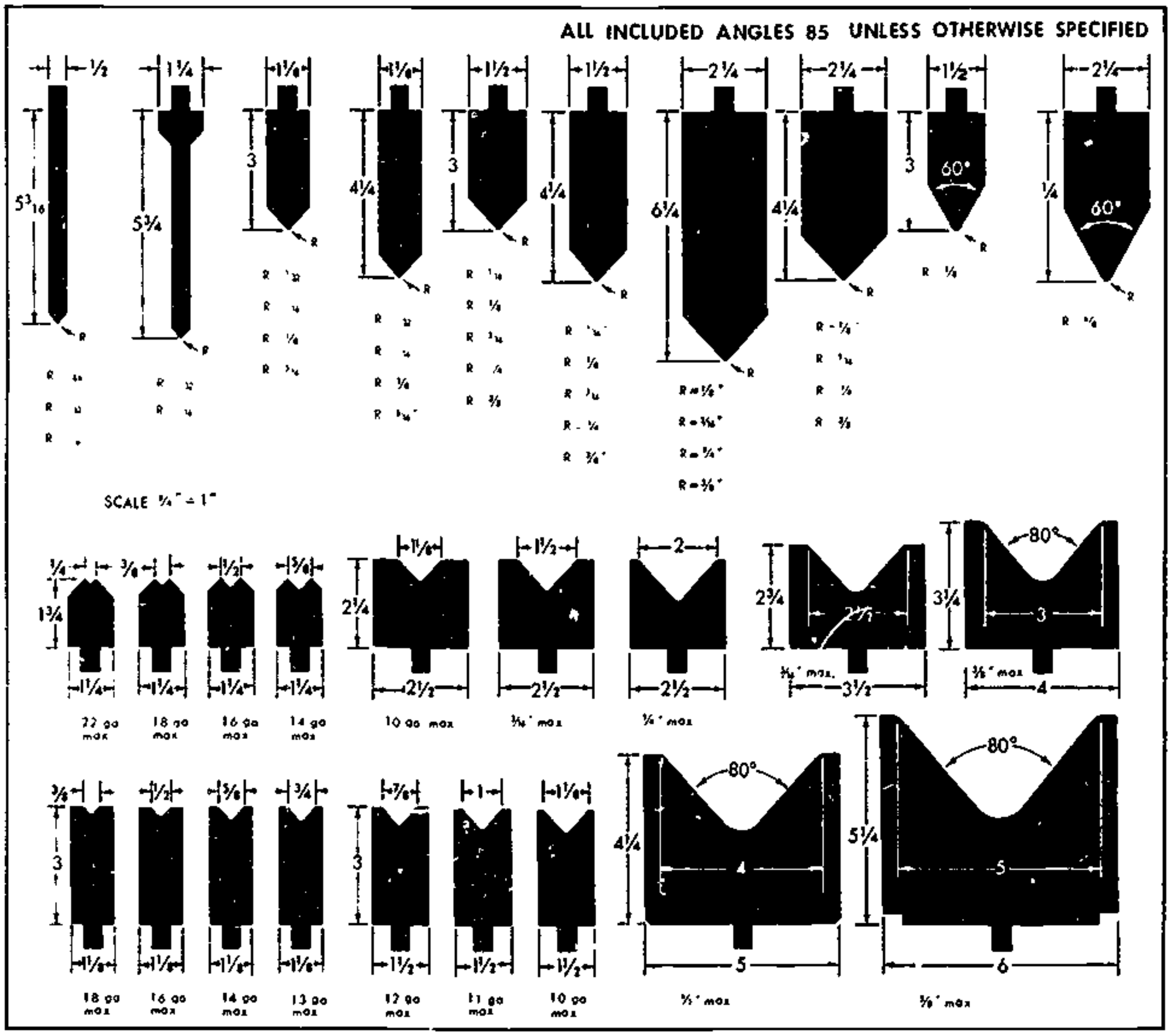


Figure 6-7. Common Air Bend Dies

Pipes are bent either by hand or machine and may be accomplished either hot or cold, depending on:

1. Pipe material
2. Mechanical properties of the material
3. Size of the pipe
4. Service requirements of the bend.

For example, a handrail fabricated from pipe has less stringent requirements than a bend to be used on a high pressure steam line.

In bending pipe or tube, the outer edge is stretched and the inner edge compressed. This distorts the circular shape of the pipe (Figure 6-8).

A technique used to reduce the amount of distortion to acceptable levels is to plug one end of the pipe (a wooden plug can be used) and fill it with sand. Care should be taken to avoid any possible voids in the pipe; use a vibrator, if available, to ensure complete filling. When the pipe is filled, seal the other end of the pipe (again, a wooden plug can be used). Sand is a suitable material for either hot or cold bending. On smaller tubing, a lead alloy can be melted and poured into the pipe. Although very efficient for small tubes, this method is both impractical and costly for larger diameter tubing. (See Figure 6-9.)

Not all bends can be performed in one operation. The radius of the bend determines

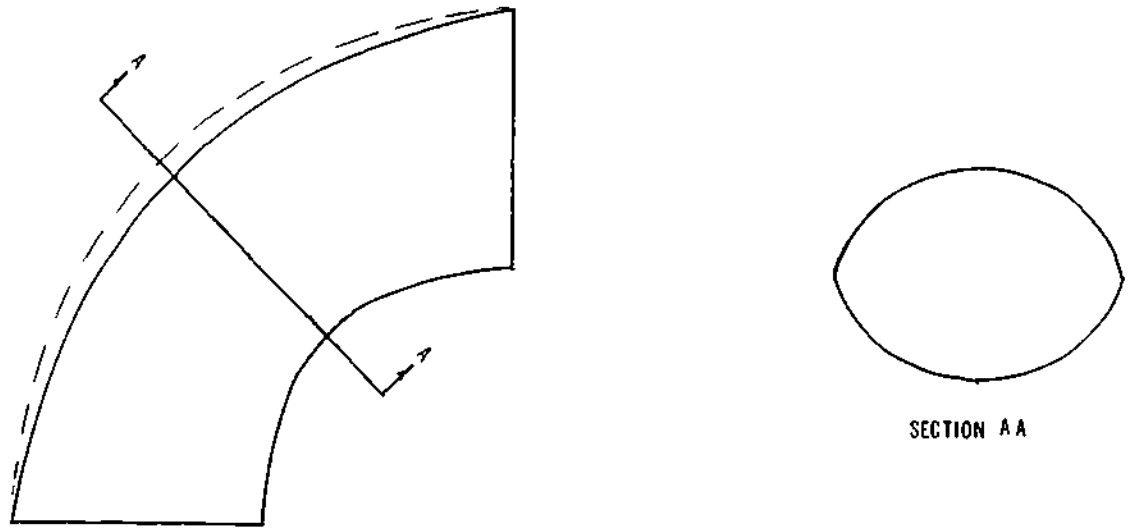


Figure 6-8. Example of Distorition of Circular Shape

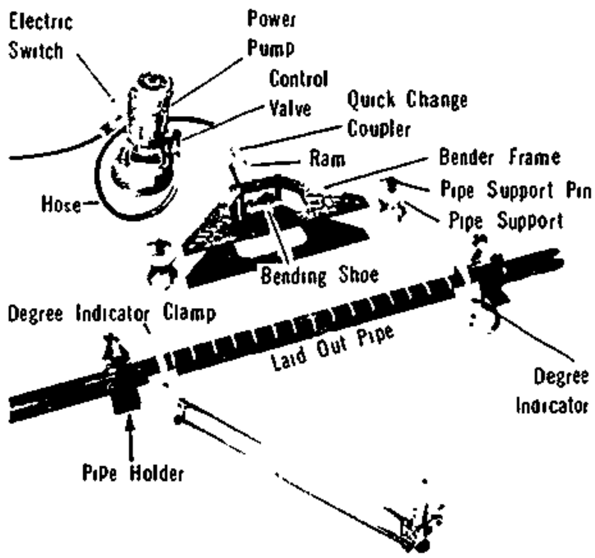


Figure 6-9. Large Sweep and Concentric Pipe Bending

how many "shots" are required to complete the bend.

Before beginning the operation, the following information is required:

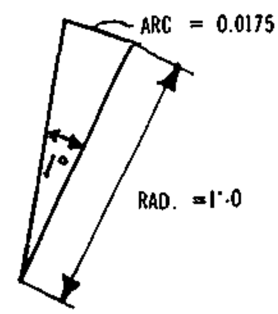
1 Size of pipe to be formed
2 Radius of the bend to the centre of the pipe
3 Total number of degrees in the bend.

By calculation, the true length of the pipe can be determined. The formula for a 90° bend is:

$$\frac{\text{Radius} \times \pi}{2}$$

The formula for any degree bend is:
Number of degrees x Radius x 0.0175
The figure 0.0175 is derived from the length of the arc radius 1.0 for 1°.

Example: Angle = 1° Radius = 1'-0



After determining the length of the bend, the straight section of the pipe can be added.

In all layout and fabrication, use centre lines wherever possible. A simple and accurate method of marking a centre line on a pipe is to place the pipe in machined Vee blocks. Because of deflection in the pipe, a rule of thumb is to locate one Vee block every 8'. If the Vee blocks are 6" wide, place a square or straight edge against the block and measure in 3" as shown in Figure 6-10. The measure can be taken on either end of the pipe, and a chalk line used to join the two measurements.

FORMING A 90° BEND

An example of the procedure is described in a layout required for a 90° bend.

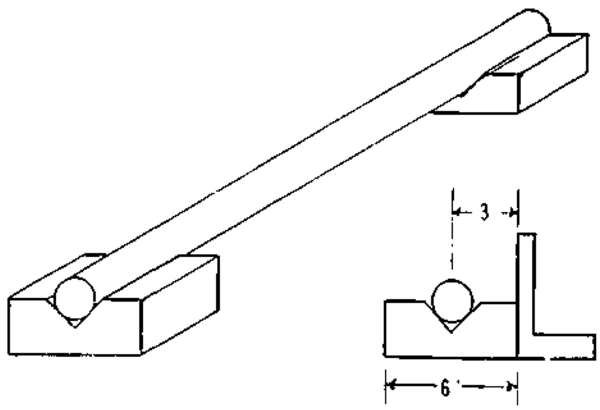


Figure 6-10. Marking a Centre Line

Step 1 Calculate the bending data for a 90° bend, 48" riser or stubup, with 46" leg length, having a 30" radius to the centre line. (See Figure 6-11) On the 30° radius the developed length would be:
30" x 1.57 or
(.175 x degree of bend x bend radius)
= 47.10";
= 47 1/8" rounded out
= developed length which is the portion of pipe that has to be bent.

Step 2 Calculate the gain. On 90° bends, gain equals:
2 x radius - developed length
= (30 x 2) - 47 1/8
= 12 7/8" gain

Step 3. To determine the overall length of pipe, add the two right angle dimensions and subtract the gain of the bend:
(48" + 46") - 12 7/8"
= 81 1/8" overall length of the pipe.

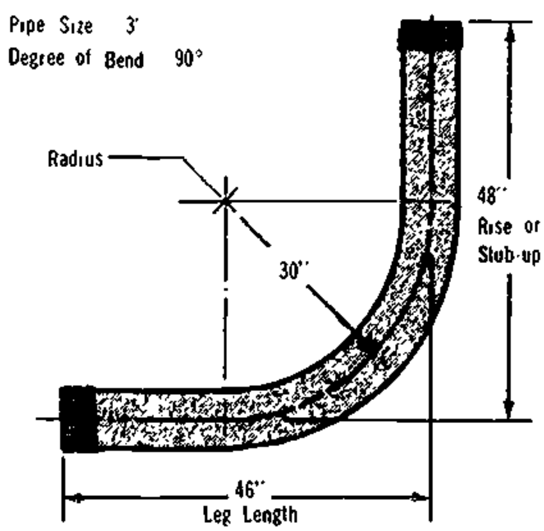


Figure 6-11. Sample Layout for 90° Bend

Step 4. Locate the centre of the required bend using the riser or stubup dimension of 48". Subtract the radius and add one half of the developed length:
(48" - 30") + 23 1/2" = 41 1/2" from the end to the centre of the bend

Step 5. To measure the riser from the bottom of the pipe, add one half the O.D. of the pipe: 41 1/2" + 1 3/4" = 42 1/4"

As a rule 6° bends or less gives a good bend on a 30° radius. In this case 6° per bend will be used, requiring 15 bends:
90° ÷ 6° = 15 bends.

Step 6. To determine the distance between the bends divide the developed length by 15: 47.125 ÷ 15 = 3.14" or 3 1/8"

Step 7. Clamp the pipe firmly in pipe holders. Make the centre mark 41 1/2" from one end of the pipe (Figure 6-12). Mark seven marks on each side of the centre mark, 3 1/8" apart, making a total of 15 marks.

It is always good practice to check the distance between the first and last bend marks to be sure marking is correct. The distance from the first mark to the last mark is the developed length minus the width of one space:
47 1/8" - 3 1/8" = 44"
between the first and last mark.

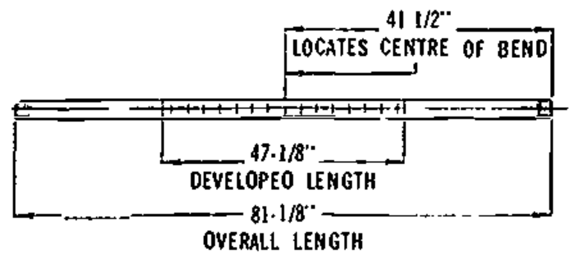


Figure 6-12. Marking Lengths

After the pipe has been located in the bender as shown in Figure 6-13, attach bending degree indicator in the most convenient location. The pipe supports are located with the proper face toward the pipe, the pipe support pins inserted and locked in position by turning the small lock pin.

Using the equipment set-up as shown in Figure 6-13, a 6° bend is made on the first mark. The in-

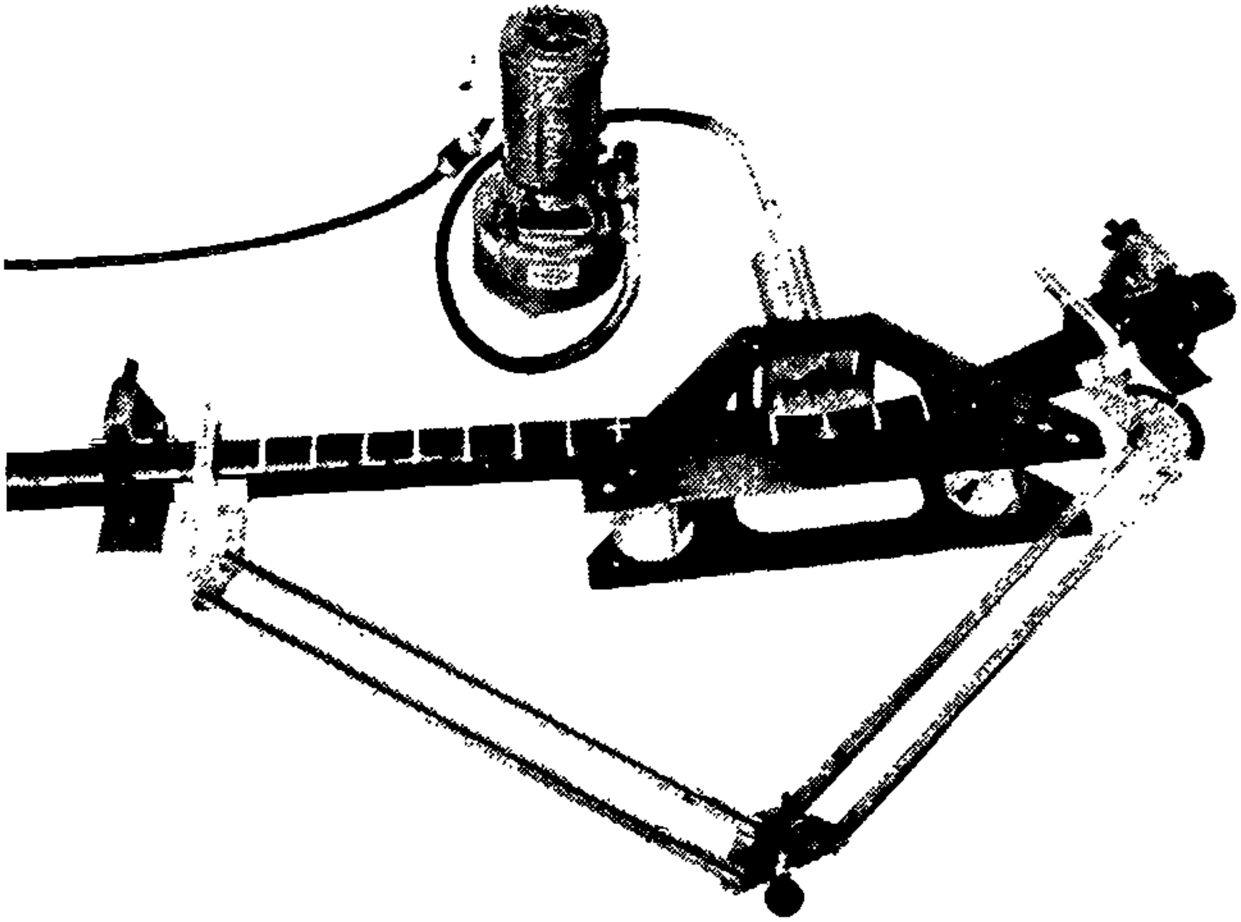


Figure 6-13. Pipe Bent to 18 Degrees-3 Shots

dicator will read 6 . Release the pressure, check the spring back, if any, and overbend the same amount.

When using a bender with a rigid frame, move the pipe support one hole position toward the ram, that is, on the side of the completed bend.

Bend up to 12° on the second mark; check the spring back.

When the bent pipe gets past the one pipe support, the ram travel on the balance of bends is exactly the same.

Follow this procedure until the last mark is reached at which point the bend would be 90° Stop exactly at 90°, release the pressure, check the spring back and overbend the same amount This produces a 90° bend without any wows or twists in the pipe.

Tables 6-1 through 6-4 provide further useful information on this procedure.

TABLE 6-1. FORMULAS

GAIN

Gain for 90° bends = 2 x radius developed length''

DEVELOPED LENGTH

Developed length of any degree of bend

Developed Length = 0175 x degree of bend x radius of bend

Developed length of any degree of bend shown in the chart — multiply the radius of the bend by the constant

Developed Length = radius x constant

DEGREE OF BEND	15°	30°	45°	60°	75°	90°
CONSTANT	262	523	785	1 05	1.31	1 57

EXAMPLE Find the developed length on a 90° bend with a 40'' radius

Developed Length = 40 x 1 57
= 62 80 or 62 13/16''

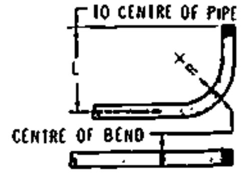
Developed length for 90° bend with any radius up to 100'' is listed on chart shown below

EXAMPLE Find the developed length for a 90° bend with a 25'' radius

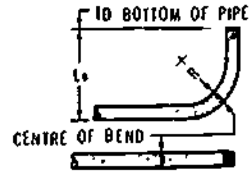
To find this 25 inches, break it down into "20" and "5" The "20" is found in the left column and the "5" is found at the top of the chart Take "20" in the left hand column of the chart and read across to column 5 and the answer is 39 25 or 39 1/4''

TO LOCATE CENTRE OF 90° BEND

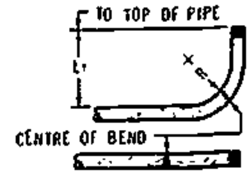
1 Determine leg length to centre Subtract radius of bend Add 1/2 the developed length



2 On leg length to bottom of pipe — subtract the radius and 1/2 the O D of the pipe and add 1/2 the developed length



3 Leg length to top of pipe subtract radius and add 1/2 the O D and 1/2 the developed length



It is useful to know the outside diameter of the pipe and also 1/2 the diameter when bending to make a certain length of leg to the top or bottom of the pipe

OUTSIDE DIAMETER PIPE			ONE HALF THE OUTSIDE DIAMETER	
SIZE	O.D.	FRACTION	O.D.	FRACTION
1/2'' =	840 =	27/32	420 =	27/64
3/4 =	1 050 =	1 3/64	525 =	17/32
1 =	1 315 =	1 5/16	658 =	21/32
1 1/4 =	1 660 =	1 21/32	830 =	53/64
1 1/2'' =	1 900 =	1 29/32	950 =	61/64
2 =	2 375 =	2 3/8	1 187 =	1 3/16
2 1/2 =	2 875 =	2 7/8	1 437 =	1 7/16
3'' =	3 500 =	3 1/2	1 750 =	1 3/4
3 1/2'' =	4 000 =	4	2 000 =	2
4'' =	4 500 =	4 1/2	2 250 =	2 1/4
5 =	5 562 =	5 9/16	2 786 =	2 25/32
6 =	6 625 =	6 5/8	3 312 =	3 5/16

FORMULA FOR MAKING 90° BENDS: R x 1.57 = Developed Length (See Table)

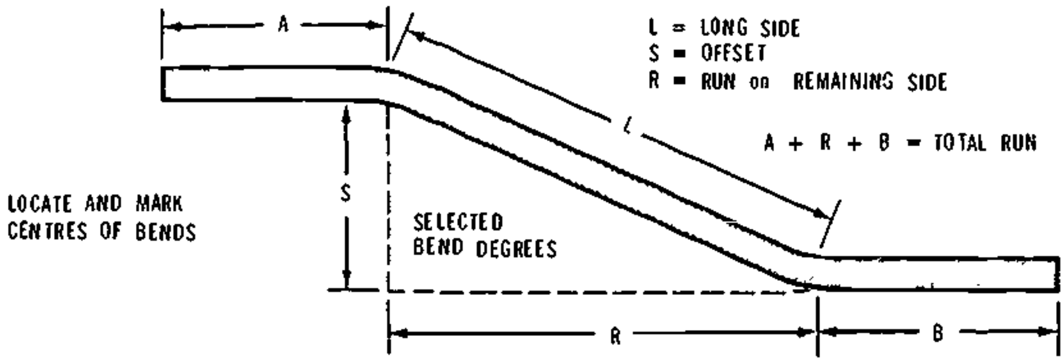
RADIUS— INCHES BY TENS	RADIUS INCREMENTS BY INCHES: 0	1	2	3	4	5	6	7	8	9
0	0	1.57	3.14	4.71	6.28	7.85	9.42	10.99	12 56	14.13
10	15.70	17 27	18.84	20.41	21.98	23.55	25.12	26.69	28.26	29.83
20	31.40	32.97	34.54	36.11	37.68	39.25	40.82	42.39	43.96	45.53
30	47.10	48.67	50.24	51.81	53.38	54.95	56.52	58.09	59.66	61.23
40	62.80	64.37	65.94	67.50	69.03	70.65	72.22	73.79	75.36	76.93
50	78 50	80.07	81.64	83.21	84.78	86.35	87.92	89.49	91.06	92.63
60	94.20	95.77	97.34	98.91	100.48	102.05	105.19	106.76	108.33	
70	109.90	111.47	113.04	114.61	116.18	117.75	119.32	120.89	122.46	124.03
80	125.60	127.17	128.74	130.31	131.88	133.45	135.02	136.59	138 16	139.73
90	141.30	142.87	144.44	146.01	147.58	149.15	150.72			

Developed length for following angles use fraction of 90° chart

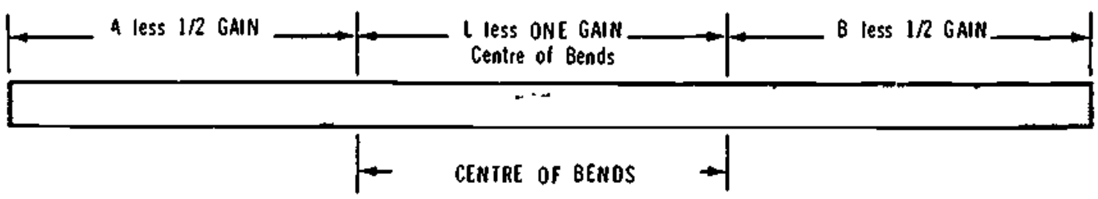
FOR	15°	22 1/2°	30°	45°	60°	67 1/2°	75°	90°
TAKE	1/6	1/4	1/3	1/2	2/3	3/4	5/6	See chart

For any other degrees Developed length = 01744 x radius x degrees

TABLE 6-2. CALCULATING OFFSETS AND LOCATING BEND CENTRES



A + L + B less TWO GAINS = TOTAL LENGTH



TIMES CORRESPONDING MULTIPLIER EQUALS

TO FIND UNKNOWN	KNOWN	TABLE OF MULTIPLIERS FOR SELECTED DEGREES OF BEND 5 5/8°	11 1/4°	15°	22 1/2°	30°	37 1/2°	45°	60°	UNKNOWN
L	S	10 207	5 126	3 864	2 613	2 00	1 643	1.414	1.155	L
S	L	098	195	259	383	50	609	707	866	S
R	S	10 158	5 027	3 732	2 414	1 732	1 303	1 00	.577	R
S	R	098	199	268	.414	577	767	1 00	1 732	S
L	R	1 005	1 02	1 035	1 082	1 155	1 260	1.414	2 00	L
R	L	955	981	966	933	866	793	707	50	R
GAIN PER BEND	RADIUS OF SHOE	0002	0006	0015	0051	0124	0212	0430	1076	GAIN PER BEND

When making offsets it is necessary to make two bends with the same degree of bend The problem involved is how to figure the distance between the two bends Refer to chart above this makes it easy to arrive at the length between the two bends

First determine offset needed, then the degree of bends to be made Then multiply offset measurement by figure directly under degree of bend

The above applies to all sizes of pipe

EXAMPLE 18" offset with two 45° bends 18" x 1 414 = 25½" between bends

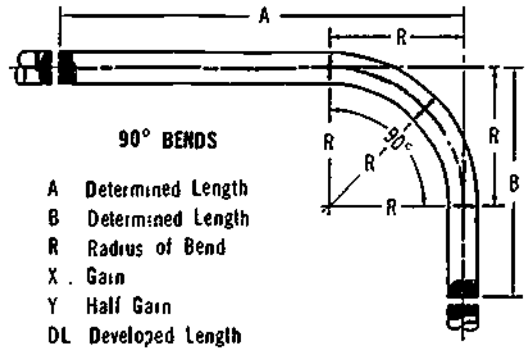
To connect the two ends of an offset to two pieces of pipe already in place it is necessary to know the overall length of the offset from end to end before bending A + L + B 2 gains = overall length

Gain is shoe radius x decimals shown on last line under degree of bends

EXAMPLE 3" pipe 45° offset A36" + L25½" + B48" = 109½" 2 gains 1 9/32" = 108 7/32" Gain is figured 15" radius = 15 x 0430 = 645 for one gain Two gains = 1 9/32"

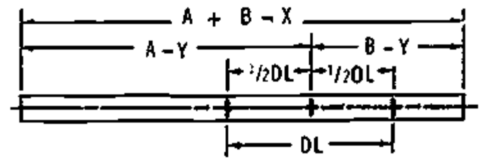
TABLE 6-3. HOW TO LAY OUT 90° BENDS WHEN USING STANDARD 90° SHOES

PIPE	RADIUS OF BEND R	DEVELOPED LENGTH 90°	GAIN X	HALF GAIN Y
1/2	4	6 5/16	1 11/16	7/8
3/4	4 1/2	7 1/16	1 15/16	15/16
1	5 3/4	9"	2 1/2	1 1/4
1 1/4	7 1/4	11 3/8	3 1/8	1 9/16
1 1/2	8 1/4	13"	3 1/2	1 3/4
2	9 1/2	14 15/16	4 1/16	2"
2 1/2	12 1/2	19 5/8	5 3/8	2 11/16
3	15"	23 9/16	6 7/16	3 3/16
3 1/2	17 1/2	27 1/2	7 1/2	3 3/4
4	20	31 7/16	8 9/16	4 1/4

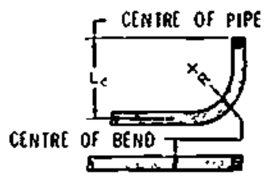


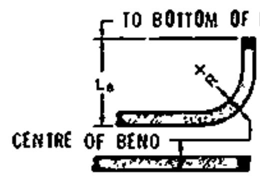
90° BENDS

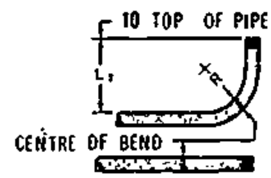
A Determined Length
B Determined Length
R Radius of Bend
X . Gain
Y Half Gain
DL Developed Length
A + B X Length of Pipe Required



LOCATING CENTRE OF BEND FOR REQUIRED LEG LENGTH OR RISE HEIGHT
AS PER A & B WHEN USING STANDARD RADIUS SHOES SHOWN IN ABOVE CHART







PIPE SIZE	Lc MINIMUM		LESS G
	880 M2	883 & 884	
1/2	10 5/16	11 1/8	7/8
3/4	10 7/16	11 15/16	15/16
1"	11 3/8	11 1/4	1 1/4
1 1/4	13 3/16	16 9/16	1 9/16
1 1/2	15 1/16	19 3/4	1 3/4
2"	17 15/16	23"	2"
2 1/2	—	24 11/16	2 11/16
3"	—	29 3/16	3 3/16
3 1/2	—	31 3/4	3 3/4
4"	—	35 1/4	4 1/4

PIPE SIZE	LB MINIMUM		LESS H
	880 M2	883 & 884	
1/2	11"	12 5/16	1 5/16
3/4	11"	12 1/2	1 1/2
1"	13"	14 7/8	1 7/8
1 1/4	15"	17 3/8	2 3/8
1 1/2	17"	20 11/16	2 11/16
2"	18 7/8	24 3/16	3 3/16
2 1/2	—	27 1/8	4 1/8
3"	—	30 15/16	4 15/16
3 1/2	—	33 3/4	3/4
4"	—	37 1/2	6 1/2

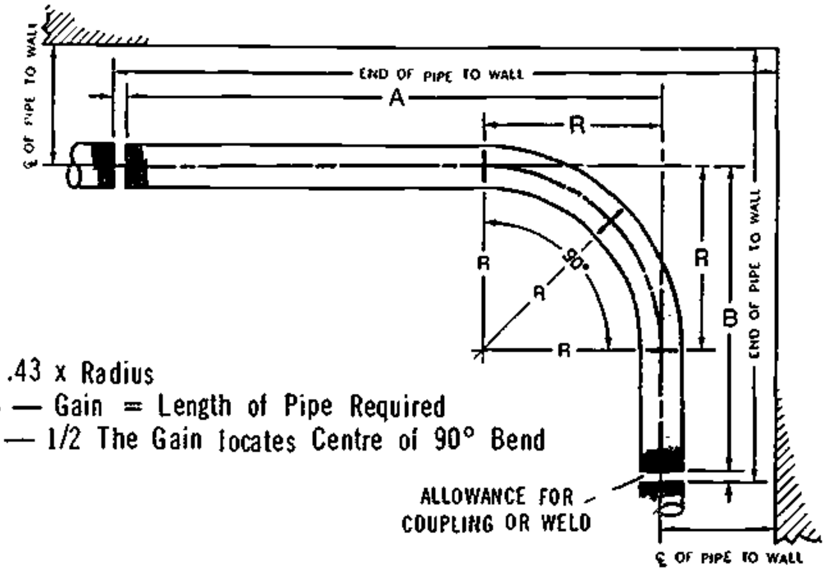
PIPE SIZE	LT MINIMUM		LESS K
	880 M2	883 & 884	
1/2	10 1/8	11 7/16	7/16
3/4	9 15/16	11 7/16	7/16
1"	11 3/4	13 5/8	5/8
1 1/4	13 3/8	15 3/4	3/4
1 1/2	15 1/8	18 13/16	13/16
2"	16 1/2	21 13/16	13/16
2 1/2	—	24 1/16	1 1/4
3"	—	27 7/16	1 7/16
3 1/2	—	29 3/4	1 3/4
4"	—	33"	2"

NOTE The figures for G, H and K remain constant for leg lengths above minimum. Add 4 1/2 to minimum Lc, LB and LT when using No 18D7 Bending Degree Indicator

EXAMPLE Find the centre of bend for a 30" leg measured from the bottom of 2" pipe

Centre of Bend = LB-H
= 30-3 3/16 (see middle chart)
= 26 13/16

TABLE 6-4. HELPFUL CHART WHEN LAYING OUT A 90° BEND



Gain = .43 x Radius
A + B — Gain = Length of Pipe Required
A or B — 1/2 The Gain locates Centre of 90° Bend

Gain for 90° bends can also be arrived at by taking 2 x radius — developed length

JIGS, FIXTURES AND POSITIONERS

Jigs and fixtures are devices used to align parts during fabrication. Positioners are devices that hold units in preferred positions to permit welding in the downhand position.

Jigs, fixtures and positioners are often combined in one apparatus to enable the operator to align the parts and weld them together with the minimum effort, the least cost and assurance that the parts will meet precise specifications. The design of the aligning and positioning assembly should be simple and easy to operate. Clamping devices should operate quickly and efficiently: clamps, toggles, wedges and locating pins are preferred to nuts and bolts which are time consuming to fasten and tighten. Figure 6-14 shows a machine used in welding. The table on the positioner can be rotated and tilted to the most favourable welding position.

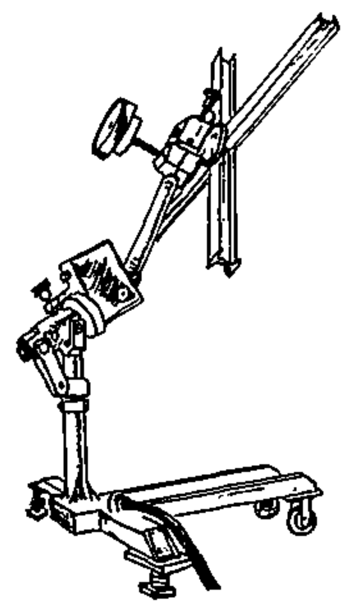
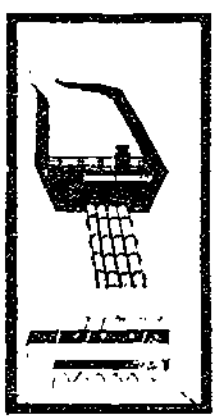
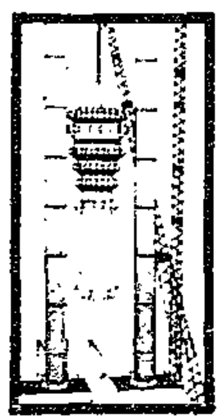


Figure 6-14. Positioner used in Boilershop Fabrication

Chapter 7

RIGGING AND ERECTION





INTRODUCTION

The field Boilermaker relies upon a variety of lifting and support mechanisms to transfer and secure material and equipment on the jobsite At one extreme, immense, sophisticated cranes perform massive lifting and moving operations while at the other, simple systems of ropes and pulleys having sufficient mechanical advantage manage smaller operations to enable "manpower" to provide the required energy. In both cases, the fundamental unit of the system is the line or rope, and the Boilermaker must have a complete understanding of the composition, characteristics, capabilities and uses of all types of line and rope. This chapter describes natural fibre, synthetic fibre and wire rope.

KNOTS AND HITCHES

Both natural and synthetic fibre lines can be tied in various ways to produce knots and hitches to serve specific functions in rigging and erection operations.

In making knots and hitches, the rope (Figure 7-1) is described as having three parts:

1 The **running end** or free end used when making a knot or hitch.
2 The **standing part** is the main line or inactive length of rope
3 The **bight** is the part, usually a loop, between the running end and the standing part.

SECURING LINE ENDS

When a rope is cut, the raw end(s) tends to unravel or untwist and should be secured to prevent losing functional cord. Knotting the raw end is simple, but whipping has several advantages:

1. It does not significantly increase the rope's circumference and thus will still thread through openings.
2 It is a more durable and secure fastening.
3 It can be applied before a rope is cut to prevent any untwisting.

Figure 7-1. Parts of the Rope

WHIPPING A LINE END

Figure 7-2 illustrates the steps involved in whipping a line end:

Step 1. Using a small cord, make a bight near the end and lay the doubled cord along a groove in the rope between two strands. The bight should project about 1/2 beyond the end of the rope.

Step 2. Begin wrapping the standing part of the cord tightly around the line and cord.

Step 3. Continue to wrap toward the end of the rope, ending about 1/2 from the cut. The wrapped portion should be as long as the equivalent of 1-1 1/2 times the rope diameter.

Step 4. At the end of the wrap, slip the cord end through the bight. Then pull the free end of the cord until the bight is drawn under the whipping and the cord is tightened.

Step 5. Cut off ends at the edge of the wrapping leaving a finished termination.

KNOTS AT THE END OF A LINE

1. The **overhand knot** (Figure 7-3) is the simplest knot to make, but should be used only with small cord or twine on parcels. On a larger rope used in handlines and rope blocks this knot jams when pulled tight and damages the fibres of the rope.
2. The **figure eight knot** (Figure 7-4) does not injure the rope fibres and is larger than an overhand knot for tying on the end of a rope to prevent it from slipping through a fastening or a loop in another line.

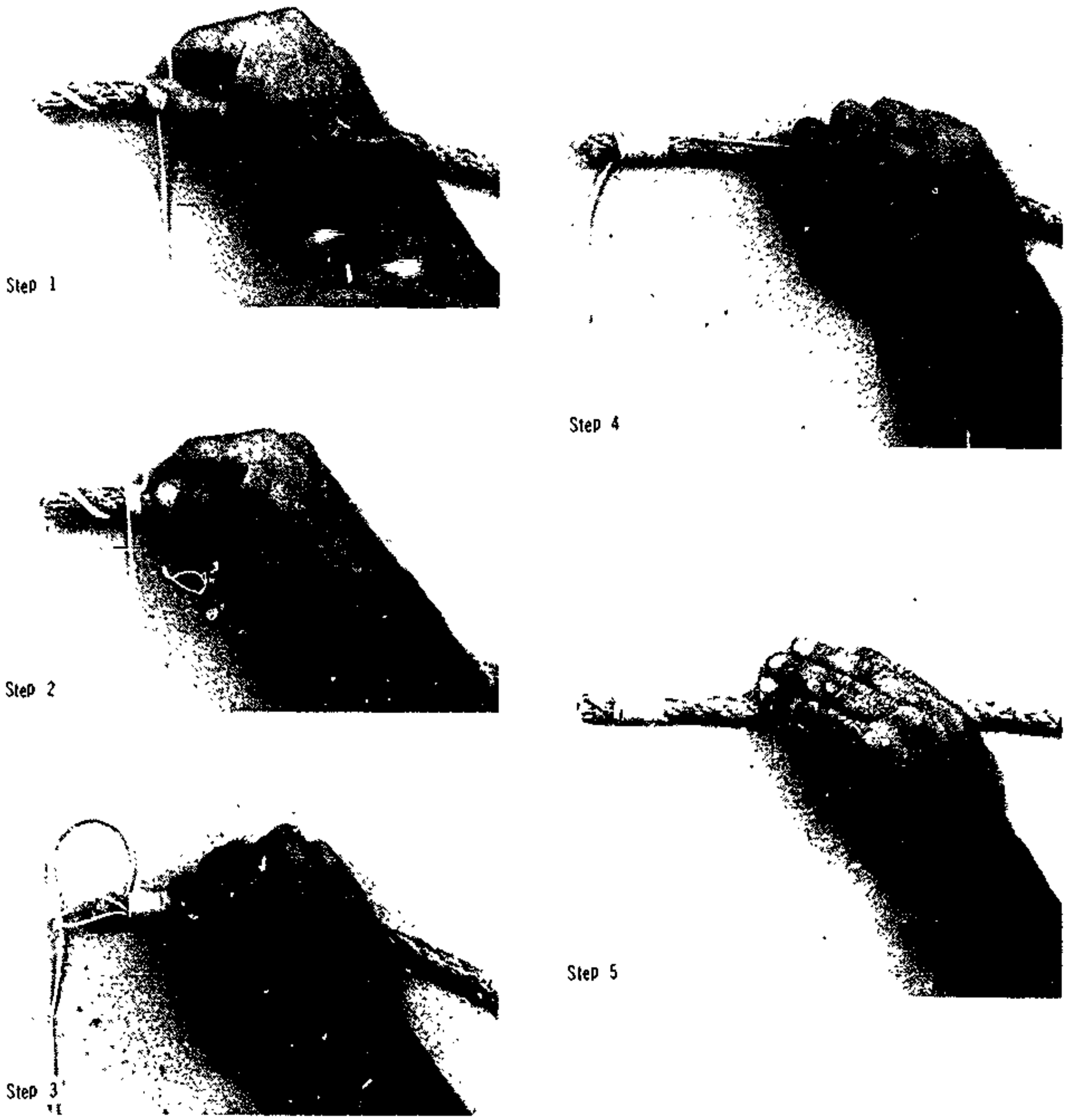


Figure 7-2. Whipping a Line End

KNOTS FOR JOINING TWO LINES

1 The **square or reef knot** (Figure 7-5) is used for tying together two ropes of the same size, or for tying together the ends of a short rope to make a temporary endless sling. Properly tied, a square knot will not slip when the rope is dry and has 50% of the rope strength.

   When tying a square knot, the standing part and the running end of each rope must pass through the bight of the other rope in the same direction. A square knot is easily untied by grasping the ends of the two bights and pulling the knot apart.

2 The **granny knot** or the **thief knot** (Figure 7-6) looks like a square knot, but will slip and jam under a load

3 A **single sheet bend** (sometimes called a **weaver's knot**) is used to tie together two dry ropes of unequal size Figure 7-7

Figure 7-3. Overhand Knot

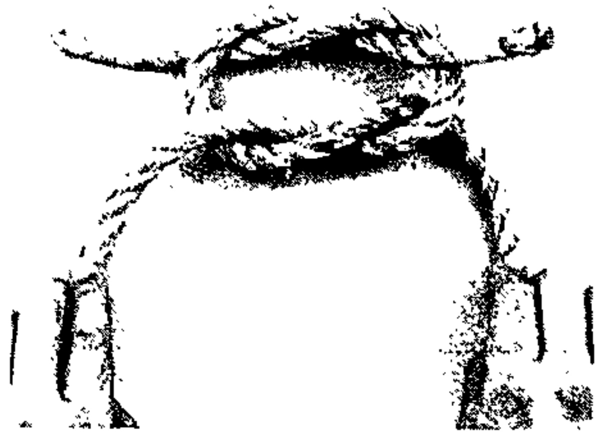


Figure 7-6. Granny Knot

Figure 7-4. Figure Eight Knot

illustrates the method of tying a single sheet bend. The knot will draw tight under light loads but will loosen or slip when the lines are slackened.

4 A **double sheet bend** (Figure 7-8) is used to join wet or dry lines of equal or unequal size. It will not slip or draw tight under heavy loads.

First tie a single sheet bend (do not pull it tight), then take one extra turn around the bight, passing the running end under the

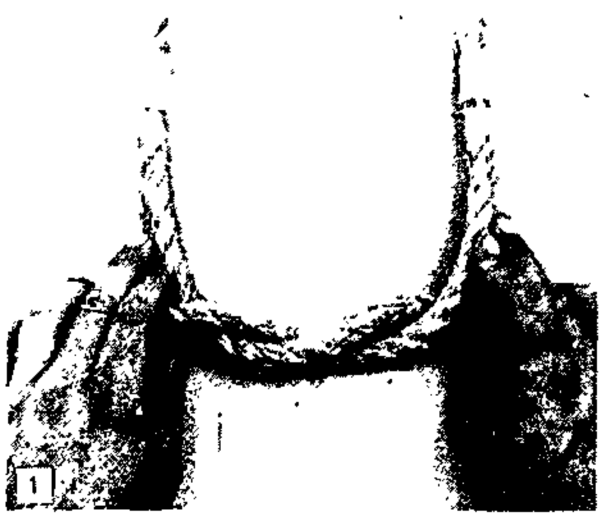


Figure 7-5. Tying a Square Knot

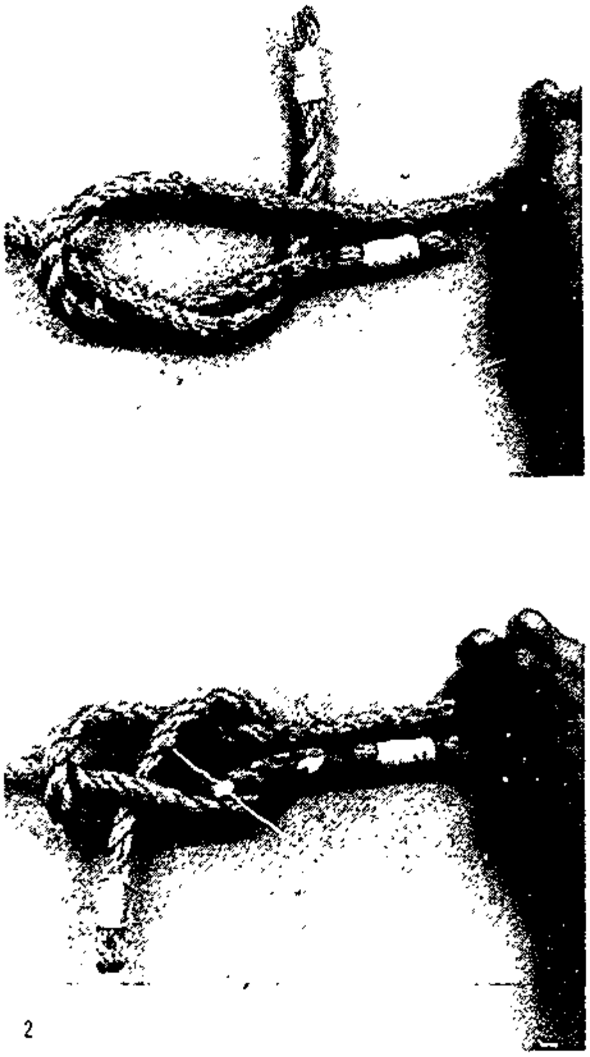


Figure 7-7. Tying a Single Sheet Bend

Figure 7-8. Double Sheet Bend

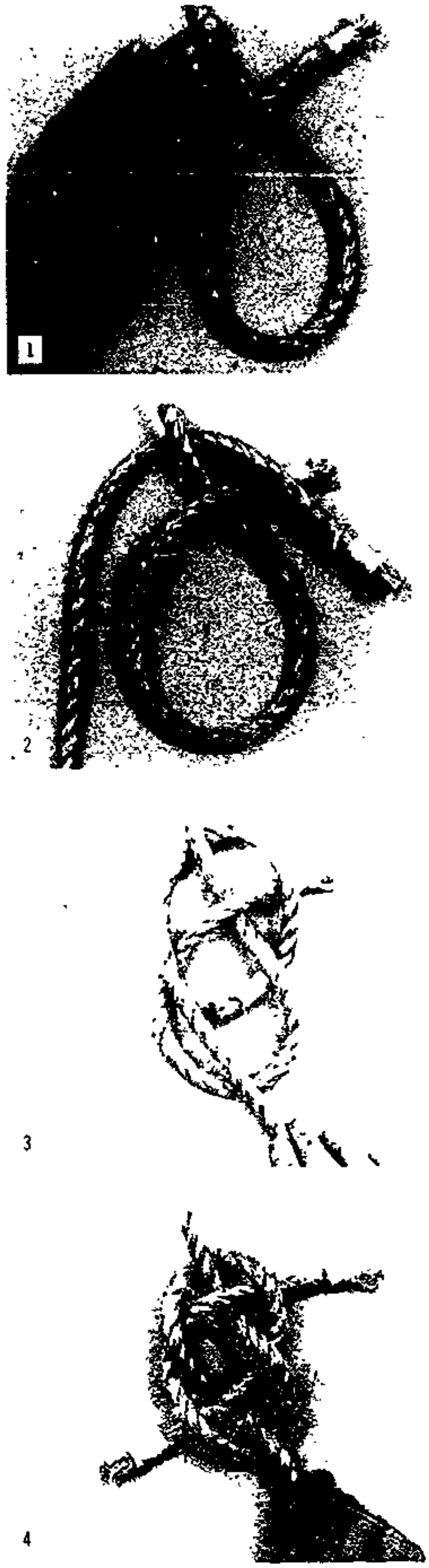


Figure 7-9. Tying a Carrick Bend

smaller line and over the larger line as for the single short bend.

5 The **carrick bend** is used for heavy loads and for joining heavy line It will not draw tight under a heavy load. Figure 7-9 illustrates the steps in tying a carrick bend

KNOTS FOR MAKING LOOPS

1 The **bowline knot** makes a non-slip loop that will not tighten under straining and can be untied easily when the rope is slack. Figure 7-10 illustrates the steps in tying a bowline knot

2 The **double bowline knot** (or **French bowline**) provides a secure, two-loop sling that can serve as a seat for an operator (by passing a small, notched board through the loops) or as spreaders to sling a load. Figure 7-11 illustrates the steps in tying a double bowline.

3. The **running bowline knot** is the basic knot used in rigging for raising or lifting loads as it produces a choker type sling at the end of

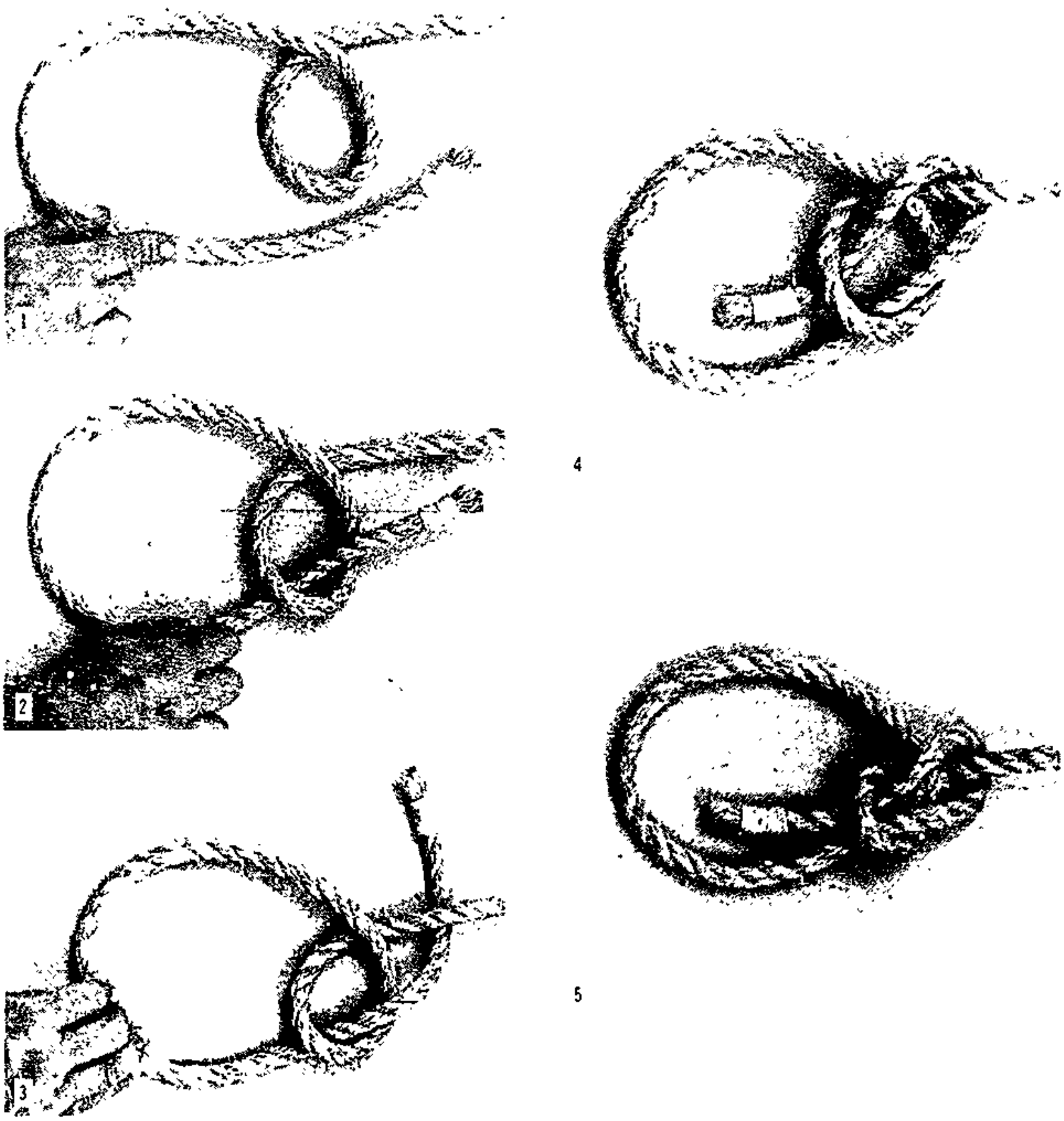


Figure 7-10. Tying a Bowline Knot

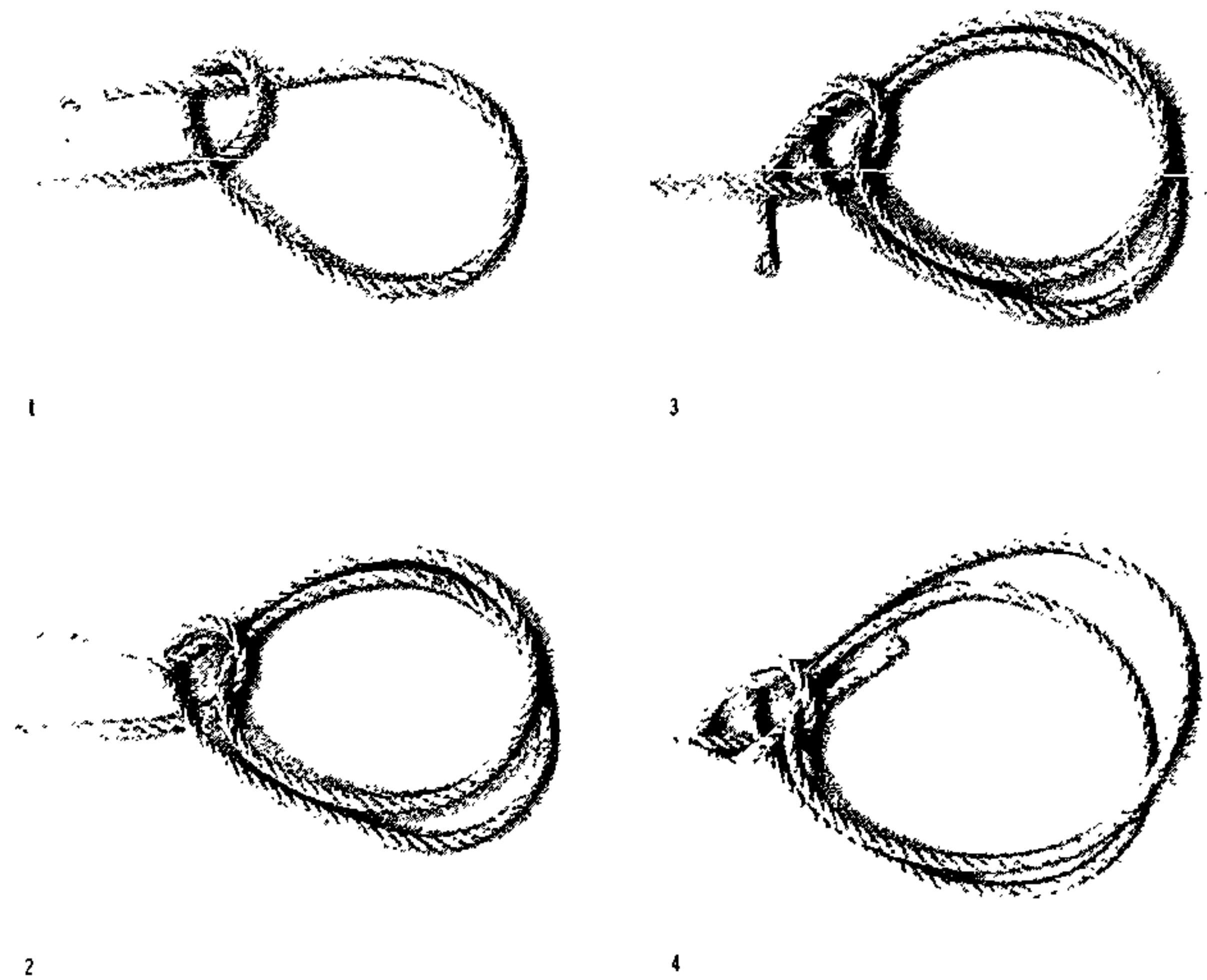


Figure 7-11. Tying a Double Bowline Knot

a single line. Figure 7-12 illustrates the steps in tying a running bowline knot.

4 A **bowline on the bight** is tied to form a double loop in the middle of a line that can be used as a seat or as a spreader to sling a load Figure 7-13 illustrates the steps in tying a bowline on the bight.

5 A **Spanish bowline** forms two loops or "rabbit ears" providing a double sling for lifting round objects or for rescue work Figure 7-14 illustrates the steps in tying a Spanish bowline

6 The **harness hitch** produces a loop in a line which will not slip. Figure 7-15 illustrates the steps in tying the harness hitch.

HITCHES

1. The **half hitch** is used to secure the free end of a line to a timber or to another larger line. Figure 7-16 shows unsafe and safe half hitches.

   Two half hitches (Figure 7-17) provide a more secure fastening to a pole or timber. It is important that the second half hitch is made by passing the running end around the standing part and back under itself again as shown in Figure 7-17.

2 A **round turn and two half hitches** is an alternative method of fastening a line to a timber or pole, and involves passing the running end of the line in two complete

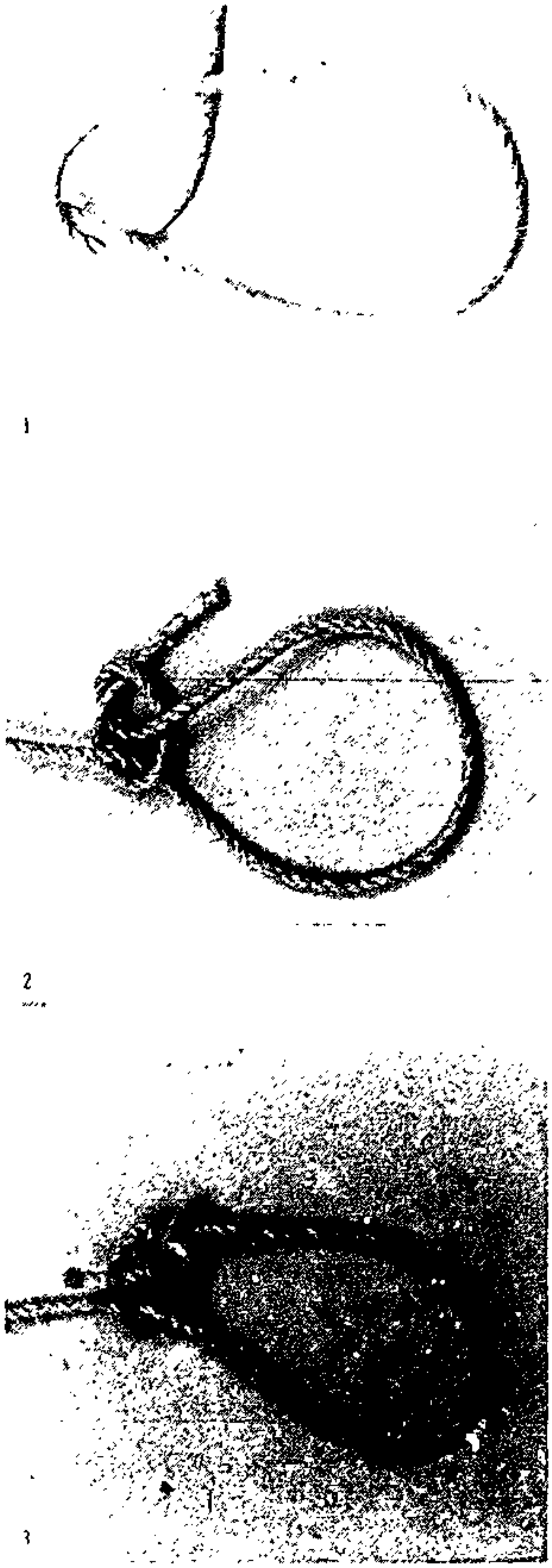


Figure 7-12. Tying a Running Bowline Knot

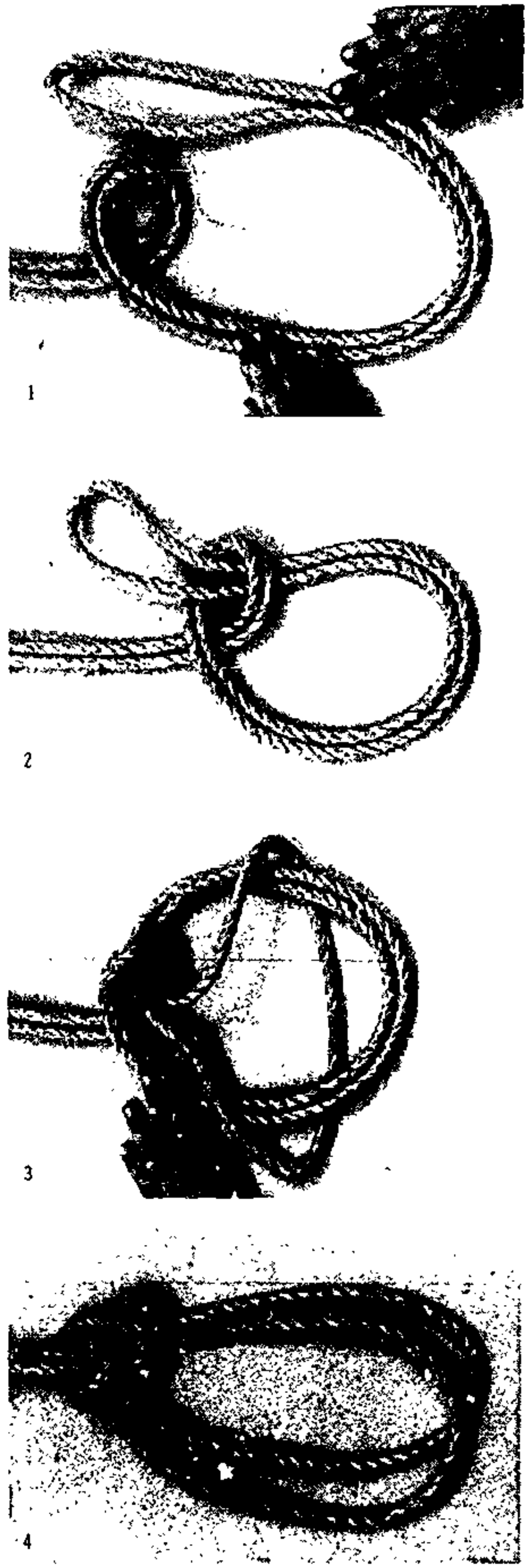


Figure 7-13. Tying a Bowline on the Bight

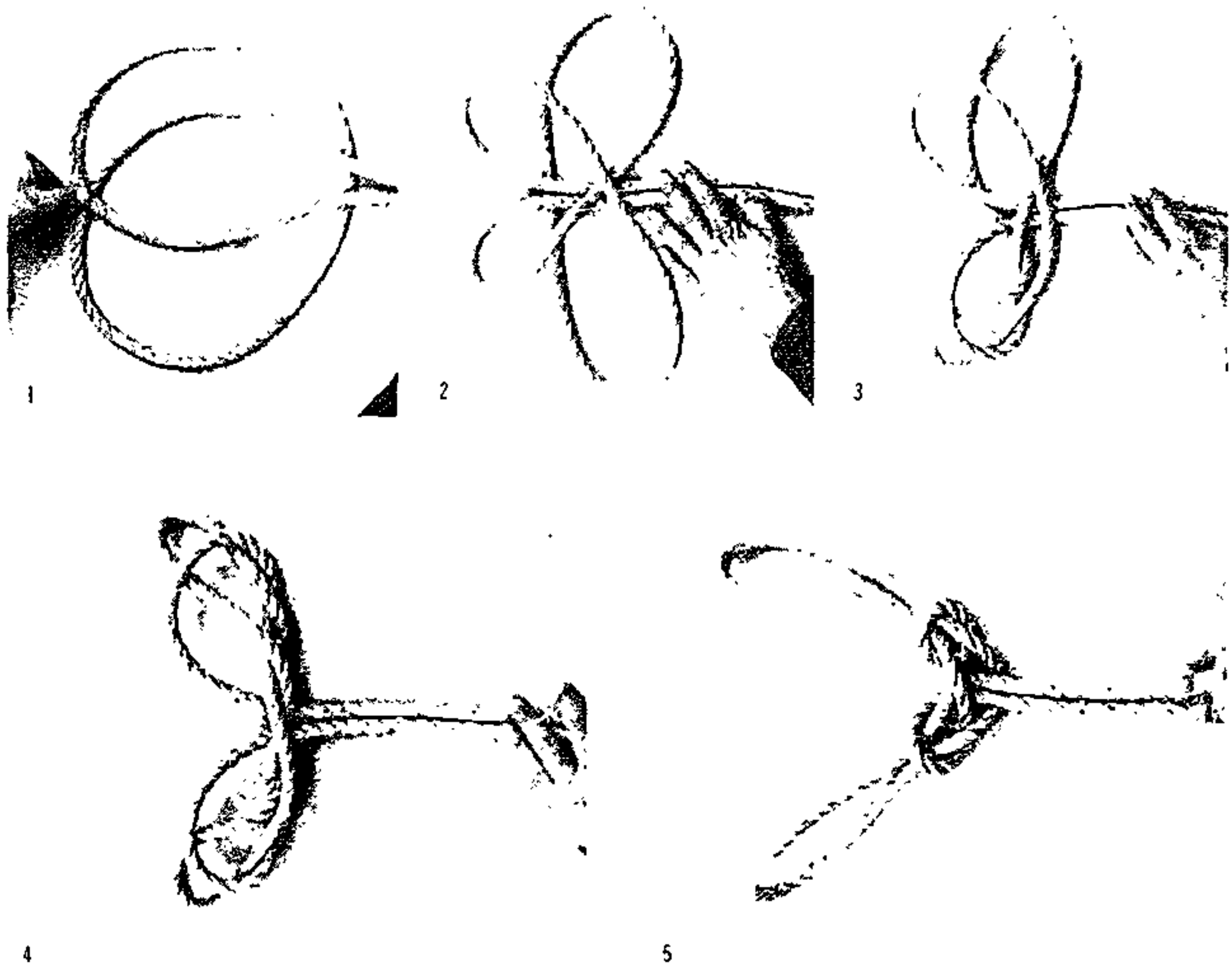


Figure 7-14. Tying a Spanish Bowline

turns around the pole before making the two half hitches as shown in Figure 7-18.

3 The **clove hitch** offers a fast, simple way of fastening a line to a post, timber or pipe and can be tied at any point in the line. To tie a clove hitch in the middle of the line, make two turns close together in the line and twist them to bring them back to back as shown in Figure 7-19. Slip the loops over the post To tie a clove hitch at the end of the line, two underhand loops are tied around the post as shown in Figure 7-20.

4 The **rolling** or **Magnus hitch** is used to fasten a line to another line, cable, timber or post and it will remain tight under tension or pull This hitch is also known as the **mooring hitch** Figure 7-21 illustrates the steps in tying the rolling hitch.

5. A **sheepshank** is used to shorten a rope as a temporary measure. This may be necessary to take the load off a weak or damaged part of the line before replacement can be accomplished Figure 7-22 illustrates the steps in tying the sheepshank.

6. The **timber hitch** is used to fasten rope to steady loads of posts, planks, timbers and pipes. The knot will loosen when the tension or pull is relieved. The hitch begins with a half hitch and is completed by turning or twisting the running end around itself two or three times following the lay of the rope (Figure 7-23).

7 A **timber hitch and half hitch** provides a more secure hold on heavy poles or timbers for lifting or hauling This involves tying one or two half hitches around the load, and further along tying a timber hitch with the running end of the line (Figure 7-24).

8 A **catspaw** (Figure 7-25) is a particularly useful method of attaching the middle of a

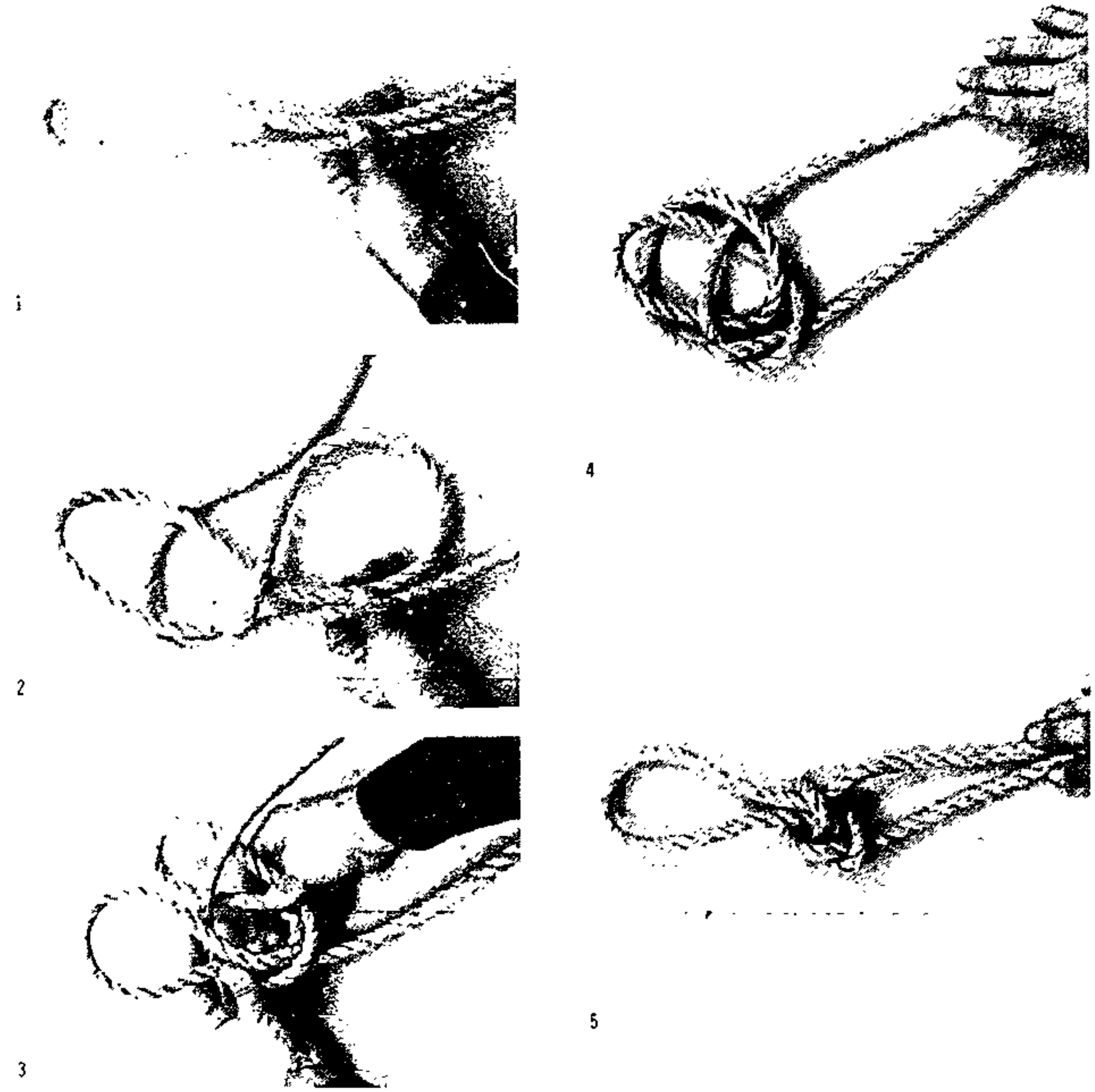


Figure 7-15. Tying a Harness Hitch

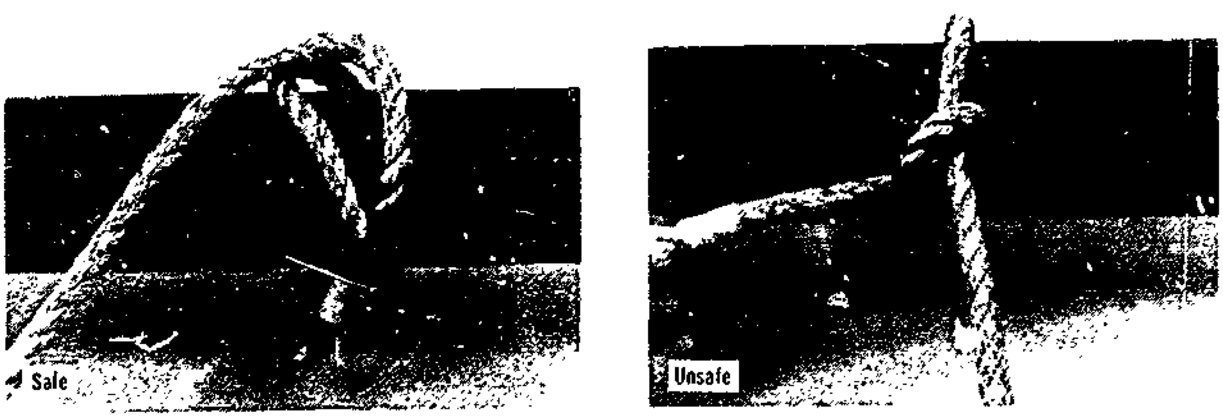


Figure 7-16. Safe and Unsafe Half Hitches

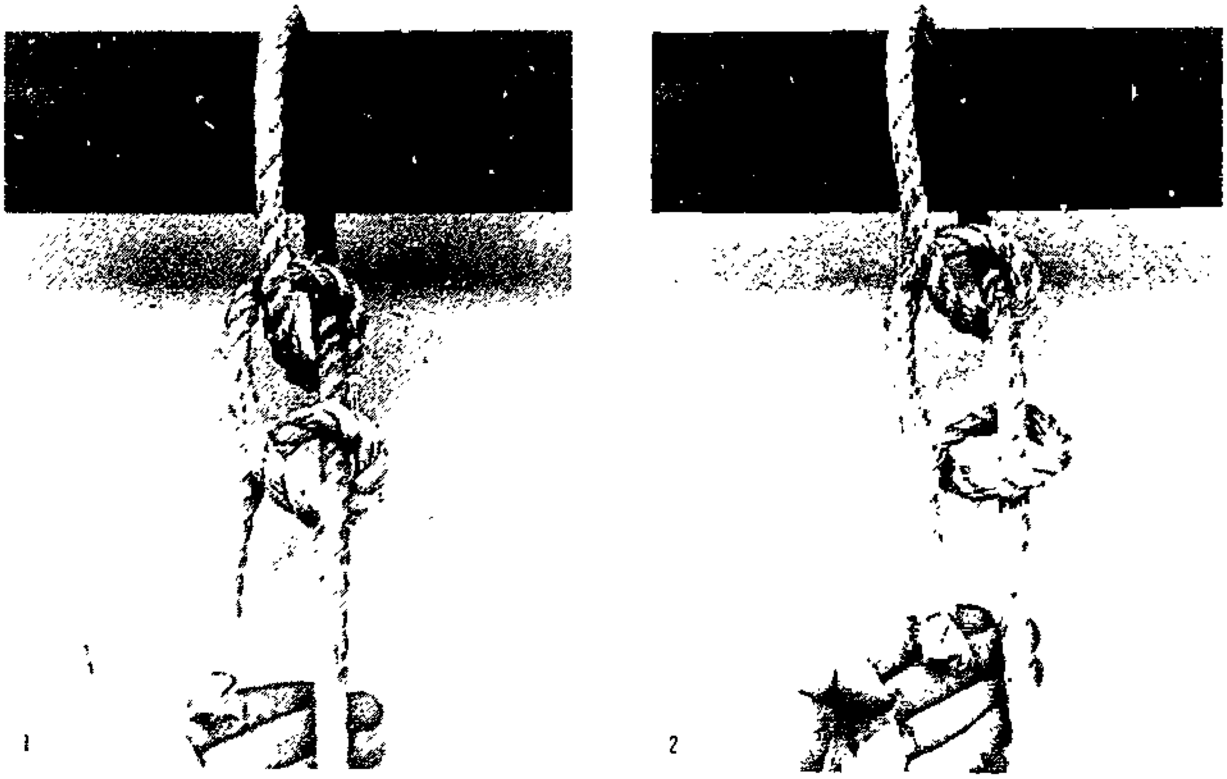


Figure 7-17. Two Half Hitches

Figura 7-18. Round Turn and Two Half Hitches

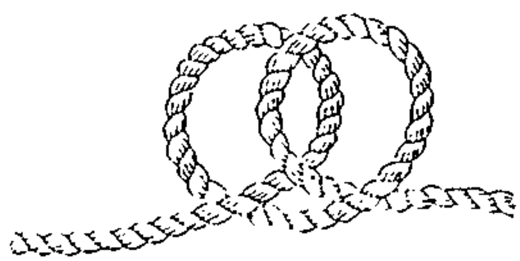


Figure 7-19. Tying a Clove Hitch in the Middle of a Line

line to a hook When removed from the hook, it unties itself.

9 The fisherman's bend provides a secure fastening for a line or cable to an anchor or other situations where alternate tightening and slackening in the line occurs Figure 7-26 illustrates a fisherman's bend. With the running end, take two turns through or around the object to be fastened, then around the standing part and through the loop formed by the turns. Finally, make a half hitch around the standing part and seize the running end to the standing part

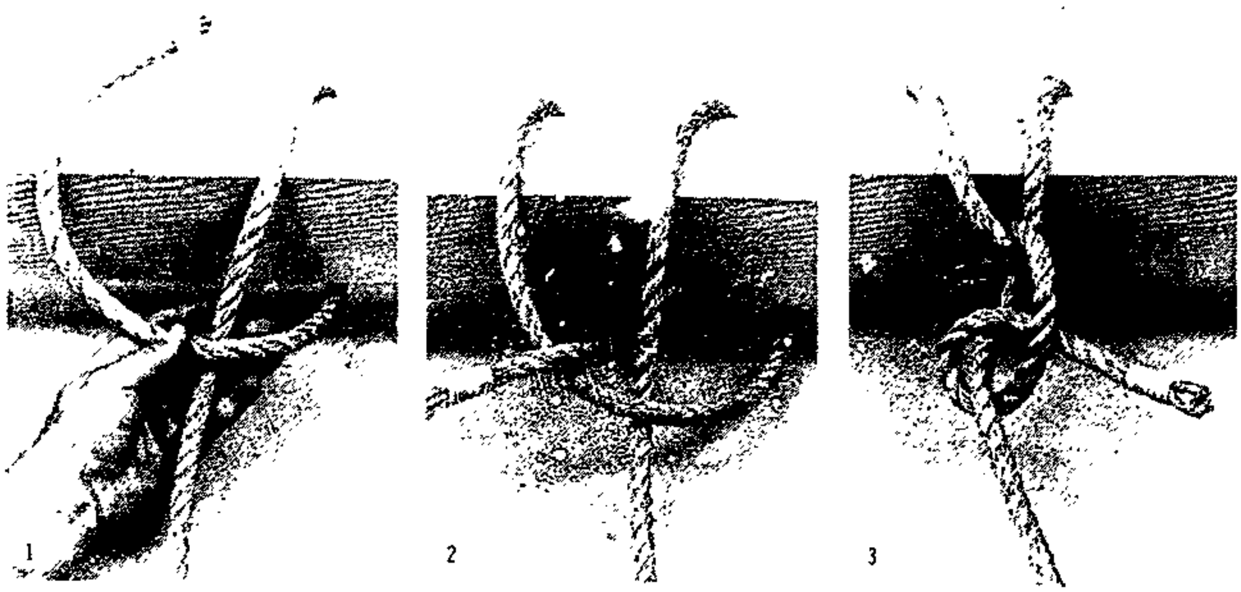


Figure 7-20. Tying a Clove Hitch at the End of Line

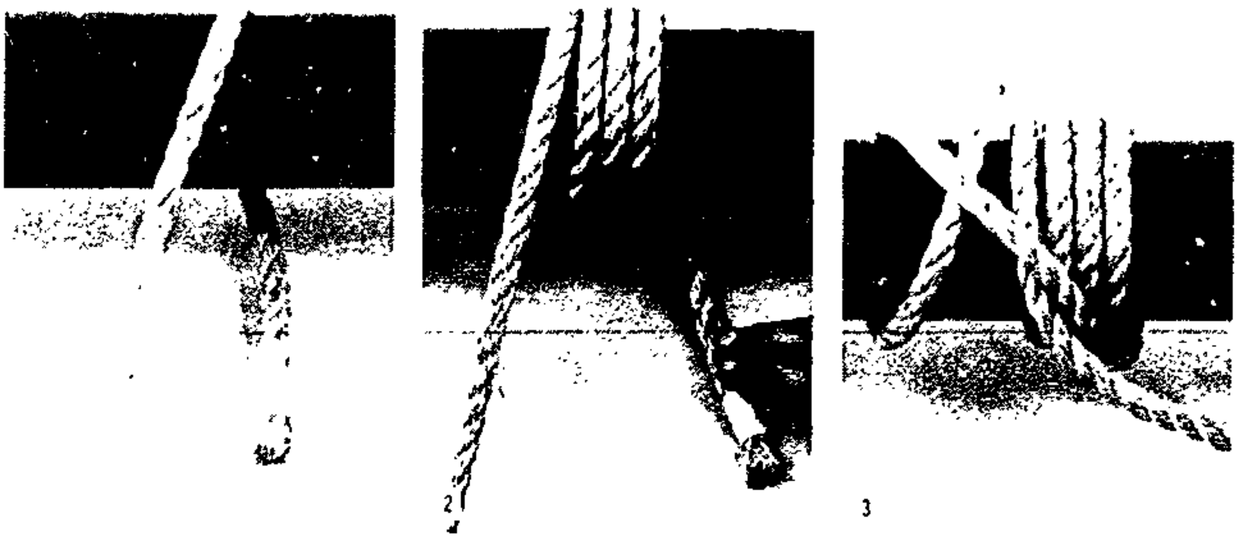


Figure 7-21. Tying a Rolling Hitch

10 The **scaffold hitch** is used to support single scaffold planks so they will hang level and be unable to tilt Figure 7-27 illustrates the steps in tying a scaffold hitch.

11. The **Speir knot** provides a constant loop with a non-slipping knot and can be released easily by a pull on the running end. Figure 7-28 illustrates the steps in tying a Speir knot.

12 The **becket hitch** provides a secure means of fastening a line to a ring such as the becket of a block Figure 7-29 illustrates the steps in tying a becket hitch. Pass the running end of the line through the eye of the ring, back around the standing part of the line, then over both sides of the loop and up through the bottom half of the loop as shown. Pull tight.

13 **Barrel slings** can be tied to hold barrels horizontally or vertically. The **horizontal sling** (Figure 7-30) is made by tying a bowline with a long loop. Make two "ears" by bringing the line at the bottom of the loop up over the sides of the loop and slide

Figure 7-22. Tying a Sheepshank

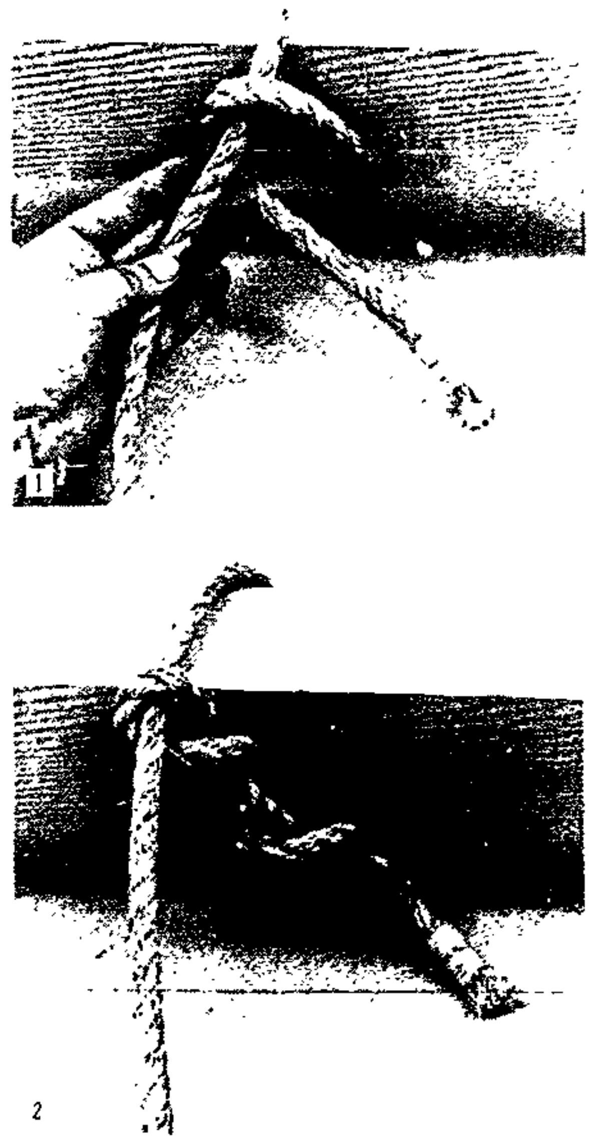


Figure 7-23. Tying a Timber Hitch

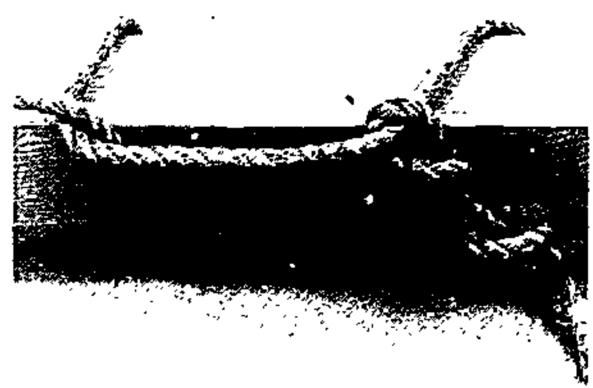


Figure 7-24. Tying a Timber Hitch and Half Hitch

the "ears" over the ends of the barrel. The vertical sling is made as illustrated in Figure 7-31.

Note: Rope strength is reduced to 50% when a knot or bend is tied anywhere along its length.

Rope strength is reduced to 75% when a hitch is tied anywhere along its length.

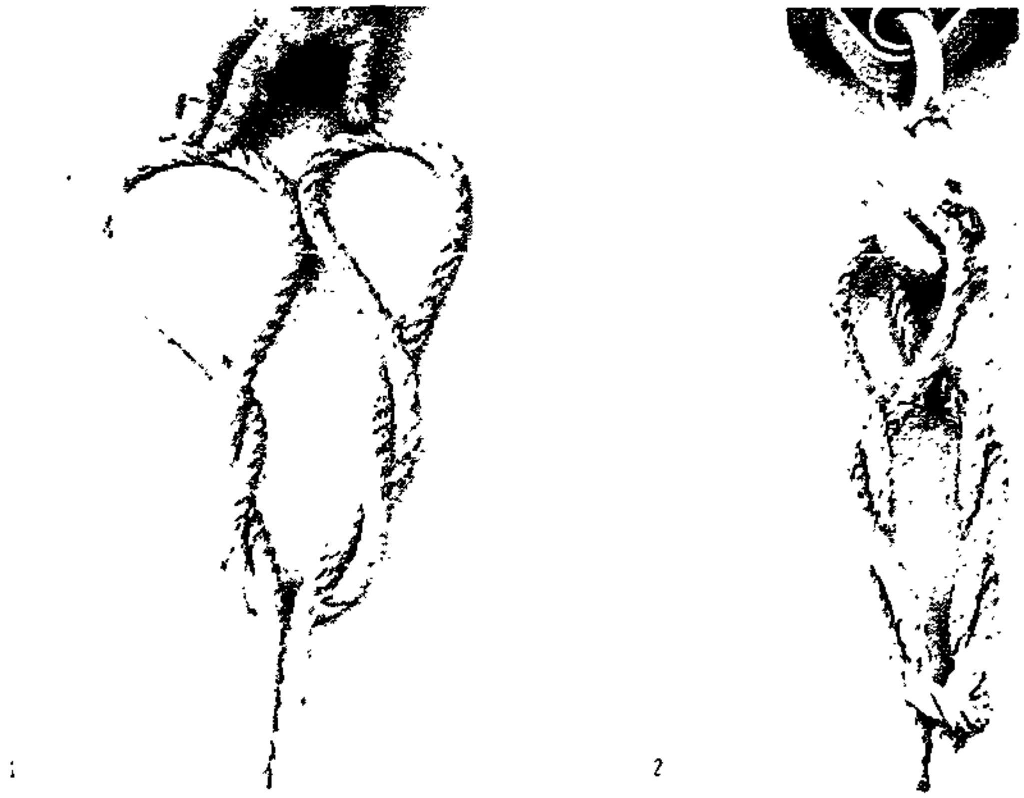


Figure 7-25. Catspaw Hitch

Figure 7-26. Fisherman's Bend

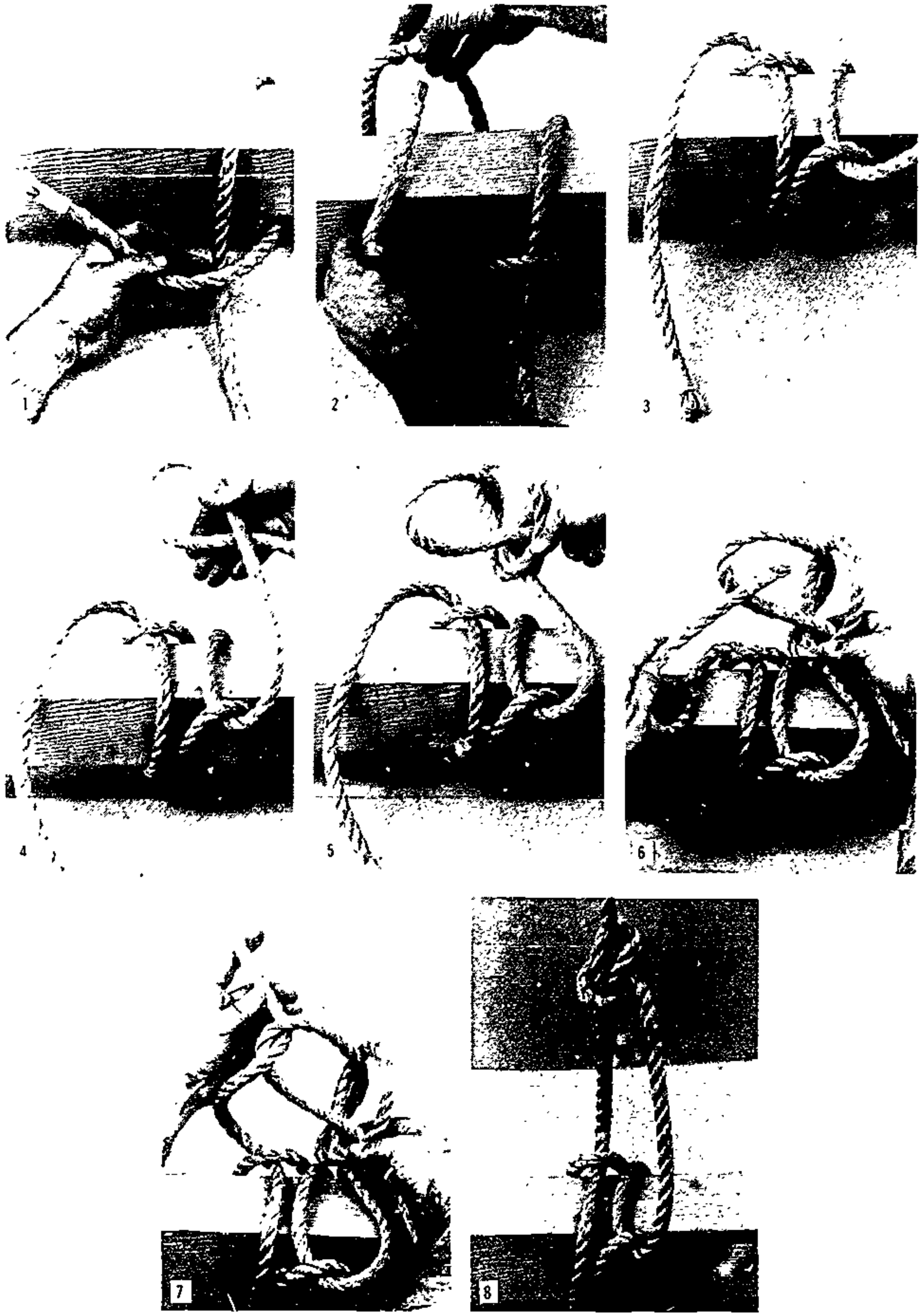


Figure 7-27. Tying a Scaffold Hitch

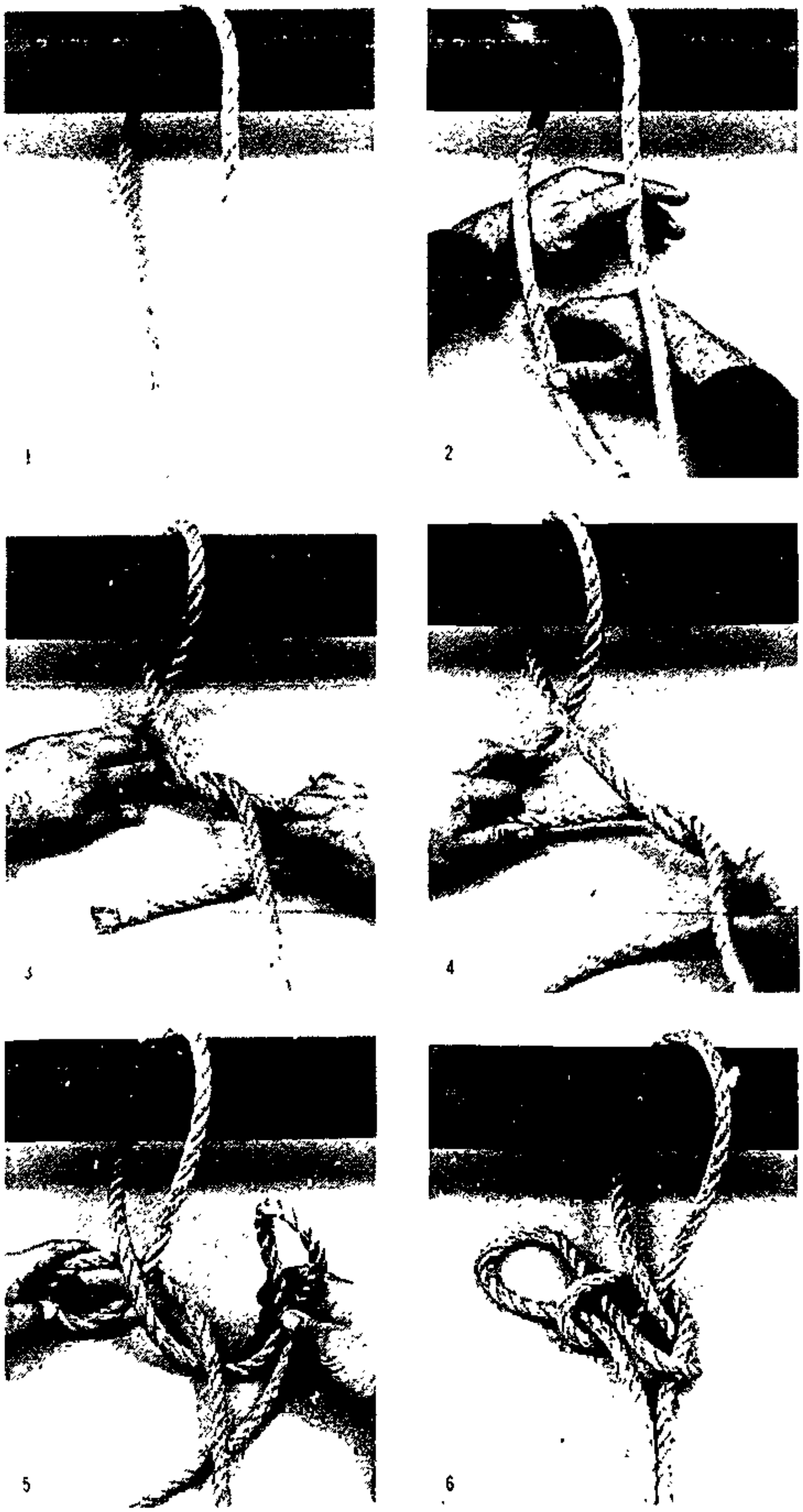


Figure 7-28. Tying a Speir Knot

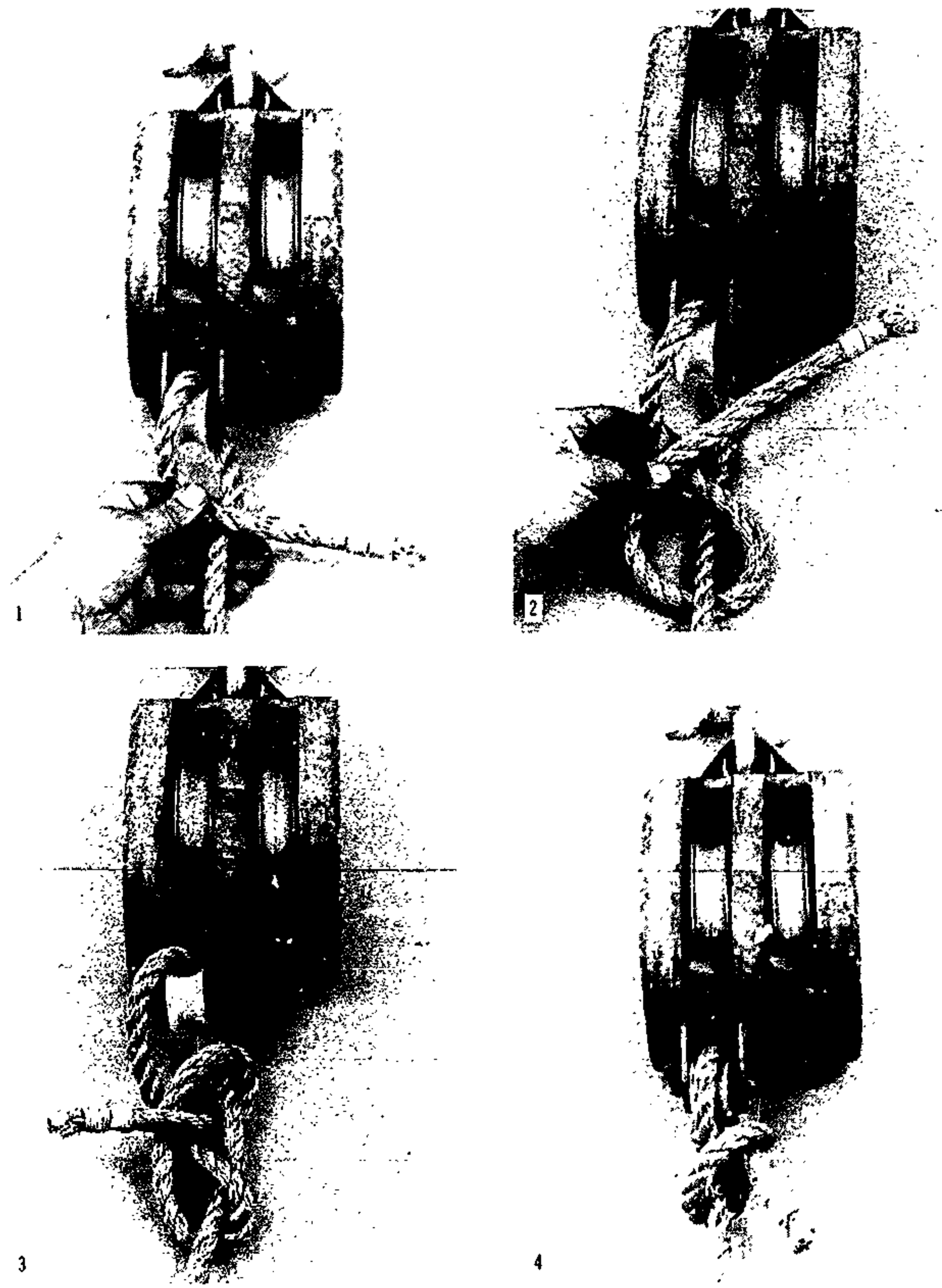


Figure 7-29. Tying a Becket Hitch

Figure 7-30. Horizontal Barrel Sling

SPLICES

Splicing is a process of joining two ropes together, or joining the end of a rope to a point on the standing part. Splicing reduces the rated strength of the rope by 10-15%. Both natural and synthetic fibre ropes can be spliced, but for all types of splices, or more extra tucks are required for synthetic fibre rope. An important consideration in making splices is the care that must be taken in unlaying the rope and reweaving the strands so that the form and lay of the rope are not disrupted.

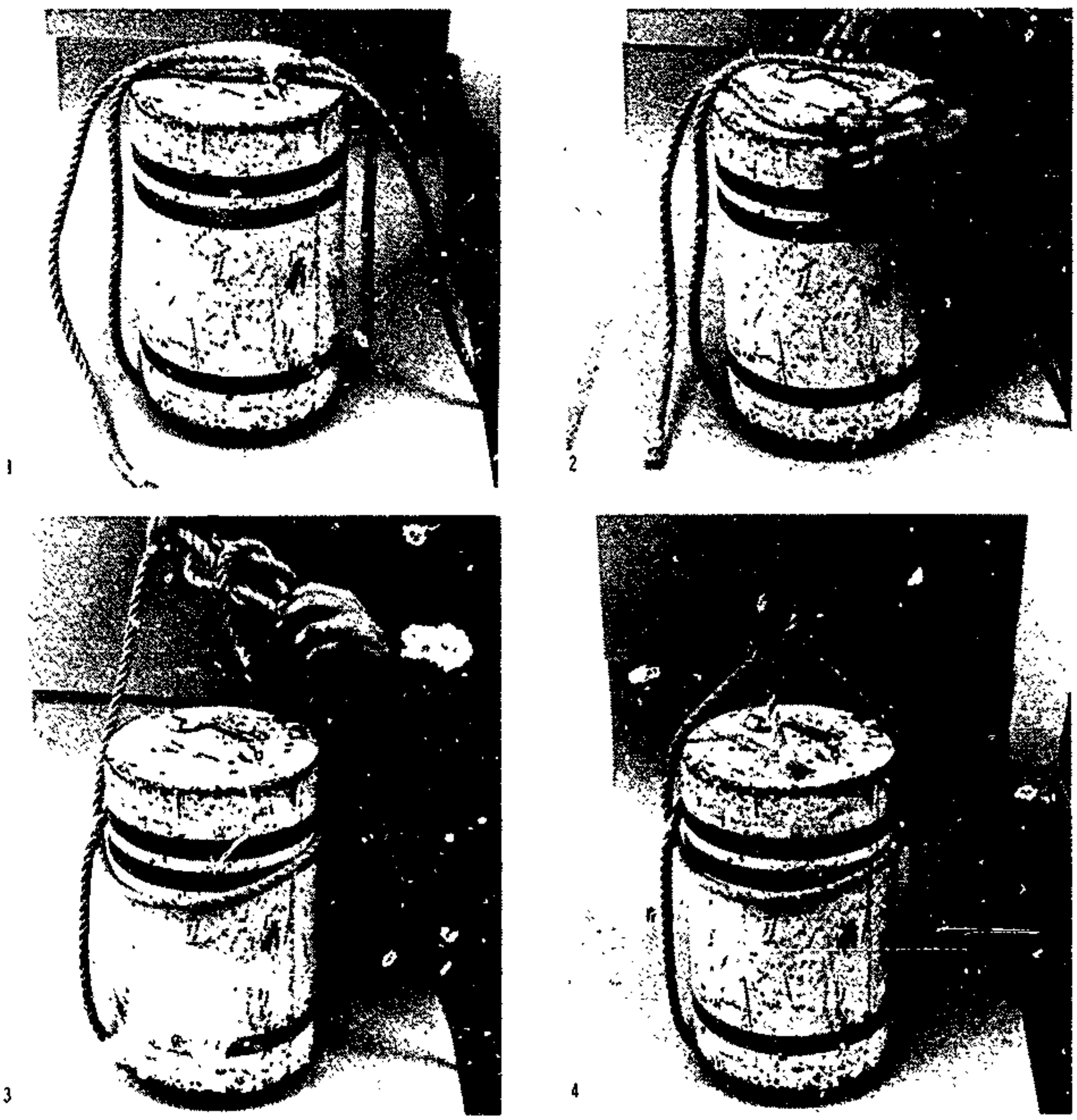


Figure 7-31. Making a Vertical Barrel Sling

SHORT SPLICE

The Short Splice is the strongest type of splice; however, it has the disadvantage of increasing the diameter of the rope to such an extent that it is unsuitable for some uses such as running through blocks or sheaves

Procedure

Step 1 Unlay the strands at end of each rope for six or eight turns Whip the ends of the strands to prevent their untwisting, and bring together so that each strand of one rope alternates with a strand of the other (Figure 7-32, Step 1).

Step 2 Bring the ends tightly together and apply a temporary seizing where they join (Figure 7-32. Step 2).

Step 3. Take any one strand and begin tucking, the sequence being over one and under one Figure 7-32. Step 3. shows how Strand A is passed over the strand nearest to it, which is Strand D, and then under the next strand, Strand E.

Step 4 Rotate the splice away from you one-third of a turn and make the second tuck; Strand B is passed over Strand E and then under Strand F (Figure 7-32, Step 4)

Step 5 Before making the third tuck, rotate the splice again one-third of a turn away from you Strand C is then passed over Strand F, and under the next one, Strand D. The splice now appears as in Figure 7-32, Step 5.

Step 6 This completes the first round of tucks in the left hand half of the splice. Each strand should now be tucked at least twice more, always over one and under one as before, making sure that each strand lies snug and is without kinks.

Step 7 To finish the splice, reverse the rope end for end so that Strands D, E and F are now at the left instead of the right (in the same position of Strands A, B and C in the illustrations) and repeat the tucking operation on their side of the rope Each of the six strands will now have had at least three tucks. A tapered splice is made by taking two more tucks with each strand, cutting away some of the threads from each strand before each extra tuck.

Step 8 When tucking is finished, remove the centre seizing and cut off the ends of all strands, leaving at least 3/4" on each end. To give a smooth appearance, roll the splice back and forth, either under your foot or between two boards. The completed Short Splice should look something like the illustration in Figure 7-32, Step 8.

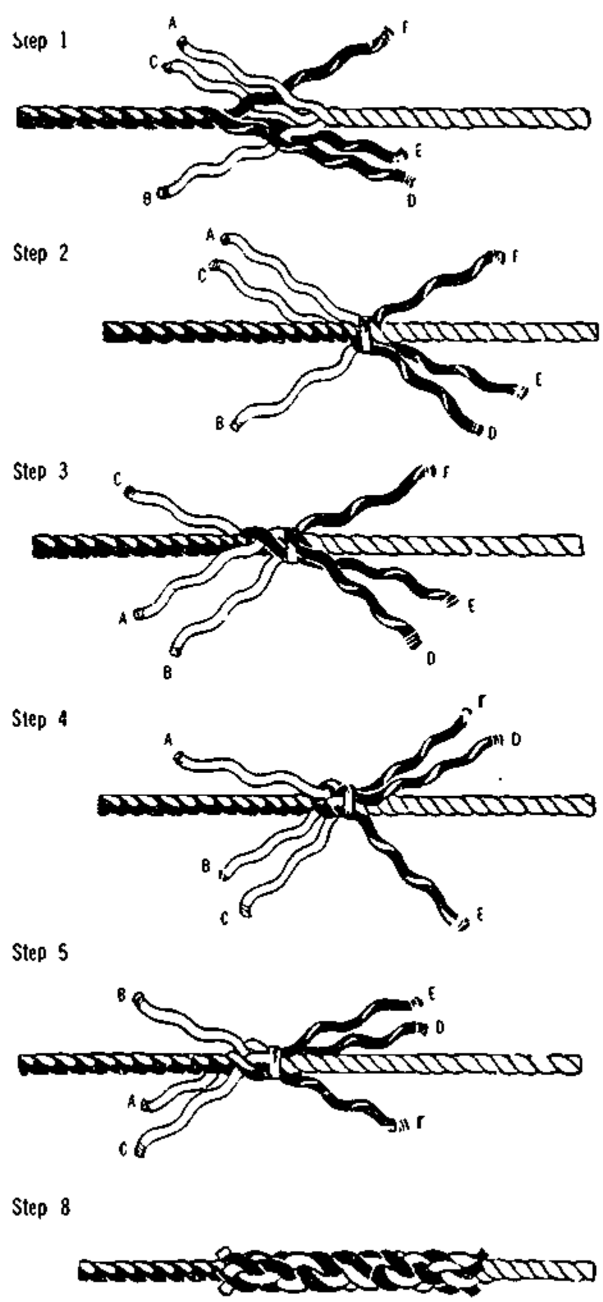


Figure 7-32. Making a Short Splice

LONG SPLICE

The Long Splice is used for pulley work since it permits ropes that have been spliced to be run through sheave blocks without jamming or chafing. Unlike the short splice, the diameter of the spliced rope is increased very slightly.

Procedure

Step 1 To make this splice, begin by unlaying one strand of each rope for 10 or 15 turns, and whip the ends of each strand to prevent untwisting. Then lock the two ropes together by alternating the strands from each end as illustrated in Figure 7-33, Step 1.

Step 2. Starting at one end, take an opposite pair of strands, A and B, and unlay Strand A. Follow it with Strand B, turn by turn, continuing until only 1' or less of Strand B remains. Keep Strand B tight during this step and pull it down firmly into Strand A's former place. Repeat this operation with Strands C and D. Strand D is unlaid and Strand C is laid in its place. The splice at this stage is illustrated in Figure 7-33, Step 2

Step 3 Now each pair of strands is tied loosely together with a simple overhand knot, as indicated by Strands A and B in Figure 7-33, Step 3. Each knot is then pulled down into the rope like Strands C and D.

Step 4. Each strand is now tucked twice, over and under, as done in making the Short Splice. Figure 7-33, Step 4 shows Strands C and D after tucking. If a smaller diameter splice is desired, tapering can be done by tucking each strand twice more, cutting away some of the threads for each additional tuck

Step 5. When tucking is finished, cut all strands off close to the rope and roll the splice on the floor under your foot to smooth it out. The completed Long Splice is illustrated in Figure 7-33, Step 5

SIDE SPLICE

The Side Splice is also called the Eye Splice because it is used to form an eye or loop in the end of a rope by splicing the end back into its own side. This splice is made like the Short Splice except that only one rope is used.

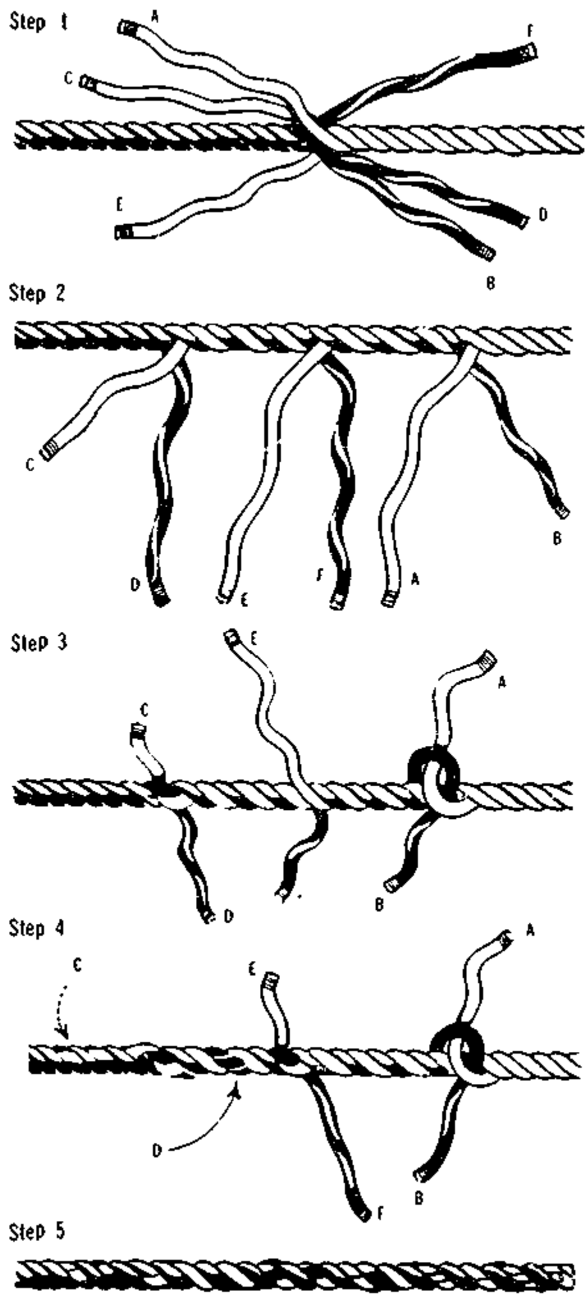


Figure 7-33. Making a Long Splice

Procedure

Step 1. Start by seizing the working end of the rope. Unlay Strands A, B and C, to the seizing and whip the end of each strand. Then twist the rope slightly to open up Strands D, E and F of the standing part of the rope, as indicated in Figure 7-34, Step 1.

Step 2. The first tuck is shown in Figure 7-34, Step 2. The middle strand is always tucked first, so Strand B is tucked under Strand E, the middle strand of the standing part.

Step 3. The second tuck is now made as illustrated in Figure 7-34, Step 3. Left Strand A of the working end is tucked under Strand D, passing over Strand E.

Step 4. Figure 7-34, Step 4 illustrates how the third tuck is made. To make Strand F easy to get at, the rope is turned over. Strand C now appears on the left side.

Step 5 Strand C is then passed to the right of and tucked under Strand F, as illustrated in Figure 7-34, Step 5. This completes the first round of tucks.

Step 6. Figure 7-34, Step 6 illustrates the second round of tucks started, with the rope reversed again for ease in handling. Strand B is passed over Strand D and tucked under the next strand to the left. Continue with Strands A and C, tucking over one strand and then under one to the left. To complete the splice, tuck each strand once more

Step 7. Remove the temporary seizing and cut off the strand ends, leaving at least 1/2" on each end. Roll the splice back and forth under your foot to even up and smooth out the strands. The completed Eye Splice is illustrated in Figure 7-34, Step 7.

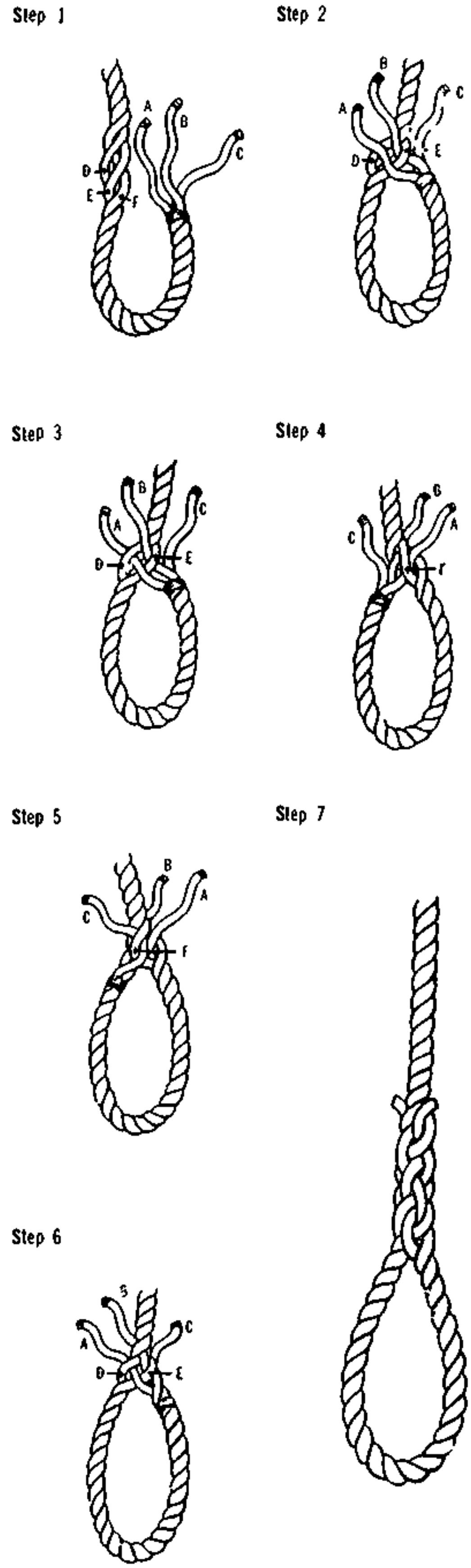


Figure 7-34. Making a Side Splice

NATURAL FIBRE LINE

MANUFACTURE OF NATURAL FIBRE LINE

Natural fibre line is constructed by a process of twisting vegetable fibres together. Individual fibres are grouped and twisted to form yarns, and yarns are grouped and twisted together to form strands (Figure 7-35). Finally, a number of strands are twisted to form a line. The line twist is balanced by reversing the direction of twist for each set of components: fibres and strands are twisted opposite to yarns.

TYPES OF NATURAL FIBRE LINE

Fibre line is classified on the basis of the kind of vegetable fibres used to manufacture it:

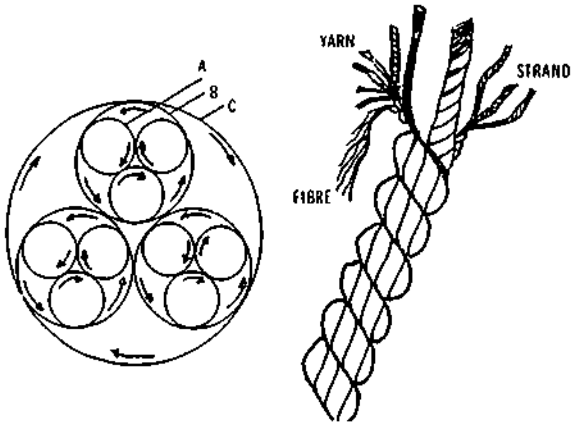


Figure 7-35. Construction of Natural Fibre Line

Manila fibres are made from plantain leaves. Superior quality manila line is made from long fibres of light colour, as it is softer, more elastic, stronger, durable and water resistant. Its smoothness makes it preferable for running over blocks and sheaves.

Sisal line has a harsher feel than manila and is about 80% as strong. It has the advantage of tolerating exposure to sea water very well

Hemp fibres are short and soft, but it produces a strong, rough line. Tar soaking, although reducing the line's strength and flexibility, is necessary to reduce deterioration from dampness

Coir and Cotton Coir line is rough and elastic and floats on water. It is only 25% as strong as hemp Cotton can tolerate a great deal of bending and running, but is too light for most uses

Forms of Natural Fibre Line

The arrangement of strands in a line is an important feature of its construction. The three principal forms are hawser laid, shroud laid and cable laid line.

Hawser laid line is composed of three strands in a right hand lay (Figure 7-36).

Shroud laid line is composed of four strands in a right hand lay around a centre core (Figure 7-36)

Cable laid line is composed of thee lines (right hand Hawser) arranged in a left hand lay (Figure 7-36)

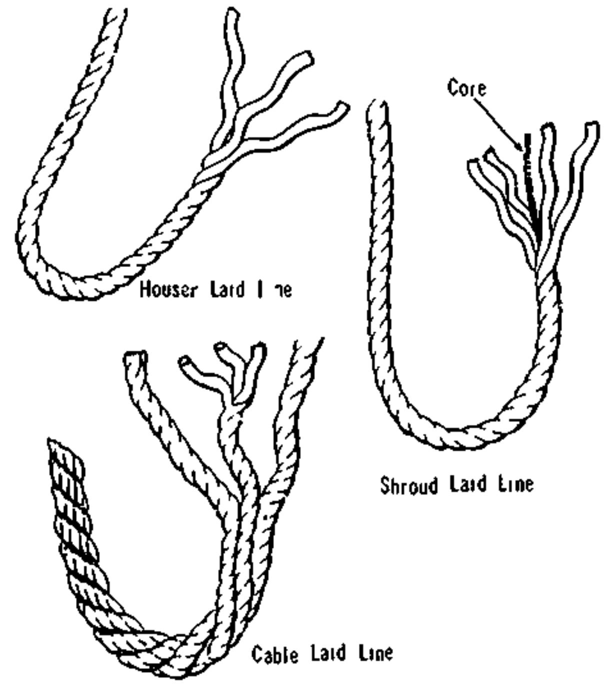


Figure 7-36. Forms of Natural Fibre Line

CHARACTERISTICS OF NATURAL FIBRE LINE

Size Fibre line is designated by diameter and circumference (in inches).

Weight The number of feet per pound of line can be estimated with the following formula within 12% accuracy:

$$\frac{3.4}{(\text{diameter})^2}$$

Example: for 5/8 inch line

$$\frac{3.4}{(5/8)^2}$$

$$= 8.7 \text{ feet per pound}$$

Strength Line strength is described in terms of 1) breaking strength and 2) safe working capacity. The breaking strength divided by the factor of safety gives the safe working capacity which should **never** be exceeded Excess loads damage the fibres and reduce the strength and life of the line The condition of the line, in terms of exposure, wear, use and bending, must be considered in estimating its strength as these factors over time will greatly reduce the line's capability.

Rated capacities for safe loads are listed in tables **for new line only.** (See, for example, Table 7-1.)

A rule of thumb for estimating the safe working capacity (in tons) of manila line is to square the diameter (in inches), for example, a 1 1/8" manila line would have a safe working capacity of 1 17/64, or approximately 1 1/4 tons.

CARE AND MAINTENANCE OF NATURAL FIBRE LINE

The functional life of natural fibre line can be extended with proper care in handling and maintenance. Knowledge of the characteristics and limitations of each kind of line will provide guidelines for good handling practices.

Inspect lines frequently to determine the actual condition of the inner fibres, which is not evident on the surface. Grasping the line firmly with two hands, untwist it slightly to expose the inner portion, and look for the following:

1. Mildew — inner fibres are dark and stained and have a musty odour
2. Broken strands or yarns
3. Chafing residue — dirt and sawdust-like material inside the line
4. Fragmentation of the core — core breaks away in small pieces, indicating overstrain

Examine the line in this way in a number of places and finally pull out and stretch a few random fibres to test for breakage resistance. Any line found to be deficient should be destroyed or cut into pieces too short for hoisting.

Protection of Line Ends Raw or cut ends of line should be secured to prevent unlaying. Tying a knot at the end of a line, or whipping will secure the lay.

Storage Deterioration of natural fibre line can be prevented by good storage practices. These include the following conditions:

1. Storage areas should be dry.
2. Lines should be dried before storing.
3. Circulation of air around coiled line should be provided such as gratings to support the coils.
4. Fibre line should not be covered unless absolutely required.

TABLE 7-1. PROPERTIES OF MANILA AND SISAL LINE

Nominal diameter (inches)	Circumference (inches)	Weight per 100' (pounds)	No 1 Manila		Sisal	
			Breaking Strength (pounds)	Safe Load (pounds) F.S. -4	Breaking Strength (pounds)	Safe Load (pounds) F.S -4
1/4	3/4	1.71	550	150	440	120
2/3	1 1/8	3.45	1.275	325	1.020	260
1/2	1 1/2	7.36	2.650	660	2.120	520
3/5	2	13.1	4.400	1.100	3.520	880
3/4	2 1/4	16.4	5.400	1.350	4.320	1.080
7/8	2 2/4	22.0	7.700	1.920	6.160	1.540
1	3	26 5	9.000	2.250	7.200	1.800
1 1/8	3 1/2	35.2	12.000	3.000	9.600	2.400
1 1/4	3 3/4	40.8	13.500	3.380	10.800	2.700
1 1/2	4 1/2	58.8	18.500	4.620	14.800	3.700
1 3/4	5 1/2	87.7	26.500	6.625	21.200	5.300
2	6	105 0	31.000	7.750	24.800	6.200
2 1/2	7 1/2	163.0	46.500	11.620	37.200	9.300
3	9	237.0	64.000	16.000	51.200	12.800

NOTE Breaking strength and safe loads given are for new line used under favorable conditions As line ages or deteriorates, progressively reduce safe loads to one-half of values given

Prevention of Moisture Damage Since fibre line will contract when wet, it should be slackened before exposure to rain or dampness.

Prevention of Damage to Strands Although continued use will result in some fibre damage, this can be minimized by:

1. Washing line that is muddy or sandy
2. Using softeners to pad sharp corners over which the line must be pulled
3. Keeping line out of sand and dirt as much as possible
4. Using knots that are easy to untie
5. Repairing broken strands in the line as soon as possible.

Coiling and Uncoiling New natural fibre line is delivered in coils of 600'-1200' and lashed or bound. Generally an instruction tag will accompany the coil. After cutting the bindings or lashings, grasp the line end inside the coil at the bottom and pull it up through the middle to prevent kinks from forming (Figure 7-37).

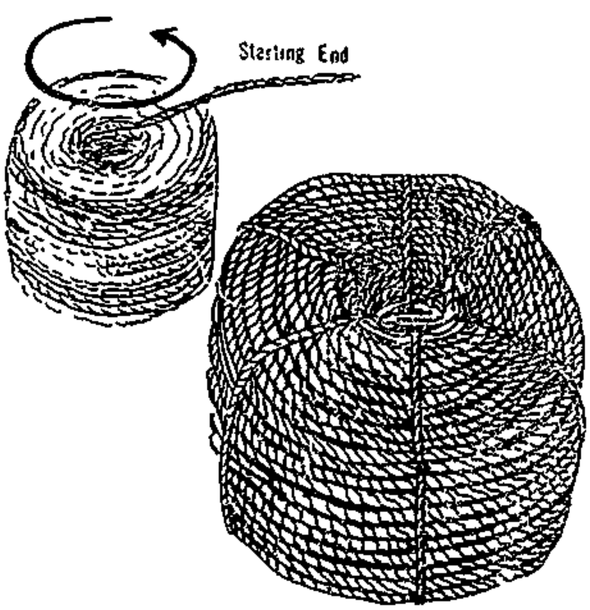


Figure 7-37. Uncoiling a Coil of Fibre Line

SYNTHETIC FIBRE ROPE

CHARACTERISTICS OF SYNTHETIC FIBRE ROPE

Synthetic fibre ropes, particularly nylon and polypropylene, are becoming more widely used, replacing manila rope in many instances. These ropes have individual fibres running the entire length of the line rather than short, overlapping fibres as in natural fibre rope. This accounts for the greater strength of synthetic fibre line (See Table 7-2).

TABLE 7-2. RELATIVE STRENGTH OF FIBRE ROPES (DRY)

Type of Rope	Relative Capacity (Related to Nylon)
Nylon	100%
Polyester	94%
Polypropylene	81%
Polyethylene	73%
Manila	67%

Synthetic fibre ropes are generally impervious to rot, mildew and fungus and have good resistance to chemicals. They are lighter and easier to handle, and have excellent impact, fatigue and wear resistance, outwearing manila ropes by four or five times. They are liable to melt at high temperatures, however, and should not be used where heat is excessive or friction is high enough to melt the fibres. They should not be used near welding operations. Generally, synthetic fibre rope is abrasion resistant and can tolerate long exposure to water without any noticeable loss of strength or change in appearance.

TYPES OF SYNTHETIC FIBRE ROPES USED IN RIGGING

Nylon Rope Nylon rope is two and one half times stronger than manila and is the most widely used of the synthetic rope family. It is chalky white in colour, has a smooth surface, is soft and pliant and has a feeling of elasticity.

Some properties of nylon ropes are:

1. High breaking strength (wet or dry)
2. Light weight per unit of strength
3. Excellent elasticity and tensile recovery
4. Superior absorption of impact and shock loads
5. Excellent flex and abrasion resistance
6. Good flexibility
7. Excellent resistance to rot
8. Good sunlight and weather resistance
9. High melting point.

Due to its continuous fibre construction, nylon rope is strong and resistant to creep under sustained load. Its elasticity recommends its use where high energy absorption is needed or where shock loading is a factor. The high degree of stretch can be a serious disadvantage if headroom for lifting is restricted and slings must be as short as possible. Under actual service conditions, nylon rope will stretch to about 16% under working loads and over 40% under breaking loads. The initial loading of a nylon rope produces a permanent elongation of approximately 8%, but recovery is complete from subsequent stretching under load. Therefore, nylon ropes should be broken in prior to field use.

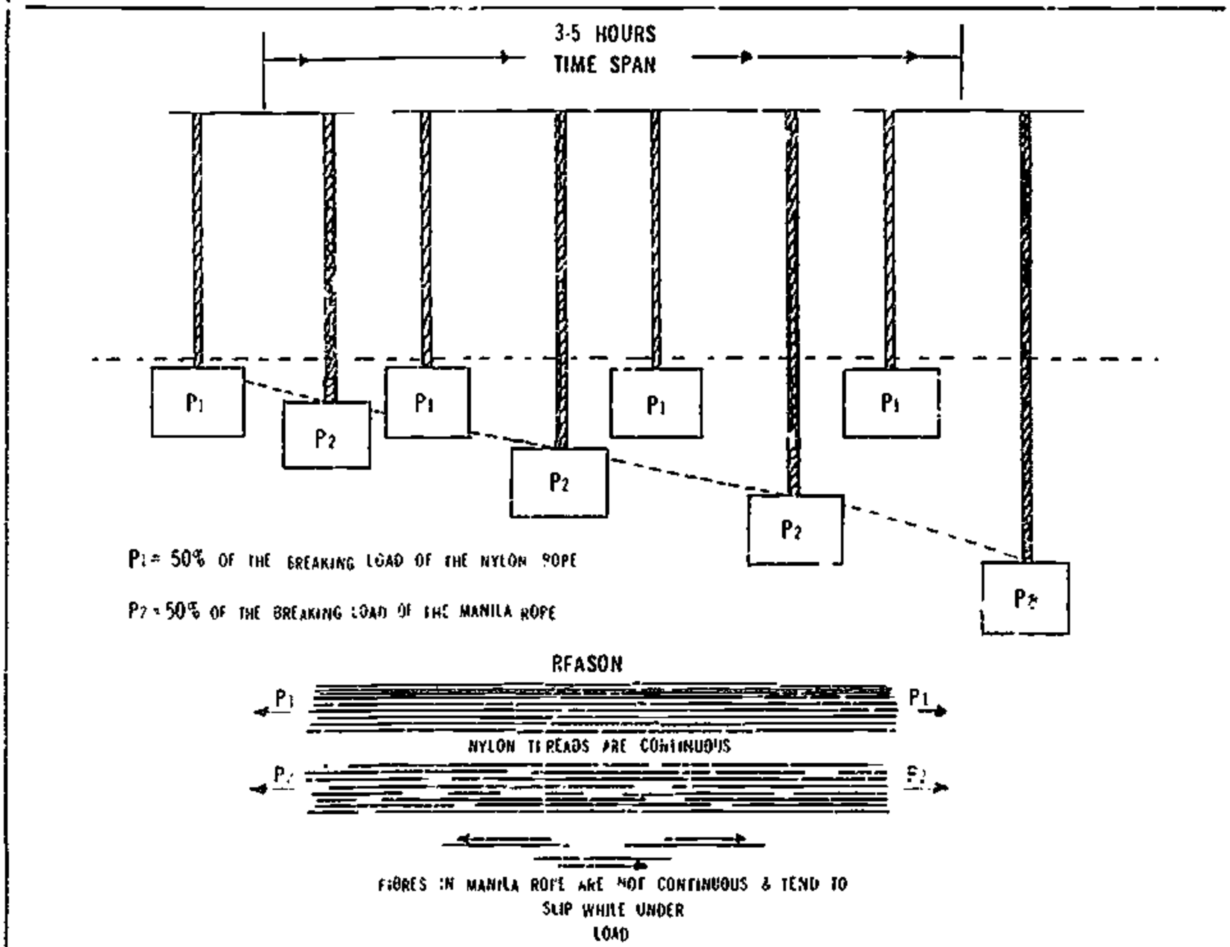
Nylon rope tolerates heat without loss of strength or physical properties up to 300 F (melting point 482 F.). Nylon ropes absorb moisture and lose approximately 10% of their strength when wet as well as becoming very slippery. Full recovery occurs when the rope dries out. Table 7-3 compares nylon and manila ropes under a heavy sustained load.

Store nylon rope away from heat and exposure to sunlight. Nylon is highly resistant to alkalies, but can be degraded by most acids, paints and linseed oil, and all contact with chemicals should be avoided. If contact is suspected, wash the rope thoroughly in cold water and then carefully examine the fibres for evidence of weakening.

Braided Nylon Rope Braided nylon rope provides the highest possible strength since the load is divided equally between a braided sheath and a braided core. The rope is soft and flexible and does not twist or kink. Twisted three strand rope transmits a turning, twisting motion under load while braided nylon does not.

Braided nylon presents approximately 50% more surface area for wear and grip, is stronger for size and more stable, exhibits less stretch when

TABLE 7-3. COMPARISON OF NYLON AND MANILA ROPES UNDER HEAVY SUSTAINED LOAD



working, has less permanent stretch and greater flexibility than three strand nylon ropes.

The braided sheath and core construction is available in synthetic combinations in addition to nylon:

1. Nylon core/nylon cover — high strength, more stretch, good wearing qualities
2. Polypropylene core/nylon cover — lower strength, lower stretch
3. Polypropylene core/polyester cover — very low stretch, high strength and good abrasion resistance.

For example, a nylon core/nylon cover rope with a nominal diameter of 7/8 inch carries a safe working load of 4,800 pounds, while a polypropylene core/nylon cover rope will carry a safe working load of 4,150 pounds. A polypropylene core/polyester cover rope will support a safe working load of 3,800 pounds. The safety factor for braided synthetic combinations is 5.

Polyester Rope Polyester rope (Trade names: Dacron, Terylene) is nearly identical to nylon in appearance but has little or no elastic feeling. Size for size, it is heavier and not as strong as nylon rope, although similar in construction. This is a continuous filament rope and resists creep under sustained loads. The low stretch properties of polyester rope represent a considerable advantage where headroom is limited since after the initial permanent stretch of approximately 6%, subsequent loads produce a temporary lengthening of approximately 5.9% (compared to 16% for nylon). Polyester ropes should be broken in before field use.

Abrasion resistance is similar to nylon rope. Like nylon, polyester rope is unaffected by temperatures up to 300 F. It absorbs much less water than nylon and thus does not lose strength when wet. Polyester rope resists sun and weather damage as well as attack by rot and mildew, however, precautionary storage practices are recommended. Polyester is more resistant to chemicals than nylon, but exposure and contact should be avoided. Slings should be washed frequently in cold water.

Polypropylene Rope Polypropylene and polyester ropes are almost identical in appearance; they are available in various colours and are smooth and pliant and somewhat slippery, particularly polypropylene.

A singular advantage of polypropylene rope is its ability to float on water, however, it is not as strong as nylon or polyester and ranks between natural fibre ropes and the more sophisticated nylon and polyester.

Stretch properties of polypropylene ropes vary with the type of construction; however, they generally exceed those of polyester. Energy absorption is approximately half that of nylon.

Polypropylene ropes have a heat tolerating capacity comparable to nylon and polyester, however, some deterioration occurs in sunlight. Chemical resistance is generally good as is resistance to rot and mildew. An important feature is polypropylene rope's safety around electricity as it is a non-conductor because it absorbs no water.

Polyethylene Rope Polyethylene ropes are low in strength compared with the other synthetic fibre ropes. They tolerate heat only up to 250 F and undergo some deterioration in sunlight. They are, however, resistant to chemicals except sulphuric acid.

WIRE ROPE

CHARACTERISTICS OF WIRE ROPE

Wire rope is used for so many purposes today that it is not practical to enumerate them all. Because of this widespread use it cannot be expected that one type or construction of rope, varying only in size and strength, will meet all requirements.

Listed below are some common terms and their abbreviations used to designate types of construction of wire rope:

R.L.	Regular Lay
L.L.	Lang Lay
F.C.	Fibre Core
I.W.R.C.	Independent Wire Rope Core
6-19	6 strands 19 threads
6-24	6 strands 24 threads
6-37	6 strands 37 threads
M.S.	Mild Steel
C.C.	Cast Crucible
I.P.	Improved Plow
S.I.P.	Special Improved Plow
Gal	Galvanized

To determine the breaking strengths and safe working loads for the various types of wire rope used in the Boilermaking trade it is essential to know the construction of the rope The most commonly used wire rope is 6-19 and 6-24 Plow Steel in Ordinary Lay Galvanized wire rope is used under certain unusual environmental conditions such as near salt water or chemical plants and pulp mills. Lang Lay wire rope is mostly used on shovels and drag lines Under ordinary conditions Fibre Core is used, but where additional strength or resistance to compression is required Independent Wire Rope Core is chosen

A process called Preforming of wire rope permanently shapes the fibres into the position they will occupy in the finished rope. This makes the rope more stable and more resistant to unstranding by reducing internal stresses.

GRADES OF WIRE ROPE

Grade 120/130 Special Improved Plow Type II is used in the manufacture of wire ropes for special installations where maximum rope strength is required and conditions permit use of this heavy grade rope with existing hoisting equipment

Grade 115/125 Special Improved Plow Type I is also used for special applications when breaking strengths in excess of those obtained with Grade 110/120 are required and existing equipment can handle the rope size.

Grade 110/120 Improved Plow has high tensile strength, tough wearing qualities and fatigue resistant properties This is the most frequently used wire rope.

Three further grades of wire rope are in less frequent use. Their capabilities make them suitable only in situations where strength is secondary to fatigue resistance. These grades are Grade 100/110 Plow, Grade 90/100 Mild Plow and Grade 80/90 Cast Crucible.

Galvanized wires are coated with zinc at finished size either by the hot dip or electro process

Drawn Galvanized wires (sometimes called Drawn After Galvanized or DAG) are coated with zinc at an intermediate size and the zinc-coated wire cold-drawn to the final or required finished size

Bryanized wire is zinc-coated by a special process employed by a British company, whereby the zinc becomes an integral part of the wire itself. Note that galvanized finishes can be applied to any grade of rope wire except phosphor bronze and copper wires

Corrosion Resisting wire is usually a chromium-nickel steel alloy with high resistance to corrosion It is used under conditions where galvanized wire will rust and fail

Phosphor Bronze and Copper wires are used only where corrosion resistance and non-sparking qualities are required as in marine and hazardous industrial applications

WIRE ROPE LAYS

Regular Lay (Ordinary Lay) ropes have the wires in the strands laid in one direction while the strands in the rope are laid in the opposite direction. This results in the wire crowns running approximately parallel to the longitudinal axis of the rope. These ropes resist kinking and twisting and can withstand considerable crushing and distortion due to the short length of exposed wires.

Lang Lay ropes have the wires in the strands and the strands in the ropes laid in the same direction Thus the outer wires run diagonally across the rope and are exposed for longer length than in Regular Lay ropes, providing greater wearing surface and greater resistance to abrasion. Lang Lay ropes are more flexible than Regular Lay and resist fatigue better. Lang Lay ropes are more liable to kink and untwist and will not tolerate the same degree of distortion and crushing. The ends of Lang Lay Ropes should be permanently fastened to prevent untwisting.

Right Lay or Left Lay ropes have strands "rotating" to the right, while a Left Lay rope is the opposite. Most ropes in use are Right Lay ropes (See Figure 7-38).

Preformed wire rope is constructed of strands and fibres shaped permanently into the contour they will take up in the completed rope. In Non-Preformed rope the wires are forcibly held in position throughout the life of the rope, as can be seen by cutting such a rope at any point, when strands and wires will immediately fly apart. Preforming the wires and strands prevents this as they all lie naturally in their true

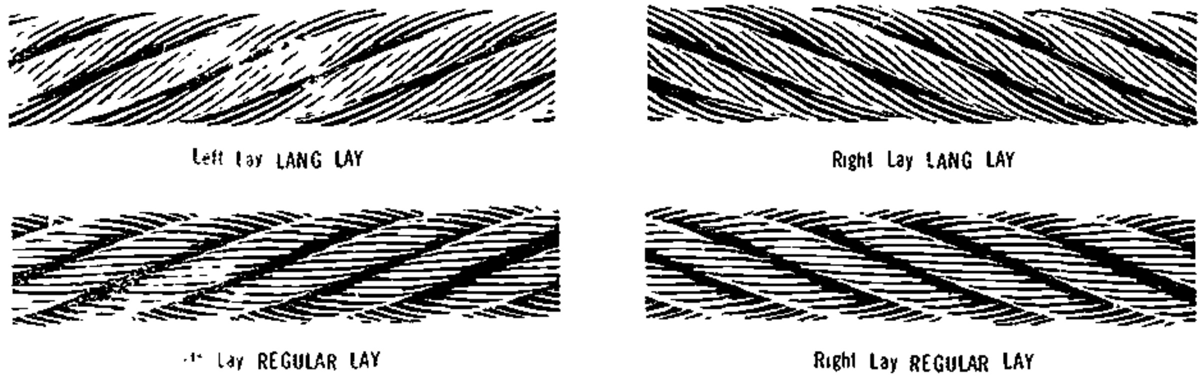


Figure 7-3. ypes of Wire Rope Lays

p sition fre d stress The ad vantag of Pre wire rope are

1 It exib nd easy to handle
2 It s sm nly ov sheaves
3 It makes La ay construction practical for many applications Preformed rope in Lang Lay or Regular Lay is completely inert
4 It gives considerably longer life than Regular Lay rope of equivalent size due to reduction and uniform distribution of internal stresses
5 It is the only wire rope that evenly balances the load on individual strands and wires The load distribution on the single wires is remarkably uniform
6 It is safer to use as broken wires do not wicker out to tear at hands and clothing
7 It is more easily spliced. since there is no need to seize the strands as they fall into correct position more easily
8 It resists kinking better than other ropes
9 It tolerates many of the abuses to which wire rope is often unavoidably subjected

TYPES OF WIRE ROPE

Round Strand ropes are the simplest of the true rope types and are almost universal in their use They consist of from 3 to 36 strands laid in various arrangements concentrically around a core The use of round wires laid in geometric patterns results in a round strand Figures 7-39 illustrates only two of many round strand wire arrangements available

Where strands are made up of two or more layers of wires around a centre wire the wires in these layers may be cross-laid That is the pitch or length of lay will be longer for the outer

6 x 7 Round Strand Fibre Core

18 x 7 Round Strand Fibre Core

Figure 7-39. Round Strand Rope

layers as related to the next inner layer This construction is limited to small ropes and cords. to some ship ropes and to standing ropes in larger sizes

For all other purposes ropes of equal-laid construction are preferable By this method all layers of wires have the same pitch or length of lay Each wire in each layer therefore lies either in a bed formed by the valleys between the wires of an underlayer or alternatively along the crown of an underlying wire Because no layer of wires ever crosses over another an equal aid rope maintains its diameter in service. has more solid cross section and improved fatigue life as compared to cross-laid ropes

Flattened Strand ropes are built up of triangular shaped strands or strands of oval shape Certain types. specifically non-rotating ropes. are built of a combination of oval around triangular. or sometimes oval around round In the case of triangular shaped strands the wires forming the strand are laid on a triangular shaped core formed of a single triangular shaped wire or of three or more round wires The wires forming an oval strand are laid on an oval shaped centre ribbon or around a group of usually four round wires laid parallel Because of the triangular shape of the strands. flattened strand ropes have smaller fibre cores than do round strand ropes. Hence, size for size, flattened strand ropes have approximately 10% greater metallic area with comparable increased breaking strength Figure 7-40 illustrates two of the various flattened strand wire arrangements available

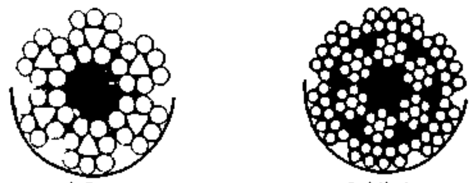


Figure 7-40. Flattened Strand Rope

With ropes of this type frictional wear is spread over a greater number of outer wires of the rope as compared with a round strand rope In the flattened strand construction, with the friction distributed over a greater external surface, wear is more even and the loss of sectional area of the vital outside wires much reduced Because of the smooth surface and circular cross section obtained with flattened strand rope the wear on sheaves and pulleys is materially reduced and in the case of ropes used for endless haulage systems the increased external bearing surface enables grips and clips to be more securely employed. Also, owing to its more solid construction, this type of rope is less likely to be forced out of shape by such clips.

Locked Coil rope differs completely from both round strand and flattened strand rope. Instead of a group of individual strands closed around a central core member it is a single strand built up of layer upon layer of wires. The centre or core of the locked coil rope consists of a concentric laid strand of round wires Around this core are laid one or more layers of shaped wires, the outer layer always being interlocking. The shape or shapes of all shaped wires in a locked coil rope depend on the rope diameter and its end use. Typical locked coil wire arrangements are illustrated in Figures 7-41.

Locked coil ropes have a higher breaking strength than stranded ropes for equal diameter and the same nominal strength grade. Because of their smooth external surface depreciation in

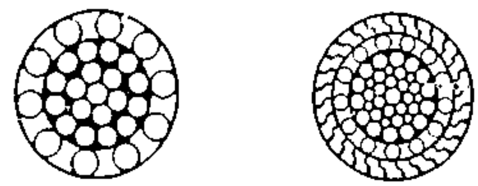


Figure 7-41. Locked Coil Rope

strength caused by frictional wear on drums or pulleys is greatly reduced. Because of their design locked coil ropes are less subject to rotation and stretch than stranded ropes.

Concentric Strand rope as its name implies consists of round wires laid layer upon layer around a centre wire. This simple strand construction is used exclusively for static purposes such as bridge suspension ropes, standing rigging and similar purposes. (See Figure 7-42).

Two general arrangements of wires are used. The first consists of concentric layers of wires of one size around a somewhat larger centre wire. The second consists of one or more concentric layers of wires of one size around a core group made up of an equal laid strand.

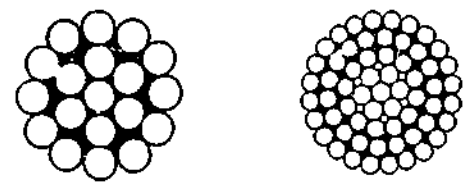


Figure 7-42. Concentric Strand Rope

WIRE ROPE CORES

The core forms the heart of the rope and is the component about which the main rope strands are laid. The core supports the strands and is intended to keep them from jamming against or contacting each other under normal loads and flexings The core may take one of several forms depending on the conditions under which the rope will be used.

Fibre Core (Figure 7-43) is adequate for many types of service providing maximum flexibility and elasticity to the wire rope Generally made of hard fibres, usually sisal and occasionally manila, it may also be manufactured from man-

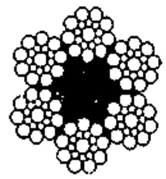


Figure 7-43. Fibre Core

made fibres such as polypropylene or nylon. These latter cores are useful where conditions surrounding the rope's use could result in premature failure of vegetable fibre cores. Sisal and manila fibre cores are impregnated during the cordage process with a suitable lubricant having preservative properties. Cotton and jute fibres are frequently used in cores for small cords such as sash cords, etc.

Independent Wire Rope Core (IWRC) (Figure 7-44) consists of a 6 x 7 stranded steel wire rope with a 7 wire centre strand. Its greatest use is where ropes are subjected to severe pressure while running over sheaves or winding on to drums. This core should be used when rope operates in temperatures damaging to natural or man-made fibres. It provides additional strength and less stretch with less resilience.

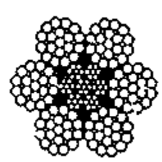


Figure 7-44. Independent Wire Rope Core

Strand Core (Figure 7-45) consists of a strand of steel wires, nominally 7, 19 or 37. It is occasionally used in running rope of smaller diameters rather than IWRC. It may also be used in standing ropes, guys, suspender ropes, etc. where extra strength reduced stretch and maximum resistance to weathering are required.

Armoured Core (Figure 7-46) is made of a layer of steel wires laid around a fibre centre. It provides superior wire-to-wire contact with the main rope strands as compared to IWRC s. The armoured core provides greater strength and resistance to crushing than fibre core.

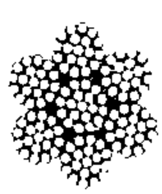


Figure 7-45. Steel Strand Core

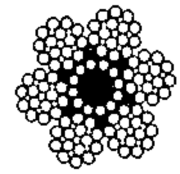


Figure 7-46. Armoured Core

WIRE ROPE CLASSIFICATIONS

6 x 19 Classification This classification covers ropes with 6 strands closed around a fibre or steel core and includes ropes having 17 to 26 wires per strand; an example is shown in Figure 7-47. Rope of 6 x 19 classification is used on a greater variety of applications than any other. Such ropes will be found on bridge cranes and gantrys, shop cranes and mobile cranes, hoists and derricks, dredges and clam shells, draglines and scrapers, power shovels and trench hoes, blast-holes drills and in industry generally.

Ropes in this class are available in regular lay or lang lay, with fibre core or with independent wire rope core. While usually right lay, left lay is made for special purposes as, for instance, blast-hole drilling. The use of lang lay rope, where possible, also improves flexibility, and provides additional resistance to abrasive wear.

A wide choice of wire arrangements in the strands is available, giving varying combinations of flexibility and resistance to abrasive wear. This adaptability is primarily achieved through the number of outer wires in each strand, ranging from 8 to 12.

The diameter of wire rope is the main factor in the size of load that the rope can safely take. Table 7-4 gives the breaking strains and safe working loads for 6 x 19 plowsteel F.C. wire rope.

Figure 7-47. 6 x 26 Right Regular Lay, Fibre Core

TABLE 7-4. BREAKING STRAINS AND SAFE WORKING LOADS

6 x 19 Plowsteel F C Wire Rope

Diameter	Breaking Strain in Tons	S.W.L, Tons
3/8	6 0	1 1
1/2	10 7	2 4
5/8	16 5	3 3
3/4	23 8	4 7
7/8	32 0	6.2
1	41 7	8 3
1 1/8	53 0	10 6
1 1/4	65 5	13 2
1 1/2	96 0	19 1
2	169 0	53.8

6 x 37 Classification This classification covers ropes with 6 strands closed around a fibre or steel core and includes ropes having 27 to 49 wires per strand This rope is designed for maximum flexibility with a reasonable degree of resistance to crushing and is in general use on applications such as overhead shop cranes where high rope speeds and multiple reeving are encountered and where layer-on-layer winding is normally involved Such ropes also find wide-spread use in their larger sizes on power shovels. dredges. drag lines. etc. where. for considerations of mobility and weight. winch drums and main rope sheaves must be limited in size

Ropes in this class are available in regular lay (Figure 7-48) or lang lay. with fibre core or independent wire rope core While usually made right lay. left lay is made for special purposes. as. for instance. where ropes operating in pairs may consist of one right lay and one left lay to cancel out torque.

A wide choice of wire arrangements in the strands is available. thus giving varying degrees

Figure 7-48. 6 x 36 Right Regular Lay, Fibre Core

of flexibility and resistance to abrasive wear. All rope sizes are not necessarily manufactured in every strand construction? Adaptability is primarily achieved through the number of outer wires. ranging from 12 to 18 per strand. The use of lang lay rope, where possible, also improves flexibility and provides additional resistance to wear.

6 x 7 Galvanized Rigging and Guy Rope This group includes ropes with 6 strands closed around a fibre core and having 6 or 7 wires per strand. These ropes are used as standing ships' rigging and for guying of towers. derricks. smoke stacks. etc. on shore. Individual wires are galvanized before being fabricated into ropes in accordance with Canadian Standards Association Standard G-4 requirements for Galvanized Wire (Figure 7-49).

Figure 7-49. 6 x 7 Galvanized Right Regular Lay, Fibre Core

SPLICING WIRE ROPE

The length of a long splice in wire rope is governed by the size of the rope The length of splice for 6-strand ropes of various diameters is calculated as follows:

Multiply the diameter of the rope by 80 (gives length of splice in feet)

Example:

For 3/4 " rope: 3/4 x 80 = 60'

PROCEDURE FOR SPLICING WIRE ROPE

Step 1. Mark off 1/2 the total splice length from each of the two rope ends. These marks represent the point of marriage (Figure 7-50).

Step 2 Unlay two strands from each piece to the marks and interlay the pairs as shown in Figure 7-51 Pull the ropes together snuggly at the marry.

Step 3. Unlay Strands 1 and 2 back to the 15' mark and lay Strands A and B in their

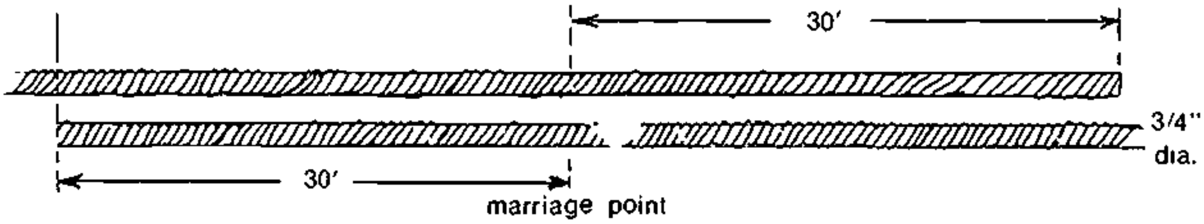


Figure 7-50. Marriage Point of Two Ropes

place. Then take Strand 1 and unlay it further, back to the 25′ mark and lay Strand A in its place (Figure 7-51).

Step 4 Unlay Strands C and D back to the 15′ mark (in the opposite rope) and lay Strands 3 and 4 in their place. Then take Strand C and unlay it further, back to the 25′ mark and lay Strand 3 in its place (Figure 7-51).

Step 5. Unlay Strand 5 back to the 5′ mark and lay Strand E in its place. Then unlay Strand F back to the 5′ mark (in the opposite rope) and lay Strand 6 in its place. The splice should now be laid out as in Figure 7-52.

Step 6. Cut all ends, leaving 5′ on each end for tucking; the ends are laid into the rope replacing the core. To open the rope for cutting the core and tucking, divide the rope in half with a marlin spike which enters the rope from the opposite side to the position of the strand to be tucked. With a smaller marlin or pliers, pull out the core and cut, pulling the end out slightly in the direction in which the tuck will be made. With the end of the tucking strand underneath the large marlin, rotate the marlin in the direction of the tuck to force the tucking end into the centre of the rope as the core is being pulled out at the end of the tuck, cut off the core so it does not abut the end of the tucked strand.

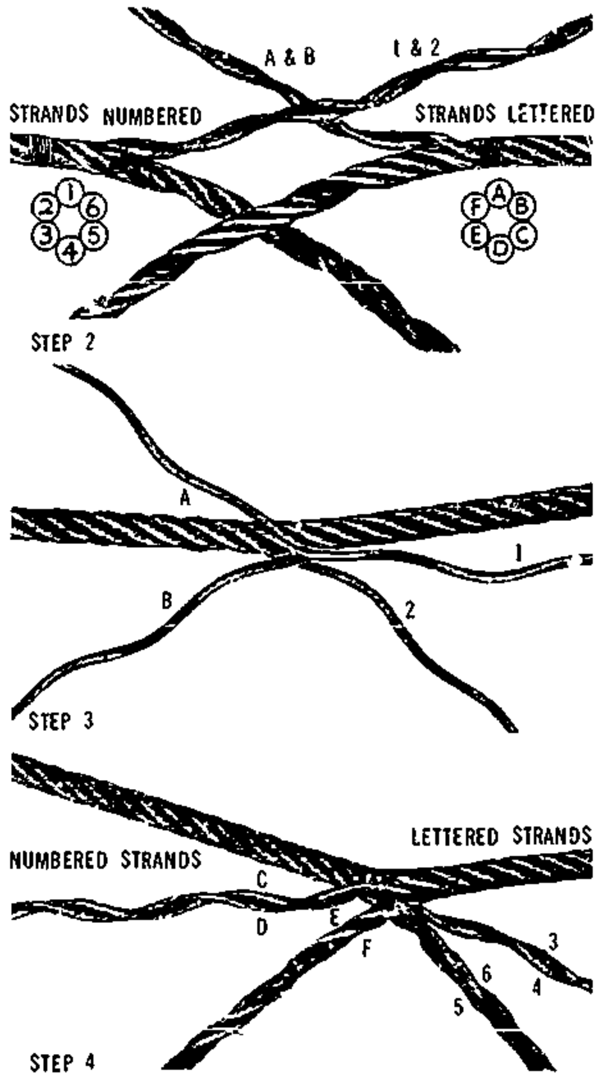


Figure 7-51. Splicing Wire Rope

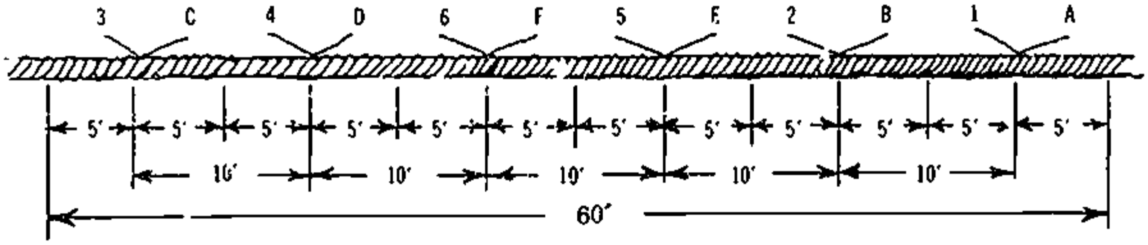


Figure 7-52. Splicing Wire Rope — Step 5

Step 7 Repeat this procedure for all tucks. A slight bulge will be noticeable where each tuck begins but this can be tapped down with a wooden mallet and will disappear entirely as soon as the rope is used

A competent long splice in wire rope produces 95% of the rope's rated capacity.

EYE SPLICE IN WIRE ROPE

A number of acceptable variations of the wire rope eye splice are in common use. The method set out here represents a logical step by step procedure resulting in a smooth splice of maximum strength.

In Figure 7-53 the cross-sectional illustrations with lines indicate the direction and placement of strands entering the main rope. The solid arrow illustrates the point of entry and direction of the marlin spike.

Procedure:

Step 1 Secure the rope in the vise with the desired eye below and the required length of dead rope alongside the main rope above (Figure 7-53, step 1).

Step 2. If an upper suspension vise can be secured to the main rope, and the lower vise can rotate, take one complete turn against the lay of the rope to loosen the tension of the strands in the lay. At this time unlay the strands of the dead end of the rope as illustrated in Figure 7-53 step 2.

Step 3. Drive marlin **from front to back** at the point of entry passing under two strands to the left of the entry point (keep the main core to the right of the spike). Rotate the spike upward with the lay for a half turn around the rope (Figure 7-53, step 3).

Step 4. Enter Strand 1 under the marlin, pull through, and rotate the spike back down toward the vise (in a direction against the lay) forcing the strand down with the left hand at the same time to nest the strand well down.

Step 5. Determine Strand 2 on the dead end (next strand up the lay), unlay and separate.

Step 6. Drive the marlin **from front to back** entering over the top of Strand 1 but coming out b[illegible]nd the next strand to the right at t[illegible]k (keep the main core to the right of the spike). Rotate the spike upward as before (Figure 7-53, step 8).

Step 7. Enter Strand 2 under the marlin and nest it well down as with Strand 1.

Step 8. Select and unlay Strand 3.

Step 9 Drive marlin **from the back** passing under two strands to the right of the initial entry point. (Keep main core on opposite side of marlin from previous paths.) Rotate upward as before. (See Figure 7-53, step 9.)

Step 10. Enter Strand 3 from front under marlin and nest it well down.

Step 11. Select and unlay Strand 4.

Step 12. Drive marlin **from the back** passing under one strand to the right of the initial entry point. Rotate upward. (See Figure 7-53, step 12.)

Step 13. Enter Strand 4 from front under marlin and nest.

Note: Four strands are now tucked and note that all four enter at the same place but come out between four consecutive strands from left to right at the back of the main rope.

Step 14. Drive marlin **from the front** at the entry point passing under one strand to the left of the spike. Do not drive the spike in too far.

Step 15. Force the spike hard to the left and at the same time force the core of the dead end of rope under the back of the spike. Rotate the spike upward for the usual half turn to run the dead core up alongside the main core (Figure 7-53, step 15).

Step 16. Select and unlay Strand 5.

Step 17. Enter Strand 5 under marlin and nest as before but do not withdraw spike. Continue upward for three more tucks with Strand 5 in the same manner,

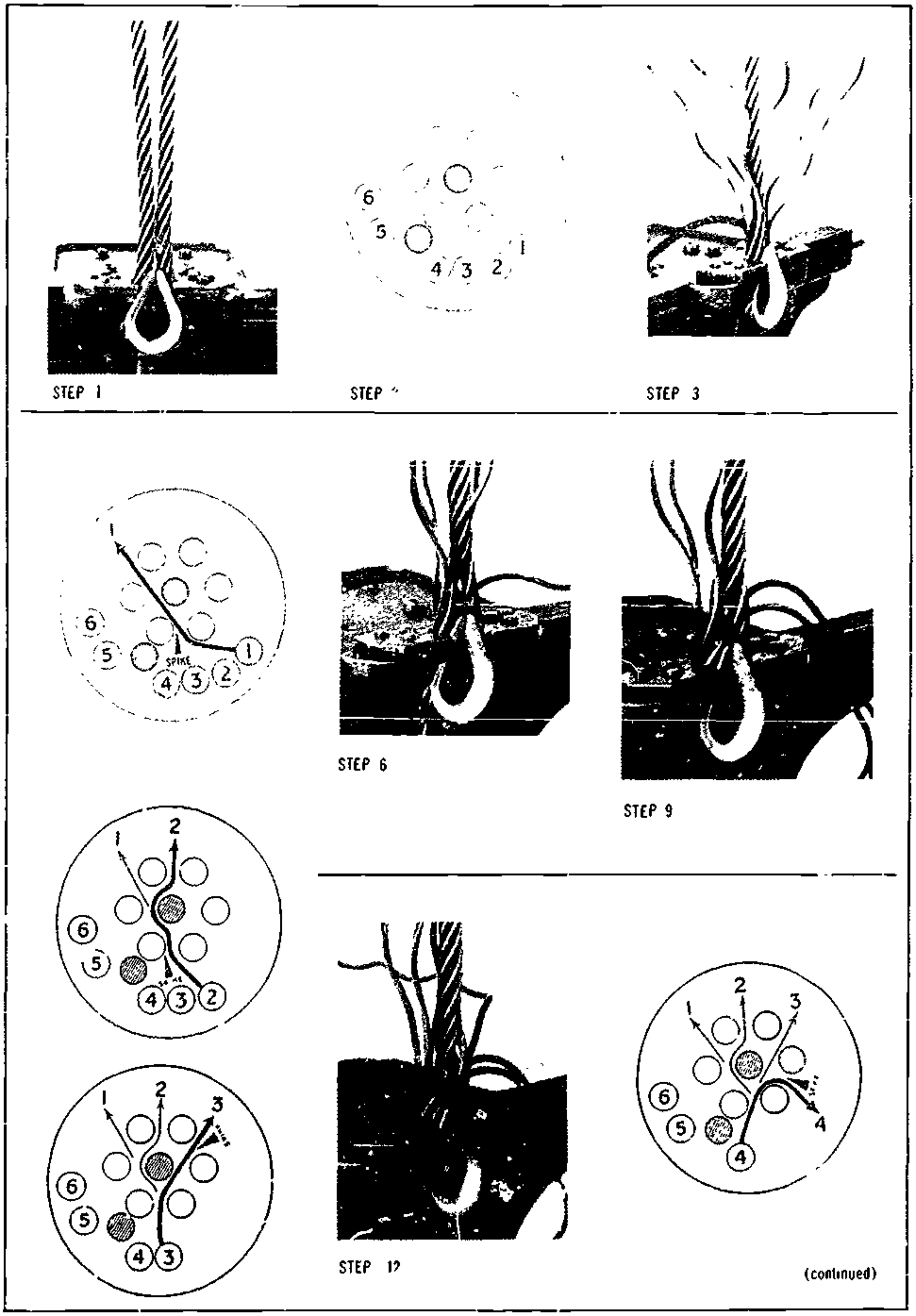
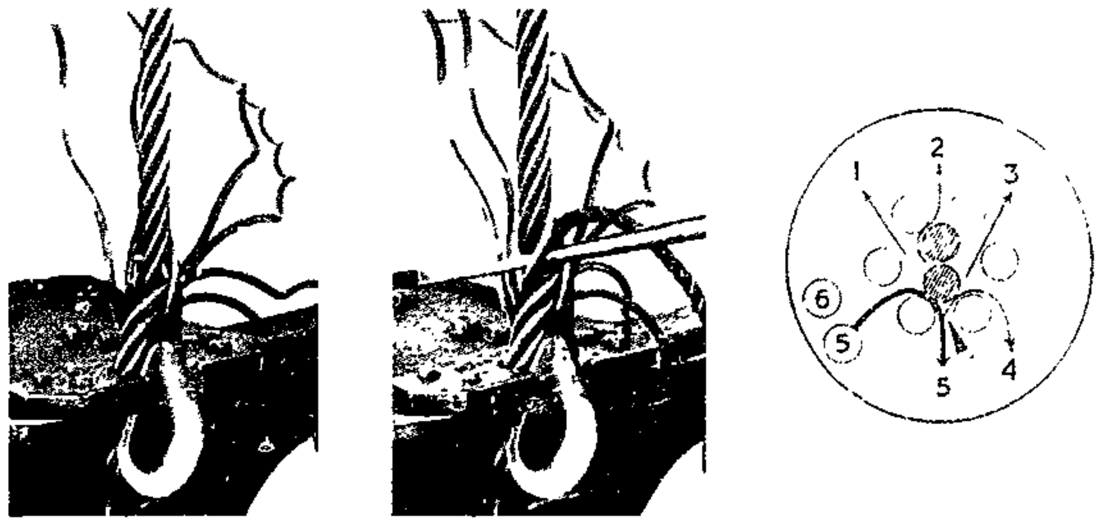
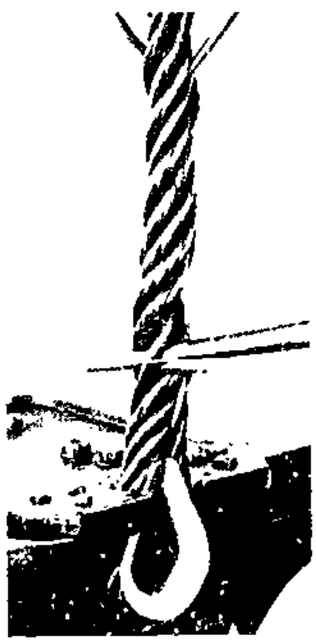


Figure 7-53. Making an Eye Splice



STEP 15

STEP 19



STEP 21

STEP 24

Figure 7-53. Making an Eye Splice (continued) keeping the core ahead of the spike. forcing it into the centre

Step 18 Cut core short at this point and lay the end into the centre of the main rope

Step 19 Drive marlin from the front under the second strand to the left of the initial entry point (keep cores to the right) rotate upward as before (Figure 7-53. step 19)

Step 20 Enter Strand 6 under marlin and nest as before. without withdrawing the spike Continue upward for three more tucks. nesting each tuck in turn

Step 21 Complete three additional tucks for Strands 4, 3, 2 and 1 in the same manner (Figure 7-53. step 21)

Step 22 Check the splice for uniformity of tucks around the main rope. If any strands are buried. drive the marlin under the strands at the top of the splice and rotate the spike downward to ease them into position

Step 23 Remove the eye splice from the vise and lay it on a flat wooden surface and shape it by pounding it on all sides with a wooden or soft faced metal mallet

Step 24 Cut off excess from tucked strands (Figure 7-53. step 24).

FLEMISH EYE LOOP IN WIRE ROPE

The Flemish Eye Loop is a quick method of creating a temporary eye at the end of a wire rope.

Procedure:

Step 1 Unlay the rope into two sections for a distance equal to the length of the loop plus ten times the diameter of the rope (Figure 7-54. step 1).

Step 2 Tie an overhand knot with the two parts at the top of the eye (Figure 7-54. step 2)

Step 3 Take Part 2 and lay it into the grooves of Part 1 down to the throat of the eye (Figure 7-54. step 3).

Step 4. Take Part 1 and lay it into the grooves of Part 2 down to the throat of the eye.

Step 5 Bring Parts 1 and 2 together and recombine them as in the original lay (Figure 7-54. step 5)

Step 6 Apply a U-bolt and Saddle clip to secure the dead end to the main rope at a point approximately eight times the rope diameter below the throat of the eye (Figure 7-54. step 6)

END ATTACHMENTS FOR WIRE ROPE

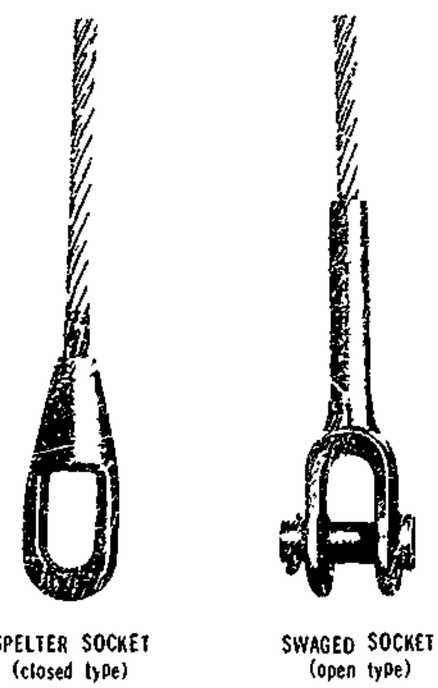
Steel wire ropes may be terminated for convenient attachment to hooks. pulley blocks. equipment. etc by several satisfactory methods.

Zinc (Spelter) Socket A properly attached zinc-type socket will develop 100% catalogue rope strength. This socket is available in both open and closed types (Figure 7-55).

Swaged Socket Swaged sockets are applied by pressure to the rope end and will develop 100% of catalogue rope breaking strength These are available in both open and closed types (Figure 7-55).

Mechanically Spliced Eye These are generally of two types: the Flemish Rolled Eye and the Fold Back Eye.

For satisfactory life the eye should be protected by a wrought steel or a cast steel thimble. Either



SPELTER SOCKET (closed type) SWAGED SOCKET (open type)

Figure 7-55. Socket End Attachments

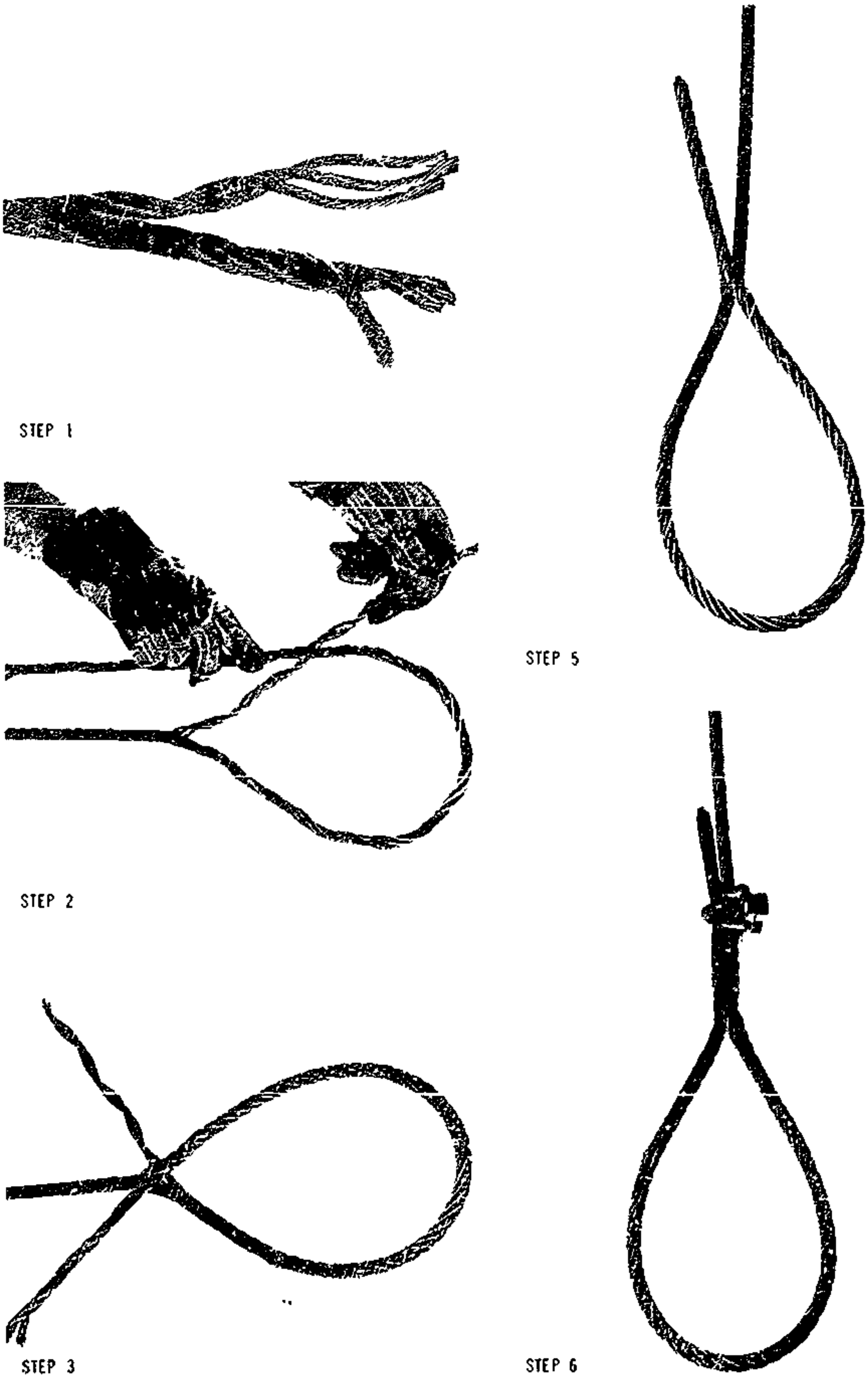


Figure 7-54. Making a Flemish Eye Loop

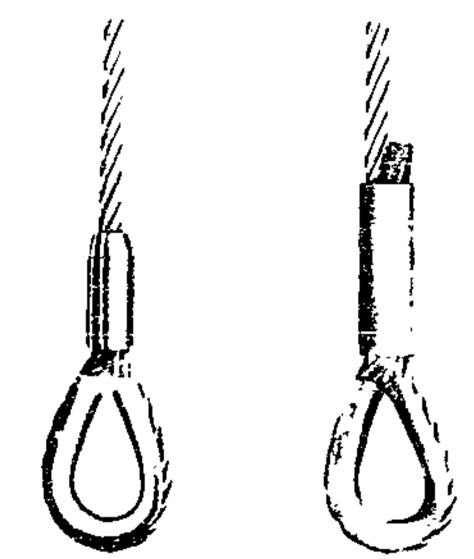
of these splices will develop strengths better than 95% of catalogue rope strength

Flemish Rolled Eye

A flemish rolled eye (Figure 7-56) is made and the strand ends secured against the live portion of the rope by means of a steel or aluminum sleeve set in place with an hydraulic press under specified pressures.

Fold Back Eye

A fold back eye (Figure 7-56) is made simply by bending the rope to the eye dimension required and securing the free or dead end of the rope against the live portion of the rope by means of a steel or aluminum sleeve set in place with an hydraulic press under specified pressures



FLEMISH ROLLED EYE FOLD BACK EYE

Figure 7-56. Mechanically Spliced Eye End Attachments

Swaged or Zinced Ferrule The swaged or zinced ferrule (Figure 7-57) is used mainly in the logging industry to provide a fast means of securing chokers to logs or tag lines These end fittings are used in conjunction with "Bardon" type choker hooks, butt hooks, arch hooks, etc Such ferrules are also used to anchor hoisting ropes to drums on small overhead electric- and air-powered hoists

Figure 7-57. Swaged or Zinced Ferrule End Attachment

HANDLING AND CARE OF WIRE ROPE

UNLOADING

Ropes should be unloaded from trucks, trailers, railway cars, etc. with care (Figure 7-58). The reel should never be dropped because the impact could fracture or separate the reel drum from the reel flanges. The best way to lift a reel of rope is to place a bar or heavy pipe through the central hole of the reel and connect by slings to a suitable hoist. If a hoist is not available, improvise a ramp of heavy planks and trestles and roll the reel down under control at all times.

UNREELING AND UNCOILING

When removing wire rope from the shipping reel or from the coil in which it is received it is essential that the reel or the coil rotate as the rope unwinds. Any attempt to remove a rope from a stationary reel or coil will almost inevitably result in a kinked rope and the rope will be ruined beyond repair at that point

Unreeling To unwind a rope from a reel one of three methods may be used.

Method 1. Pass a shaft through the reel, mounting the shaft on two jacks, one on either side Grasp the free end of the

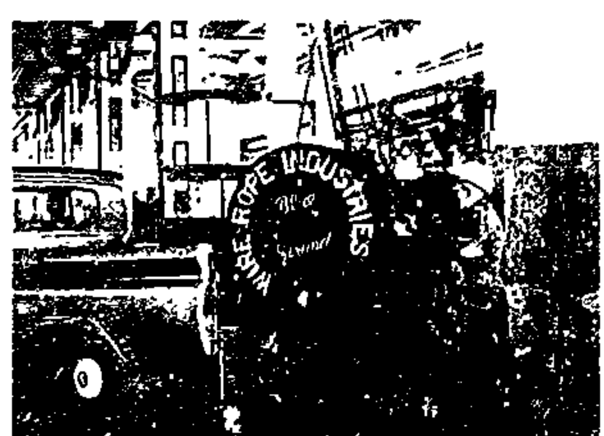


Figure 7-58. Unloading Wire Rope

rope and walk away from the reel which rotates as the rope unwinds Apply a piece of planking as a lever to one of the flanges to act as a brake to keep the rope tight and the reel from overwinding (Figure 7-59)

Method 2 Hold the free end of the rope while the reel is rolled along the ground or floor (Figure 7-60)

Method 3 Upend the reel with one flange on a turntable. Unwind the rope in a similar manner to Method 1. Extra braking must be maintained to keep the rope under sufficient tension so that slack will not accumulate resulting in the rope's dropping below the lower reel-flange or turntable (Figure 7-61).

When re-reeling rope from the rope reel as in Method 1 to a drum on a piece of equipment, the

Figure 7-61. Unwinding Wire Rope-Method 3

rope should travel from the top of the reel to the top of the drum or from the bottom of the reel to the bottom of the drum (Figure 7-62). This avoids putting a reverse bend into the rope as it is being installed A reverse bend would make the rope livelier and harder to handle.

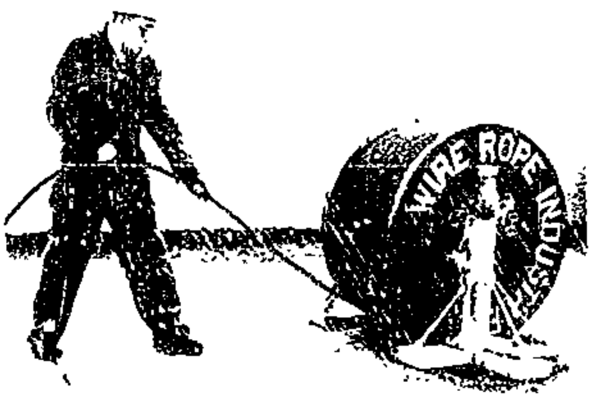


Figure 7-59. Unwinding Wire Rope-Method 1

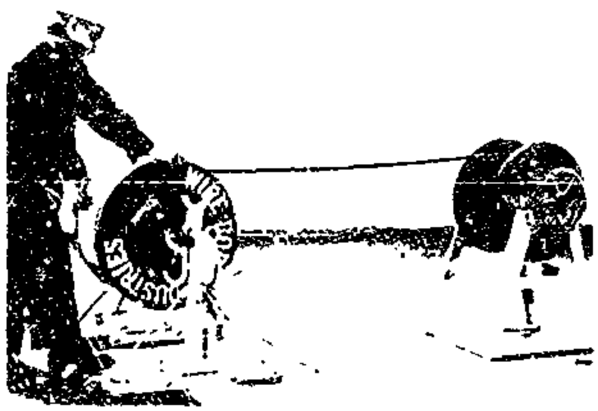


Figure 7-62. Re-Reeling Wire Rope

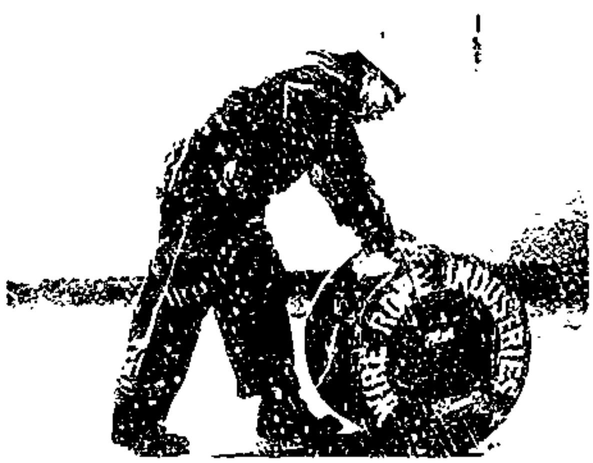


Figure 7-60. Unwinding Wire Rope-Method 2

Uncoiling To unwind a rope from a coil, either of two methods may be used

Method 1. The preferred method is to secure the free end of the rope and then roll the coil of rope along the ground like a hoop (Figure 7-63). Exercise care at all times to ensure that all rope remaining in the coil is held together so that no tight coils or kinks will occur.

Method 2. The coil of rope may be laid on a turntable and the free end pulled out as the turntable and coil revolve (Figure 7-64). The turntable should

Figure 7-63. Uncoiling Rope-Method 1

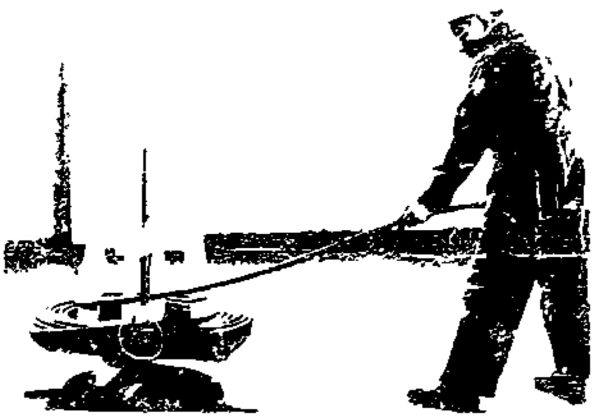


Figure 7-64. Uncoiling Rope-Method 2

have a centre of approximately the same diameter as the eye in the coil and some means should be provided to ensure that the turns of the rope will not flip up and fall over this centre. Apply a wooden plank brake to the periphery of the turntable prevent overwinding.

STORAGE

Unwrap and examine new rope immediately after delivery. Apply a fresh coating of rope dressing if necessary. Rewrap rope and store under cover in a clean, dry area, keeping the reel off the ground by steel or timber cribbing (Figure 7-65). Examine rope periodically, and renew dressing as required.

SEIZING THE ENDS OF WIRE ROPE

It is most important that tight seizings of annealed iron wire or strand be maintained on the ends of ropes, whether Preformed or not. If ropes are not properly seized prior to cutting, wires and strands are apt to become slack with consequent upsetting of uniformity of tensions in the rope. This could result in overloading of some wires and strands and underloading of others, leading to high strands, birdcaging of wires or breakage of wires and strands. Non-rotating ropes, regardless of construction, depend on retention of built-in torsional balance to resist rotation under load.

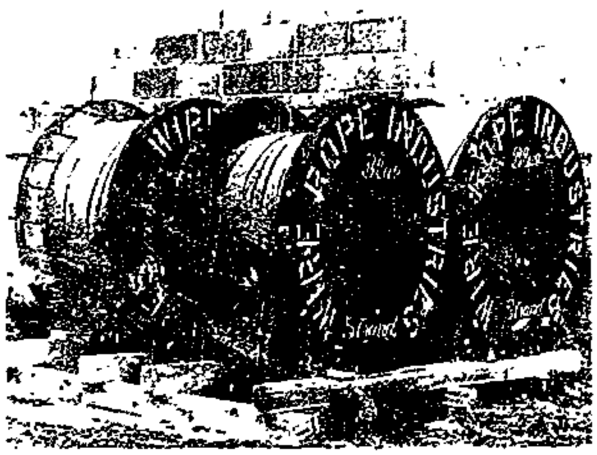


Figure 7-65. Wire Rope Stored on Cribbing

There are two approved methods of seizing.

Method 1 This method is generally used on ropes larger than 1" diameter. Place one end of the seizing wire in the valley between two strands (Figure 7-66), then turn its long end at right angles to the rope and wind back over itself and the rope in a close, tight winding, in a direction opposite to the lay of the rope, until a length of seizing not less than a rope diameter has been wound. Twist the two ends together and by alternately tightening and twisting these ends, draw the seizing tight. Best results are obtained when the seizing is applied with a serving bar.

Figure 7-66. Stranding Rope-Method 1

Method 2. This method is usually used on ropes and strands of 1" diameter and smaller Wrap the seizing wire around the rope in a close, tight winding in a direction opposite to the lay of the rope (Figure 7-67). Each seizing should consist of from 8-10 closely wound wraps of seizing wire. Twist the two ends together by hand in a counter-clockwise direction approximately at the centre of the seizing and about 1/2 from the rope. Using cutters, alternately twist and take up the slack until the serving is tight on the rope Twist seizing ends tightly against the serving, wind twisted ends into a knot and cut off the ends of seizing wire.

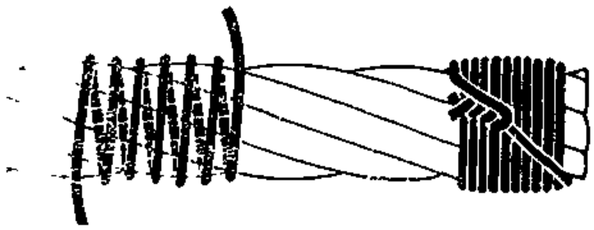


Figure 7-67. Stranding Rope-Method 2

Seizings on locked coil ropes will range in length from 10-20 rope diameters and their number will vary with rope diameter and construction Should it be necessary to cut off a piece of rope containing one or more original seizings, apply an equal number further up the rope before making the cut. Seizings on locked coil ropes must be applied with a serving bar or mallet and soldered in place. The seizing wire or strand must hence be either tinned or galvanized. Table 7-5 lists the number of recommended seizings for various types of ropes.

LUBRICATING METHODS

Whether stationary or in motion, steel wire ropes must be protected from corrosion. When in motion they must be lubricated to minimize wear between the metal-to-metal (wire-to-wire) surfaces. During manufacture a lubricant that will satisfy both these requirements at least for a time is built into the strands of wire and the core. Exposure to the elements and normal rope operation over sheaves and on and off drums will gradually deplete and contaminate the lubricant. Most ropes should be lubricated at intervals depending on the type of service to minimize corrosion and wear and extend rope life.

Clean a used rope with wire brushes, scrapers, compressed air or superheated steam. In some

TABLE 7-5. RECOMMENDED NUMBER OF SEIZINGS AND SIZE OF SEIZING WIRE OR STRAND

Rope Diameter Inches	Minimum Number of Seizings				Approx Diameter of Seizing, Inches		
	6 and 8 Strand Ropes Round and Flattened Strand		Non-Rotating Ropes Round and Flattened Strand		Stranded Ropes		Locked Coil Ropes
			Preformed and Non-Preformed				
	Reg Lay, Fibre Core Preformed Elevator	Lang Lay, Fibre Core Reg Lay, Steel Core Lang Lay, Steel Core	Groups	Seizings per Group	Wire	Strand	Wire*
3/32 & smaller	2	2	2	3	020		
1/8 to 1/4	2	3	2	3	024		
5/16 to 1/2	3	4	2	3	032		
9/16 to 7/8	3	4	2	3	040	1/16	052
15/16 to 1 1/2	3	4	3	3	080	3/32	062
1 9/16 to 2	4	5	3	3	106	1/8	072
Larger than 2	4	5	3	3	128	5/32	072

*Seizing wire for Locked Coil Ropes must be tinned or galvanized instances it may be necessary to soften the old lubricant and accumulated dirt with a penetrating oil or a good grade kerosene

Then apply a lubricant suited to the conditions under which the rope is operating Several methods are suggested. choose the one most suited to the installation and the lubricant being used It is better to lubricate lightly and frequently than heavily and infrequently

A suitable rope lubricant should have the following properties

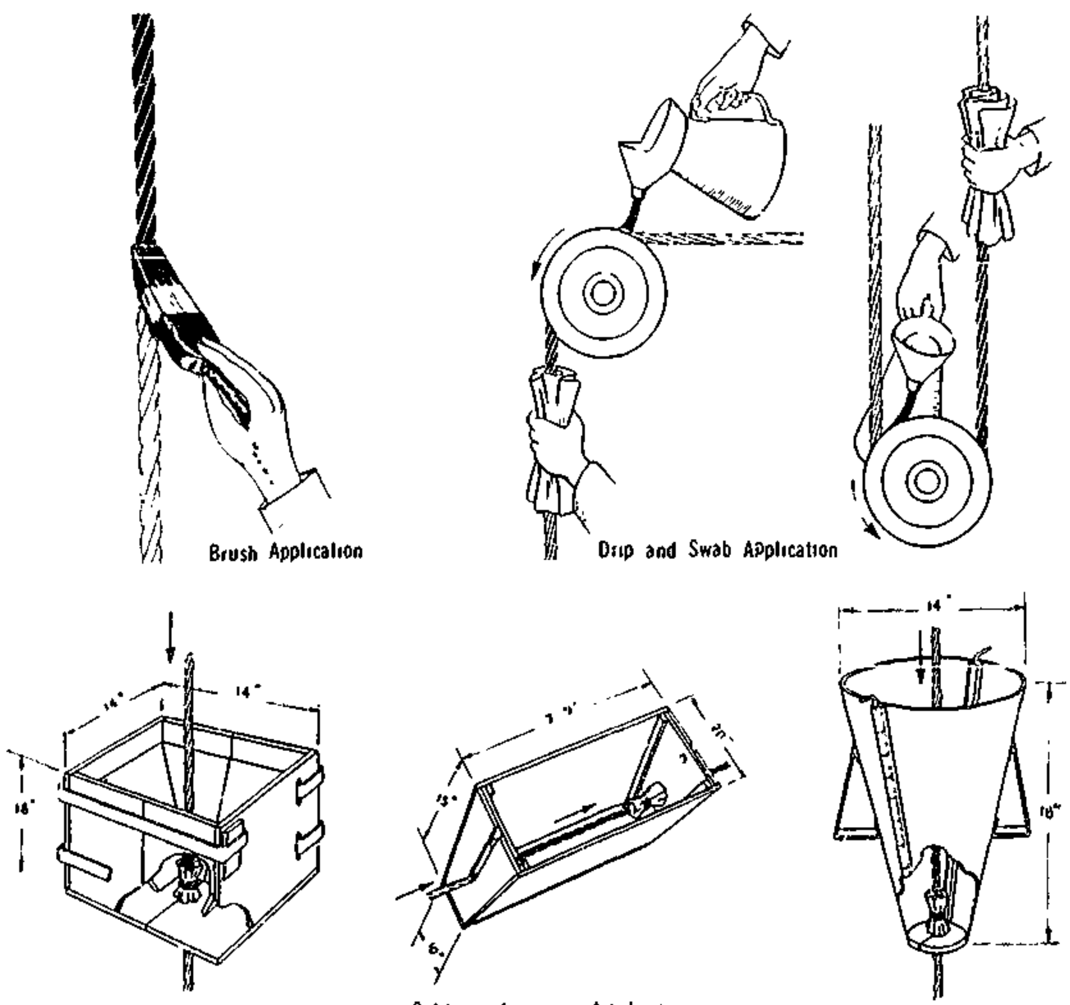
1 Freedom from acids and alkalies
2 Sufficient adhesive strength to stay on the rope without throw-off at maximum rope speed
3 Ability to penetrate between strands and reach the core
4 Non-solubility under conditions of rope use
5 Resistance to oxidation
6. High film strength is an advantage

When a wire rope is taken out of service for storage against possible future use, first clean and then lubricate it. Then cover and store the rope in a dry location and protect against mechanical damage.

Figure 7-68 illustrates some simple methods of lubricating ropes externally while in use Other lubricators and cleaning devices are, of course, available commercially or readily fabricated in a plant or local workshop.

CONDITION OF WINDING DRUMS AND SHEAVES

Flat faced drums with roughly worn surfaces and grooved drums with rough and scored grooving



Split wooden or metal boxes
Rope passes through burlap or similar wiper at outlet end of box

Figure 7-68. Methods of Lubricating Wire Rope in Use

or chipped groove separations can cause excessive rope wear.

Condition and contour of sheave grooves have a major influence on rope life. Grooves should be maintained in a smooth condition and be slightly larger than the rope to avoid pinching and binding of the rope in the groove. Since ropes are usually made slightly larger than their nominal size, new grooves for new rope should just accommodate the full over-size of the rope. Where the rope approaches the sheave at a specific angle of sheet, as for instance 1°-20′ maximum for mine shaft hoisting, the head sheave groove diameter should be equal to the nominal rope diameter plus 8%. The bottom of the groove should have an arc of support of from 120°-150°, with the sides of the groove tangent to the ends of the bottom arc.

Note that the more closely the contour of the groove approaches that of the wire rope the greater the area of contact between the two. The greater this area of contact, the less the wear on both the groove and the wire rope. The greater area of contact lessens deformation of the rope in the groove, thus increasing its resistance to fatigue from bending.

Fleet Angle The fleet angle is that angle between the centre line through the first fixed sheave perpendicular to the axis of the drum shaft and the centre line of the rope leading to the drum (Figure 7-69). Excessive fleet angles can cause serious damage to wire rope, sheaves and grooved drums. Severe scuffing results when rope wears against groove walls, grinding them down and causing the rope to become bruised or crushed.

Maximum fleet angles on equipment should be kept small and preferably between 1° and 1°-30′. To ensure the rope crossing back and starting the second layer properly without assistance the fleet angle should not be less than 0°-30′.

The angle should not exceed 1°-30′ for smooth faced drums and 2° for grooved drums, except that in mine shaft hoisting the angle should not exceed 1°-20′. Excessive drum wear and poor spooling or winding will result if these angles are exceeded.

WINCH DRUM CAPACITY

To determine the capacity in feet of steel wire rope of a winch drum or reel:

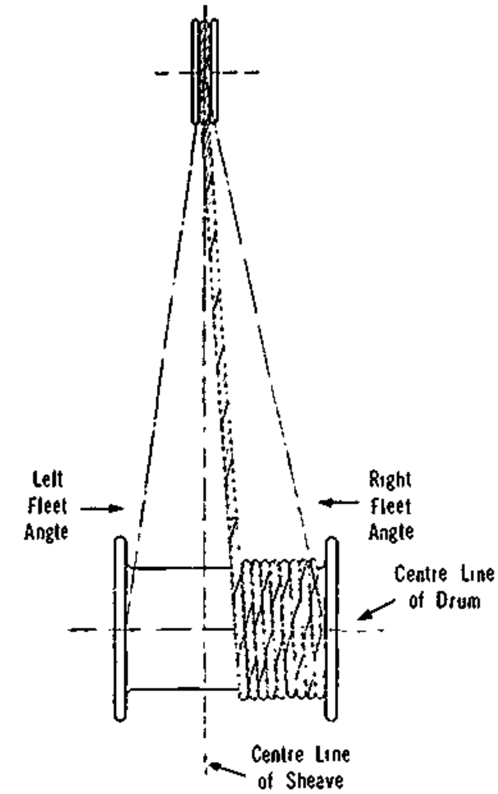


Figure 7-69. Fleet Angles

Refer to Figure 7-70. Add the diameter of the drum (B) to the depth of the flange (A). Multiply the sum by the depth of flange (A). Multiply the result by the length between the flanges (C), all in inches. Multiply the product by the factor in the right hand column opposite the size of rope required. The result will be the amount of rope in feet that the drum will hold.

Table 7-6 gives the factor F for "on-size" rope and level wind. Since new ropes are usually over-size by 1/32" per 1" of rope diameter the result obtained by the formula should be

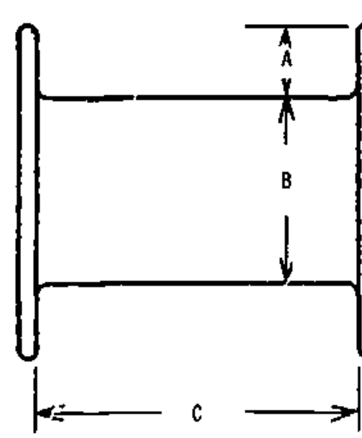


Figure 7-70. Determining Winch Drum Capacity

TABLE 7-6. "F" FACTOR FOR "ON-SIZE" ROPE

Nominal Rope Diameter Inches	F	Nominal Rope Diameter Inches	F
1/4	4 16	1 1/4	167
5/16	2 67	1 3/8	138
3/8	1 86	1 1/2	116
7/16	1 37	1 5/8	099
1/2	1 05	1 3/4	085
9/16	828	1 7/8	074
5/8	672	2	066
3/4	465	2 1/8	058
7/8	342	2 1/4	052
1	262	2 3/8	046
1 1/8	207	2 1/2	042

TABLE 7-7. SUGGESTED MAXIMUM RADIAL PRESSURES (in pounds per square inch)

Rope Construction	Sheave and Drum Materials		
	Cast Iron	Cast Steel	Manganese Steel 11 13% Mn
6x7 Reg Lay	300	550	1500
6x7 Lang Lay	350	625	1700
6x19 Reg Lay	500	900	2500
6x19 Lang Lay	575	1025	2850
6x37 Reg Lay	600	1075	3000
6x37 Lang Lay	700	1250	3500
8x19 Reg Lay	600	1075	3000
6x8 Flat Strand	500	900	2500
6x25 Flat Strand	800	1450	4000
6x33 Flat Strand	975	1800	4900
Locked Coil	on application		

decreased as follows: for rope over size decrease by from 0% to 6%; for random or uneven winding decrease by from 0% to 8%

Formula (B + A) x A x C x F for required size of rope

SHEAVE ALIGNMENT

Align sheaves so that the axis of the rope travelling over the sheaves will coincide with a line drawn from centre to centre of sheave grooves Poor alignment will result in severe wear on both the rope and the sheave flanges Even the slightest misalignment accelerates rope wear and shortens rope lift Poor alignment of the first sheave off the drum may result in poor winding A ready indication of poor alignment will be the rapid wear of one flange of the sheave

RADIAL PRESSURE ON SHEAVES AND DRUMS

Radial pressure of the rope on the sheave or drum will cause wear in the groove or the drum face Too great a radial pressure will cause excessively fast wear and result in shortened rope life Radial pressure can be reduced by decreasing the load on the rope or by increasing the diameter of the sheave or drum The amount of wear will vary with the material from which these are made Table 7-7 specifies acceptable radial pressures for different wire rope types

ROPE OPERATION

Overwinding and Crosswinding While the ideal winding condition would be a single layer of rope on the drum, this is not always possible. Where it can not be avoided the succeeding layers should not cross-wind but should wind regularly in the groove formed between successive turns of the preceding layer of rope.

Initial Operation After installing a new rope it is advisable to run through its normal operating cycle for a number of trips under light load and at reduced speed. This permits the new rope to adjust gradually to working conditions and enables the strands to become seated and some stretch to occur. The rope will then be less liable to damage when the full load is applied.

Shock Loading Never lift or stop a load with a jerk. the load so imposed may equal the static working load several times and jerking may break a rope. Jerks that do not break the rope cause rapid deterioration and result in reduced rope life.

Rope Speed Experience indicates that rope wear increases with speed. Rope economy results from moderately increasing the load and reducing rope speed. Some authorities suggest that when ropes are running light, rope speed should not exceed 4,000′ per minute whether hoisting or lowering.

INSPECTING WIRE ROPE FOR WEAR

Inspect the entire length of rope frequently paying particular attention to those sections experience indicates to be areas showing greatest wear. Watch for broken wires, excessive wear and lack of lubrication. Where drum capacity will permit and winding conditions are such that "drum crushing" of the rope is minimal, it may be wise to install a slightly longer length of rope than absolutely necessary. This extra length will permit cutting a few feet of rope at either load end or drum end to change those areas of maximum wear over drums and sheaves

In installations where rope wear is excessive at one end or the other the life of the rope may be extended by changing the drum end for the load end, that is, by turning the rope "end for end." This must be done before wear becomes too severe

A rope may have to continue in operation with broken wires, but these wires should be removed as soon as possible The method often used to get rid of a broken wire — nipping it off with pliers — is not recommended as this leaves a jagged end. It is preferable to bend the broken ends backwards and forwards with the fingers if possible, or if the ends are short or the wire large use a marlin spike or a piece of wood. In this way, the wire breaks inside instead of outside the rope. The ends are left tucked away between the strands where they will do no harm. (See Figure 7-71).

THREATS TO SAFE OPERATION AND MAXIMUM SERVICEABILITY

1. Drums and sheaves of too small diameter
2. Reverse bends in the rope
3. Overloading the rope
4. Incorrect rope construction for the job
5. Overwinding or incorrect winding on drums
6. Lack of lubrication
7. Handling or kinking damage
8. Insufficient or faulty guides or rollers
9. Sheaves out of alignment
10. Deeply worn grooves in drums
11. Broken rims or grooves on sheaves
12. Sheaves that turn hard or wobble
13. Displaced rope guides
14. Stones or other objects lodged in equipment
15. Sticking or grabbing clutches
16. Uneven or jerky pull on the rope from loose bearings
17. Lines whipping
18. Improper line spooling
19. Incorrect installation of clamps, ferrules, sockets or splices

Figure 7-71. Breaking Off a Loose Strand of Wire Rope

SAFETY PRECAUTIONS

Hand Protection Gloves must be worn by all workmen handling wire rope

Use of Wire Rope Clips Tighten wire rope clips of the "U" bolt type immediately after the initial load carrying use, and frequently thereafter Malleable iron clips should not be used for hoisting lines.

Running Line Safety Running lines of hoisting equipment located within 7' of the ground or working level must be rapid off, or otherwise guarded, or the operating area restricted

INSPECTION AND ASSESSMENT OF WIRE ROPE

Wire rope or cables should be inspected by a competent person at the time of installation and once each week thereafter when in use Wire rope or cables must be removed from hoisting or load carrying service when detrimental corrosion is present or when one of the following conditions exist:

1 Three broken wires are found in one lay of 6 x 7 wire rope
2 Six broken wires are found in one lay of 6 x 19 wire rope
3 Nine broken wires are found in one lay of 6 x 37 wire rope
4 Eight broken wires are found in one lay of 8 x 19 wire rope.
5 Marked corrosion appears.
6 Four broken wires are found adjacent to each other or when sixteen broken wires are found in one lay
7 Wire rope of a type not described here should be removed from service when 4% of the total number of wires composing such rope are found broken in one lay.
8 Wire rope should be removed from service when the wires in the crown of the strand are worn to less than 60% their original diameter
9 Wire rope should be removed from service when there is a marked reduction in the diameter, even though the wires in the crown of the strand show no sign of wear. This condition can result from inner corrosion and indicates a serious weakening in the rope.

CHAIN

A chain consists of a number of interlocking sections of oval metal pieces. Each section or link has one or more visible welds. For rigging jobs, the most common chain metals are wrought iron and steel alloys Heat-treated carbon steel is used for chain slings because of its high abrasion resistance.

Certain properties of chain in operation make it preferable to wire rope, corrosion resistance, abrasion resistance, sharp bending tolerance. Since rope will stretch to some extent it has a greater shock load tolerance than chain.

Chain will fail abruptly when overloaded or if it has a faulty weld. Wire rope, on the other hand, will evidence failure more gradually as wires and strands break individually with unmistakable sounds.

Hooks are matched to chains by the manufacturer or on the basis of fit between the chain link size and the hook connector. Such a matched hook should fail before the chain fails

CARE AND MAINTENANCE

Do not leave chains where they will be run over by tractors, trucks or other equipment Never point load a link of chain with the beak of a hook as this may damage both and cause the load to drop. Never shorten a chain by twisting or knotting or with nuts and bolts.

Store chain in a clean, dry, ventilated area with a light coating of oil on it to prevent rust.

INSPECTION AND ASSESSMENT

Inspect all hoisting chains at frequent intervals for such defects as stretch, deformity, twist, cut, nicks, gouge marks, arc burns, open welds or fractures as indicated by very fine surface cracks. Remove chains from hoisting service when such defects are found.

Discard chains that have stretched more than 5% in any five link sections. Chains that show wear greater than 25% of the thickness of the metal in any individual link should be removed from service.

Alloy chains should be subjected to stricter scrutiny as some degree of damage or defect will weaken the chain more than that of a proof or BBB coil chain.

SLINGS

A sling is a means of connecting a load to a power source for lifting. Different materials used in rigging may be adapted to create slings fibre and wire rope. chain. synthetic or wire webbing. in conjunction with hooks. shackles. turnbuckles

SLING MATERIALS

Manila Rope

Advantages:

1. Flexiblity
2. Easy to handle
3. Does not tend to slip from choke position
4. Will not scratch a load
5. Relatively low cost.

Disadvantages:

1. Limited strength
2. Subject to moisture. heat and chemical damage.

Synthetic Fibre Rope

Advantages:

1. Stronger than manila rope
2. High abrasion resistance
3. Provides secure grip to the load
4. Will not scratch a load
5. Resistant to moisture. heat and most chemical damage
6. Stretch increases absorption of impact and shock loads

Disadvantages:

1. Not as strong as wire rope

Wire Rope

Advantages:

1. Strongest type of lifting material
2. Flexible
3. Abrasion resistant

Disadvantages:

1. Will slip from choke position on metal loads
2. Will scratch fragile loads
3. Subject to sharp bend damage
4. High cost factor

Chain

Advantages:

1. Not subject to sharp bend damage
2. Good lifting strength

Disadvantages:

1. Heavy material
2. Lack of stretch produces poor shock loading tolerance
3. Subject to failure if kinked or twisted while under load
4. Will slip from choke position unless softeners are used
5. Becomes brittle in cold temperatures over long periods.

Note: Use only alloy chain slings for overhead lifting. Proof Coil. BBB Coil. and High-Test chain grades are not recommended for overhead lifting.

SLING ARRANGEMENTS

Figures 7-72 illustrate various sling arrangments.

TYPES OF SLINGS

Flat Slings Flat slings are manufactured from synthetic fibre webbing and wire mesh in a variety of constructions. The design of flat slings provides the following advantages:

1. Load is protected from damage at the point of contact
2. Wide surface will hug any shape load and reduce slippage
3. Apparatus is light in weight. clean to work with and easy on the hands

Safe working loads for flat slings should always reflect manufacturer's specifications.

Synthetic Fibre Web Slings Web slings are available in nylon and polyester with various design and treatment features that adapt the slings to specific lifting requirements.

Features of Synthetic Web Slings

1. Resistant to alkalies but do not tolerate acids
2. Can be used in temperatures up to 200 F

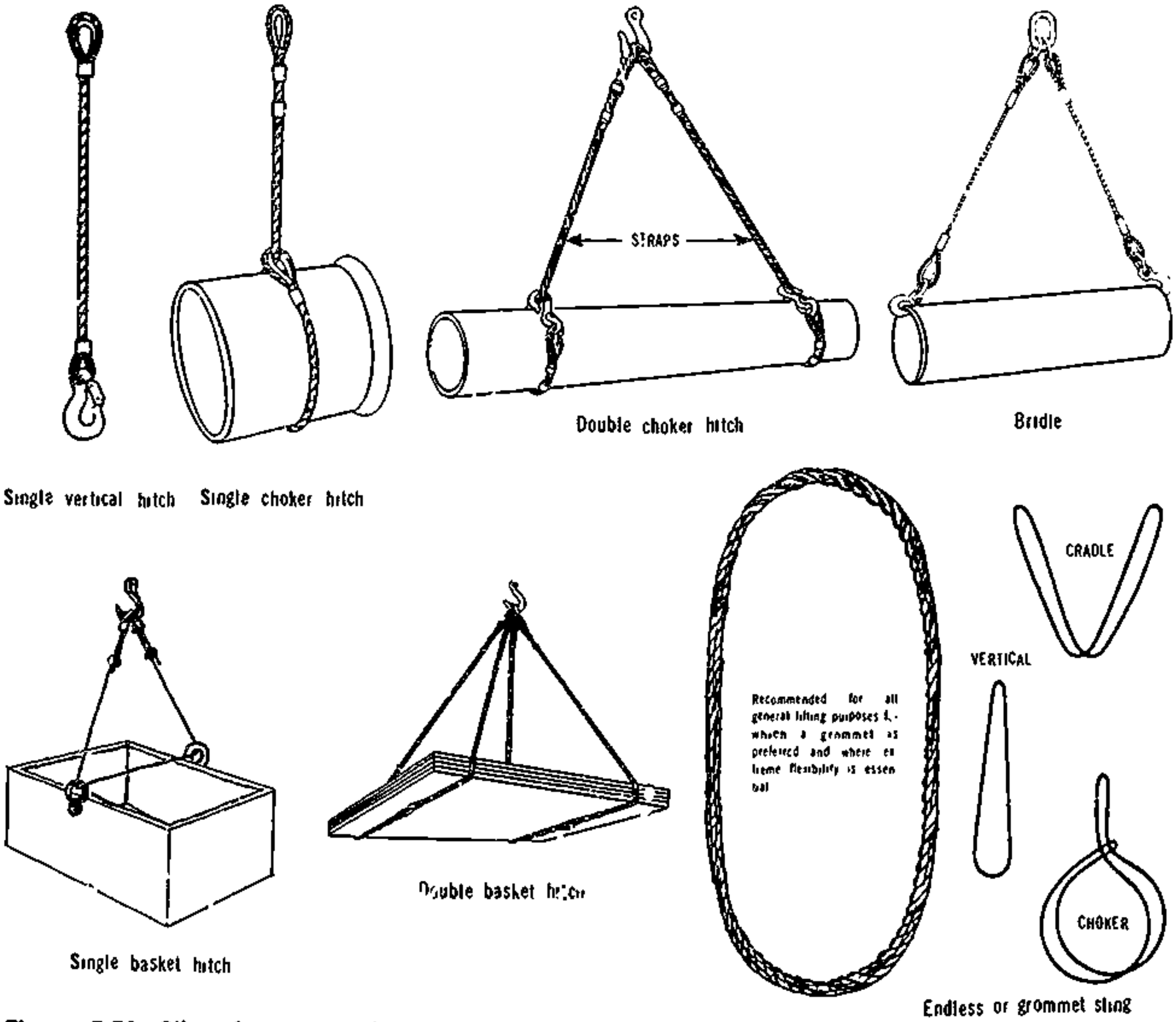


Figure 7-72. Sling Arrangements

3. Will stretch 10% rated capacity
4. Some designs are manufactured with a reinforcing core of inner load bearing yarns which carry 80% of the load and are protected from wear by the outer fibres.

Figures 7-73 illustrate the various constructions of synthetic web slings. The slings are shown in operation in Figure 7-74.

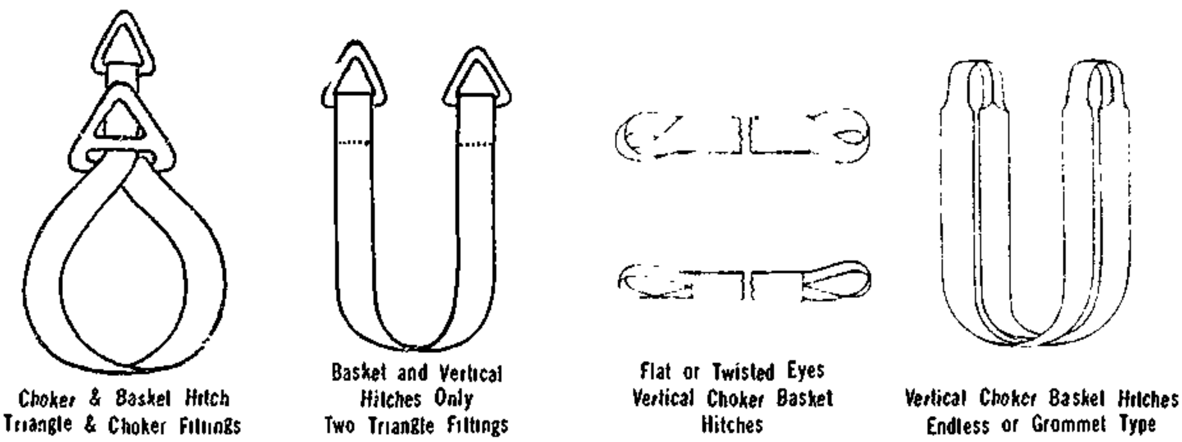


Figure 7-73. Synthetic Web Sling Constructions

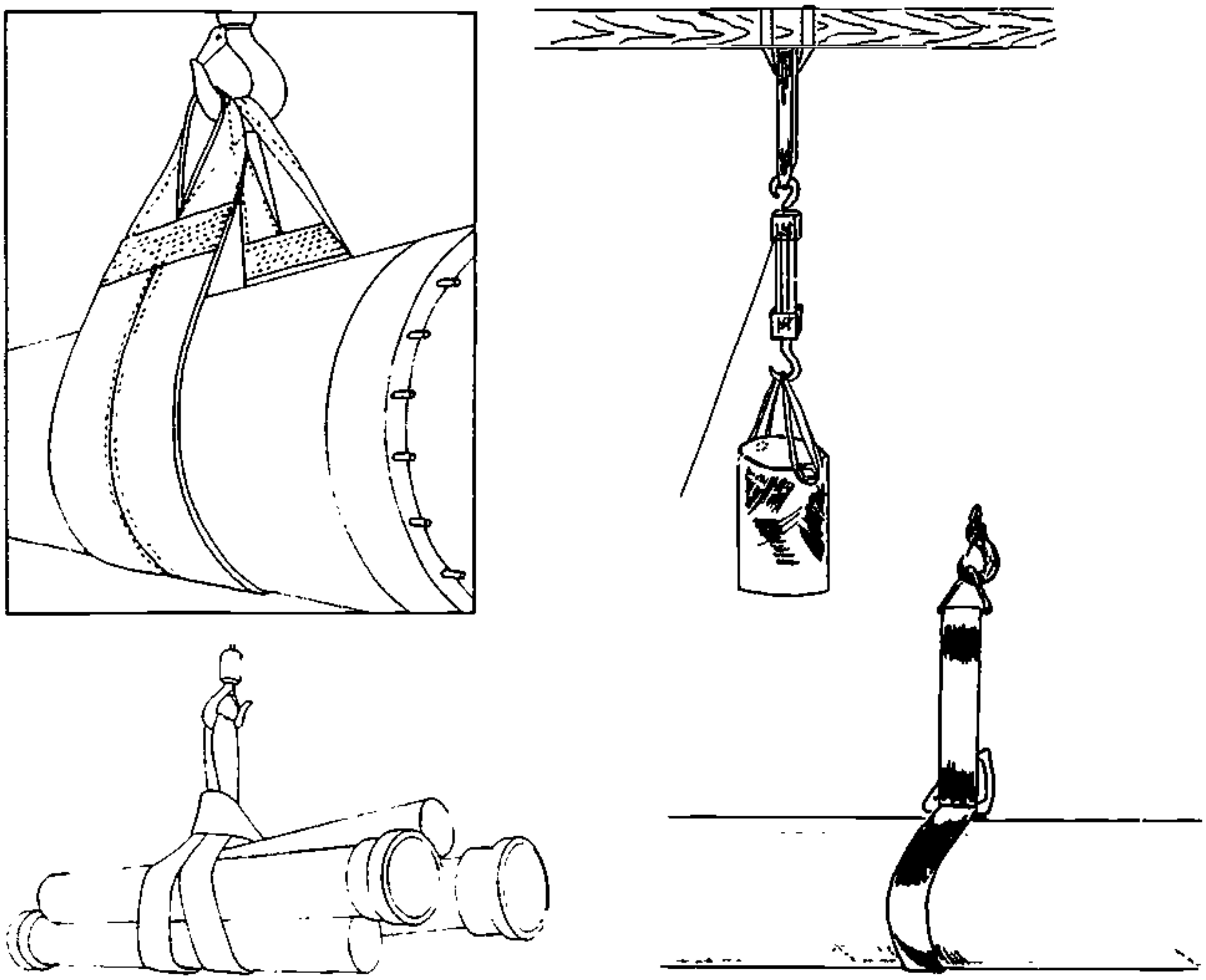


Figure 7-74. Synthetic Web Slings in Operation

Wire Mesh Slings Wire mesh slings are widely used in industries where loads are abrasive, hot or will tend to cut slings

Features of Wire Mesh Slings

1 Resistant to abrasion and cutting
2 Firm grip maintains balanced load
3 Can withstand temperatures to 550 F
4 For handling materials that would damage wire mesh or for loads with soft finishes, slings can be coated with plastic.

Wire mesh is available in a range of gauges as illustrated in Figure 7-75. Wire mesh sling arrangements are shown in Figure 7-76.

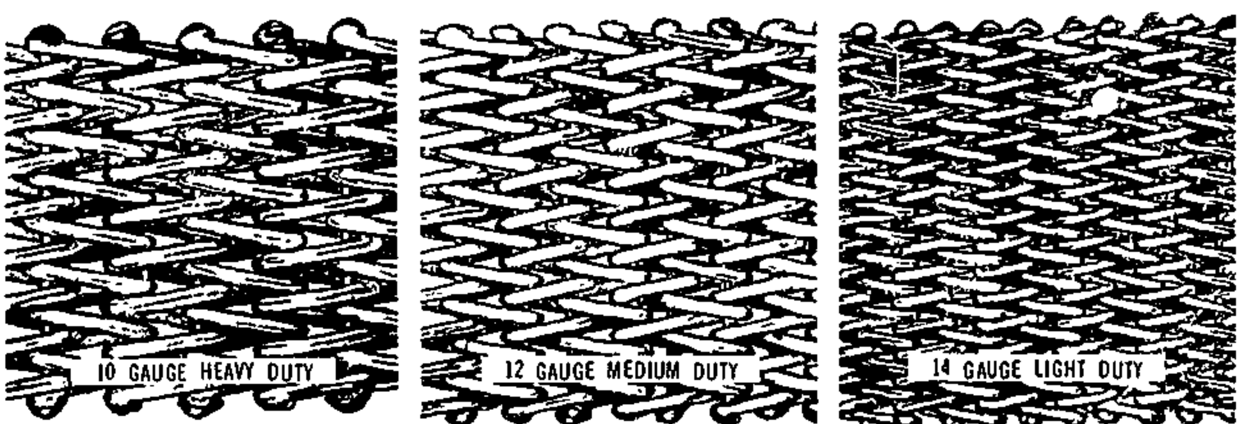


Figure 7-75. Wire Mesh Gauges

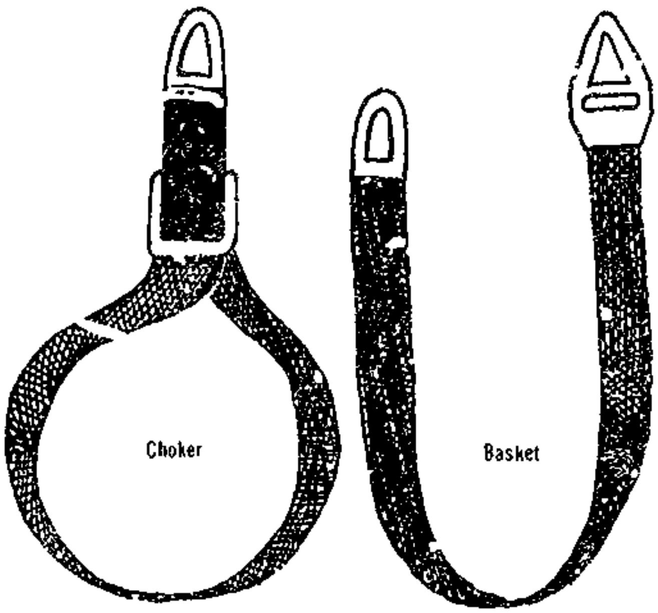


Figure 7-76. Wire Mesh Sling Arrangements

SAFE WORKING LOADS FOR SLINGS AT VARIOUS ANGLES

Different weights of pull are exerted on slings of various angles for the same load. The load on the rope equals the weight of the load **only** with a straight or vertical pull.

Example:

A load of 2,000 lbs suspended from a single vertical hitch places 2,000 lbs. strain on the line.

Where a sling having two legs is involved, the angle of pull places a significantly greater strain on the sling. If the angle between the load and the sling leg is only 30°, the strain on the sling is nearly **twice** the actual weight of the load.

The maximum recommended angle between the load and the sling is 45°. If the angle is less than 45°, the danger of the sling failing is greatly increased.

Figures 7-77 illustrate the principle of sling angles.

MEASURING AND CUTTING WIRE ROPE FOR CHOKERS

Procedure (See Figure 7-78).

Step 1. Measure and mark splicing end and put on wire stop.

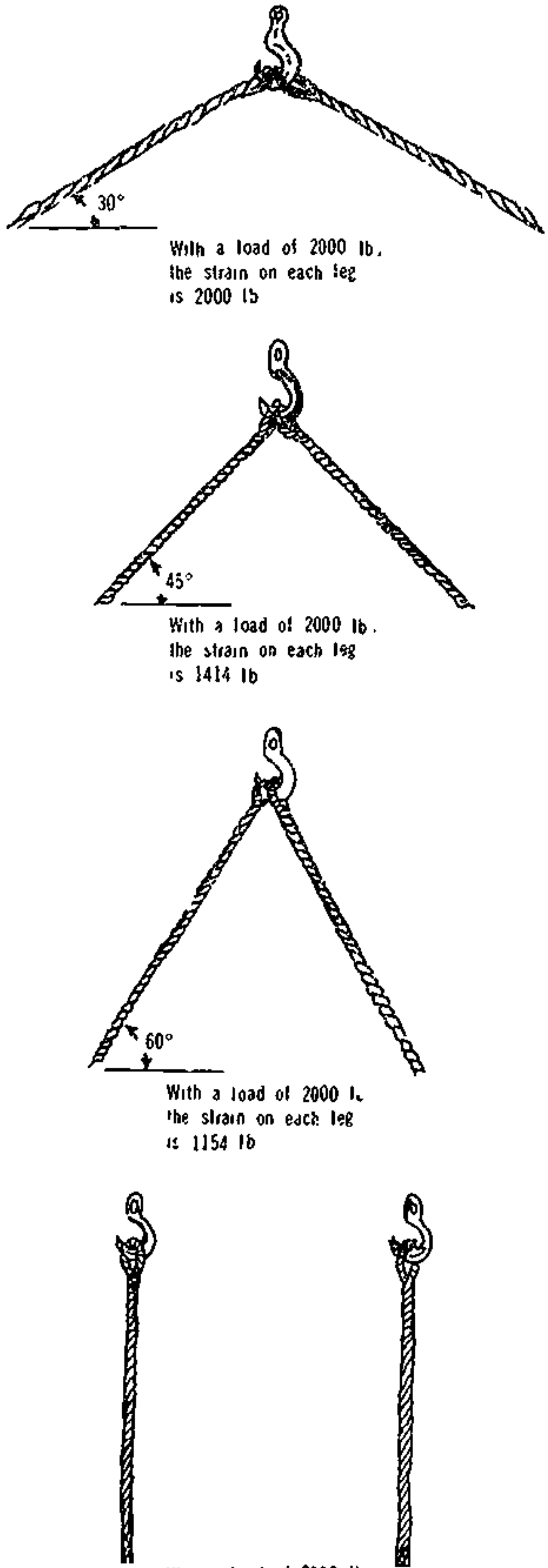


Figure 7-77. Sling Angle Principles

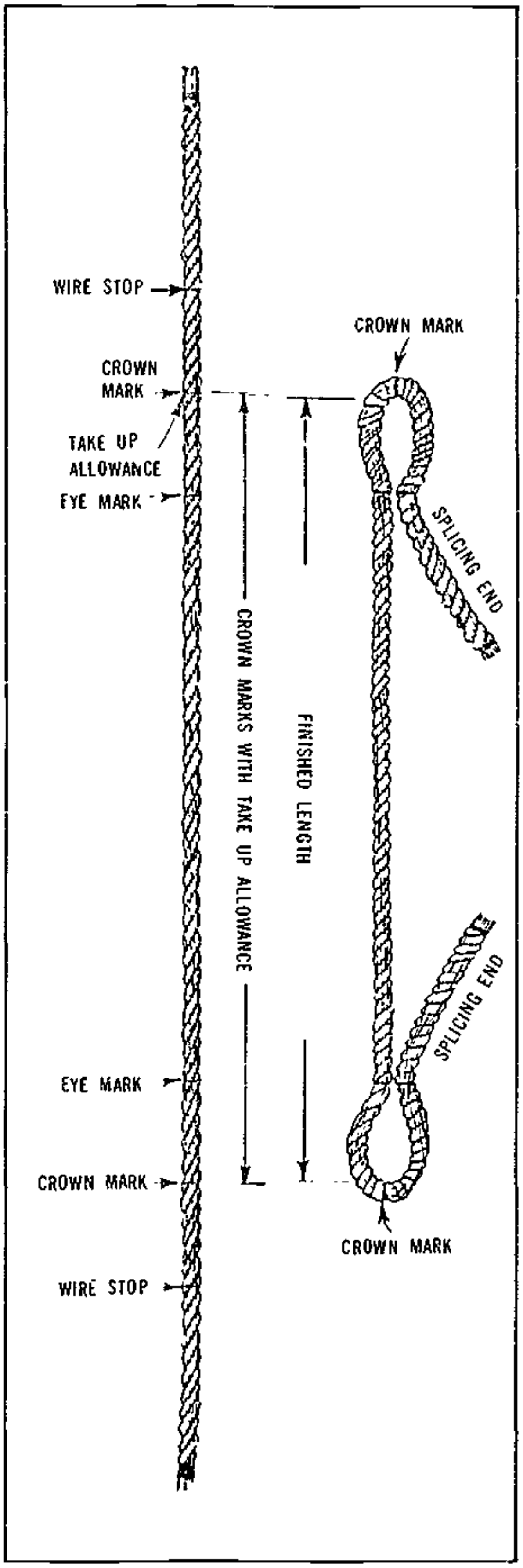


Figure 7-78. Making a Choker

Step 2. Measure and mark crown eye marks.

Step 3. Measure required length between crown marks and add twice the circumference of the wire rope for take up allowance at top as shown in Table 7-8 and then mark off eye, wire stop and splicing end.

TABLE 7-8. MEASUREMENTS FOR CUTTING WIRE ROPE

DIA OF WIRE ROPE	TAKE UP ALLOWANCE	SPLICING END	EYE
3/8"	2"	12"	8"
1/2"	3"	14"	10"
5/8"	4"	16"	12"
3/4"	5"	18"	14"
7/8"	6"	24"	16"
1	6-1/4"	30"	18"
1-1/8"	6-1/2"	36"	20"
1 1/4"	7-1/4"	44"	22"

SAFE USE OF SLINGS

1. Determine the weight of the load to be lifted.
2. Do not use the sling for any load exceeding its Rated Safe Working Load.
3. When using multi-leg sling Assemblies, remember that the angles between the legs will reduce the Safe Working Load of the Assembly. Consult the Sling Chart and Safe Working Load Tables available.
4. Endless wire rope slings are prone to misuse, and in practice they are often found to be difficult to handle. They should be used only when they have been purposely made for applications requiring a very short effective length, or for heavy lifts where a single sling of the required Safe Working Load is not available.
5. Examine all slings before use, and discard any that are defective.
6. Do not use a sling that contains a severe kink.
7. Slings found to be unfit for use should be destroyed, not put on a refuse dump.
8. When loads are being carried on a crane hook, slings not in use should not be carried on the same hook.
9. "Hooking Back" to the leg of a sling is not recommended.

10 Avoid bending wire rope slings around sharp corners of the load as it could effectively reduce their Safe Working Load

11 A sling "doubled" around a shackle has a Safe Working Load equivalent only to that of a single part of the rope

12 When using a halhing sling or reeving sling do not force the bight down on to the load. The included angle formed by the bight should not exceed 120 .

13 Protect Wire Rope Slings by suitable softeners from sharp edges of the load.

14 Do not drag wire rope slings along the floor

15 Check that the crane hook is positioned over the load's centre of gravity to prevent swinging when the load is being raised

16. Make sure that the load is free before lifting, and that all sling legs have a direct lead

17 Take your hands away from slings before the crane takes the load and stand clear.

18 Correct signals, according to the recognized code, should be given the crane driver The signals must be given by the person responsible for the lift and nobody else.

19 Never allow the load to be carried over the heads of other persons.

20 Do not ride on a load that is being slung, or allow any other person to do so.

21 Steady application of the load at the start of each lift will avoid risk and prolong the life of the sling. Beware of snatch loading.

22 Always lower the load on to adequate dunnage to prevent damage to the sling

23 After use, riggers should stow slings tidily on a suitable rack off the floor.

24 Keep wire rope slings away from welding and flame cutting operations

25 Keep wire rope slings in a dry store when not in use, to prevent corrosion.

26 Good practice requires all lifting tackle to be examined by a competent person at regular intervals This includes the wire rope slings Riggers should not stow away slings and regard them as their own private property as this could lead to their being overlooked at inspection time.

27 Slings may not be made from Lang Lay wire rope.

RIGGING

Attaching loads to lifting devices is a serious and complex responsibility and therefore, only the supervisor in charge can designate persons competent to do this. The assigned workman is fully responsible for the safety of the procedure:

1) The equipment (slings, chokers, chains, spreader bars, etc.) is of sufficient strength to lift, suspend and support the load.
2) The load must remain in a safe and stable situation while stationary or moving.
3) The total overall weight of the load to be moved must be less than the rated safe load capacity of the hoisting device.

In determining the safe working loads for cordage wire rope, chains and other rigging equipment, the manufacturers' published safe working load ratings must not be exceeded. Remember that these specifications apply to rigging in new or nearly new condition. These items must therefore be examined so that their condition can be considered in selecting the correct size and construction for a given load. Where special considerations of safety factors or special risks are involved, government regulations apply in selecting the correct size and construction to be used.

RIGGING ACCESSORIES

For ropes and lines to be used efficiently in rigging operations, certain auxillary devices can be included in the system.

HOOKS AND SHACKLES

Hooks and shackles are manufactured from forged steel or built up steel plate, however special materials may be used where certain electrical or chemical conditions demand it, e.g. bronze hooks which have anti-spark properties

1 **A Standard Eye Hook** is illustrated in Figure 7-79. The different dimensions are labelled for reference to the dimension and load charts to follow.

2. **Mousing Hooks** No open hook shall be used in any situation where accidental dislodgement of the load could cause a risk of injury to workers. In these circumstances a safety hook or a shackle must be used, or if permitted by government regulations, mousing as shown in Figure 7-80 could be applied.

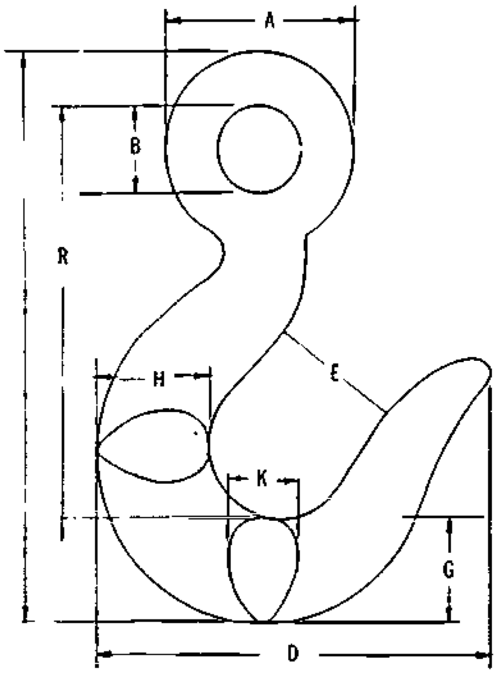


Figure 7-79. Standard Eye Hook

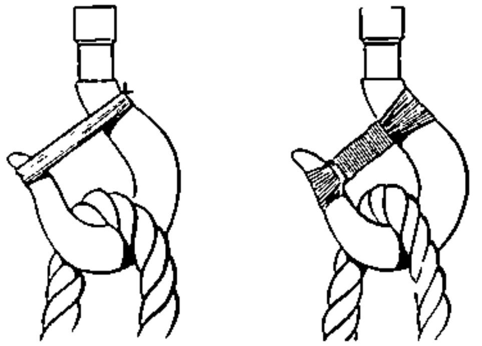


Figure 7-80. Mousing Hooks

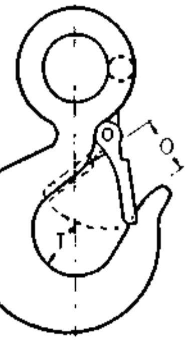


Figure 7-81. Standard Safety Eye Hook

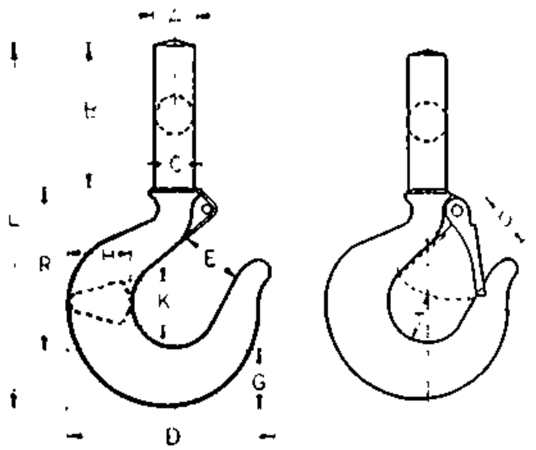


Figure 7-82. Shank Hooks

3 **A Standard Safety Eye Hook** is illustrated in Figure 7-81

4 **Shank Hooks** shall be considered to be of equal strength characteristics to eye hooks where the thickness at "G" is the same on both hooks. Open and Safety Shank Hooks are illustrated in Figure 7-82. Hooks must be inspected regularly with particular attention to load carrying sections (e.g., dimension G) and stress related areas (dimension E). Any hook showing a loss of material of 20% or more of the original thickness at any section must be destroyed and replaced. Similarly any increase in the throat opening E beyond stated specification indicates overstress, and the hook must be destroyed. Table 7-9 specifies important dimensions for eye type hooks along with the rated load capacity for each size.

5. **Shackles** are available in Screw Pin, Round Pin and Safety Type construction, as illustrated in Figure 7-83.

In determining safe working loads, the critical dimensions are the width between the eyes and the pin diameter For example, the maximum width between eyes for a 3/4" diameter pin is 1 1/16" The rated safe working load for this shackle is 5,600 pounds A 1 1/4" diameter pin can span a maximum of 1 7/8" between eyes, with a safe working load of 16,000 pounds

All shackle pins must be straight, and all pins of screw pin type must be screwed in all the way The use of rebars, bent or straight, as a substitute for pins is not permitted under any circumstances.

Shackles must be inspected regularly, and if the width between the eyes exceeds the listed

TABLE 7-9. CRITICAL DIMENSIONS FOR LOAD CARRYING HOOKS

Size No	Rated Capacity Tons 2000 Lbs	HOOK DIMENSIONS IN INCHES											Approx Weight Each Lbs
		A	B	D	E	G	H	K	L	O	R	T	
22	46	1	[illegible]	2 [illegible]	1	[illegible]	[illegible]	[illegible]	4 [illegible]	[illegible]	3 [illegible]	[illegible]	54
23	56	1 [illegible]	[illegible]	3 [illegible]	1 [illegible]	[illegible]	1	[illegible]	4 [illegible]	[illegible]	3 [illegible]	[illegible]	75
24	74	2	1	2 [illegible]	1 [illegible]	1	1 [illegible]	[illegible]	5 [illegible]	1 [illegible]	4	15/16	11
25	1 4	2 [illegible]	1 [illegible]	4	1 [illegible]	1 [illegible]	1 [illegible]	[illegible]	7 [illegible]	1 [illegible]	4 [illegible]	1 [illegible]	1 7
26	1 7	2	1 [illegible]	4 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	[illegible]	6 [illegible]	1 [illegible]	4 [illegible]	1 [illegible]	2 5
27	2 1	2 [illegible]	1 [illegible]	5 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	7 [illegible]	1 [illegible]	5 [illegible]	1 [illegible]	3 5
28	2 5	3 [illegible]	1	5 [illegible]	1 [illegible]	1 [illegible]	2	1 [illegible]	8 [illegible]	1 [illegible]	6 [illegible]	1 [illegible]	4 9
29	3 2	3 [illegible]	1 [illegible]	6	1 [illegible]	1 [illegible]	2 [illegible]	1 [illegible]	9 [illegible]	1 [illegible]	6 11/16	1 [illegible]	7 3
30	4 2	3 [illegible]	1 [illegible]	7 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	1 [illegible]	10 [illegible]	1 [illegible]	7 [illegible]	1 [illegible]	9 1
31	4 7	4 [illegible]	2	7 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	1 [illegible]	11 [illegible]	2 [illegible]	8 [illegible]	2 [illegible]	12 0
32	7 0	4 [illegible]	2 [illegible]	8 [illegible]	2	2 [illegible]	2 [illegible]	1 [illegible]	13 [illegible]	2 [illegible]	9 [illegible]	2 [illegible]	17 6
33	8 0	5	2 [illegible]	9 [illegible]	3	2 [illegible]	3 [illegible]	1 [illegible]	14 [illegible]	2 [illegible]	10 [illegible]	2 [illegible]	23 5
34	9 4	6 [illegible]	3 [illegible]	11 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	2 [illegible]	16 [illegible]	3 [illegible]	12 [illegible]	2 13/16	35 1
‡34A	12	6 [illegible]	3 [illegible]	11 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	2 [illegible]	16 [illegible]	3 [illegible]	12 [illegible]	2 [illegible]	35 1
35	16	7	3	13 [illegible]	4	4 [illegible]	4 [illegible]	2 [illegible]	19 [illegible]	3 3/4	14	3 [illegible]	5/ 6
‡35A	19	7	3 [illegible]	13 [illegible]	4	4 [illegible]	4 [illegible]	2 [illegible]	19 [illegible]	3 [illegible]	14	3 [illegible]	57 6
36	20	8	4	15 [illegible]	4	4 [illegible]	5 [illegible]	3 [illegible]	22 [illegible]	4 [illegible]	15 [illegible]	3 [illegible]	86 8
‡36A	24	8	4	15 [illegible]	4 [illegible]	4 [illegible]	5 [illegible]	3 [illegible]	22 [illegible]	4 [illegible]	15 [illegible]	3 [illegible]	86 8

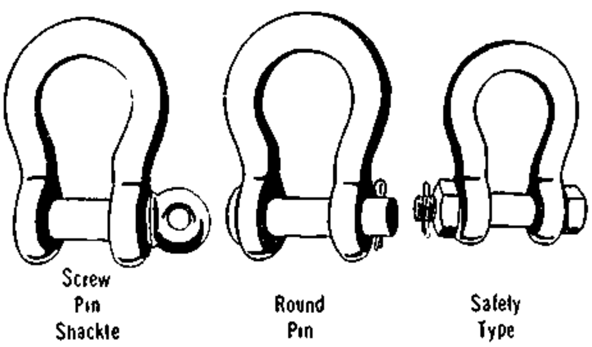


Figure 7-83. Types of Shackles

specification, the shackle has been overstrained and must be destroyed.

Caution: When using any of the above equipment, never under any circumstances exceed the safe working load When in use all gear should be inspected daily and any parts showing excessive wear or distoriton should be discarded immediately. All hooks should be used with caution and watched closely for excessive wear or any distortion.

WELDED LUGS

Specifications for welded lugs are illustrated in Figure 7-84 and in Tables 7-10 and 7-11.

END ATTACHMENTS FOR WIRE ROPE

Eye Using Wire Rope Clips Wire rope clips may be of the U-Bolt and Saddle type or of the Double Integral Saddle and Bolt type (Safety or Fist Grip). (Figure 7-85)

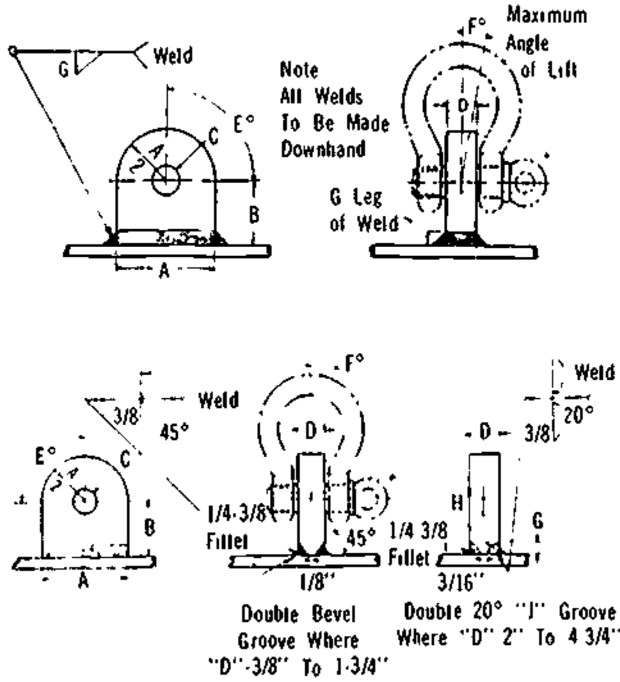
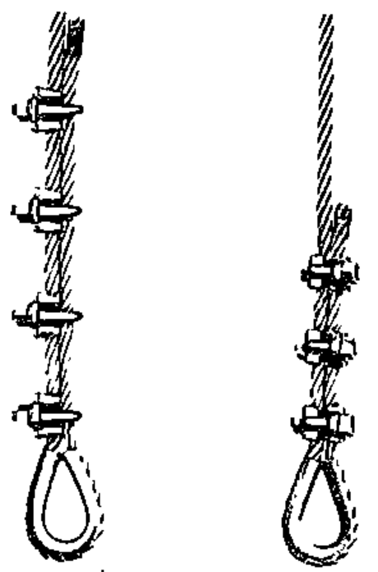


Figure 7-84. Dimensions for Welded Lugs

TABLE 7-10. STANDARDS FOR FILLET WELDED WELD-ON LIFT LUG FOR LIGHT DUTY USE							
					Load Angle		
Safe Load Tons	A	B	C	D	E	F Max	G
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 to 90°	20°	[illegible]
[illegible]	1 [illegible]	1 [illegible]	[illegible]	[illegible]		"	[illegible]
[illegible]/4	2	1 [illegible]	[illegible]	[illegible]			[illegible]
1	2	1 1/4	[illegible]/8	[illegible]/8		"	"
1 [illegible]	2 1/4	1 3/8	3/4	3/4		"	[illegible]
2	2 [illegible]	1 1/2	7/8	7/8		"	1/2
3	3	1 5/8	1	1	"	"	1/2
4	3 1/2	2	1 1/8	1 1/4		"	1/2
5 1/2	4	2 1/8	1 1/4	1 1/2	"	"	1/2
6 1/2	4 1/4	2 1/4	1 3/8	1 1/2	"	"	3/4
8	4 3/4	2 1/2	1 1/2	1 3/4	"	"	3/4
10	5	2 3/4	1 5/8	2	"	"	3/4
12	5 1/2	2 7/8	1 3/4	2 1/4	"	"	3/4
16	6 3/4	3 1/4	2 1/4	2 1/4	"	"	7/8
21	7 1/2	3 3/4	2 1/2	3	"	"	7/8
27	8 1/4	4 1/4	2 3/4	3 1/2	"	"	1
34	9	4 1/4	3	4	"	"	1
40	9 3/4	4 1/4	3 1/4	4 1/4	"	"	1
50	10 1/2	4 3/4	3 1/2	4 3/4	"	"	1



U Bolt and Saddle Clip — Fist Grip Clip

Figure 7-85. Clips For Wire Rope

When applied with proper care, following the regulations for number and spacing of clips, the formed eye will have 80% of the rated strength of the rope.

Never use fewer than the recommended number of clips and turn back the correct amount of rope for dead ending to permit proper spacing of the clips. (See Table 7-12.) The use of a thimble in the loop will prevent rope wear in the eye and provide a safer connection.

Application of Rope Clips U-bolt clips must be attached so the "U" part of the clip is **over the dead end** of the rope as shown in Figure 7-86.

Step 1. Apply first clip one clamp diameter from dead end of wire rope. Tighten nuts.

Step 2. Apply second clip nearest thimble Do not tighten nuts.

Step 3. Apply all other clips leaving equal space between each clip

Step 4 Take up rope slack and tighten all nuts evenly on all clips.

Step 5. Inspect fastenings periodically When load is placed on rope it will stretch and decrease in diameter. Tighten nuts to compensate.

TABLE 7-11. STANDARDS FOR GROOVE WELDED WELD-ON LIFT LUG FOR HEAVY DUTY USE

Safe Load Tons	A	B	C	D	Load Angle E°	Load Angle F° Max	G	H RAD
[illegible]	1/4	7/8	3/8	3/8	0 to 90°	15		
[illegible]	1 [illegible]/4	1 [illegible]/8	[illegible]/16	[illegible]		15		
3/4	2	1 1/4	1/2	1/2		15		
1	2	1 1/4	[illegible]/8	[illegible]/8		15		
1 1/2	2 1/4	1 3/8	3/4	3/4		20		
2	2 1/2	1 1/2	7/8	7/8		20		
3	3	1 5/8	1	1		20		
4	3 1/2	2	1 1/8	1 1/4		20		
5 1/2	4	2 1/8	1 1/4	1 1/2		20		
6 1/2	4 1/4	2 [illegible]	1 3/8	1 1/2		20		
8	4 3/4	2 1/2	1 1/2	1 3/4		20		
10	5	2 3/4	1 5/8	2		20	3/4	[illegible]
12	5 1/2	2 7/8	1 3/4	2 1/4		20	3/4	[illegible]
16	6 1/4	3 1/4	2 1/4	2 1/4		20	3/4	[illegible]
21	7 1/2	3 3/4	2 1/2	3		20	[illegible]/8	[illegible]
27	8 1/4	4 1/4	2 1/4	3 1/2		20	1	[illegible]
34	9	4 1/2	3	4		20	1 [illegible]	[illegible]
40	9 3/4	4 1/4	3 1/4	4 1/4		20	1 [illegible]/8	[illegible]
50	10 1/2	4 3/4	3 1/2	4 [illegible]		20	1 1/4	[illegible]

TABLE 7-12. SPECIFICATIONS FOR ATTACHING WIRE ROPE CLIPS

	U-Bolt and Saddle Type			Integral Saddle and Bolt Type		
Rope Diam Inches	Minimum No of Clips	Amount of Rope to turn back in inches from Thimble	Torque in Lbs Foot	Minimum No of Clips	Amount of Rope to turn back in inches from Thimble	Torque in Lbs Foot
1/4	2	4 3/4	15	2	3 1/4	30
5/16	2	5 1/2	30	2	4	30
3/8	2	6 1/4	45	2	5	45
7/16	2	6 3/4	65	2	5 3/4	65
1/2	3	11	65	2	6 1/2	65
9/16	3	11 1/4	95	3	7 1/4	130
5/8	3	12	95	3	8	130
3/4	4	18	130	3	14	130
7/8	4	21 1/2	225	4	23	225
1	4	21	225	4	26	225
1 1/8	5	28	225	4	29	225
1 1/4	5	30	360	5	40	360

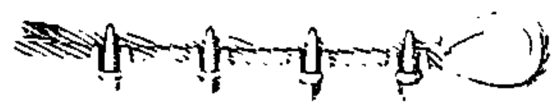


Figure 7-86. Applying U-Bolt Clips

Wedge Socket Wedge sockets are intended for "on the job" attachment and for quick rope replacement. Efficiencies will range from 80% to 90% of rated rope strength. These are available in both open and closed types (Figure 7-87).

Application of Wedge Socket The wedge socket must be applied so that the line of stress follows the **live** portion of the rope (Figure 7-88).

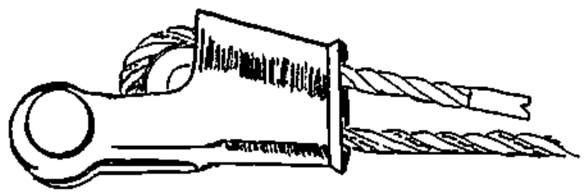


Figure 7-87. Wedge Socket (Open Type)

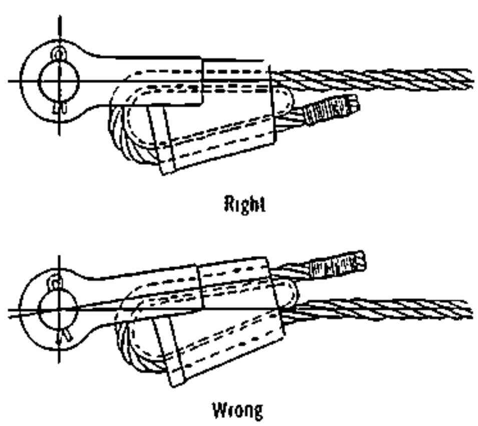


Figure 7-88. Applying a Wedge Socket

TURNBUCKLES

A turnbuckle is a device used to tighten or loosen a stress on a rope by using right and left handed threads at opposite ends of a matching threaded centre piece. It is used where precise load balancing is required or as a temporary measure on offset loads.

Turnbuckles used in rigging should be steel drop forgings. They are available with a variety of end fittings or combinations of fittings (Figure 7-89).

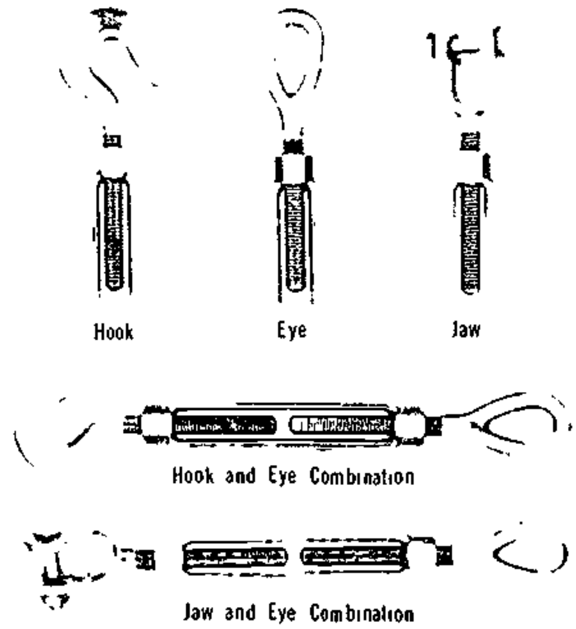


Figure 7-89. Types of Turnbuckles

Using Turnbuckles:

When using turnbuckles with multi-leg slings, the following guidelines must be observed:

1. No more than one turnbuckle per leg should be used.
2. The angle of the leg at the horizontal should never be less than 30°.
3. The turnbuckle must be of sufficient size and strength to support the entire load since each leg of a two-leg sling at 30° carries tension equal to the full load.

General Precautions:

1. Welding to repair damage on a turnbuckle is not permitted.
2. Never turn turnbuckles with long levers such as bars or pipes.
3. The maximum torque applied to turn a turnbuckle should be equal to that required to tighten a bolt of comparable size.
4. Avoid shockloading when using turnbuckles.
5. Turnbuckles must be free from contact with any other stationary object when supporting a load.
6. Turnbuckles must be secured to prevent unscrewing under load tension; threaded portions must be fully engaged.

Inspection and Assessment:

1. If a turnbuckle does not turn easily on the threads, this indicates overloading. Replace the turnbuckle by one of adequate size.
2. Turnbuckles should be inspected for
   a) Nicks in the body
   b) Signs of abuse or overloading
   c) Corrosion
   d) Wear or distortion of jaws, hooks or eyes
   e) Distortion of male and female threads
   f) Straightness of the rod.
3. Refer to Table 7-13 to determine safe working loads for turnbuckles.

TABLE 7-13. SAFE WORKING LOADS FOR TURNBUCKLES

Stock Diameter of End Fitting (inches)	Safe Working Load of Turnbuckle having any combination of jaw, or eye end fittings (pounds)	Safe Working Load of Turnbuckle having hook end fitting (Pounds)
1/4	500	400
[illegible]	800	700
3/8	1,200	1,000
1/2	2,200	1,500
5/8	3,500	2,250
3/4	5,200	3,000
7/8	7,200	4,000
1	10,000	5,000
1 1/4	15,200	5,000
1 1/2	21,400	7,500
1 3/4	28,000	not applicable
2	37,000	not applicable
2 1/2	60,000	not applicable
2 3/4	75,000	not applicable

Figure 7-90. Chain Fall — Spur-Gear Hoist

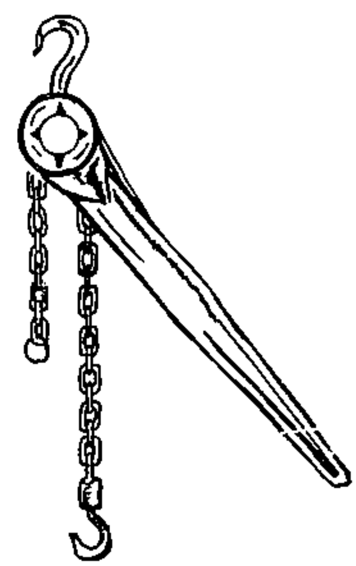


Figure 7-91. Come Along Hoist

CHAIN FALLS

The chain fall or chain hoist (Figure 7-90) is a dependable and economical device for lifting loads. The most commonly used chain fall is the spur-geared hoist. This hoist uses an endless chain to drive a pocketed sheave. This sheave in turn drives a gear reduction unit that is fitted with a second chain, the load chain. A brake is built into the gear box that engages when the hoisting or lowering action on the hand chain ceases. The brake disengages when the hand chain is operated.

COME ALONGS

The come along (Figure 7-91) is a type of chain operated hoist for raising and lowering loads as well as pulling loads horizontally. A ratchet operated by a lever drives the gear reduction unit to power the load chain.

TIRFOR JACKS

The tirfor jack (Figure 7-92) is a hand operated pulling or lifting device with an unlimited amount of rope travel. It operates by a direct pull on the rope, the pull being applied by two pairs of self-energizing, smooth jaws. These exert a grip on the rope in proportion to the load being lifted or pulled. The initial pressure causing the jaws to grip the rope starting the self-energizing action is derived from springs that give an initial pressure of about 120 lb. Two levers operate

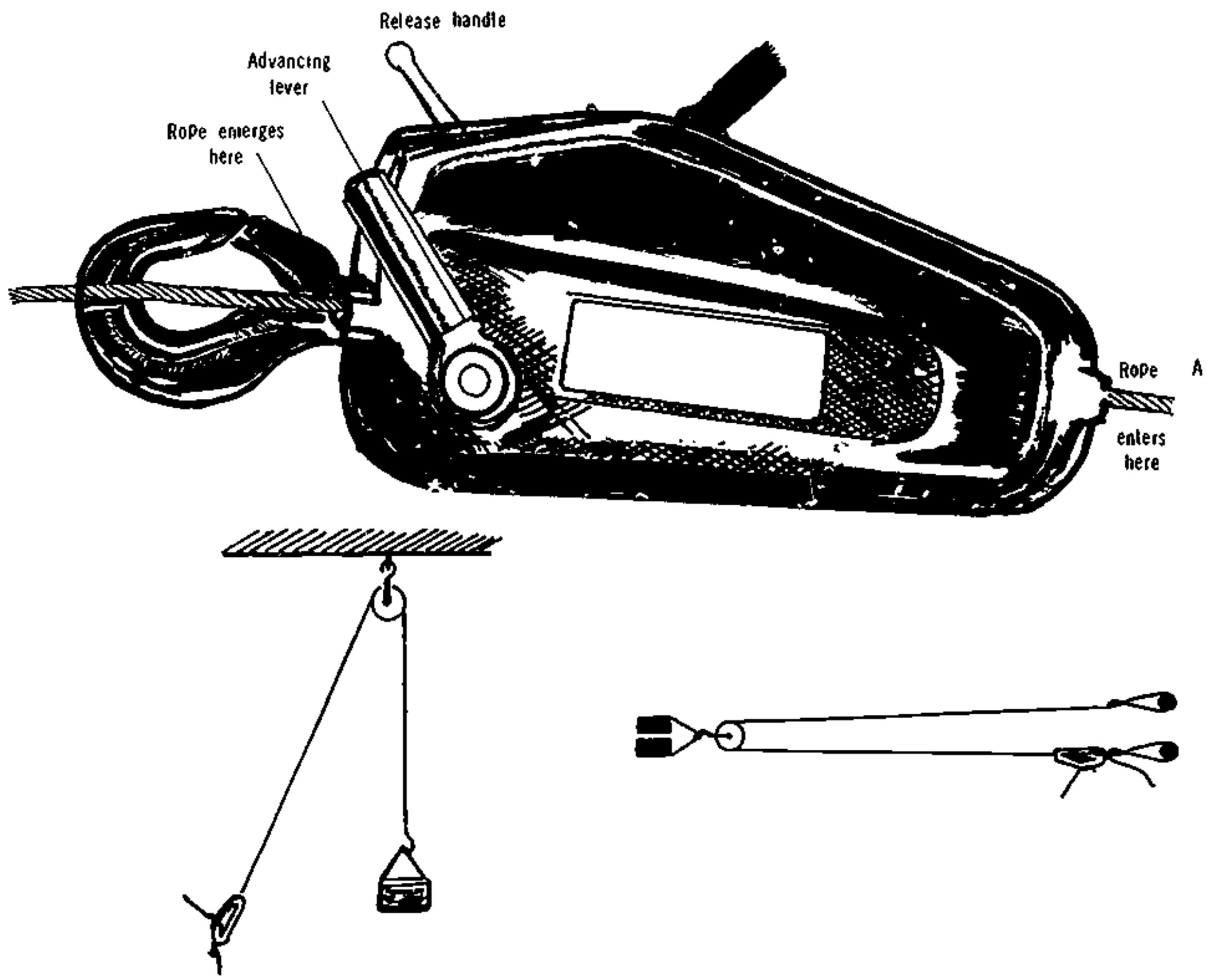


Figure 7-92. Tirfor Jack

these jaws which provide a forward or backward motion depending on the lever used.

JACKS

Jacks are used to raise or lower heavy loads over short distances. Smaller jacks are often of the screw or ratchet type while larger jacks are usually hydraulic, operated with either a hand or power assisted pump. Jacks are of various types (Figure 7-93)

Advantages of Hydraulic Jacks:

1. Small size relative to lifting capability
2. Ability to raise and lower loads precisely
3. Several jacks can be connected to one pump so that loads can be lifted with uniform tension on each jack.

Lever jacks with foot lift (sometimes called a railroad jack or track) are designed to lift loads from a low position. They are used for lifting rails or for raising a tank float from ground level for placing shims under it. The steam boat ratchet is capable of pulling loads together or pushing them apart.

BEAM CLAMPS

A beam clamp is a stationary device that permits safe, easy suspension of hoists from beams or girders, eliminating the use of nuts, bolts, shackles, slings. Figure 7-94 illustrate beam clamps.

Guidelines for Safe Use

1. Obtain approval before applying a beam clamp to any structural member to ensure that the member is capable of supporting the load being raised.
2. The clamp must fit the beam and be fastened securely to it.

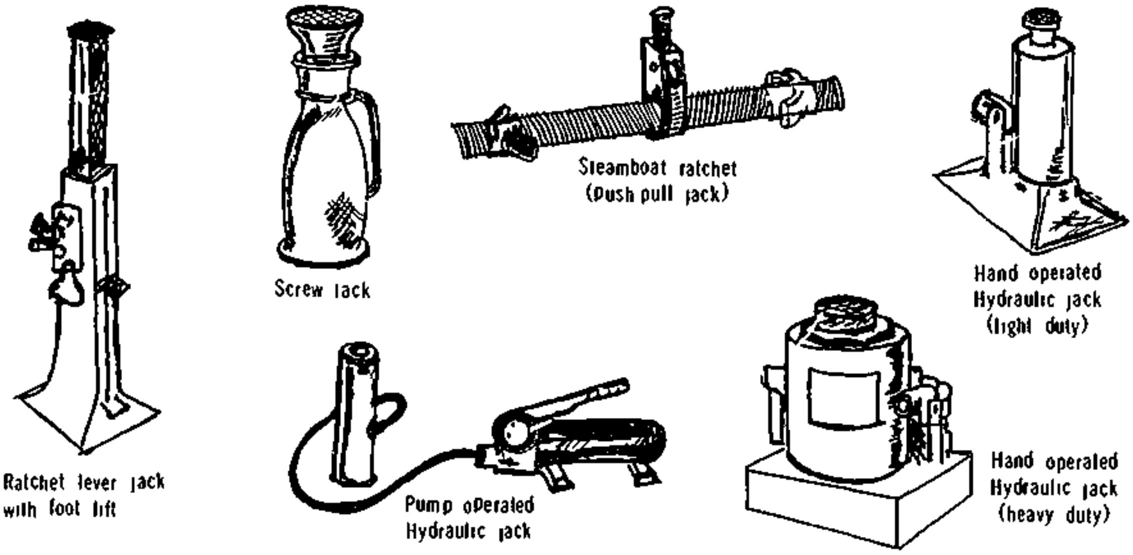


Figure 7-93. Types of Jacks

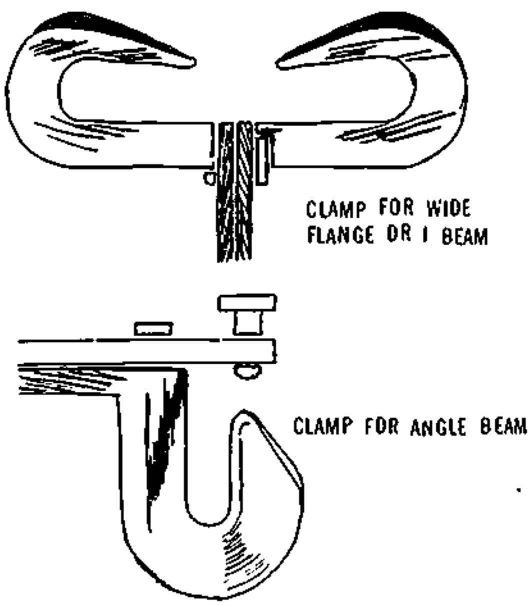


Figure 7-94. Beam Clamps

3 The clamp must be adequate to support the load being raised.

4. Beam clamp capacity ratings are based on **straight lifts only.** Angle lifts will place the beam flange under multiple stresses and the beam clamp under a point of load concentration that is liable to exceed design capacity.

5 Never use plate grips, tongs, girder hooks, pipe clamps, etc as substitutes for beam clamps.

6. Use a shackle to attach rigging to a beam clamp. Never place a hoist hook directly into the lifting eye of a beam clamp.

BEAM TROLLEYS

A beam trolley serves the same purpose as a beam clamp with the added advantage of being moveable along the beam by means of a wheel assembly that rides along both flanges of the beam. The wheel system may be designed for push travel or geared travel. Some models are manufactured specifically for straight lift while others are provided with a flexible lug that will permit a side pull. (See Figure 7-95.)

Procedure for Mounting

Step 1. The bolt and nut arrangement connecting the wheels must be separated.

Step 2. The wheels are set on the beam flanges.

Step 3. The bolt and nut assembly is secured.

PLATE CLAMPS

Plate clamps (Figure 7-96) are rigging devices with a serrated jaw designed to grip pieces of plate for hoisting. Plate clamps may be locking or non-locking, however, locking grips are recommended for maximum safety. **Plate clamps are designed to grip only one plate for each hoist.**

SPREADER REAMS

The spreader beam (Figure 7-97) also known as a spreader bar or rocker beam is most commonly used to support long or flimsy loads during lifting. The load cannot tip, slide or bend because of the support provided at two or more points along the load (Figure 7-98).

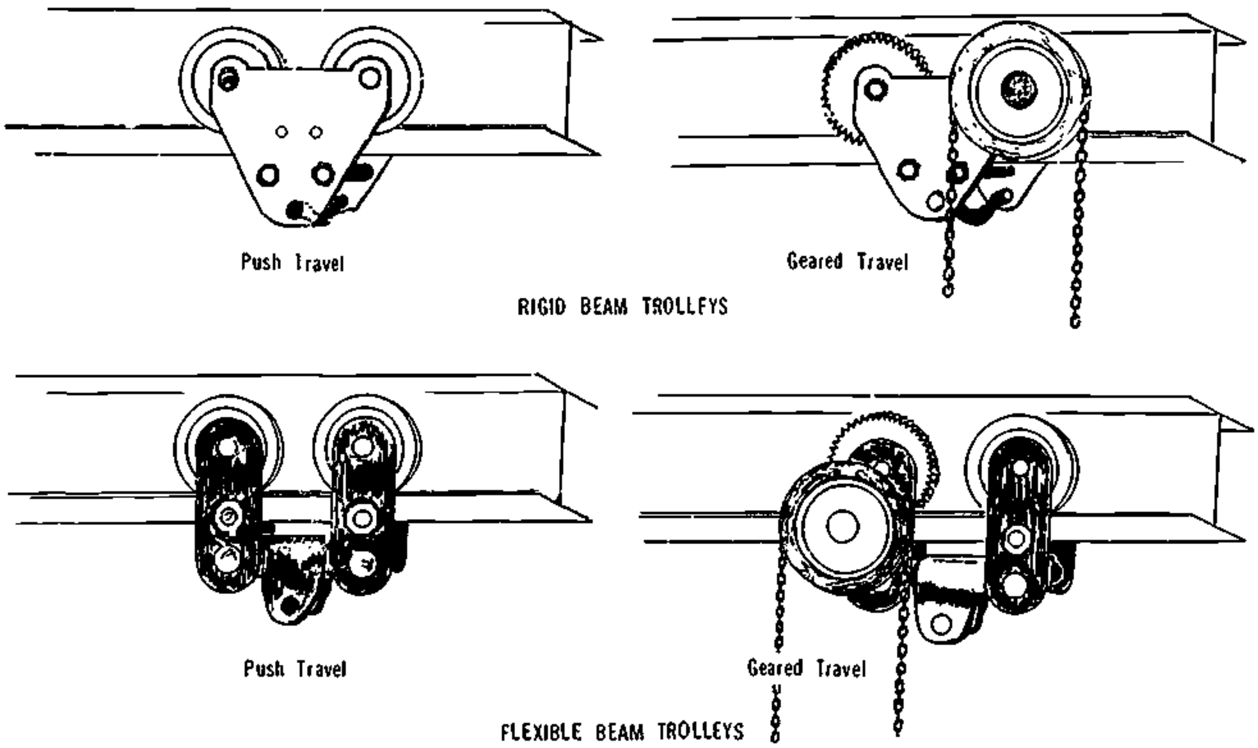


Figure 7-95. Beam Trolleys

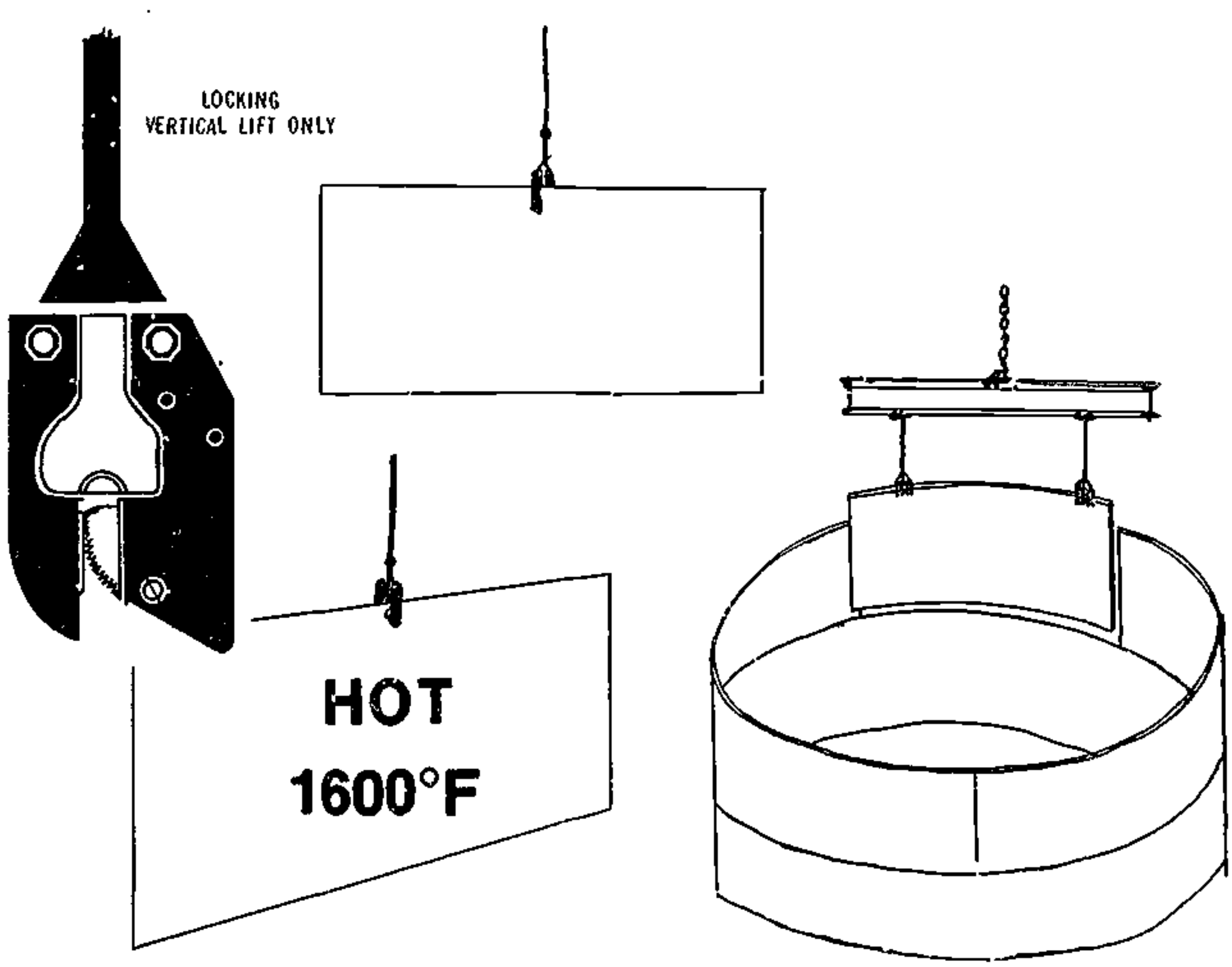


Figure 7-96. Uses of Plate Clamps

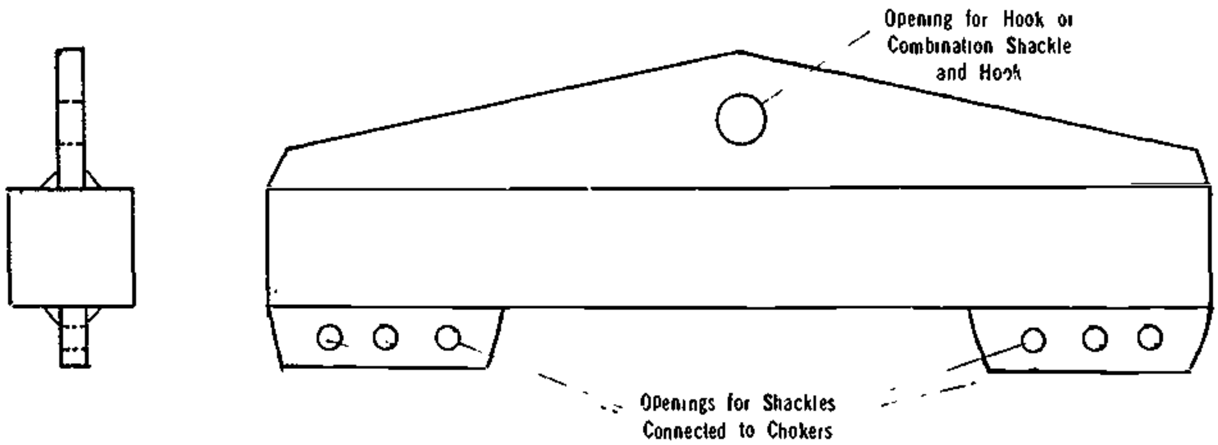


Figure 7-97. Spreader Beam or Bar

Figure 7-98. Spreader Beam in Use

SKIDS, ROLLERS, CRIBBING AND JACKS

It is not always feasible to hang rigging or use cranes to move heavy objects such as vessels where, for example, overhead wiring or piping limit the work space. Under these circumstances an arrangement of skids, rollers, cribbing and jacks can provide a safe means of transporting and/or raising large objects.

Timber skids can be set out longitudinally to distribute the weight of the vessel over a larger area The skids also serve to make a smooth surface over which the vessel may be moved or to make a runway if rollers are used. The angle of incline of the skids should be kept as low as possible to prevent the vessel from "running away" or getting out of control. If any incline is involved, it is advisable to use a tugger or a tirfor jack as a holdback.

Rollers made of pipe or, less frequently, hardwood provide a rolling platform over the skids. The rollers must extend beyond the outside dimensions of the vessel. To ensure continuous support for the rollers along the moving distance, the skid joints should butt securely together or the ends be arranged in a side by side overlap. Skid joints should also be staggered so that the rollers pass over only one joint at a time.

To move the vessel, four or five rollers are positioned underneath and several additional rollers placed ahead. As the vessel rolls forwards, the rollers left behind are moved in position in front of it. If the moving path involves a turn, the skid timbers must be positioned to describe the turn angle in stages. As the vessel approaches the turn, its course can be redirected by knocking the leading rollers toward the required angle.

Cribbing is a layered arrangement of uniform sized, clean blocking timbers that distributes the weight of the vessel safely on the crib platform. The blocking is cribbed in alternate directions at each level, either tightly packed or spaced at even intervals, depending upon the requirements of the vessel weight. Where the cribbing is spaced, all layers of blocking must be in a direct vertical line with other members cribbed in the same direction in the system. The foundation for cribbing must be solid and level.

Cribbing may be required to provide a level, stable platform for a load that cannot be placed directly on rollers It is also used to raise loads in stages using jacks The raising procedure is as follows

Step 1 Using jacks on a stable footing, raise the load to the maximum stable height

Step 2. Place one or more rows of cribbing under the load and lower the jacks to rest the load onto the crib platform

Step 3 Set the jacks on blocking and raise the load further, adding more rows of cribbing under the load. Repeat the stepwise jacking and cribbing until the required elevation is reached.

The weight of the load and the rated capacities of the jacks determine the number and type of jacks required for the lifting operation.

TACKLE BLOCKS

Like any piece of equipment, tackle blocks cannot be abused or neglected without loss of effectiveness and life Keep them clean Remove sheaves occasionally and clean and oil the centre pins. Inspect sheaves for wear, and, store them in a dry place when not in use. Throwing them around carelessly will damage them and is injurious to the rope. With reasonable maintenance, replacements and repairs will be minimal.

In theory the mechanical advantage of a set of tackle blocks is determined by the number of parts of rope at the moving block. For example, with four parts of rope, 1 lb. pull on the lead line should lift 4 lbs. Friction reduces this advantage, however For practical purposes a loss of approximately 10% occurs for each sheave in manila rope blocks and about 3% for each sheave in wire rope blocks. Each snatch block must be considered an additional sheave

Many factors govern the selection and use of tackle blocks Trouble will result from:

1. Overloading
2. Undue friction
3. Angle of pull
4. Condition of rope
5. Sudden application of load
6. Lack of lubricant.

The actual weight of the load to be moved does not necessarily determine the stress on the blocks. Avoid obstruction to the free movement of the load, twisted ropes due to improper reeving or rigging, or improper angle of the tackle in relation to the load Moving heavy loads over rough ground or on an incline or without rollers or rollers that are too small can introduce severe stresses.

A load suspended on two sets of tackle blocks should be evenly distributed or one set will be subjected to more than its calculated share of the load. Careless preparation may result in any or all of these conditions to such a degree that the load on a set of blocks will greatly exceed the actual weight of the load itself.

TERMINOLOGY OF TACK BLOCK OPERATION

Parts of Line — a term used in multiple reeving for heavy loads. The number of parts of line can easily be determined by counting the number of cables reeved in movable blocks, including the dead end if applicable.

Sheave — a grooved pulley over which the rope passes.

Snatch Block — a block to maintain a straight pull on a line or to decrease the strain on cables

Mechanical Advantage

As previously stated, the mechanical advantage of the system is determined by the number of parts of rope at the moving block. (Figures 7-99 and 7-100).

OPERATION OF SHEAVES

As illustrated in Figure 7-101, to raise a load 1′ the lower block must be raised 1′, and in accomplishing this, each working rope must be shortened 1′.

In the example in Figure 7-101, Ropes 1 must be shortened 1′ to raise the load 1′. Assuming that the circumference of each sheave is 1′, Sheave No. 1 must make one revolution to shorten Rope 1; Sheave No. 2 must make one revolution to take up the one foot slack from Rope 1 and one additional revolution to shorten Rope 2; Sheave No. 3 must make two revolutions to take up the 2′ slack from Ropes 1 and 2 and one additional revolution to shorten Rope 3 and so on for each succeeding sheave.

Thus: Rope 1 must travel 1′ on Sheave No. 1
Rope 2 must travel 2′ on Sheave No. 2

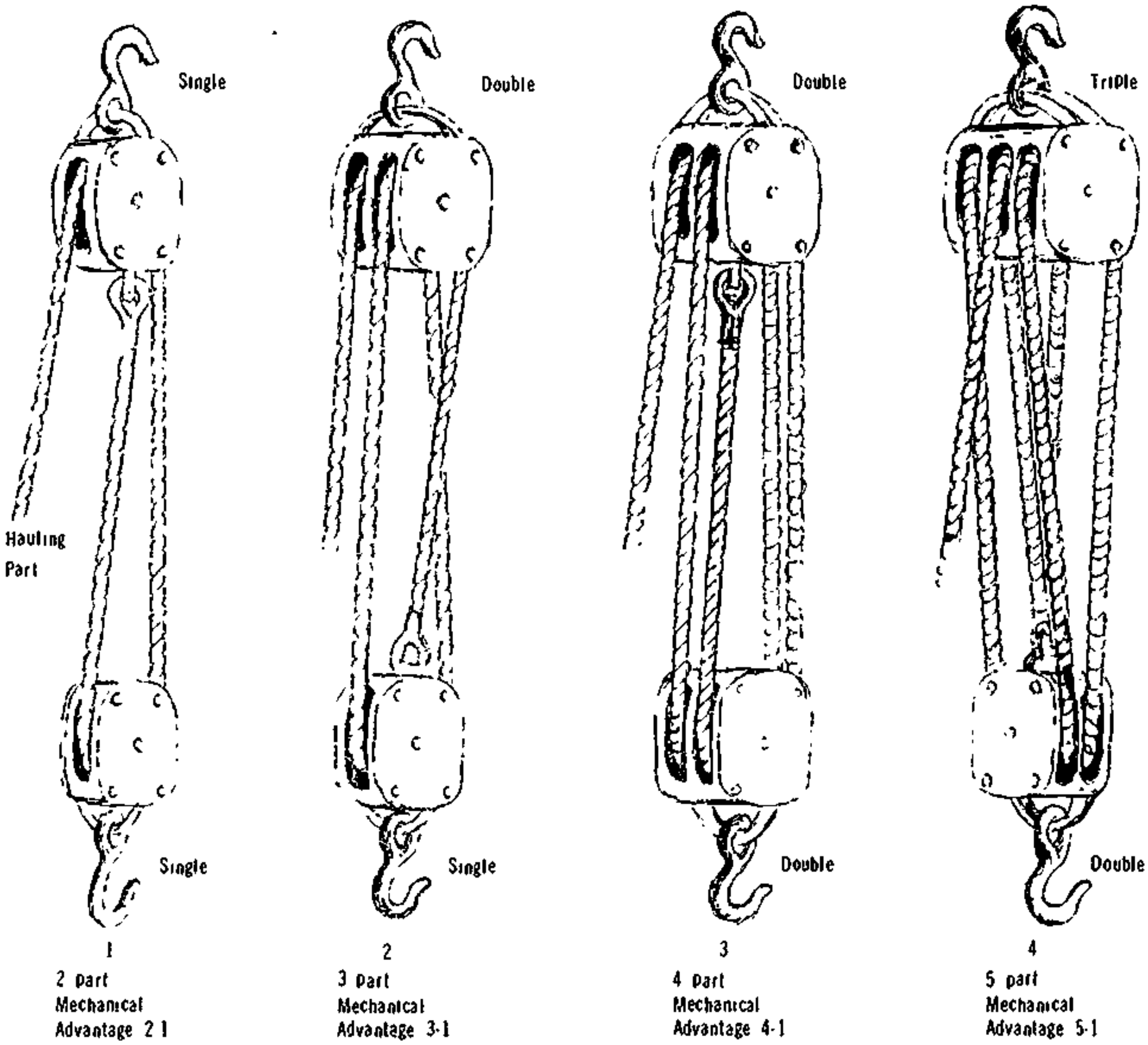


Figure 7-99. Mechanical Advantage of Tackle Block Systems

Rope 3 must travel 3′ on Sheave No. 3

Rope 4 must travel 4′ on Sheave No. 4

Rope 5 must travel 5′ on Sheave No. 5

Therefore all the sheaves in a set of blocks revolve at different rates of speed Sheave No 2 rotates twice as fast as sheave No 1. Sheave No 4 four times as fast as Sheave No 1, etc Consequently, the sheaves nearest the lead line, rotating at a higher rate of speed, wear out more rapidly.

All sheaves should be kept well oiled when in operation to reduce friction and wear.

REEVING TACKLE BLOCKS

In reeving a pair of tackle blocks one of which has more than two sheaves, the hoisting rope should lead from one of the centre sheaves of the upper block.

When so reeved, the hoisting strain comes on the centre of the blocks and they are prevented from toppling, with consequent injury to the rope by cutting across the edges of the block shell.

To reeve by this method, the two blocks should be placed so that the sheaves in the upper block are at right angles to those in the lower one, as illustrated in Figure 7-102.

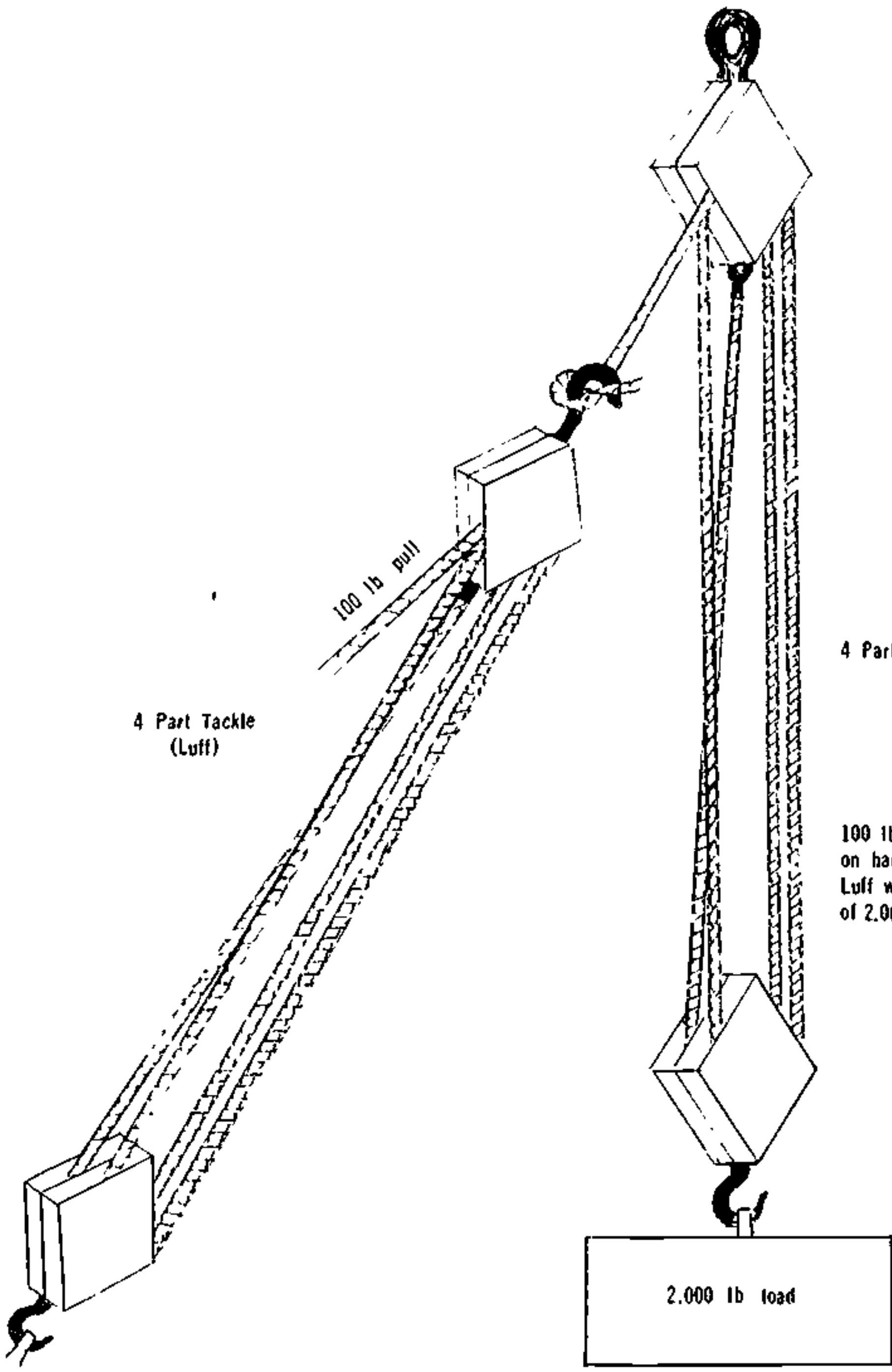


Figure 7-100. Compound Tackle (Luff)

General Rules for Reeving

1 Always reeve tackle right-handed.

2 If the number of sheaves in each block is equal, fasten the rope to the becket of the standing block.

If the number of sheaves is unequal, fasten the rope to the becket of the block with the smaller number of sheaves.

3. To determine the maximum size of fibre rope that can be used to reeve a tackle, divide the length of the shell of the block by 3, which will give the circumference of the rope to be used.

Example:

6" shell divided by 3 = 2 which is the circumference of 5/8" rope.

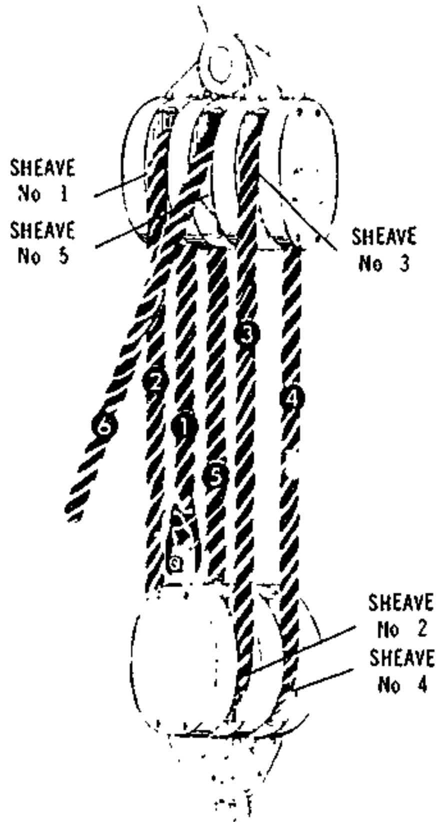


Figure 7-101. Sheave Operation

DETERMINING LINE PARTS OR REQUIRED LINE PULL

To help figure the number of parts of line to be used for a given load or the line pull required for a given load, the ratio table is provided with examples of how to use it (Table 7-14).

$$\frac{\text{TOTAL LOAD TO BE LIFTED}}{\text{SINGLE LINE PULL IN POUNDS}} = \text{RATIO}$$

Example 1:

To find the number of parts of line needed when weight of load and single line pull is established.

Sample Problem:

$$\frac{72{,}480 \text{ lbs. (load to be lifted)}}{8{,}000 \text{ lbs. (single pull)}} = 9.06 \text{ RATIO}$$

Refer to ratio 9.06 in table or number nearest to it, then check column under heading "Number of Parts of Line" — 12 parts of line to be used for this load.

Example 2:

To find single line pull needed when weight of load and number of parts of line are established.

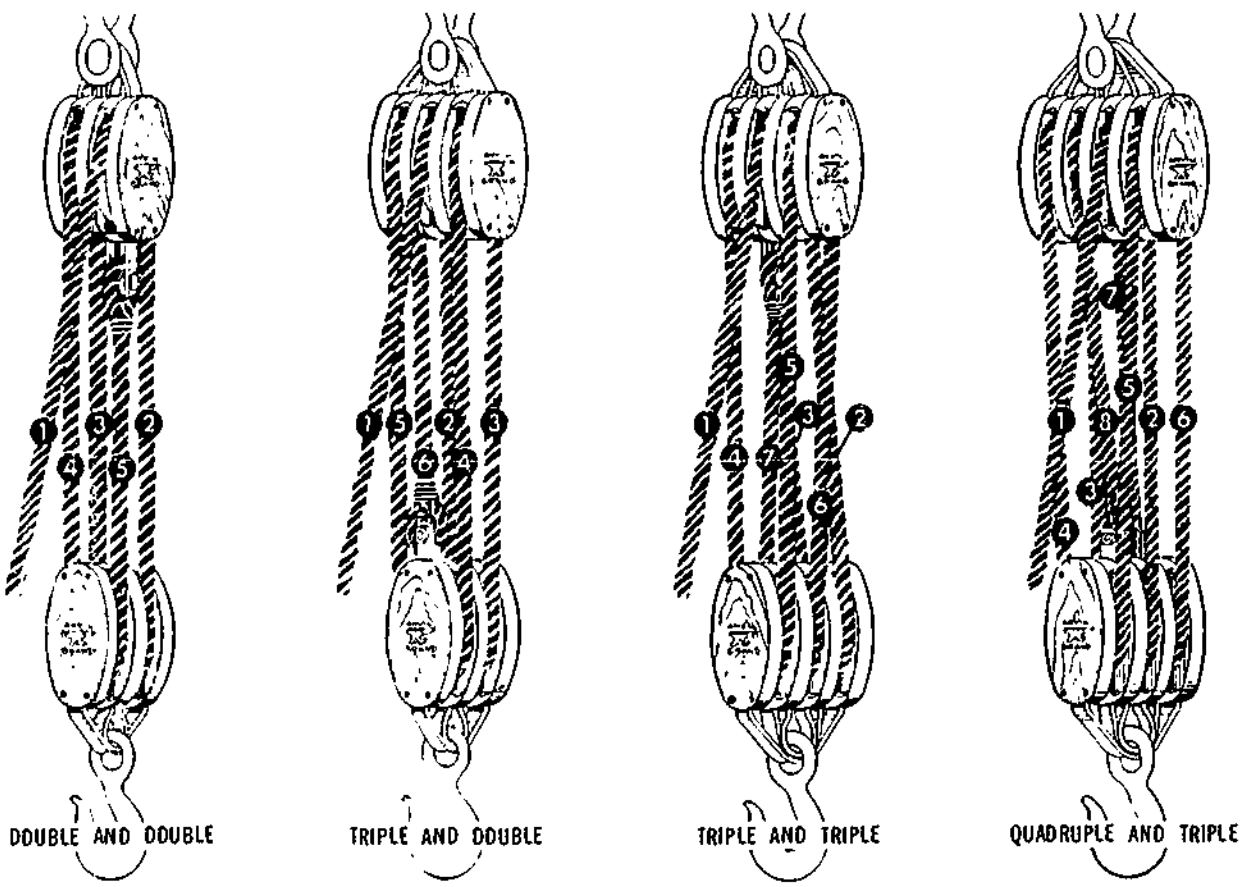


Figure 7-102. Tackle Blocks Placed at Right Angles to One Another

TABLE 7-14. LINE PARTS

Number of Parts of Line	Ratio for Bronze Bushed Sheaves	Ratio for Anti Friction Bearing Sheaves
1	.96	.98
2	1.87	1.94
3	2.75	2.88
4	3.59	3.81
5	4.39	4.71
6	5.16	5.60
7	5.90	6.47
8	6.60	7.32
9	7.27	8.16
10	7.91	8.98
11	8.52	9.79
12	9.11	10.6
13	9.68	11.4
14	10.2	12.1
15	10.7	12.9
16	11.2	13.6
17	11.7	14.3
18	12.2	15.0
19	12.6	15.7
20	13.0	16.4
21	13.4	17.0
22	13.8	17.7
23	14.2	18.3
24	14.5	18.9

Sample Problem:

$$\frac{68{,}000 \text{ lbs. (load to be lifted)}}{6.60 \text{ (ratio of 8 part line)}}$$

= 10,300 lbs. (single line pull)

10,300 lbs. single line pull required to lift this load on 8 parts of line.

LOADS ON SNATCH BLOCKS

The stress on a snatch block varies with the degree of angle between the lead and load lines. When the two lines are parallel, 1,000 lbs. on the lead line results in a load of 2,000 lbs. on the hook. As the angle between the lines increases, the stress on the hook is reduced as illustrated in Figure 7-103. To determine the stress on a hook, multiply the pull on the lead line by a suitable factor from Table 7-15 adding 10% for friction.

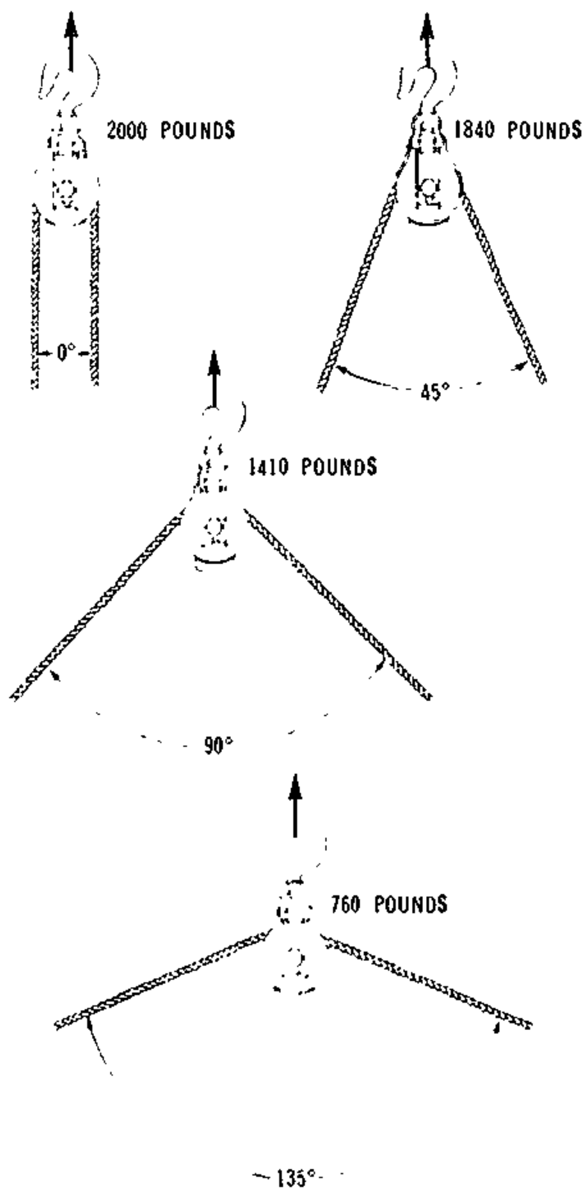


Figura 7-103.

TABLE 7-15. SNATCH BLOCK ANGLE FACTORS

Angle	Factor	Angle	Factor	Angle	Factor	Angle	Factor	Angle	Factor	Angle	Factor
5°	1.998	35°	1.90	65°	1.69	95°	1.35	125°	.92	155°	.43
10°	1.99	40°	1.87	70°	1.64	100°	1.29	130°	.84	160°	.35
15°	1.98	45°	1.84	75°	1.58	105°	1.22	135°	.76	165°	.26
20°	1.97	50°	1.81	80°	1.53	110°	1.15	140°	.68	170°	.17
25°	1.95	55°	1.77	85°	1.47	115°	1.07	145°	.60	175°	.08
30°	1.93	60°	1.73	90°	1.41	120°	1.00	150°	.52	180°	.00

Pressure on Sheave or Pulley Bearings When a rope path is deflected by means of a sheave, pulley or roller, pressure is placed on the bearings The pressure will vary depending on the angle of deflection of the rope

Placement of Shackle Block and Hook Block It is good practice to use a shackle block as the upper one of a pair and a hook block as the lower one. A shackle is much stronger than a hook of the same size, and the strain on the upper block is much greater than on the lower one The lower block supports only the load, while the upper block carries the load as well as the hoisting strain. A hook is more convenient on the lower block because it can be attached to or detached from the load more readily

RIGGERS RULES OF THUMB

It is much easier to learn a simple formula than to memorize complex tables and graphs

These "Rules of Thumb" are reasonably accurate and most are on the "safe side" of recognized safety practices. **But, it must be remembered, these formulas are only close estimates and are not intended to replace manufacturer's specifications in critical situations.**

FIBRE LINE

The lay of rope can be determined by running your thumb away from you along the strands in the line (If strands go to the right, it is a right lay, etc)

Coil line in the direction of the lay. (E.g., right lay, clockwise, etc)

Uncoil a new bail counterclockwise to avoid kinds

Natural Fibre — (Manila)

1 Breaking strength in tons = Dia ^{2} x 4
2 Safe working load in tons = $\frac{\text{Dia}^2 \times 4}{10}$

(safety factor = 10)

Synthetic Fibre — (Nylon, Polypropylene)

1 Nylon = Approximately $2^1/_2$ times the strength of manila.
2 Polypropylene = Approximately $1^1/_2$ times the strength of manila.

TACKLE SYSTEMS

1 **Friction** in a tackle system = Approximately 8% per sheave @ 180 bend, 4% per sheave @ 90 bend. (For wire rope tackle — approximately 6% for bronze bushed sheaves and 3% for ball bearing sheaves)
2 **A Simple Tackle System** = 1 line and one or more blocks

   Mechanical advantage = Number of lines on travelling block.
3. **A Compound Tackle System** = Two or more simple tackle systems compounded

   Mechanical advantage = The M A. of each system multiplied in series.

WIRE ROPE

(Determine lay, and coil like "Fibre Line")

1 **Lang Lay** — Wire laid up in same direction as strands of rope.

   Regular Lay — Wires layed up in opposite direction as strands of rope
2. **Wire Core** (I.W R C.) is approximately 10% stronger than fibre core.

   Galvanzing reduces strength approximately 10%.
3 **Breaking Strength in Tons** = (Dia $)^2$ x 40 (For 6 x 19 I.P.S. F.C)
4 **Safe Working Load in Tons** = (Dia.$)^2$ x 40 ÷ Safety Factor.
5 **Safety Factors** = Slings = 8

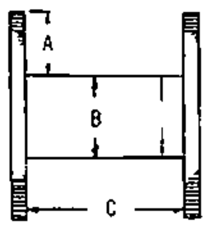
Slings	= 8
Non rotating lines	= 8
Cranes and Derricks	= 6
Derrick Guys	= 5
Hoisting Tackle	= 5
Guy Lines	= 3 5
6 **Broken Wires** = Unsafe when 4% of total wires in the rope are broken within the length of one rope lay.
7 **Choker Stress** — $\frac{W}{N} \times \frac{L}{V} = T$

   N = Number of Chokers
   W = Weight of load in pounds
   V = Vertical distance in feet
   L = Choker leg length, in feet
   T = Tension, in pounds
8. **Sheaves** — The critical diameter of a sheave is 20 times the diameter of the rope.

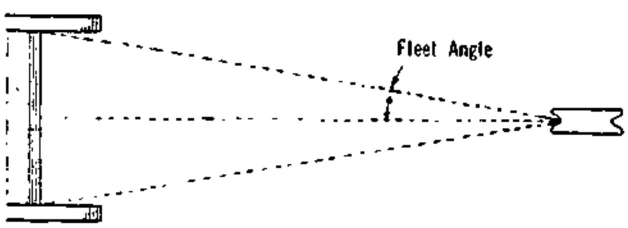
9 **Drums** – For spooling a drum you face the lead block and place the right or left hand, which ever corresponds with the lay of the rope, palm down on the top of the drum for overwind and the bottom of the drum for underwind. The thumb will point to the flange where spooling begins.

10 **Drum Capacity** — in feet =

$$\frac{2618}{\text{Rope Dia}^2} \times (A + B) \times A \times C \text{ (in inches)}$$



11 **Fleet Angle** — Maximum 4 on grooved drums and 2 on smooth drums. The distance to the lead block should never be less than 10 times the width of grooved drums or 20 times the width of smooth drums.



WIRE ROPE ATTACHMENTS — (Safety factor of 5 included)

1 **Crosby Clips**
Number of clips required — 4 x rope diameter + 1.
Minimum spacing — 6 x rope diameter.

2 **Hooks** — S.W.L. in tons = $(\text{Dia.})^2$ where hook begins to curve or Diameter of eye in inches squared.

3 **Shackles** — S.W.L. in tons = Diameter of pin in one fourth inches squared and divided by three (or select shackle pin one-eighth inch larger than choker size.)

4 **Chains** (Alloy Steel) — S.W.L. in tons = chain stock $(\text{Dia.})^2 \times 6$.

5 **Turn Buckles** — S.W.L. in tons = bolt $(\text{Dia.})^2 \times 3$.

ESTIMATING WEIGHT OF STRUCTURAL STEEL: — (One cubic foot = approximately 490 lbs.)

1 **Round Stock** — Approximate weight per lineal foot = $(\text{Dia.})^2 \times \frac{8}{3}$

2 **Plate, Flat Bar, or Square** — Approximate weight per lineal foot = thickness times width $\times \frac{10}{3}$ (All measurements in inches.)

(Angles, Tees, or Wide Flange Beams can be calculated in the same manner by measuring the legs, or web and flange individually as Flat Bar or Plate.)

SCAFFOLD PLANKS

Two inch planks (2 x 8, 2 x 10, or 2 x 12) of fir or spruce in first class condition can be considered safe to support the weight of an average man for a "Span in Feet" that is equal to, or less than the plank "Width in Inches".

DERRICKS

GUY DERRICK

A guy derrick consists of a mast, a boom pivoted at the foot of the mast, guys and tackle (Figure 7-104). The mast is generally longer than the boom and is mounted on vertical pins at the foot and top so that the assembly of mast and boom may be rotated about a vertical axis. If the guys to the top of the mast clear the end of the boom the derrick can be rotated through a full circle. The mast and boom may be made of timbers or structural steel. Large derricks are made of hollow built up sections generally consisting of four angles and lacing bars forming a truss.

Hoisting tackle is suspended from the end of the boom and tackle is also provided for raising or lowering the boom in a vertical plane. Power is supplied by hand operated or engine driven hoists. The derrick is rotated by a bull wheel located at the base of the mast.

STIFF LEG DERRICK

The mast of the stiff leg derrick is held in the vertical position by two rigid inclined struts connected to the top of the mast (Figure 7-105). The struts are spread apart 60 -90 to provide support in two directions and are attached to sills extending from the bottom of the mast. The mast is mounted on vertical pins at its foot and top as in the case of the guy derrick. The mast and boom can swing through an arc of about 270°. The tackles for hoisting loads and raising the boom are similar to those for the guy derrick. Figure 7-106 illustrates a stiff leg derrick with long sills.

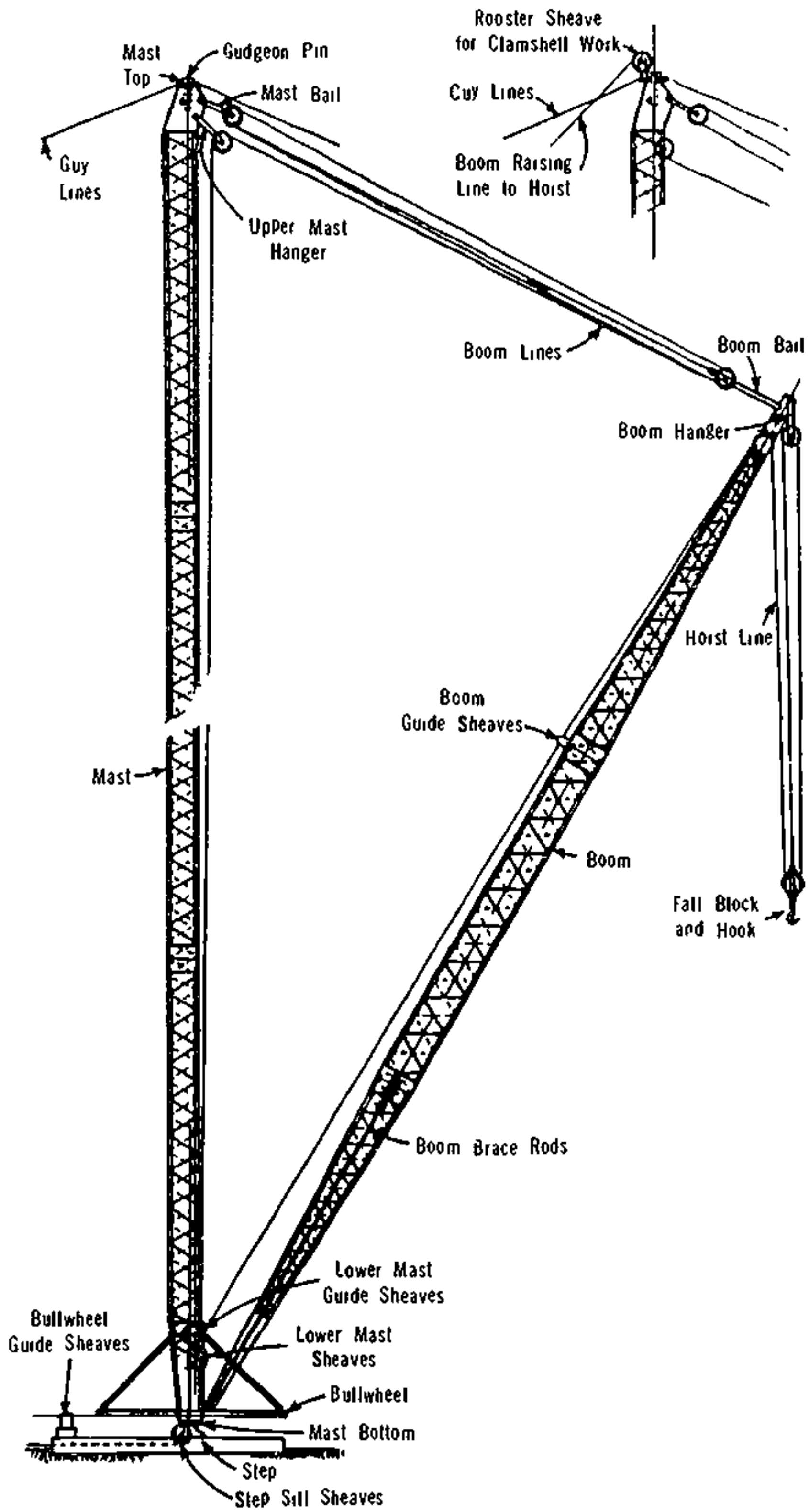


Figure 7-104. Sections of a Guy Derrick

A stiff leg derrick equipped with a boom is suitable for yard use for unloading and transferring material whenever continuous operations are carried on within reach of its boom. They are sometimes used in multi-story buildings surmounted by towers to hoist materials to the roof of the main building to supply guy derricks mounted on the towers

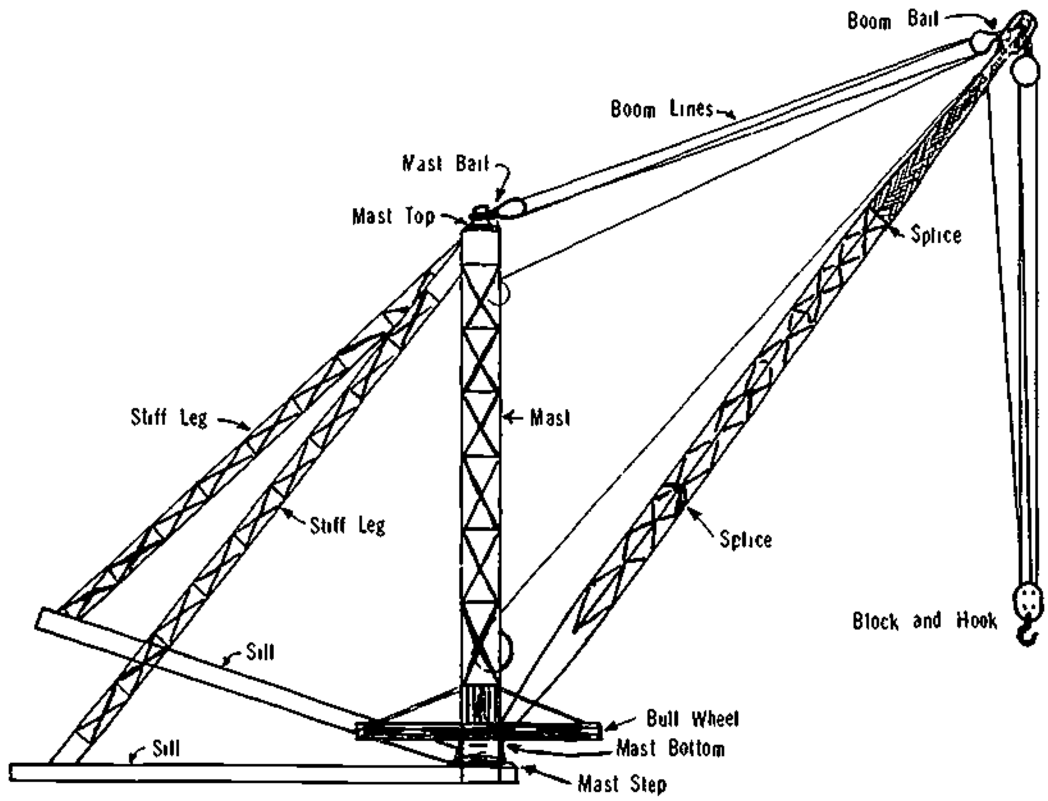


Figure 7-105. Stiff Leg Derrick

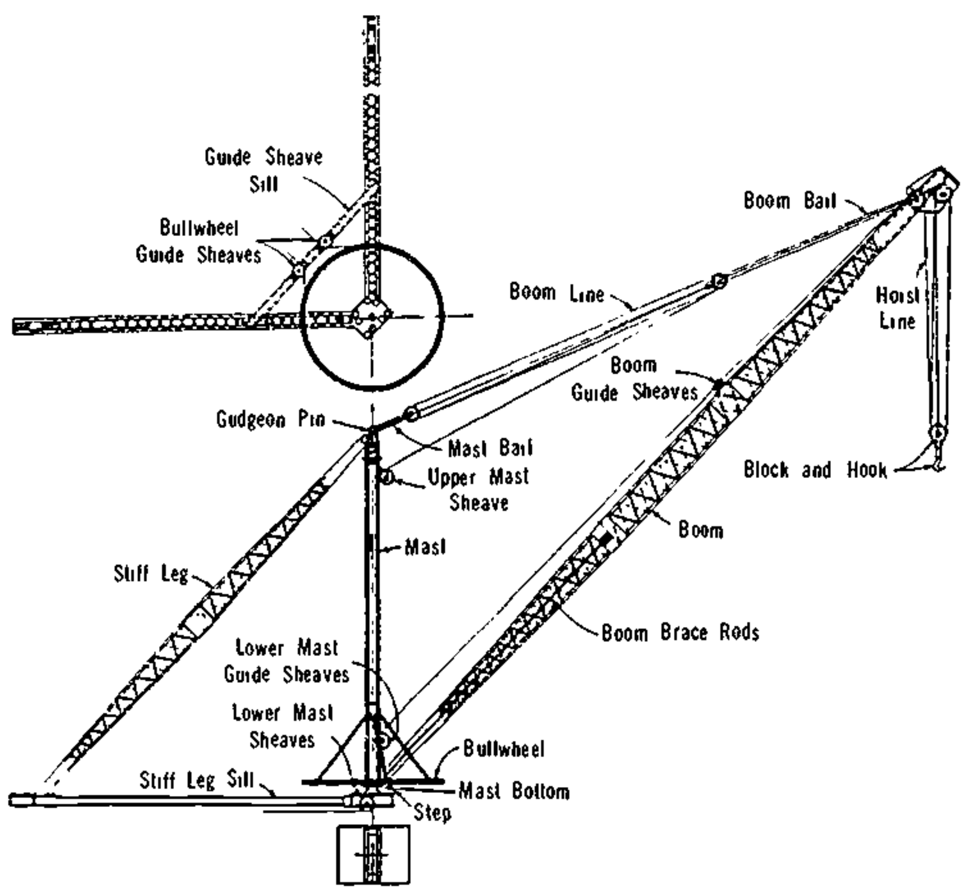


Figure 7-106. Section of Stiff Leg Derrick with Long Sills

GIN POLE

The gin pole (Figure 7-107) consists of an upright spar guyed at the top to maintain it in a vertical position and is equipped with suitable hoisting tackle. The spar may be of round or square timber, heavy wall pipe, a wide flange beam section or a built up section consisting of angles and lacing bars The load may be hoisted by hand tackle or by hand or engine driven hoists

A gin pole is a very handy and versatile piece of equipment for lifting all types of comparatively light loads To get maximum use out of a gin pole, it should be rigged with a minimum of four guys, with wire rope pendants and manila rope tackles between the pendants and the anchorages and swivel plates top and bottom. These can then be leaned at various angles and turned to lift from all sides.

The gin pole is used mostly for erection work of ease of rigging, moving and operating It is suitable for raising loads of medium weight to heights of 10′-50′ where a vertical lift is required.

Procedure

Refer to Figure 7-108 for Steps in this procedure

Step 1. Using any suitable scale, draw a sketch as shown in A.
Line TS represents the guy
Line RS represents the gin pole

Step 2. With a given load of 4,000 lb., let 1/4″ = 1,000 lb. and draw a vertical line **VU** representing the load (1″ long) as in B.
From **U**, extend a line **UW** parallel to TS (from A) to represent the guy, and a line VW parallel to RS (from A) to represent the gin pole

Step 3. To develop C, draw a line VW parallel to, and the same length as VW (from B). Drop a vertical line down from W, and draw the line VX parallel to TR (from A).

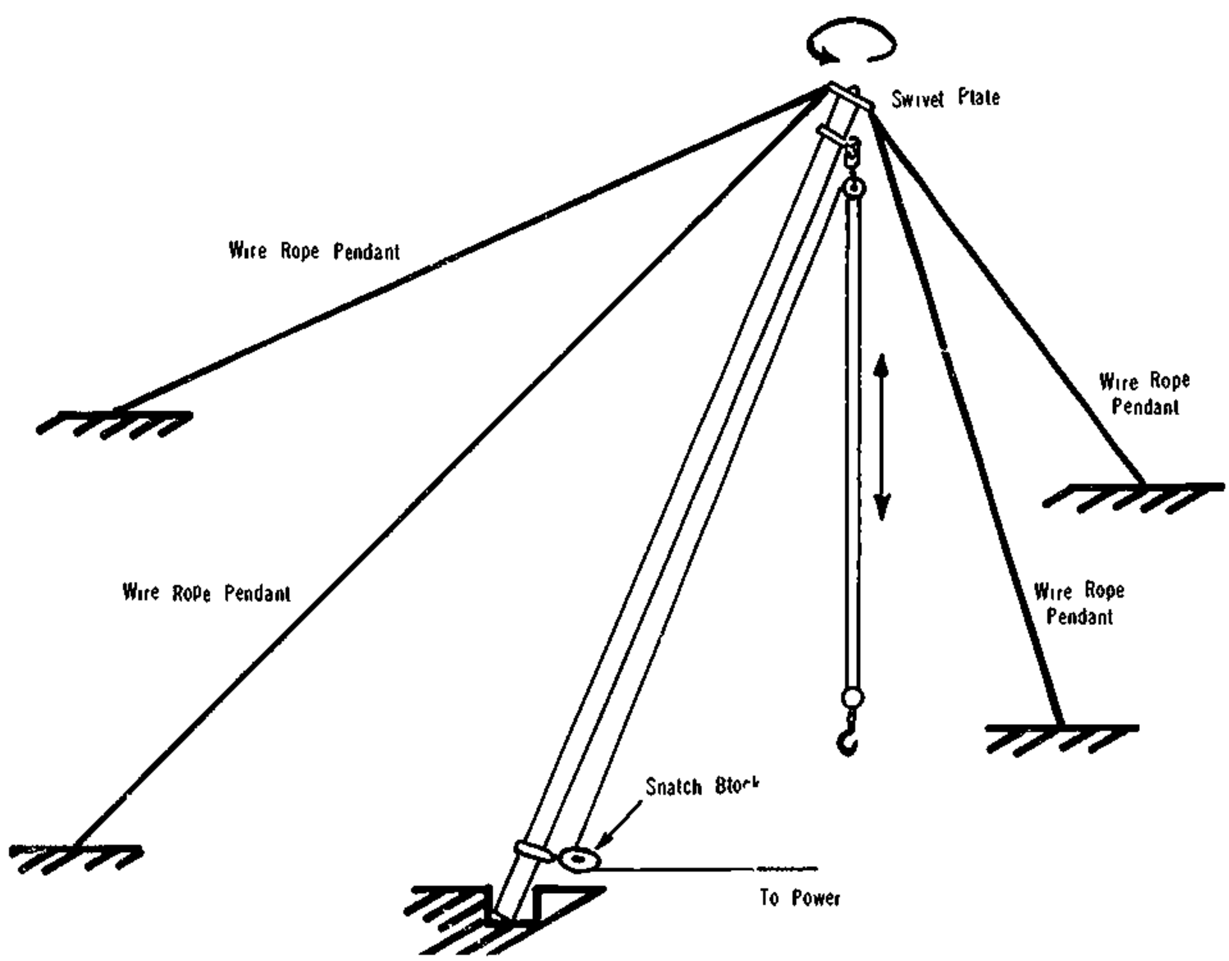


Figure 7-107. Gin Pole

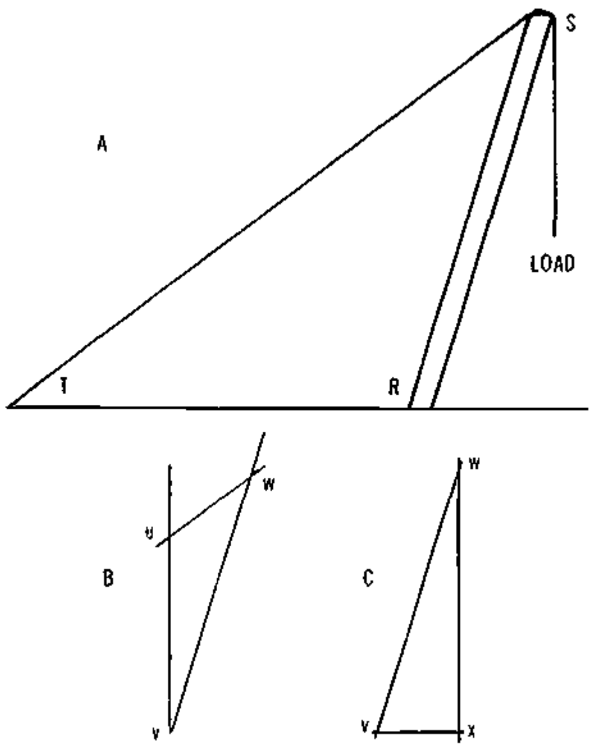


Figure 7-108. Determining the Kick at the Heel of a Gin Pole

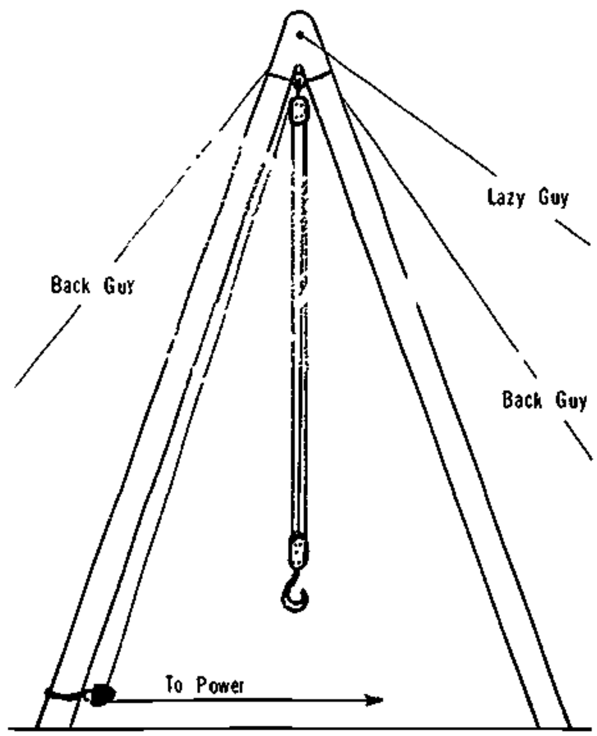


Figure 7-109. A-Frame Derrick

Measure the length VX, and, using the scale 1/4" = 1,000 lb., calculate the amount of kick on the pole.

A-FRAME DERRICK

An A-Frame (or Shear Leg) derrick is a versatile hoisting device, requiring only two back guys and one lazy guy in front for support (Figure 7-109)

For light loads, a small A-Frame derrick can be quickly constructed by drilling a hole through two pieces of square timber and bolting through the holes. A wire rope choker is put around the top of the poles with the eye hanging down to attach the block. When a load is suspended from the block, the choker tightens to hold the crossed members more securely.

MOBILE CRANES

Mobile cranes are mechanical lifting devices that can be relocated without disassembly. They may be classified into two main types. 1 those mounted on metal tracks (Figure 7-110) and 2. those mounted on rubber tires (Figure 7-111). Figure 7-112 illustrates the parts of a mobile crane.

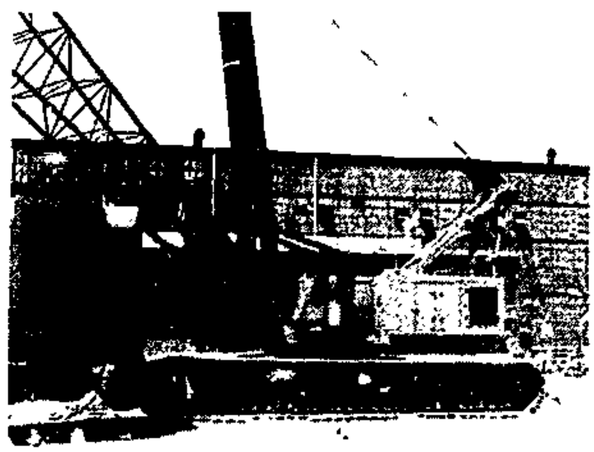


Figure 7-110. Mobile Crane on Tracks

Two types of booms (Figure 7-113) with respect to the capability on the crane are identified:

1. Conventional booms may be lowered, raised or swung sideways, however, the assembled length does not change.
2. Hydraulic booms may be lowered, raised or swung sideways, and the length can be extended or retracted without reassembly.

The choice of boom is based upon the functional requirements of the crane for the job. Where

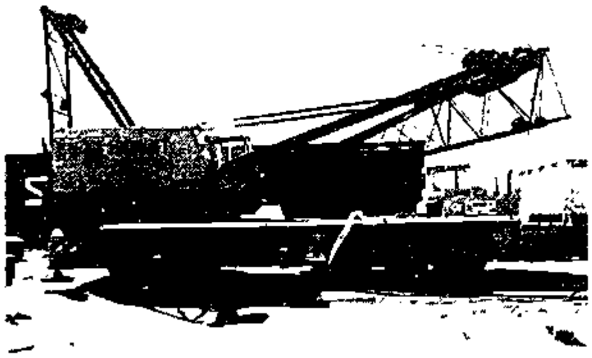


Figure 7-111. Mobile Crane on Tires

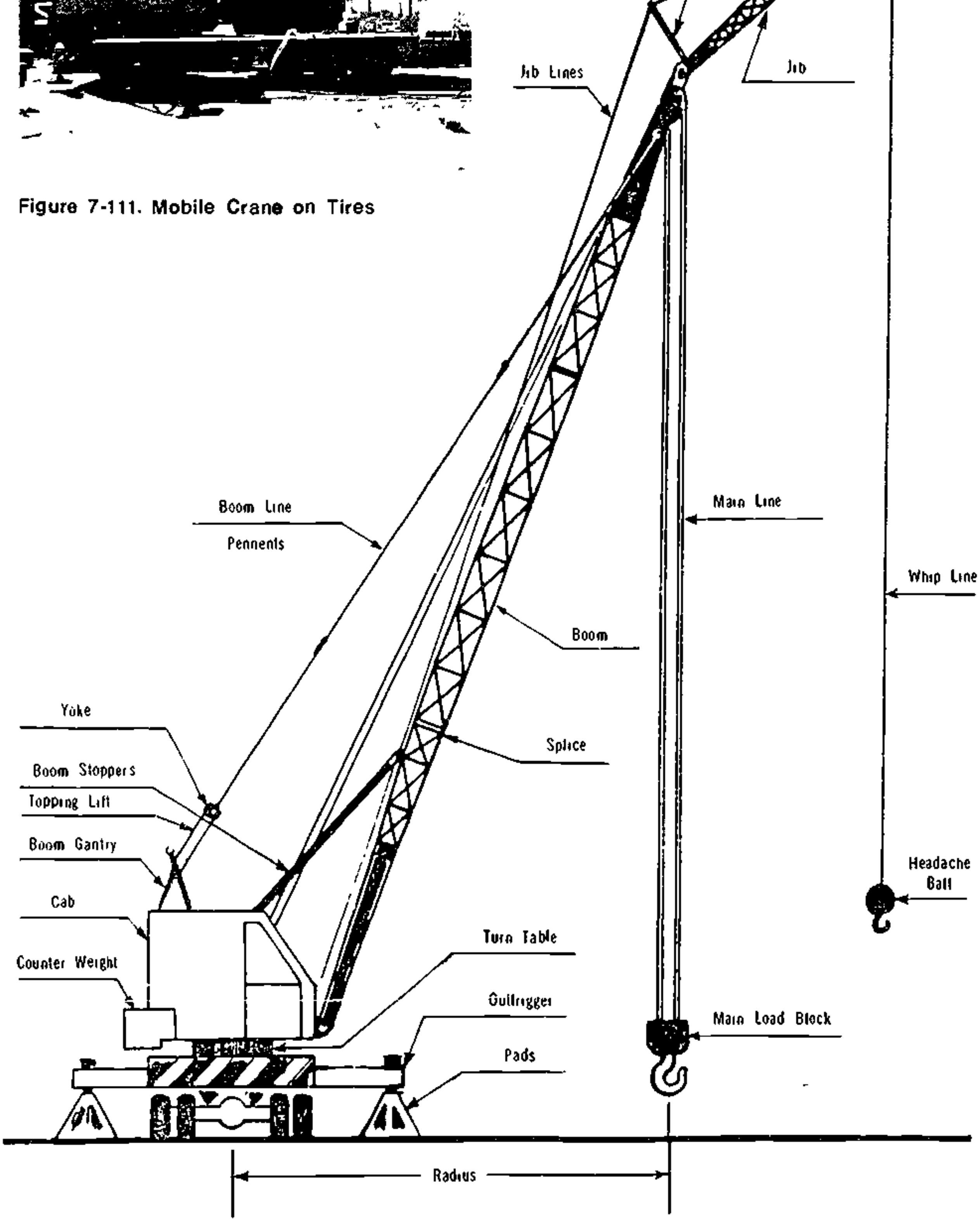
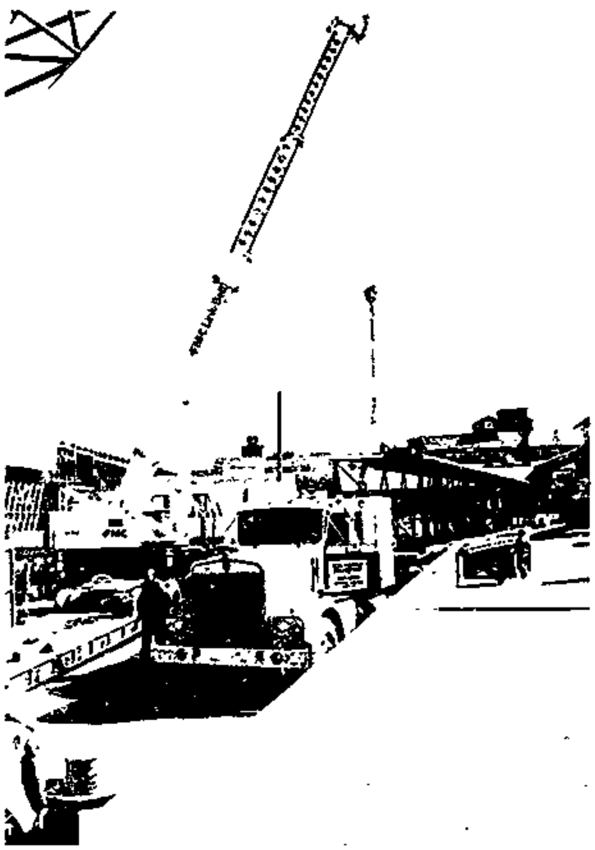


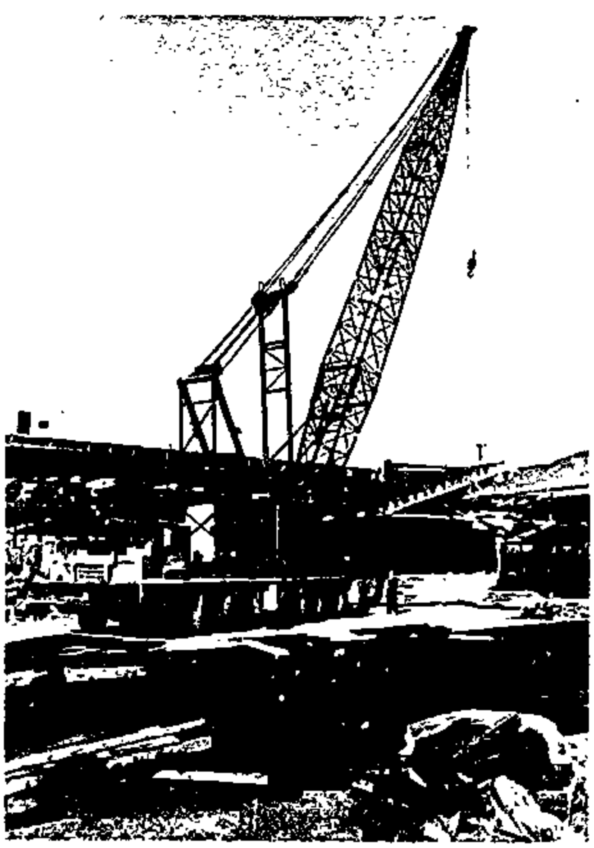
Figure 7-112. Parts of a Mobile Crane

heavy or exceptionally high lifts are involved, the conventional boom is used. Where the loads are lighter and more set-ups are required for shorter lifts, the hydraulic boom is more suitable.

When an hydraulic mobile crane is delivered to a jobsite, it is almost immediately ready to go into operation (Figure 7-114). It need only be "spot-

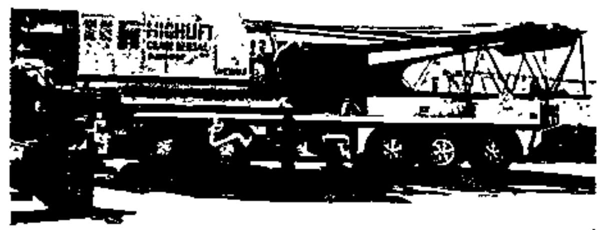


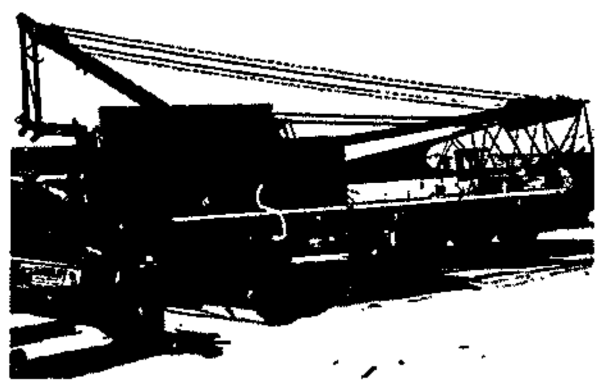
HYDRAULIC BOOM



CONVENTIONAL BOOM

Figure 7-113. Crane Booms





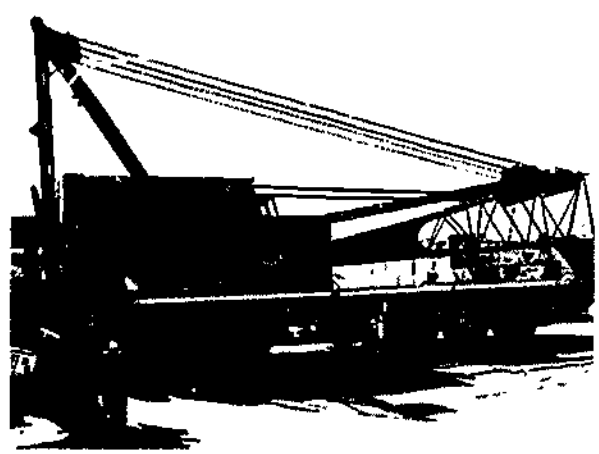


Figure 7-114. Crane Arriving on The Job, Raising Gantry to Operating Position

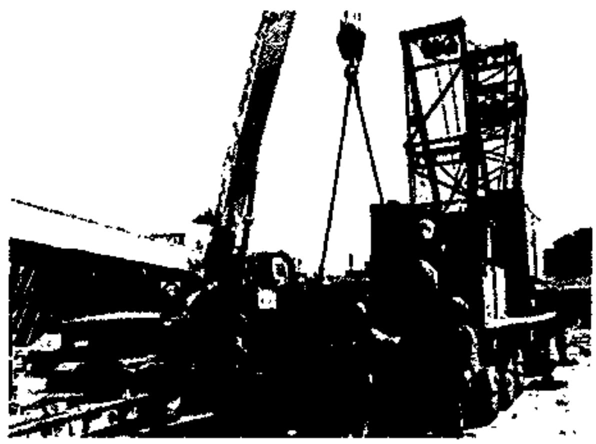
ted," the outriggers extended and the crane levelled, before the first load can be lifted.

BOOM ASSEMBLY

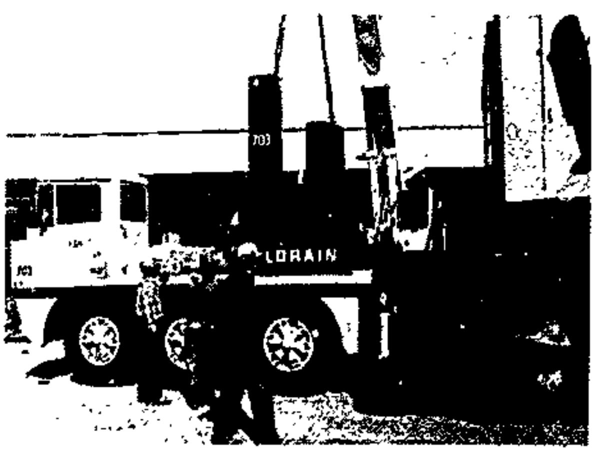
On the other hand, a conventional type mobile crane arrives in separate units. The boom components, outriggers, counterweights and main block must be offloaded (usually assisted by an on-site hydraulic crane), and assembled on the job location. Crane assembly at the jobsite falls within the jurisdiction of the erection Boilermaker.

Figures 7-114 to 7-118 illustrate a typical sequence in the assembly of a conventional mobile crane, from arrival on the job to work-ready.

INSTALL FLOAT PADS



INSTALLING FRONT COUNTERWEIGHT



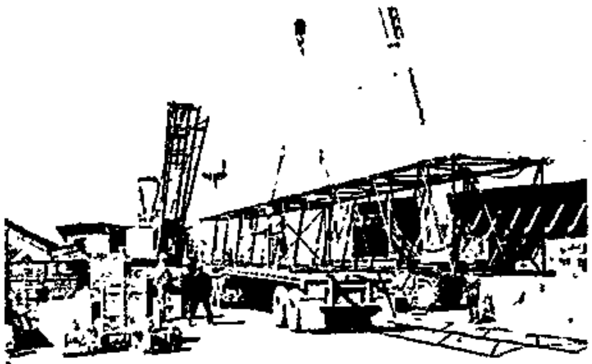
INSTALLING REAR COUNTERWEIGHT WITH SECOND RIG

Figure 7-115. Floatpads and Counterweights

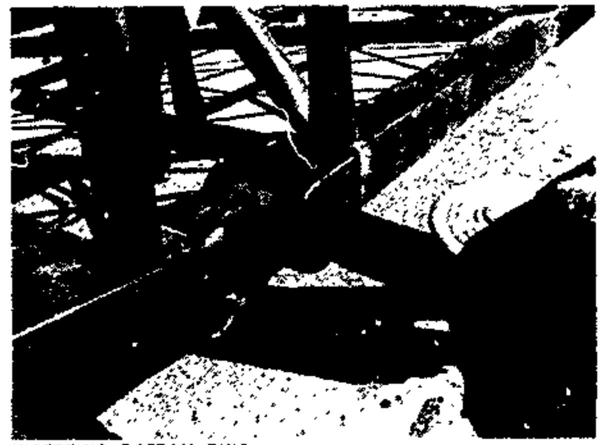
CRANE SAFETY AND SIGNALS

Assembly Precautions

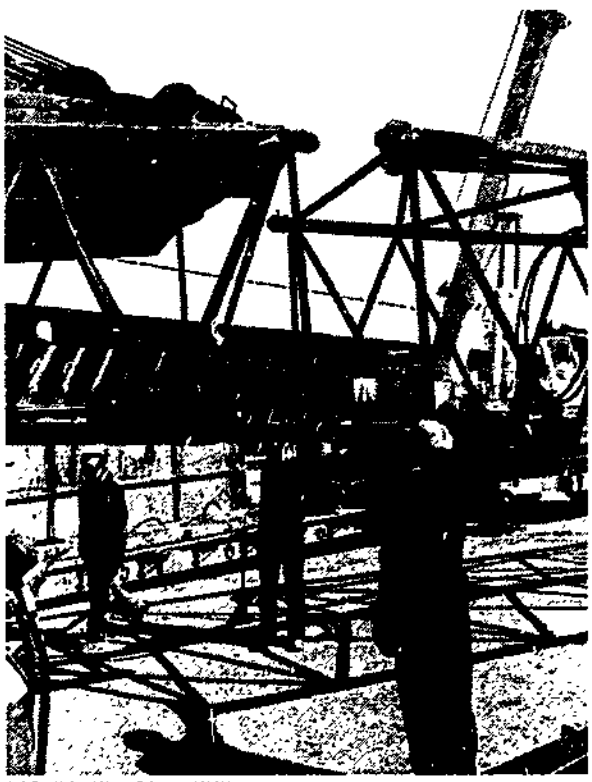
1. Check all outrigger assemblies.
2. Check all boom sections for damage.
3. Always install boom pins from the inside of the boom to the outside.
4. Ensure all boom pins are secured with cotter pins.
5. Before raising boom, machine must be levelled, outriggers fully extended and rubber off the ground.
6. When disassembling boom sections, block the section to be removed.



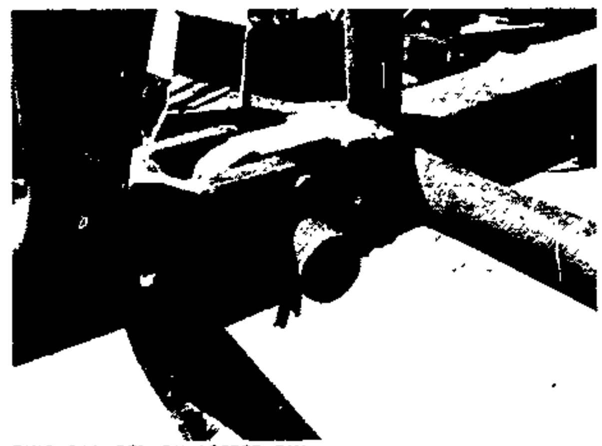
MOVING BOOM OFF TRUCK



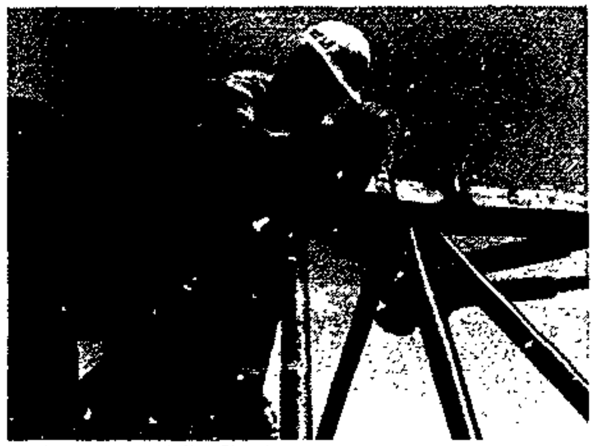
INSERTING BOTTOM PINS



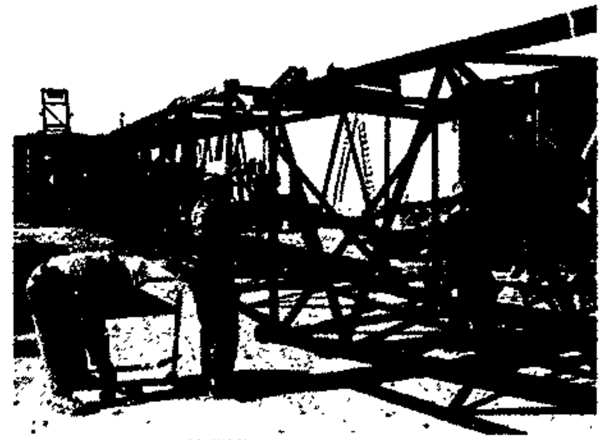
POSITIONING FOR PINNING



PINS SECURED BY COTTER PIN

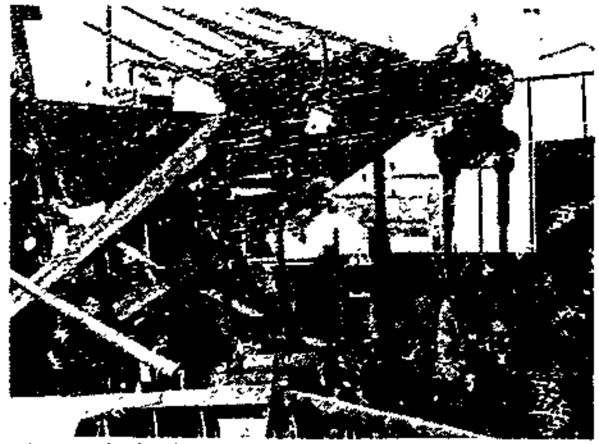


INSERTING TOP PINS FIRST

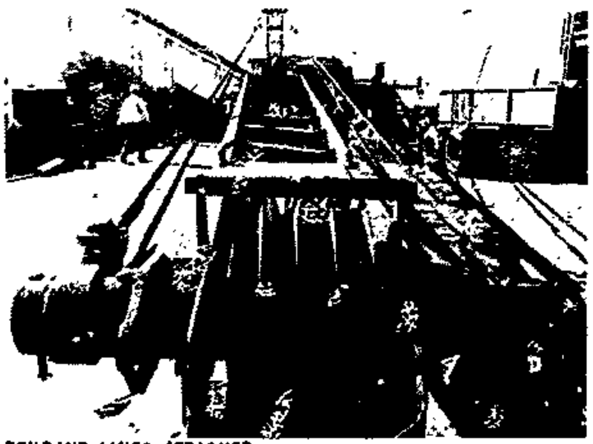


JOINING OTHER SECTIONS

Figure 7-116. Assembling the Boom



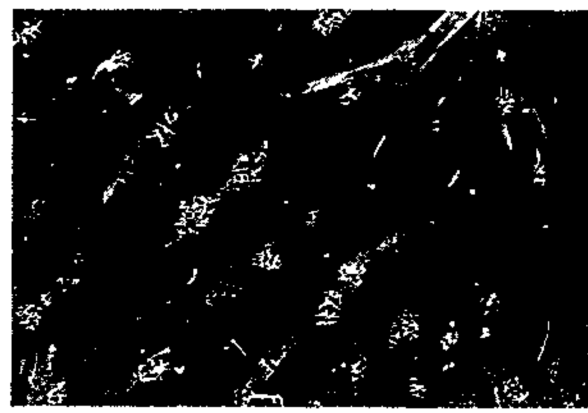
YOKE READIED FOR PENDANT LINES



PENDANT LINES ATTACHED

MAIN LINE REEVED TO MAIN BLOCK

WEDGE SOCKET ATTACHED TO MAIN BLOCKS



TERMINAL END OF MAIN LINE FITTED TO WEDGE SOCKET

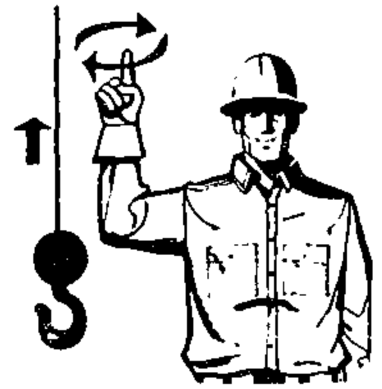
Figure 7-117. Attaching the Lines

Figure 7-116. Boom Raised and Crane Moved to Area of Lift

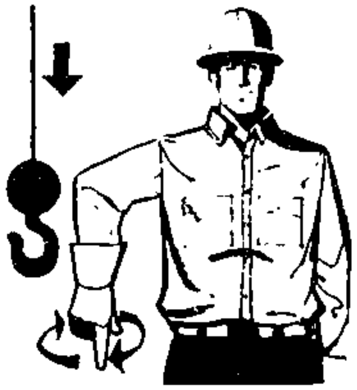
Safety During Crane Operation

1. **One man only** will be designated as signalman. The signalman must be in full view of the crane operator at all times. Crane signals are illustrated in The W.C.B. material in Figure 7-119.
2. When locating the machine, the following must be observed:
   a. As level a path as possible must be followed when moving the machine; avoid slopes and rough terrain.
   b. The boom must be in a raised position when the crane is travelling.
   c. Particularly for larger machines, the speed of travel must be slow.
   d. When "spotting" the crane, to ensure full rated capacity, the machine must be levelled, outriggers fully extended, and all rubber off the ground.
   e. Be aware of all power lines in the area where the crane is spotted.
3. Know the weight of all loads (including weight of any rigging accessories).
4. Measure (rather than estimate) the machine's load radius when making capacity lifts.
5. Avoid effects of "shock loading" to rigging and equipment, by raising and lowering loads slowly.
6. Always use a tag line to control the load when in the air.
7. When booming down, or swinging with a load, always keep the load as close to the ground as possible.
8. When swinging, always ensure that the counterweight area of swing has:
   a) sufficient clearance to clear obstructions.
   b) been barricaded wherever there is a possibility of a worker being crushed.
9. Keep all personnel out from under load.
10. No one is lowed to ride the load under any circumstances.
11. Snub heavy loads to the machine when travelling with a load.
12. When operations cease for the day, it is advisable to "tie down" the boom by attaching a choker from the hook in use to a stationary object with only enough tension to immobilize the boom.

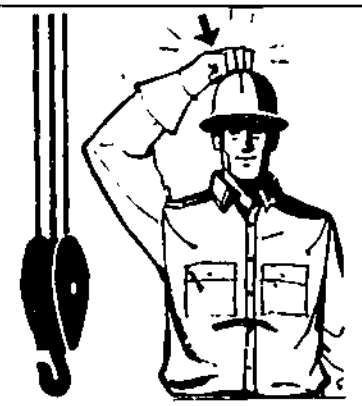
Standard Hand Signals for Controlling Crane Operations, Crawler, Locomotive and Truck Cranes



HOIST With forearm vertical forefinger pointing up move hand in small horizontal circles

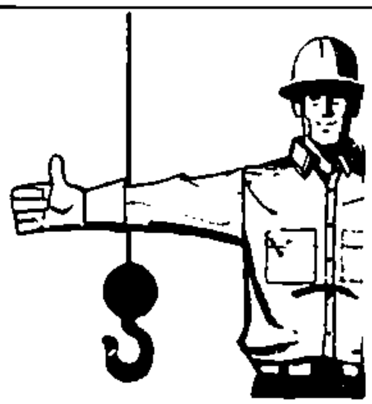


LOWER With arm extended downward forefinger pointing down move hand in small horizontal circles

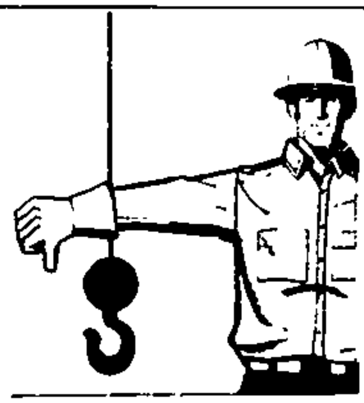


USE MAIN HOIST Tap fist on head then use regular signals

USE WHIPLINE (Auxiliary Hoist) Tap elbow with one hand then use regular signals



RAISE BOOM Arm extended fingers closed thumb pointing upward



LOWER BOOM Arm extended fingers closed thumb pointing downward

MOVE SLOWLY Use one hand to give any motion signal and place other hand motionless in front of hand giving the motion signal (Hoist slowly shown as example)

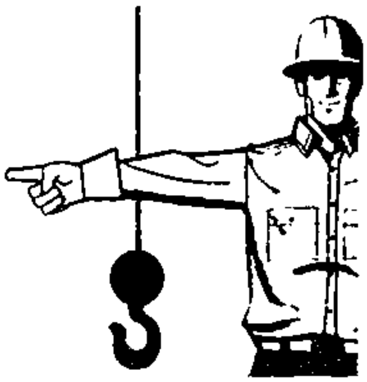
RAISE THE BOOM AND LOWER THE LOAD Arm extended fingers closed thumb pointing upward other arm bent slightly with forefinger pointing down and rotate hand in horizontal circles

LOWER THE BOOM AND RAISE THE LOAD Arm extended fingers closed thumb pointing downward other arm with forearm vertical forefinger pointing upward and rotate hand in horizontal circles

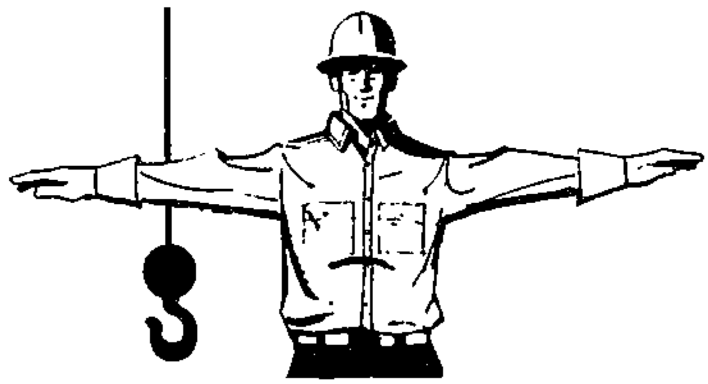
(continued)

Figure 7-119. Crane Signals

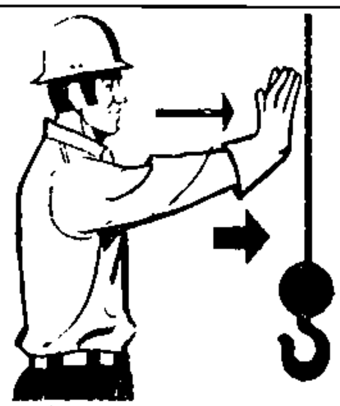
Standard Hand Signals for Controlling Crane Operations, Crawler, Locomotive and Truck Cranes



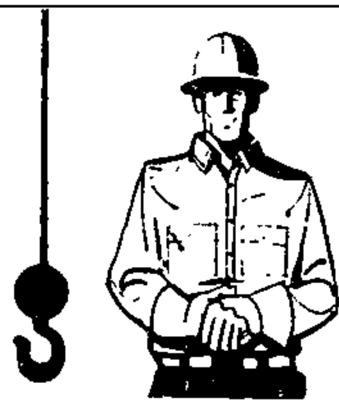
SWING Arm extended point with finger in direction of swing of boom



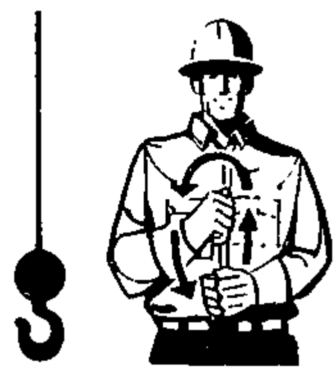
STOP Both arms outstretched at sides horizontally fingers outstretched



TRAVEL Arm extended forward hand open and slightly raised make pushing motion in direction of travel

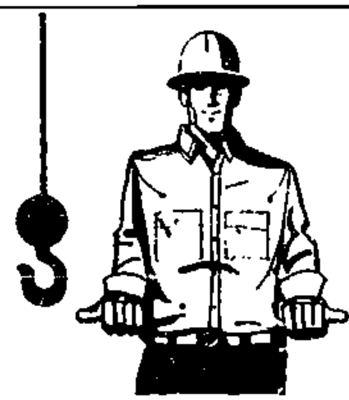


DOG EVERYTHING Clasp hands in front of body

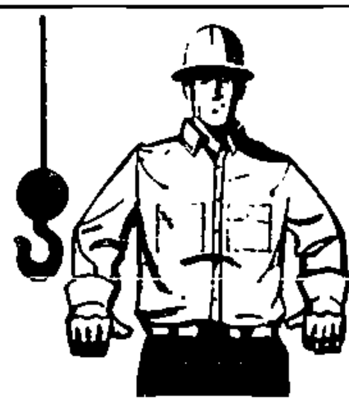


TRAVEL (Both Tracks) Use both fists in front of body making a circular motion about each other indicating direction of travel forward or backward (For crawler cranes only)

TRAVEL (One Track) Lock the track on side indicated by raised fist Travel opposite track in direction indicated by circular motion of other fist rotated vertically in front of body (For crawler cranes only)



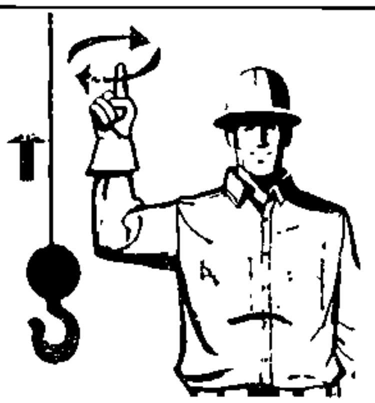
EXTEND BOOM (Telescoping Booms) Both fists in front of body with thumbs pointing outward One hand signal may be used



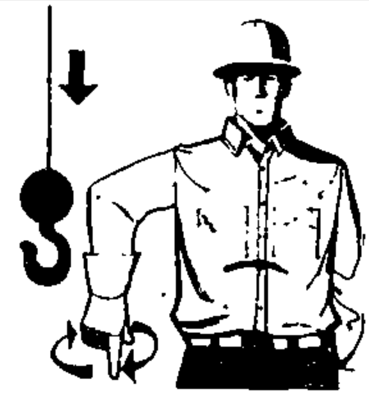
RETRACT BOOM (Telescoping Booms) Both fists in front of body with thumbs pointing toward each other One hand signal may be used

Figure 7-119. Crane Signals (continued)

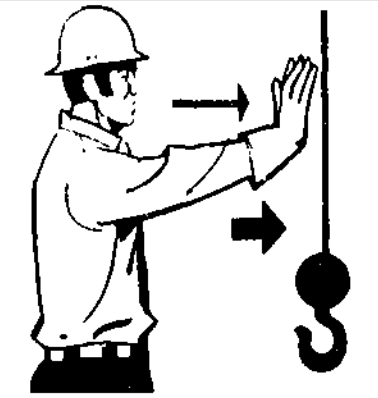
Standard Hand Signals for Controlling Crane Operations, Crawler, Locomotive and Truck Cranes



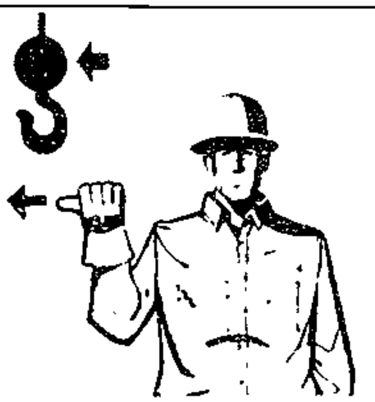
HOIST With forearm vertical forefinger pointing up move hand in small horizontal circles



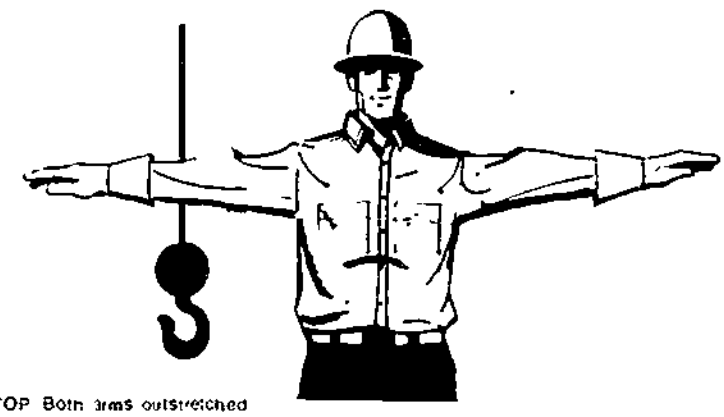
LOWER With arm extended downward forefinger pointing down move hand in small horizontal circles



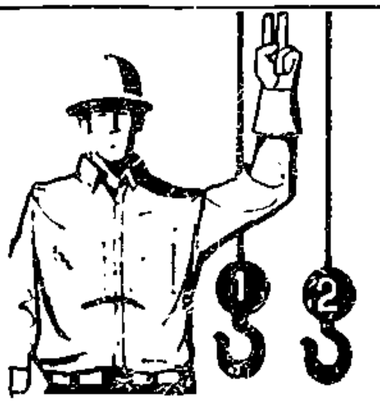
BRIDGE TRAVEL Arm extended forward hand open and slightly raised make pushing motion in direction of travel



TROLLEY TRAVEL Palm up fingers closed thumb pointing in direction of motion jerk hand horizontally

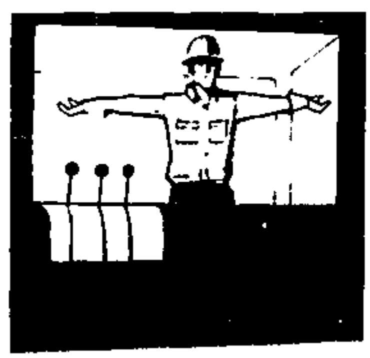


STOP Both arms outstretched at the sides horizontally fingers outstretched



MULTIPLE TROLLEYS Hold up one finger for block marked 1 and two fingers for block marked 2 Regular signals follow

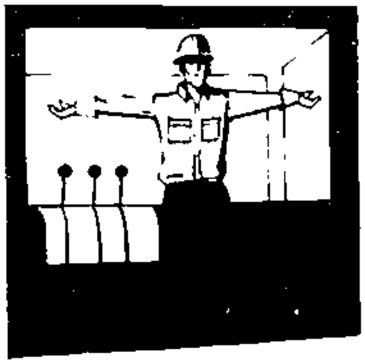
MOVE SLOWLY Use one hand to give any motion signal and place other hand motionless in front of hand giving the motion signal (Hoist Slowly shown as example)



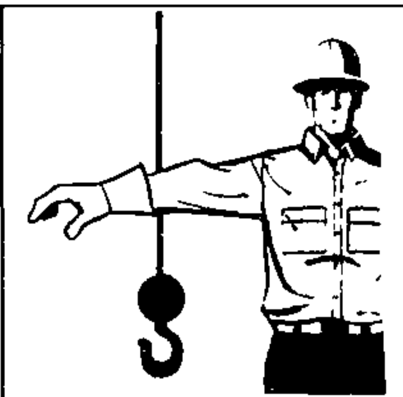
MAGNET IS DISCONNECTED Crane operator spreads both hands apart - palms up

Figure 7-119. Crane Signals (continued)

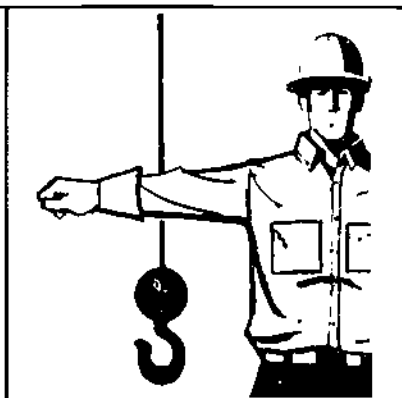
Standard Hand Signals for Controlling Crane Operations, Overhead and Gantry Cranes



MAGNET IS DISCONNECTED Crane operator spreads both hands apart Palms up

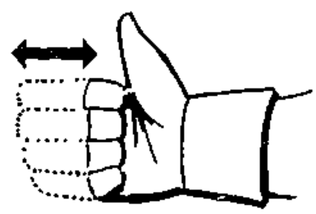


OPEN CLAM SHELL BUCKET Arm extended palm down open hand

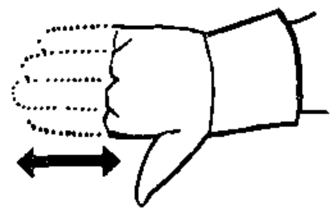


CLOSE CLAM SHELL BUCKET Arm extended palm down close hand

HOIST SLOWLY TO CLEAR FOULED LINE Hands crossed in front above shoulders fingers relaxed



BOOM UP AND LOWER THE LOAD One hand

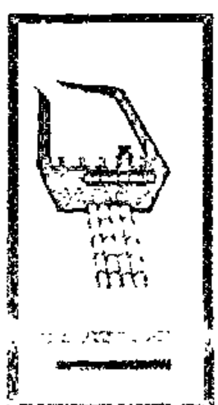


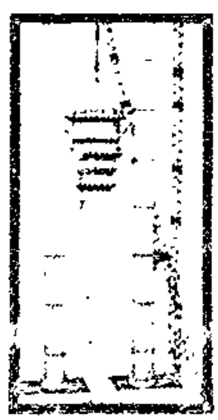
BOOM DOWN AND RAISE THE LOAD One hand

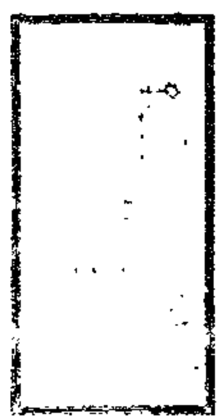
STOP One hand

WHIP LINE One hand

Figure 7-119. Crane Signals (continued)







INTRODUCTION

The technology of metallurgy and welding has become very complex, particularly during the past twenty-five years. It is therefore necessary to limit the scope of this chapter to a presentation of the fundamental principles of welding, including:

1 Accepted terminology of the trade
2 Acceptable designs of welded joints
3 Information about various welding processes.

WELD JOINTS AND WELD TYPES

Weld joints are classified into five basic categories as illustrated in Figure 8-1

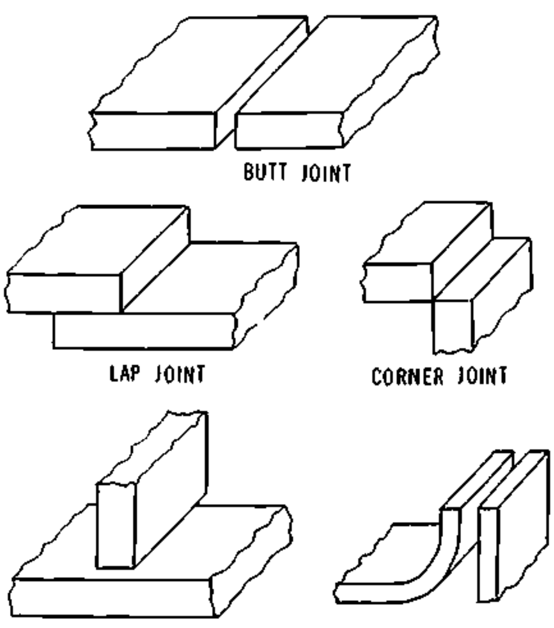


Figure 8-1. Types of Weld Joints

In their simplest form, these joints only require fitting two square edges into a suitable relationship. With thicker material, however, the metal edges must be prepared so that complete penetration will occur; otherwise the full strength of the material in the design is not achieved Physical testing of weld joints has shown that some welded joints must be restricted to static loads while others can bear dynamic or fatigue loads.

Three basic weld types are used to fuse the weld joints described above:

1. Groove weld
2. Fillet weld
3. Plug weld.

Groove welds are used on butt joints. When full fusion of the materials being welded is obtained, 100% strength of the weakest material in the joint can be obtained.

Fillet welds are used to fuse plates that form approximately a 90 angle. The angle may be an inside or open corner, an outside corner, or Tee joint. Design specifications will stipulate whether the weld is to be performed with special edge preparation or with unprepared edges. Several edge preparations could be specified, and these are described in this chapter.

Plug welds or slot welds are usually required when two plates must be joined surface-to-surface. The weld is made through an opening in the top plate, fusing it to the underlying plate. Because the welds withstand shear loads poorly, plug welds should be used only where groove or fillet welds cannot be used because of inaccessibility and where loading of the joint is comparatively low.

STANDARD WELDING SYMBOLS

A standard means of indicating complete and accurate welding instructions on a drawing or blueprint is essential. A conventional method of illustrating welds symbolically has been developed and adopted in North America. These symbols provide the following information:

1. Type of weld
2. Type of joint
3. Size of weld
4. Dimensions of the joint
5. Position of the weld
6. Finish of the weld (flush, convex, concave)
7. Process to be used
8. Type of electrode.

DEVELOPING WELDING SYMBOLS

The welding symbol is a combination of a reference line, arrow, tail, basic weld symbol and other specifications. The complete symbol is developed as follows:

A Reference Line (usually horizontal) is drawn close to the drawing of the joint to be welded. To show the location of a weld, an arrow is drawn from the reference line with the head pointing directly to the joint concerned as shown in Figure 8-2.

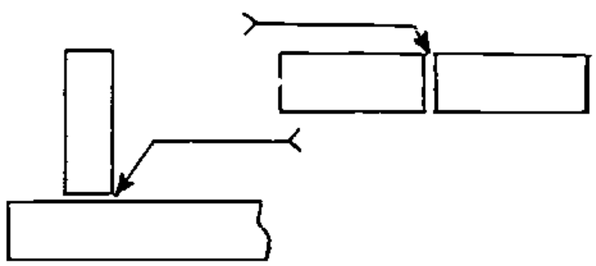


Figure 8-2. Indicating Location of a Weld

When reading the symbol, the "side" above the reference line always denotes the "other side" of the joint to be welded, and the "side" below the reference line denotes the "arrow side." The location of the "other side" and "arrow side" will be the same no matter the direction the arrow points in. (See Figure 8-3.)

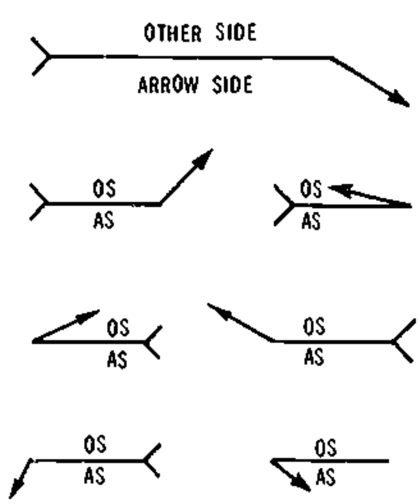


Figure 8-3. "Other" Side and "Arrow" Side

For vertical reference lines (seldom used) the usual convention of drafting is applied in locating the "other side" and "arrow side" on a drawing as shown in Figure 8-4.

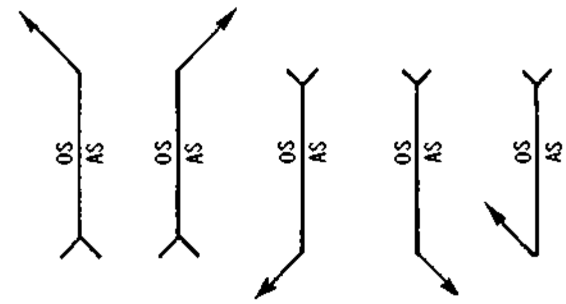


Figure 8-4. Vertical Reference Lines

Any joint has two sides, and therefore symbols placed on the "arrow side" of the reference line apply to the side of the joint to which the head of the arrow is pointing. Similarly, symbols placed on the "other side" of the reference line apply to the other side of the joint. See Figure 8-5.

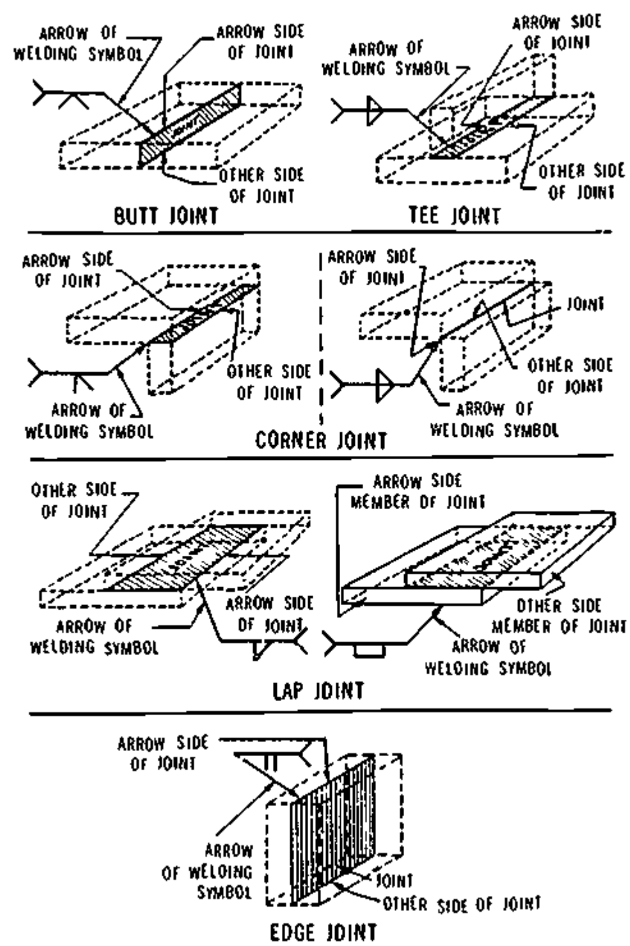


Figure 8-5. Identifying Arrow -Side and Other Side

When one member of the joint assembly requires preparation before welding (as in the case of a bevel or J-groove weld), the arrow will point with a definite break toward that member as shown in Figure 8-6. In cases where the member to be chamfered is obvious, the break in the arrow may be omitted (Figure 8-7) Note that any break in the arrow line other than for bevel or J-grooves has no bearing on the preparation of the joint

The **Basic Weld Symbol** is located on the reference line to specify both the type of weld required and its location at the joint The symbols are set out and revised periodically by the American Welding Society (Figure 8-8)

Table 8-1 and Table 8-2 shows how the basic weld symbols are placed on the reference line to signify type and location of welds

Figure 8-9 illustrates how supplementary weld symbols are placed on the welding symbol.

Other specifications concerning a desired weld on the drawing are:

1. Size: size or strength for certain welds
2. Root opening. depth of filling for plug and slot welds

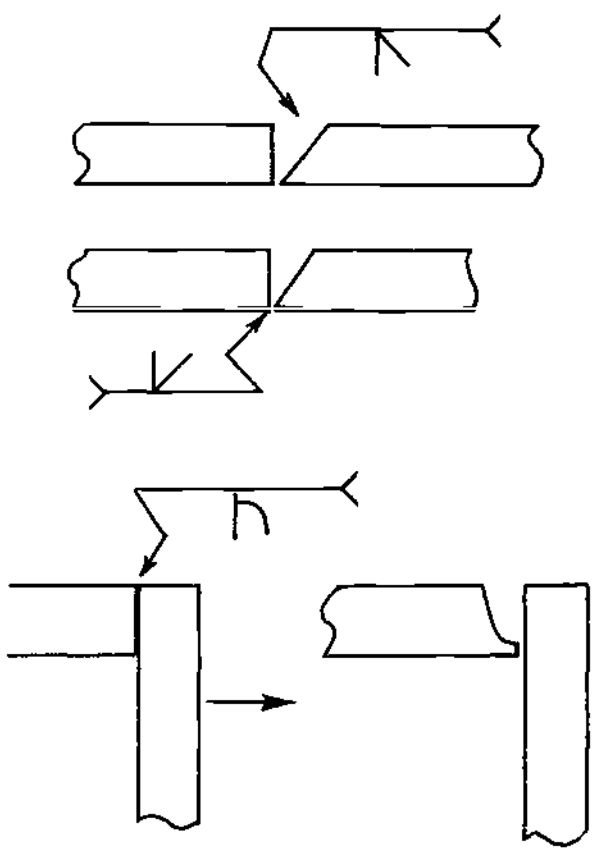


Figure 8-6. Breaks in Arrow Signifying Joint Preparation

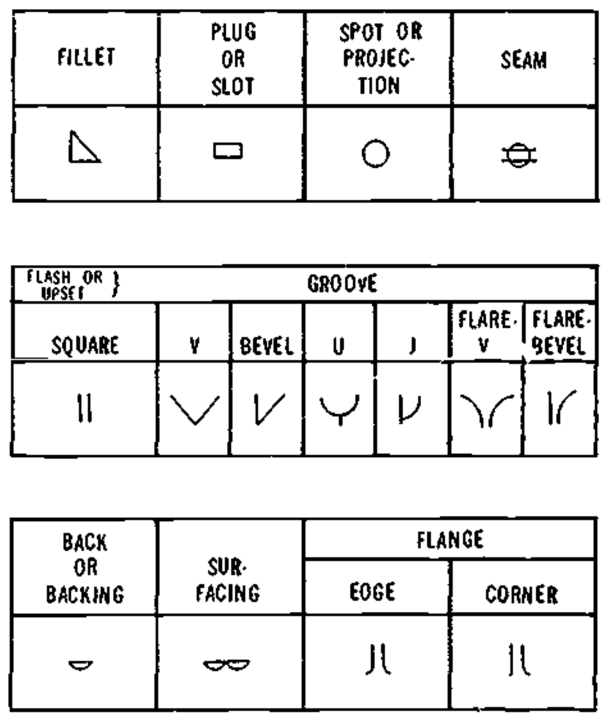


Figure 8-8. Basic Weld Symbols

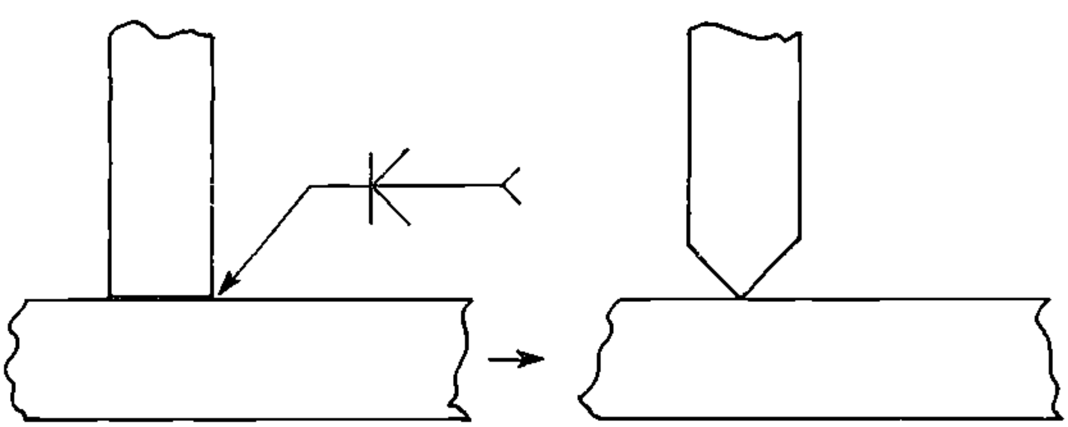


Figure 8-7. Break in Arrow Omitted When Chamfered Member Obvious

TABLE 8-1. BASIC WELD SYMBOLS FOR REFERENCE LINES

	FILLET	PLUG OR SLOT	SPOT OR PROJECTION	SEAM	FLASH OR UPSET / SQUARE	GROOVE V	BEVEL	U	J	FLARE V	FLARE BEVEL
ARROW SIDE											
OTHER SIDE											
BOTH SIDES		NOT USED	NOT USED	NOT USED							
NO ARROW SIDE	NOT USED	NOT USED			NOT USED EXCEPT FOR FLASH OR UPSET	NOT USED	NOT USED	NOT USED	NOT USED	NOT USED	NOT USED

TABLE 8-2. SUPPLEMENTARY WELD SYMBOLS

WELD ALL AROUND	FIELD WELD	MELT-THRU	CONTOUR FLUSH	CONTOUR CONVEX	CONTOUR CONCAVE

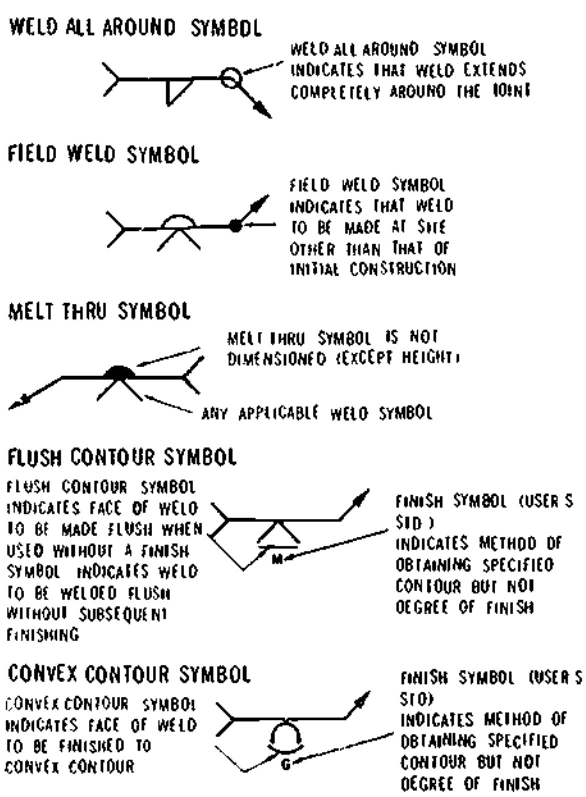


Figure 8-9. Placement of Supplementary Weld Symbols

3 Groove angle, included angle of countersink for plug welds
4 Length of weld
5 Pitch (centre to centre spacing) of welds
6 Number of spot or projection welds
7 Specification, process or other reference.

Each element in the symbol is placed in a specific position in relation to the other elements as shown in Figure 8-10

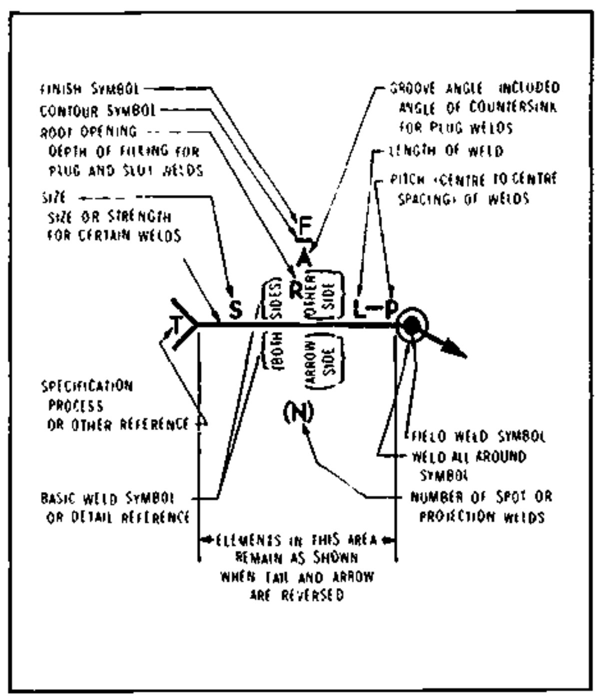


Figure 8-10. Position of Elements on Weld Symbol

TYPICAL WELDING SYMBOLS

Figure 8-11 presents some examples of welding symbols with brief explanations of their meaning.

APPLICATIONS OF FILLET WELDING SYMBOL

Figures 8-11 to 8-15 illustrate examples of typical fillet welding symbols.

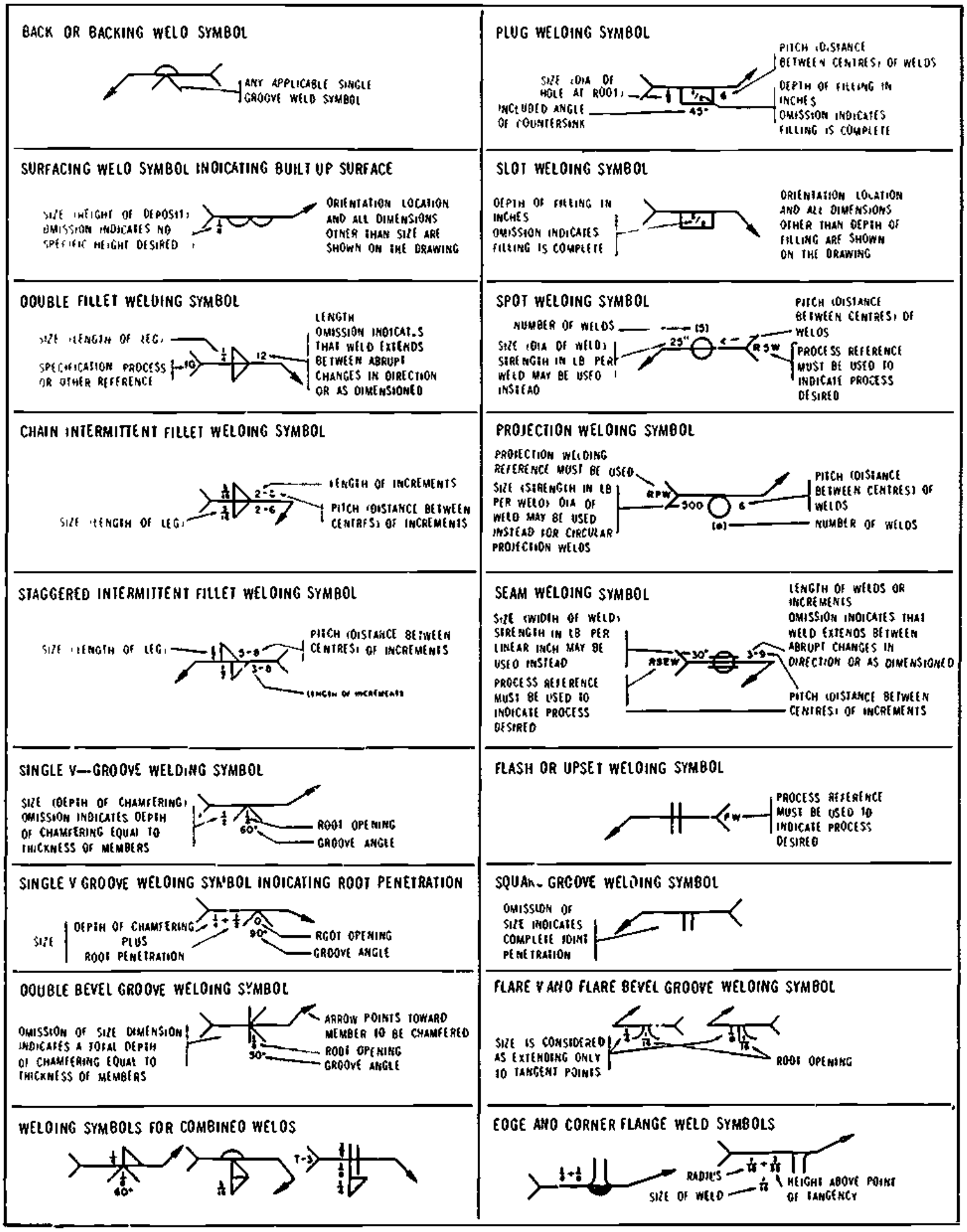


Figure 8-11. Examples of Welding Symbols

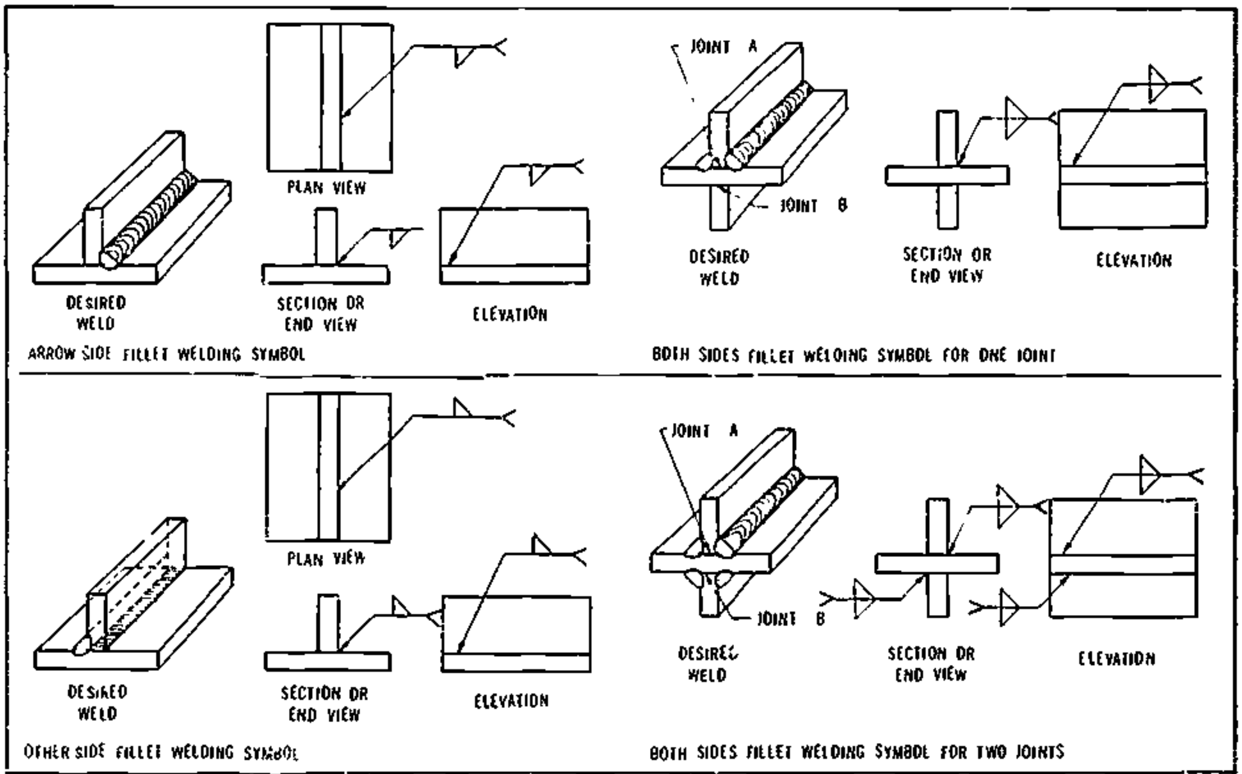


Figure 8-12. Typical Fillet Welding Symbols

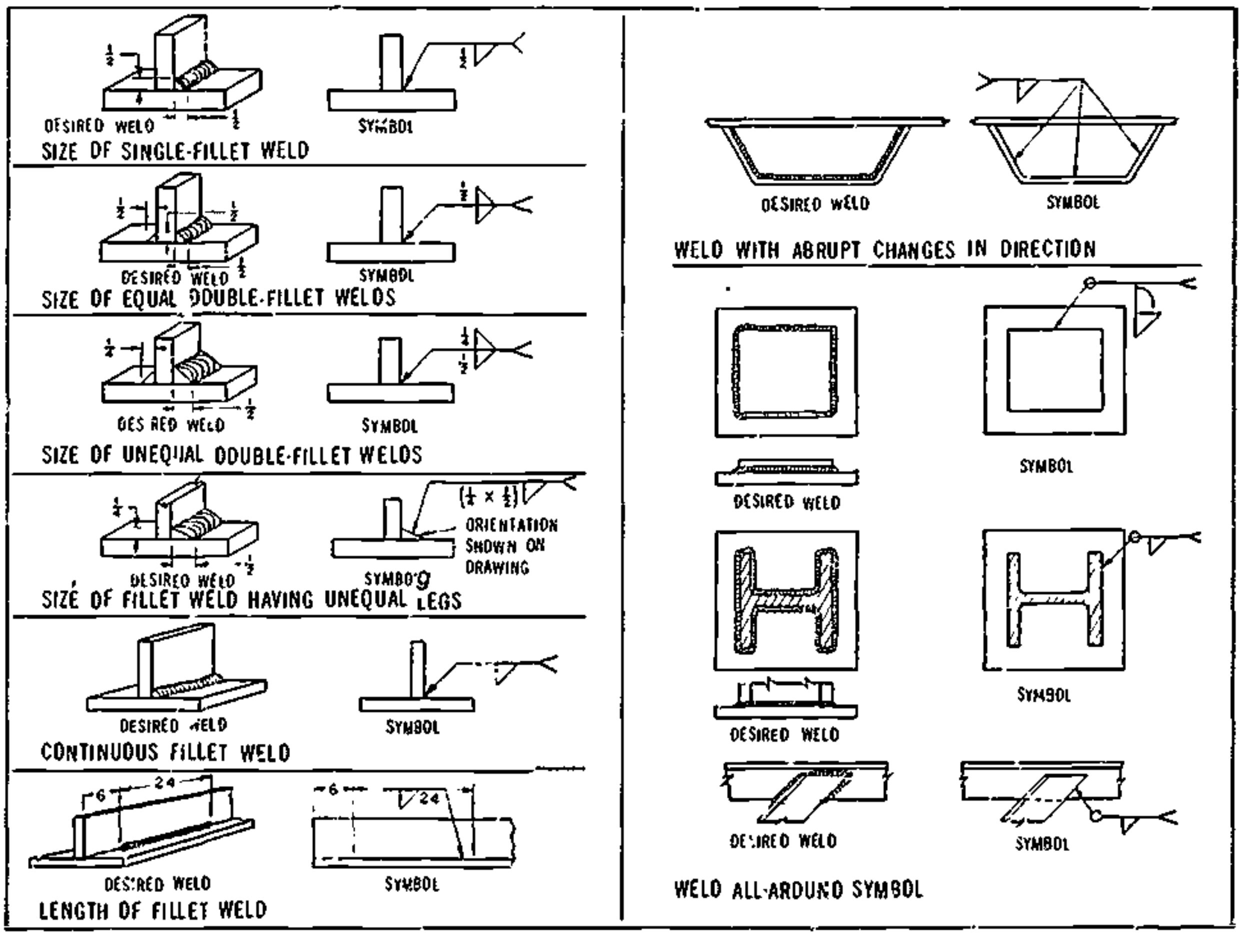


Figure 8-13. Typical Fillet Welding Symbols

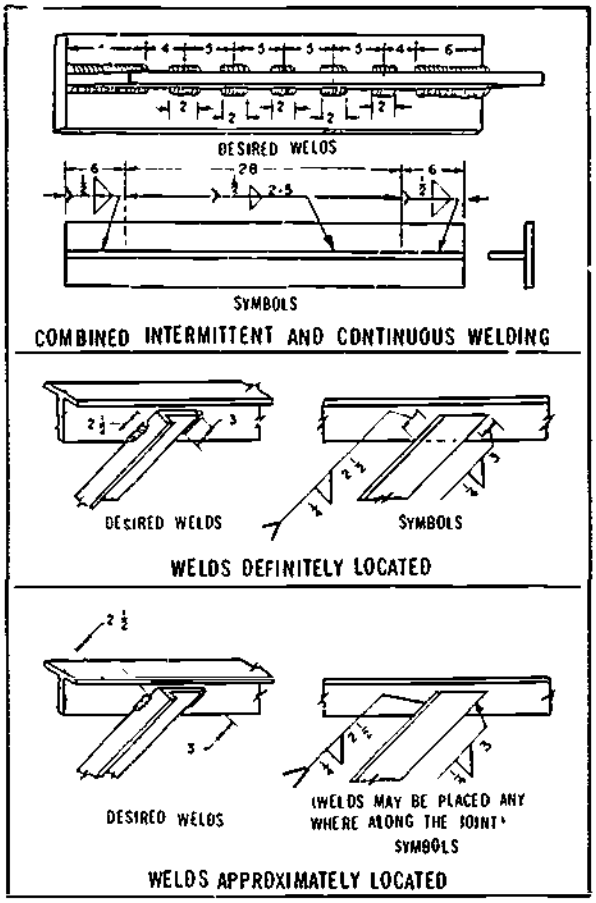


Figure 8-14. Typical Fillet Welding Symbols

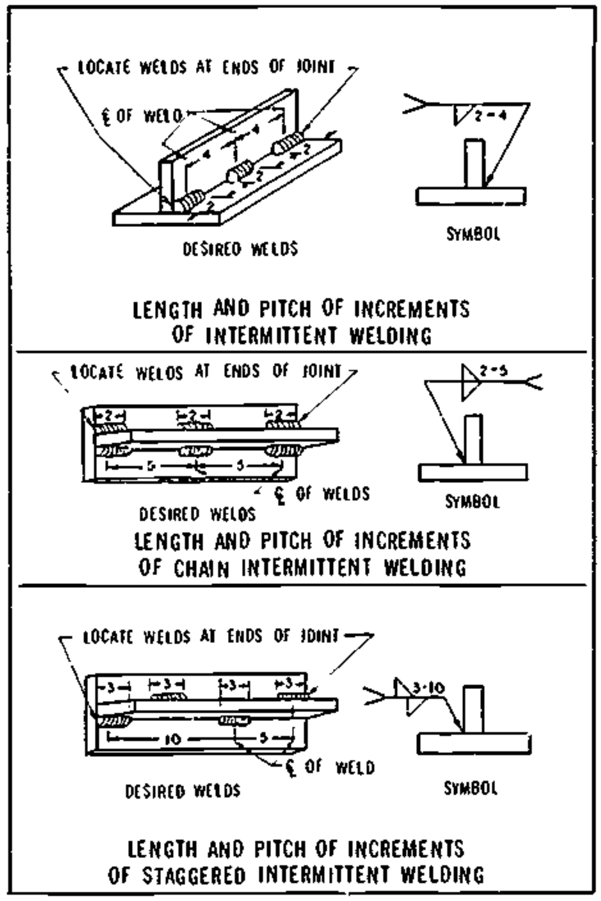


Figure 8-15. Typical Fillet Welding Symbols

APPLICATION OF DIMENSIONS TO PLUG WELDING SYMBOLS

Figures 8-16 illustrate how required dimensions (size, included angle of countersink and depth of filling) are used in plug welding symbols.

APPLICATIONS OF DIMENSIONS TO SLOT WELDING SYMBOLS

Figure 8-17 illustrates how required dimensions for depth of filling are used in slot welding symbols.

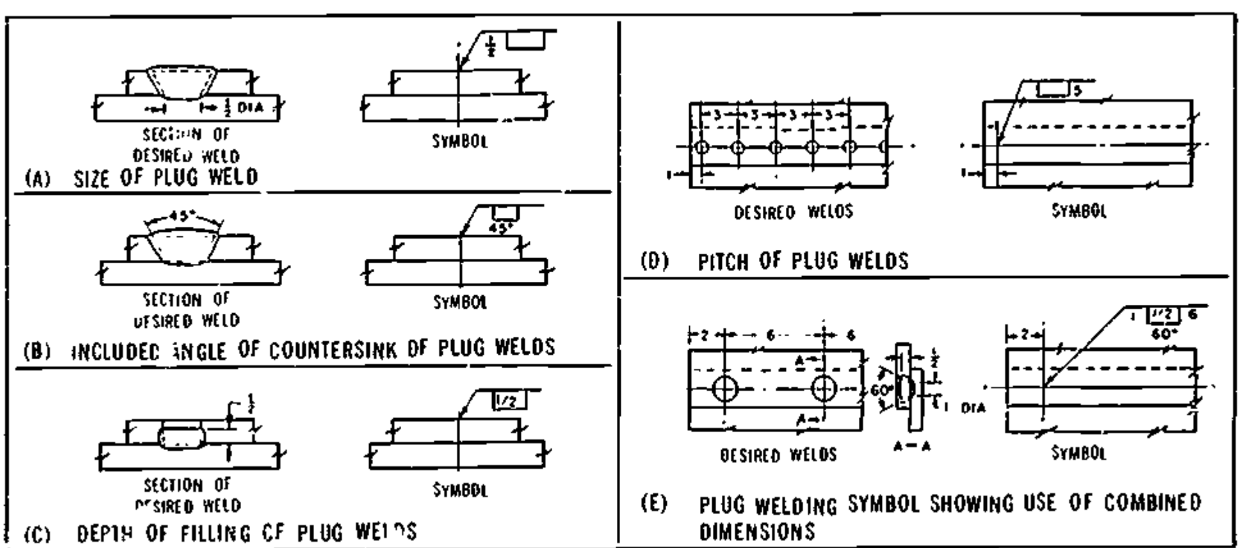


Figure 8-16. Dimension in Plug Welding Symbols

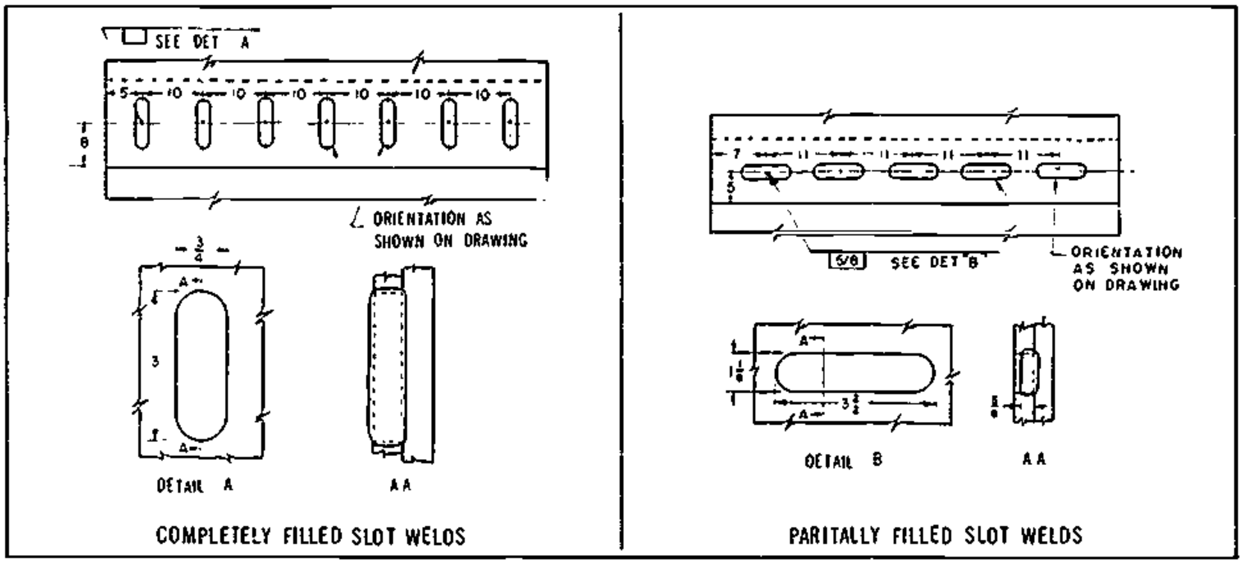


Figure 8-17. Dimension in Slot Welding Symbols

APPLICATIONS OF GROOVE WELDING SYMBOLS

Figures 8-18 and 8-19 provide examples of typical groove welding symbols.

GUIDELINES FOR INTERPRETING WELDING SYMBOLS

1. Locate the joint accurately, since some drawings do not show joints clearly.
2. Identify the "arrow side" and "other side" of the joint. The arrow points to the "arrow side."
3. Prepare the joint according to the location and type of weld symbol on the reference line. Take into account the other parts of the welding symbol, e.g. size, length, second break in arrow line, other specifications

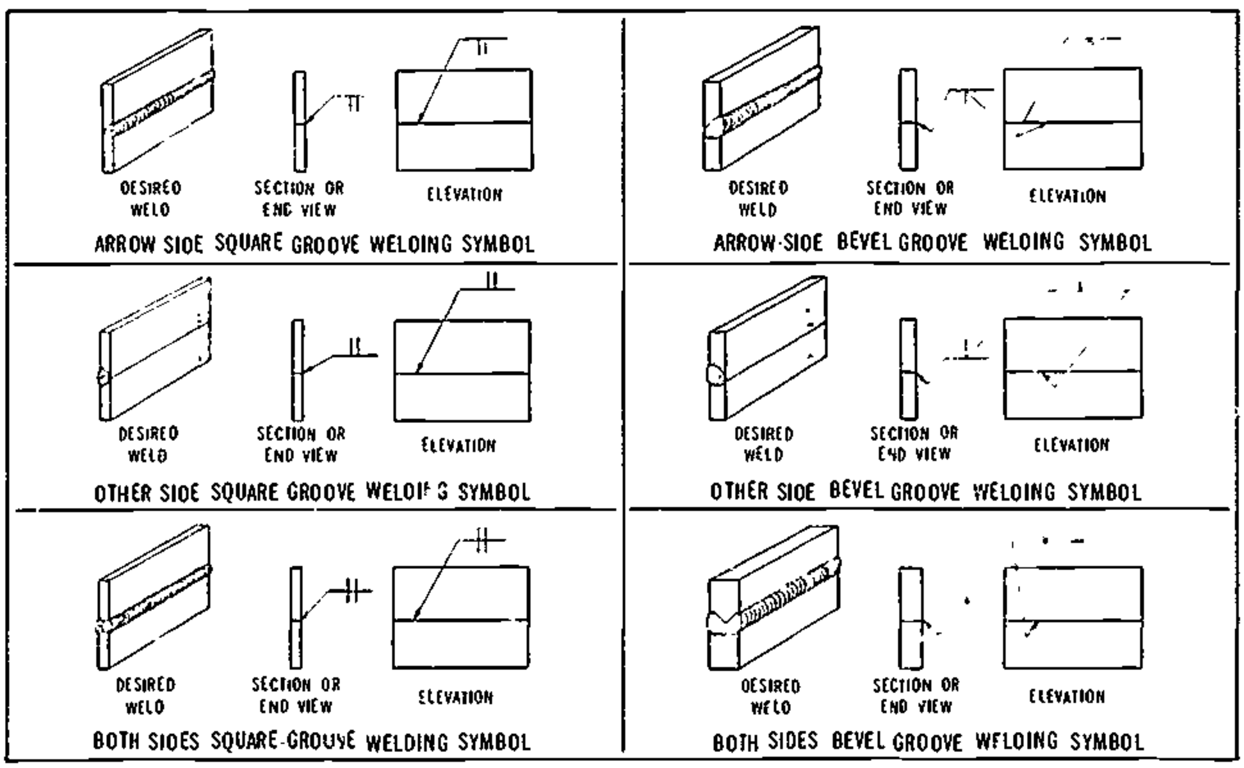


Figure 8-18. Groove Welding Symbols

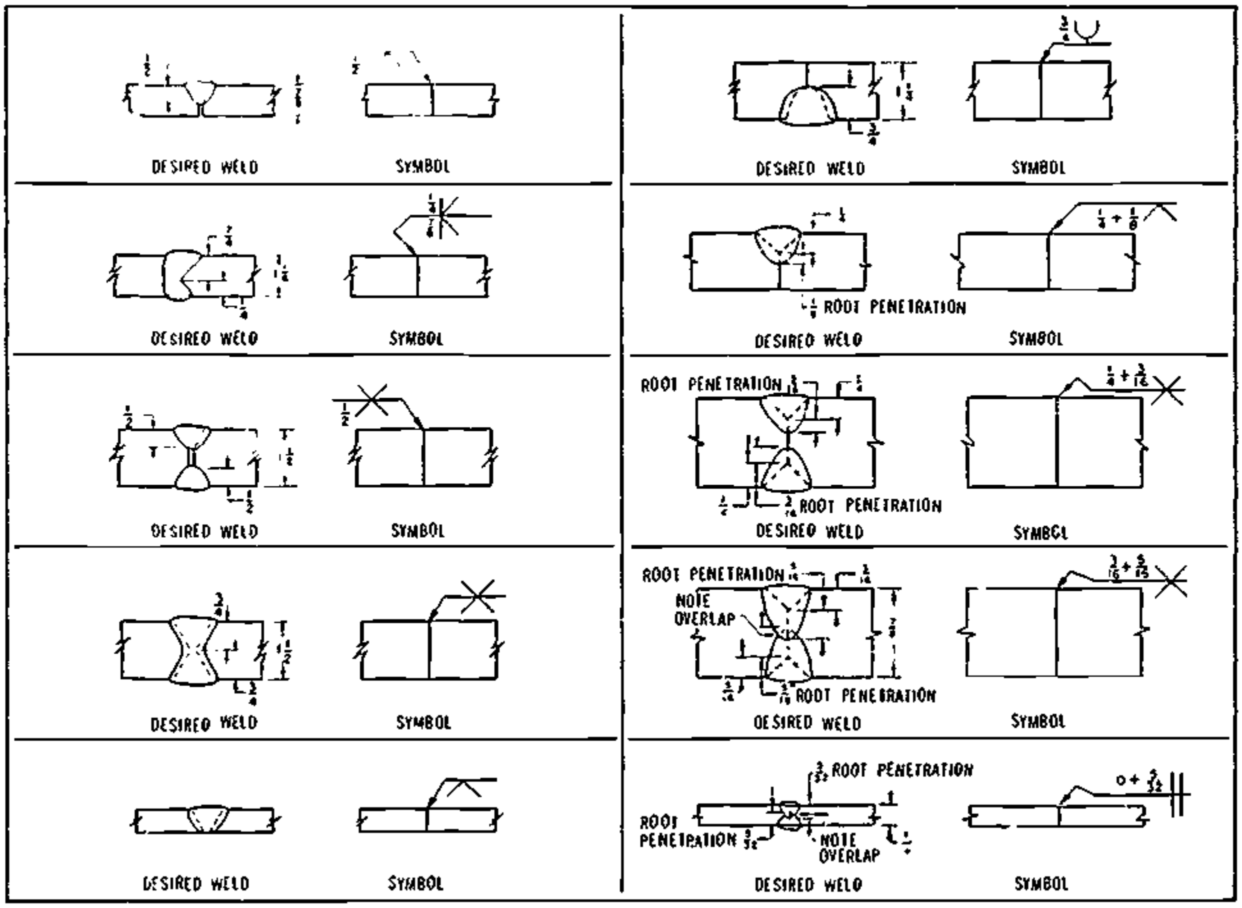


Figure 8-19. Groove Welding Symbols

PARTS OF A WELD

The terminology used to identify the parts of a weld are defined and illustrated with reference to Figure 8-20.

Root Gap or Root Opening is the distance between two prepared plates.

Root Face (Land, Shoulder) refers to a chamfer on the bevel.

Included Angle is the total angle between the two prepared plates.

Root Radius is the radius of the arc formed in a J-groove between the root face and the shoulder

Weld Size is the depth of weld from the point of deepest penetration to the face of the weld.

Root Penetration is the distance from the joint to the root of a fillet weld

Root is the point of deepest penetration of a fillet weld.

Toe refers to the junction between the face of the weld and the base metal.

Leg of a fillet weld is the distance from the point where the original surfaces intersected to the toe of the fillet.

Face of the weld is the exposed surface of a weld.

Throat of a fillet weld is the distance from the joint to the face of the weld.

WELDING PROCESSES

ARC WELDING EQUIPMENT

There are three basic types of arc welding machines:

1. Generators

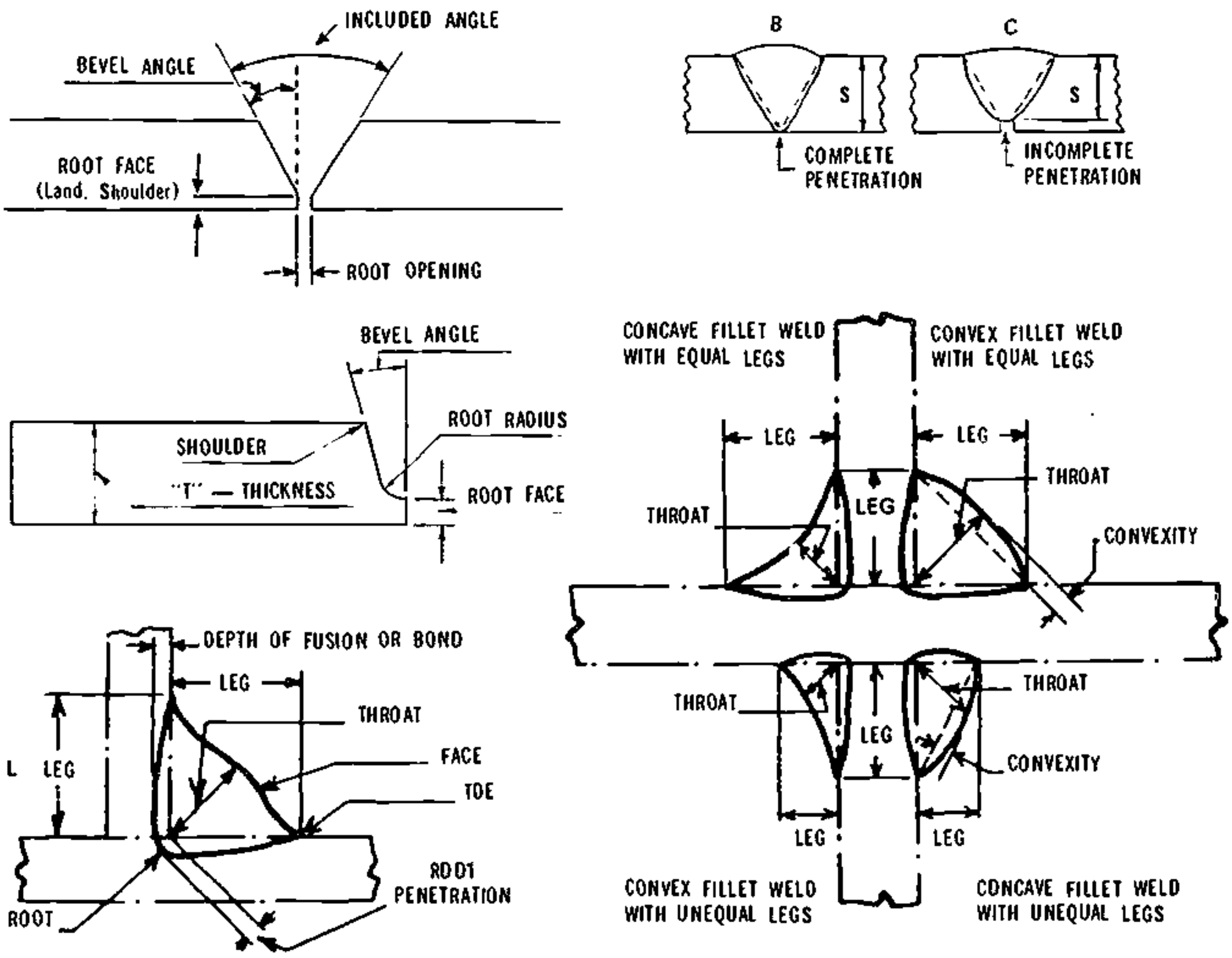


Figure 8-20. Parts of a Weld

2. Transformers
3. Rectifiers.

D.C. Motor Generator produces a D.C. current suitable for welding from an alternating current power source. All types of welding electrodes can be used.

D.C. Engine-Driven Generator is powered by a gas or diesel engine and produces a D.C. current compatible with all types of welding electrodes. These units are portable and independent of electrical supply lines.

Transformers The power source for this type is usually a single phase conversion from 115 V. to 550 V., producing an A.C. current suitable for welding at high amperages. Not all electrodes are compatible with A.C. current.

Rectifiers The power source is 220 V. to 550 V alternating current converting to D.C. by single or 3-Phase process. Some rectifiers are equipped to supply D.C. and A.C. output by setting a simple selector switch.

REQUIREMENTS FOR WELDING MACHINES

Each type of welding machine is designed to meet the following essential performance criteria:

1. It must provide current variables over a wide range.
2. It must have an open circuit voltage high enough to maintain an arc under varying conditions.
3. It must be capable of a quick response to the varying requirements of the arc for both voltage and current.

COMMON WELDING PROBLEMS

Arc Blow Arc blow is deflection of the arc forward or backward (or occasionally to the side) caused by magnetic fields around the plate and the electrode induced by direct current flowing through them.

Arc blow can produce the following weld effects: incomplete fusion, slag inclusion, weld spatter.

Corrective Measures to Reduce or Eliminate Arc Blow

1. Reduce current.
2. Switch to alternating current if available.
3. Tilt the electrode to counteract the arc blow.
4. Position ground connection some distance away from the joint being welded.
5. Hold as short an arc as possible.
6. Check weld direction and sequence:
   a. weld toward a heavy tack or a weld already made
   b. back-step on long welds
   c. start the weld some distance in from the edge and weld back to the edge (for forward blow).
7. Wrap the ground cable around the work piece such that the magnetic field is neutralized (do not burn cable insulation).

Metal Distortion Metals expand on heating and contract on cooling. During welding the heated metal expands and the subsequent cooling causes the metal to contract.

Principles of Metal Distortion

1. Expansion and contraction affect all dimensions: length, width and thickness.
2. Different metals expand and contract to varying degrees.
3. Both the weld metal and the parent metal are affected by heat and cooling
4. If thermal expansion and contraction are too rigidly restrained, the resulting stresses on the metal may weaken or impair the weld.

Guide to Welding Practices To Minimize Distortion

Do not overweld:

1. Use smallest permissible size of weld on fillets (Figure 8-21)
2. Use intermittent fillet welds rather than continuous ones if permissible.

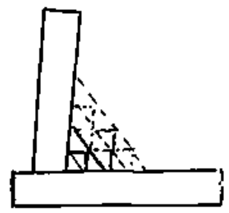


Figure 8-21. Use Smallest Weld Size Permissible

3. Use joint designs that require the least weld metal:
   a. U groove is preferable to a V groove (Figure 8-22).
   b. Use smallest permissible angle on single V groove joint (Figure 8-22).

Balance welds about the neutral axis:

1. Use deep penetrating fillet welds (Figure 8-23).
2. Place intermittent fillet welds opposite each other (Figure 8-24).
3. Use double V groove weld design rather than single V (Figure 8-25).

Deposit the greatest amount of weld metal in the shortest time:

1. Weld in flat position if possible using large size electrodes.
2. Use iron powder electrodes.
3. Use fewest possible number of passes (Figure 8-26).

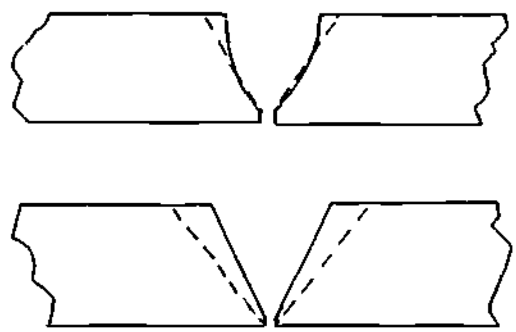


Figure 8-22. U-Groove and V-Groove

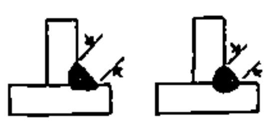


Figure 8-23. Weld Penetration

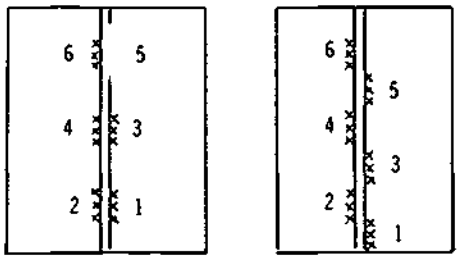


Figure 8-24. Intermittent Weld Patterns

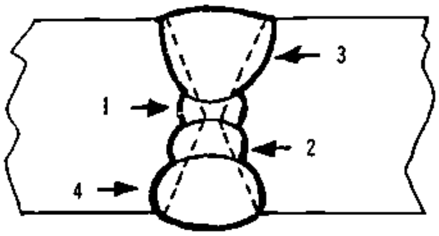


Figure 8-25. Double "V" Groove

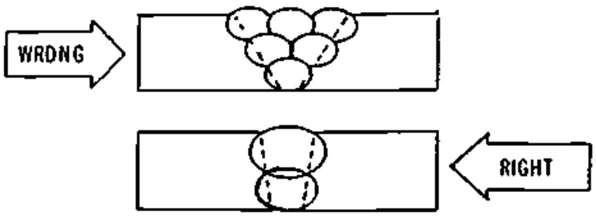


Figure 8-26. Minimal Number of Passes

4 Select fastest welding method i.e., semi-automatic or automatic welding machines.

Sequence welding to distribute heat as uniformly as possible (Figure 8-27):

1. Use back-step welding method.
2. Use staggered or wandering sequence.
3. Use ding about the centre line.
4. On longitudinal seams. start some distance in from the end of the joint with a short weld, then finish the main weld to the other end of the joint (Figure 8-28).

Divide a weldment into sub-assemblies that may be fabricated under preferred welding conditions. A weldment consisting of different parts may be tack-welded into one assembly that is then welded following correct sequence.

Use mechanical means:

1. Pre-bending using clamps and fixtures (Figure 8-29).

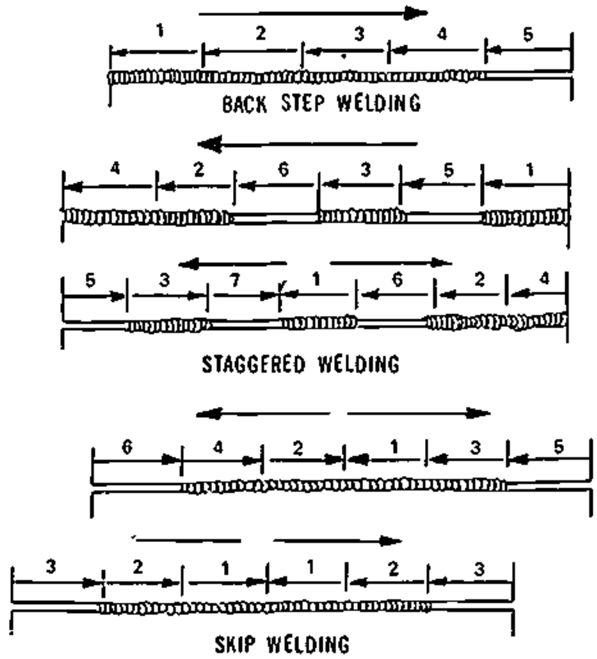


Figure 8-27. Sequence Welding To Distribute Heat

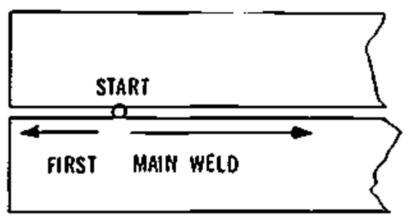


Figure 8-28. Welding Longitudinal Seams

2. Locating parts out of position or spacing to allow for shrinkage (Figure 8-30).

Preheat preferred or entire sections (Figure 8-31).

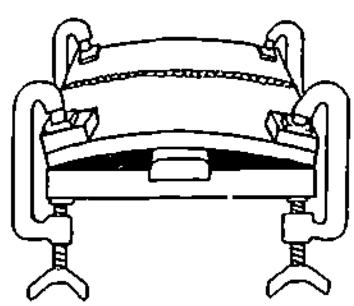


Figure 8-29. Pre-Bending

COMPARISON OF CHARACTERISTICS OF A.C. AND D.C. WELDING CURRENT

A.C	D.C.
1 Reduces incidence of arc blow where high amperages required.	1. Arc blow common, especially with high amperages.
2 Better welds with iron powder type electrodes.	2. Bead is narrow and stringy with iron powder type rods.
3 Not compatible with some types of electrodes: stainless, non-ferrous, low hydrogen (small sizes) and hardsurfacing.	3. Most universally compatible welding current for variety of electrodes and welding positions.

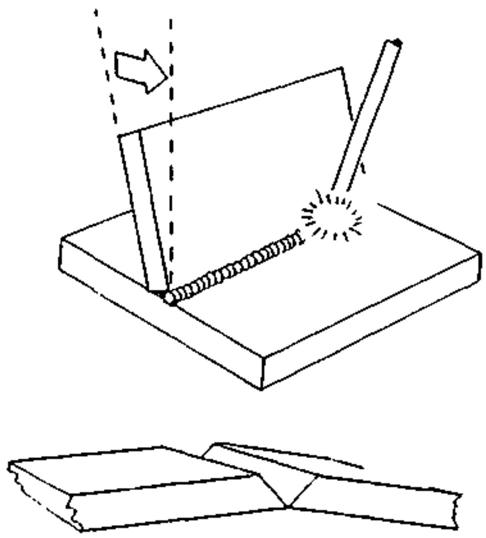


Figure 8-30. Allowances For Shrinkage

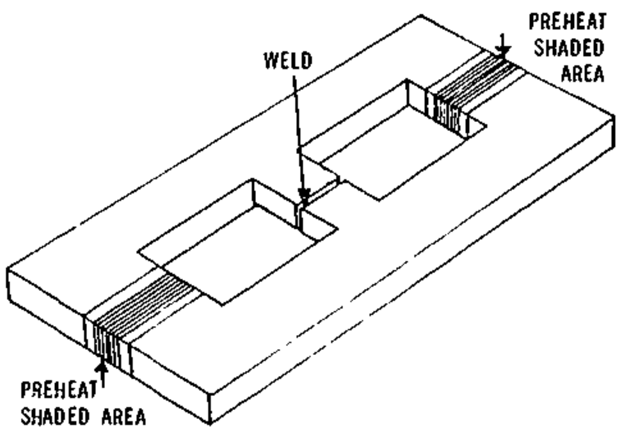


Figure 8-31. Preheating Preferred Sections

WELDING ELECTRODES

The welding electrode is the consumable metal rod or wire used in electric arc welding to strike and maintain an arc and to melt in order to add fused drops of metal to the weld.

In manual welding processes, the electrode is in the form of a metal rod or "stick." In automatic or semi-automatic processes, the electrode is a continuous length of wire that feeds into the weld area at a controlled rate.

Categories of Welding Electrodes

1. Mild steel
2. Low alloy steel
3. Corrosion-resisting chromium and chromium nickel steel
4. Hard surfacing metal (Ferrous and Nonferrous)
5. Nickel and nickel alloy
6. Aluminum and aluminum alloy
7. Copper and copper allov

Size of Electrodes for Manual or "Stick" Welding

1. Usual range from 14" to 18" in length.
2. Diameter range is 1/16" to 3/8".

Flux Amount of flux or coating varies from a light dust to heavy covering over the rod.

Composition of the flux va. s according to the function required of the rod. Functions of flux are:

1. Provides a gaseous shield for the weld
2. Produces slag to protect the deposited metal
3. Provides for easier arc handling
4. Acts as a stabilizer
5. Alloying elements may be included for strength
6. Renders the rod compatible with A.C.
7. Iron powder may be included to provide additional filler.

Slag The amount and character of slag produced by an electrode are determined by the nature of the rod coating Functions of slag are

1. Protecting the deposit from oxidation
2. Dissolving oxides and float impurities to the surface
3. Controlling shape and smoothness of the bead
4. Decreasing the rate of cooling of the deposit.

IDENTIFICATION

Spot Color Coding This was the original method used to identify welding electrodes. however, it is less commonly seen now.

Code Number Classification This system of classifying welding electrodes was established by the C.S.A., A.W.S. and A.S.T.M. and is widely accepted by most manufacturers.

The code is interpreted as follows.

1. The letter E preceding the number designates an electric arc welding rod.
2. The first two numbers (in a four digit code) or three numbers (in a five digit code) represent the minimum tensile strength of the deposited metal in thousands of pounds per square inch.

   Thus:

   E6010 designates an electrode having 60,000 psi minimum tensile strength.

   E11015 designates an electrode having 110,000 psi minimum tensile strength.

3. The second last digit denotes the welding positions in which the electrode may be operated satisfactority:

   Exx1x indicates all positions.

   Exx2x indicates flat positions only.

   Exx4x indicates vertical downhand positions.

4. The last digit has no consistent significance on its own, but the welder through experience can learn to recognize how it expresses (alone, or in conjunction with the preceding digit) certain characteristics of the flux, e.g. compatible polarity, weld penetration, bead features, contour, etc.

Table 8-3 indicates by electrode classification the type of current recommended, welding position, type of flux coating, surface appearance of the deposited weld and the type of slag produced.

SPECIAL CONSIDERATIONS IN SELECTING AND USING WELDING RODS

Stainless Steel Corrosion-resisting chromium and chromium nickel steel can be classified under the general heading of stainless steel Select electrodes to weld stainless steel with caution since the chemistry of stainless steel is complex and the type of electrode should be matched to the parent steel to achieve a weld with the desired mechanical properties. If the wrong electrode is used, the deposited weld and heat affected zone may lose its corrosion-resistant properties The welder should check the specifications of the steel and seek advice in selecting a suitable electrode.

Because of the high cost of stainless steel, carbon and low alloy steel covered or clad with stainless steel is often used to reduce the cost. Joint preparation and the welding procedure must conform to manufacturer's specifications.

Surfacing Metal Arc Electrodes are most frequently used to improve impact wear resistance or abrasion resistance of material by fusing layers of weld metal to the surface. The mining industry relies heavily on this welding procedure to renew heavy duty equipment using Tungsten Carbide, Manganese and Chromium-Carbide electrodes in various combinations.

Nickel and Nickel Alloy Electrodes are mainly used for welding nickel and its alloys in areas where gaseous or fluid acid represents a corrosion hazard or where the service temperature may be below freezing. Nickel electrodes are also used in welding cast iron since they resist carbon "pick-up" and therefore produce a relatively ductile weld.

Aluminum and Aluminum Alloy Electrodes are almost exclusively welded by the Metal Inert Gas and Tungsten Inert Gas processes described in this chapter.

Small maintenance or repair welds may be carried out by the stick welding process since normal welding machines are conveniently portable. In these cases it is important to follow recommended design procedures. Thoroughly clean surfaces and remove all flux from the weld

TABLE 8-3. ELECTRIC ARC WELDING RODS.

Classification	Current and Polarity	Welding Positions	Type of Covering	Penetration	Surface Appearance	Slag
EXX10	DC, reverse polarity (electrode positive)	All	High-cellulose sodium	Deep	Flat, wavy	Thin
EXX11	AC or DC, reverse polarity	All	High cellulose potassium	Deep	Flat, wavy	Thin
E6012	AC or DC, straight polarity (electrode negative)	All	High-titania sodium	Medium	Convex rippled	Heavy
EXX13	AC or DC, straight polarity	All	High-titania potassium	Shallow	Flat or concave, slight ripple	Medium
EXX14	DC, either polarity or AC	All	Iron powder-titania	Medium	Flat, slightly convex, smooth ripple	Easily removed
EXX15	DC, reverse polarity	All	Low hydrogen sodium	Medium	Flat, wavy	Medium
EXX16	AC or DC, reverse polarity	All	Low hydrogen potassium	Medium	Flat, wavy	Medium
EXX18	AC or DC, reverse polarity	All	Iron powder low hydrogen	Shallow	Flat, smooth, fine ripple	Medium
EXX20	DC, straight polarity or AC for H-fillets; DC, either polarity or AC for flat welds	H-fillets and flat	High iron oxide	Medium	Flat or concave, smooth	Heavy
EXX24	DC, either polarity or AC	H-fillets and flat	Iron powder titania	Shallow	Slightly convex, very smooth, fine ripple	Heavy
EXX27	DC, straight polarity or AC for H-fillets; DC either polarity or AC for flat welds	H-fillets and flat	Iron powder [illegible] oxide	Medium	Flat to slightly concave, smooth, fine ripple	Heavy
EXX28	AC or DC, reverse polarity	H-fillets and flat	Iron powder low hydrogen	Shallow	Flat, smooth fine ripple	Medium

after the job. Flux contains corrosive elements that will degrade the weld if allowed to remain when weld-up is complete.

Copper and Copper Alloy Electrodes M.I.G. and T.I.G. processes are preferred in nearly all situations involving copper and copper alloys.

STORING ELECTRODES

Storage requirements for arc welding electrodes are dictated by the properties of the coating or flux on the rods. The manufacturer's specifications must be followed in all cases

Water represents the most significant hazard to electrode coatings, thus exposure to air before use must be restricted for some types of rods, e.g., low hydrogen.

Storage Guidelines

1. Cellulose type coated electrodes can be stored in normal storage bins provided that

the air does not exceed the specified relative humidity.

2 Low hydrogen electrodes require storage in holding ovens to ensure absolutely dry conditions.

If overexposed to air, rebaking according to specifications prior to returning to holding oven will reclaim the rods. Electrodes that have been in direct contact with water must not be used.

VARIATIONS OF ELECTRIC ARC WELDING PROCESS

METAL INERT GAS (M.I.G.) WELDING

This process involves the following principles

1 The heat is generated by an arc between a consumable electrode and the work metal.
2. The electrode (a bare, solid wire) is continuously fed to the weld area.
3. The electrode, weld puddle, arc and adjacent areas of the base metal are protected from atmospheric contamination by a shield of gas (or mixture of gases) fed through the electrode holder or gun.

See Figure 8-32 for the components of a M.I.G. Welding System.

The shielding gas for mild steel welding is usually CO_2; however, for special applications, Argon and Helium, which were originally used for shielding, may still be preferred.

The process is semi-automatic with the operator guiding the weld deposited, but the arc length is automatically controlled and the elclrode or wire is fed continuously.

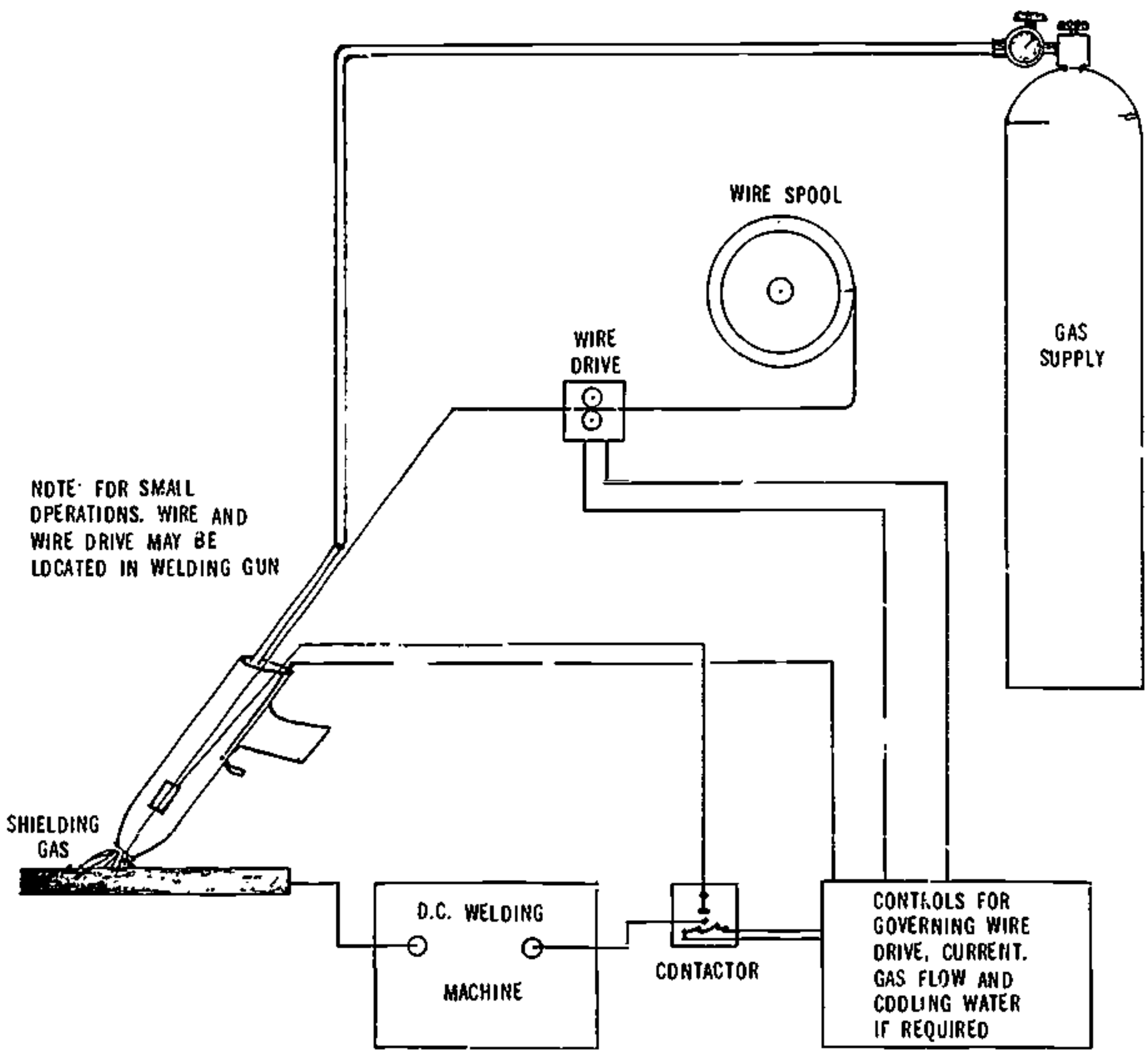


Figure 8-32. Schematic Representation of Components of M.I.G. Welding System

Forms of Transfer of Weld Metal The two main variations in the transfer of weld metal from the wire to the work are:

1. **Spray Transfer** is best suited to large fillet welds on heavier metals (1/16" to over 1" thickness) because its deposition rates are high.
2. **Drop Transfer** is effective on material less than 1/16" thick since heat input is low and distortion therefore minimal.

Use of Flux-Cored Wire Under some circumstances, a flux-cored wire may be used in M.I.G. welding. It has the following advantages over solid wire.

1. It can increase the deposition rate.
2. It gives added protection against atmospheric or local contaminations.
3. It can provide alloying elements to the weld.
4. It is preferred to gas shielding in construction work when windy conditions prevail.

The M.I.G. welding process has seen its greatest development since 1955 because of its speed, greater deposition rate and acceptance by quality control agencies. For these reasons it is claiming an increasing share of the welding market.

TUNGSTEN INERT GAS (T.I.G.) WELDING

This process was introduced in the early 1940s for fusing materials that had been classified as difficult to weld. The process involves the following principles:

1. The heat is generated by an arc between a non-consumable tungsten electrode and the workpiece.
2. Filler metal is added to the molten weld pool manually.
3. Shielding gas, usually pure argon, is introduced through a hollow cylinder that surrounds the tungsten in the T.I.G. "torch." The gas cools the electrode and protects the molten pool from contamination by the atmosphere.

COMPONENTS OF T.I.G. WELDING SYSTEM

1. Torch
2. Power Supply
3. Gas supply
4. Cooling medium

The components of a T.I.G. Welding System are illustrated in Figure 8-33.

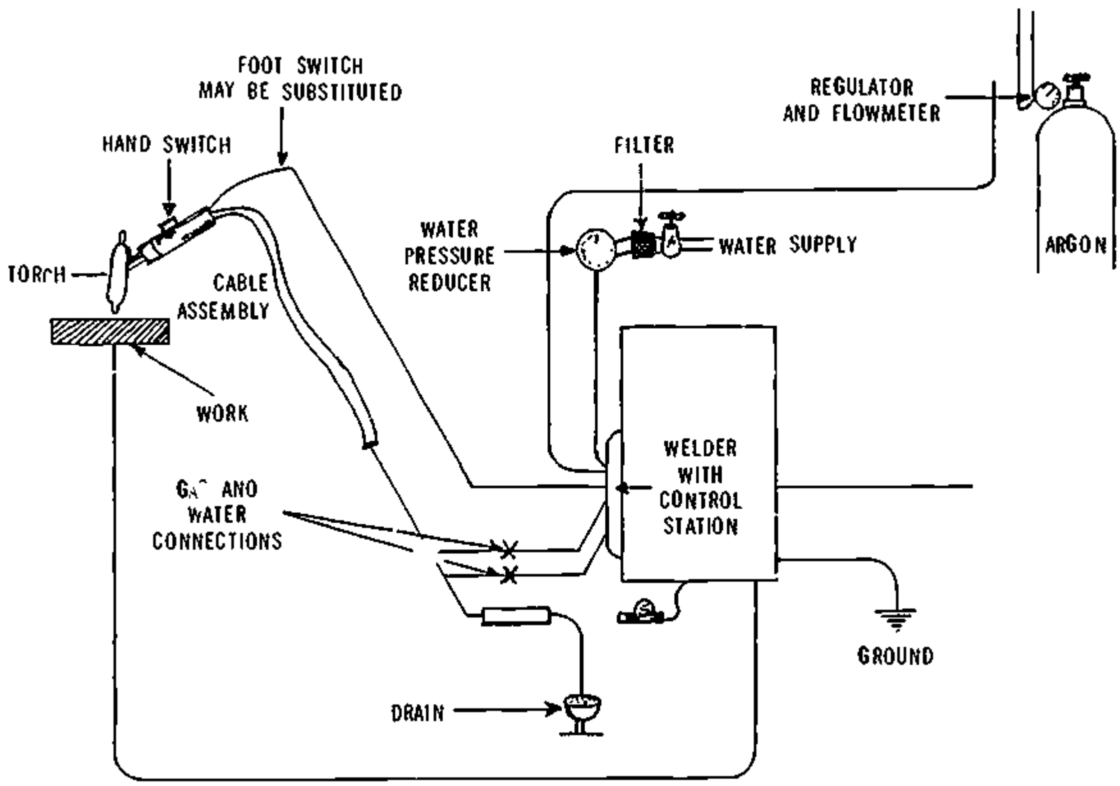


Figure 8-33. Schematic Representation of Components of T.I.G. Welding System

Torch The basic features of the T.I.G. torch are illustrated in Figures 8-34. The torch may be air cooled or water cooled. Air cooled torches are used for thin gauge applications while water cooling is necessary for thicker and more general applications

The air cooled torch comprises a holder in which a tungsten electrode is held centrally in a ceramic nozzle. The electric current and inert gas are conducted through a flexible compound cable to the torch head. The water cooled torch is suitable for currents up to 350 amps. Both the torch and welding cables are water cooled, enabling the size and weight of the metal parts to be reduced. Automatic heavy duty applications equipment is available for amperages up to 600 amps

Power Supply The power supply may be

1 Direct current supplied by either a generator or rectifier
2 Alternating current supplied by a transformer. this unit requires a high frequency feature that assists in striking and maintaining the arc

The selection of power supply depends upon the material to be welded and its thickness, as specified in Table 8-4

TABLE 8-4. POWER SUPPLY IN T.I.G. WELDING

METAL OR ALLOY	RECOMMENDED CURRENT SOURCE		
	A.C.H.F.	D.C.S.P.	D.C.R.P.
Magnesium	A	X	C
Aluminum	A	X	
Aluminum Bronze	A	X	
Beryllium Copper	A	X	
Brass	A	A	
Copper	B	A	
Inconel	C	A	
Monel	C	A	
Nickel	C	A	
Silicon Bronze (Everdur)	B	A	
Stainless Steel	A	A#	
Steel	A	A#	

— DCSP preferred on material thicknesses over 14 gauge

ACHF — Alternating Current High Frequency
DCSP — Direct Current Straight Polarity
DCRP — Direct Current Reverse Polarity

A — Excellent operation
B — Good operation
C — Fair operation
X — Not recommended

Gas Supply The inert gas is usually supplied in cylinders. unlike the familiar oxy-acetylene cylinders. the regulator must also incorporate a

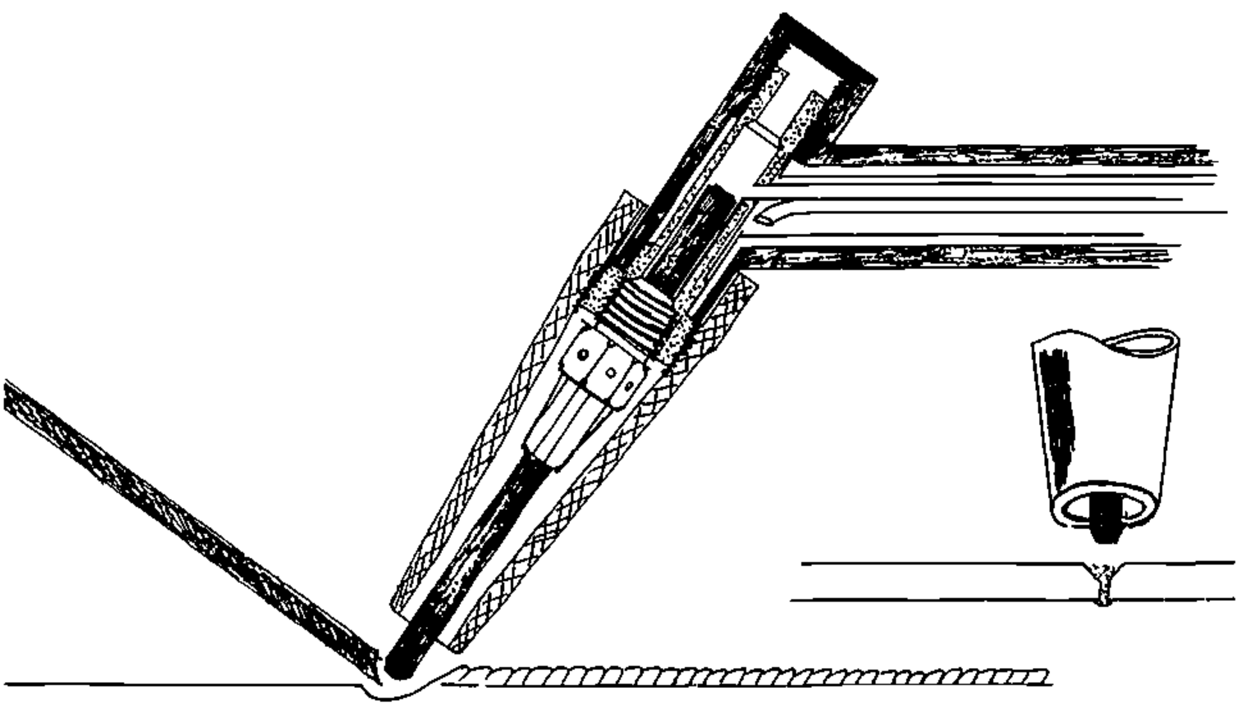


Figure 8-34. T.I.G. Torch

flowmeter to indicate the flow of shielding gas in cubic feet per hour The gas is normally Argon or Helium (hence the expression Heliarc Welding), it may also be a combination of these, or either gas mixed with oxygen or carbon dioxide The gas is not chemically invulved in the welding process, but shields the molten metal from atmospheric pollution.

Cooling Medium On thinner gauge metals requiring relatively low amperage below 200, no additional cooling medium is required for the torch or electric cables. For amperages up to 350 on manual operation, water cooling is required to protect the torch and to reduce effectively the size of cable required, thereby making it more flexible and easier to manipulate.

Joint Preparation Joints for T.I.G. welding is essentially the same as for other welds, however, due to the high localized heat, less land is required.

Advantages of T.I.G. Welding Process T I.G. welding has many advantages over other processes, especially in joining non-ferrous metals

1. The completed weld is usually more ductile than the conventional welds.
2. The welds are generally more corrosion-resistant.
3. Since no flux is used, there are no fumes or spatters; thus finishing of the weld is negligible.

Disadvantages of T.I.G. Welding Process

1. Equipment is costly
2. Effects of ultra-violet radiation represent a hazard to welders if the skin is not completely and adequately covered.
3. Outdoor operation of the process is often impractical because it is difficult to exclude all drafts from the weld area. For effective T.I.G. welding, the inert gas should be protected from dispersing drafts or the shielding effect is lost.

OTHER ELECTRIC ARC WELDING PROCESSES

Submerged Arc Weldfng In this process, a bare filler wire is fed continuously from a coil through a welding head and a heavy layer of flux (about 1" deep) is deposited separately just ahead of the welding arc. The welding arc is submerged under this flux blanket

This process allows for currents greater than 2,000 amperes to be used, and produces high quality welds on very thick plates. The process is usually fully automatic, but may be adjusted for semi-automatic operation.

Electro Slag Welding This welding process permits full thickness welds with a single pass in vertical joints. With the proliferation of nuclear power plants, it is expected that this process may be preferred to others for fusing the thick sections that house the power plant

Plasma Arc Welding This is an extension of the T.I.G. process in which temperatures as high as 90,000°F are generated.

Carbon Arc Welding This process, developed many years ago, has largely been replaced by the various forms of metal electrode welding.

Atomic Hydrogen Welding In this process, the heat source is a gas-shielded arc between two electrodes; however, M I G or T.I G. techniques are more commonly used for welding jobs of this type.

Arc Stud Welding This process is often applied in the Boilermaking trade for attaching fasteners to a variety of equipment

Arc Spot Welding This welding process is limited to thin plate and therefore is little used in the Boilermaking trade.

SAFETY GUIDELINES FOR ELECTRIC ARC WELDING

Electricity, like fire, is a good servant but a bad master. In arc welding operations where certain energized parts are exposed, a welder must be especially careful to observe relevant safety rules to ensure maximum personal safety to protect those working near him and to safeguard equipment.

1. Arc welding equipment operates with high voltage and therefore must be handled with extreme care.
2. Repairs or alterations to arc welding equipment must be made **only** by a qualified technician.
3. Since arc rays can cause painful burns.

make sure before starting a job that your face shield is free of defects.

4 Terminals for welding leads should be protected from accidental electrical contact by personnel or metal objects, e.g. hooks, shackles, chains, chokers, etc.

5. Input power terminals, tap change devices and live metal parts connected to input circuits must be completely enclosed and accessible only with tools.

6 No connections for remote control boxes are to be connected to an A.C. source higher than 120 volts

7 Blow out the entire welding machine with clean, dry compressed air when accumulated dust is visible.

8 Be sure your welding machine is properly grounded

9 Avoid standing on damp ground when operating the welding machine.

10 Do not overload cables or operate without tight-fitting connections.

11 Never change the polarity switch when the machine is under load.

12 Warn all persons in close proximity without eye protection when you are going to strike an arc — "Watch Your Eyes!"

13. Test welding heat on a piece of scrap metal, never on a compressed gas cylinder.

14 Do not lay your electrode holder down in such a way that a short circuit or contact can be made with surrounding metal.

15 Never weld a tank, pipeline or portable container without making **absolutely certain** that it is free of **any** explosive vapors.

16. Welding should not be completed on the outside of a closed vessel until an opening of some sort has been made in the vessel.

17 Where welding is done inside any enclosed space, use blowers or leave an opening in the top for adequate ventilation.

18 When chipping slag, eye protection must be worn.

SAFETY GUIDELINES FOR G.M.A.W. AND T.I.G. WELDING

1. Flash goggles (#2) should be worn under the welding shield while welding is in progress.
2. The skin should be completely covered, since a higher intensity of ultraviolet rays are generated by these processes. Cotton clothing should be covered with leathers to prevent deterioration from these rays.
3. Avoid inhalation of fumes from these welding processes through the provision of adequate ventilation.
4. The welding machine supplying power to the arc must always be turned "OFF" whenever changing electrodes in tungsten arc electrode holders or when threading coiled electrodes into consumable electrode equipment.
5. Place an electrode holder when not in use so that it will not make contact with persons, conducting objects, fuel or compressed gas tanks.
6. Electrodes in wire form for semi-automatic holders should be retracted or cut off when not in use to remove possibility of contact.
7. Remove or retract tungsten electrodes within the holder when not in use.
8. Cooling water, shielding gas and engine fuel must not be allowed to leak.

OXY-ACETYLENE WELDING

As a method of joining metals, the oxy-acetylene welding process has in most instances been replaced in recent years by the arc processes.

Advantages of Arc Welding

1. Faster
2. More productive on thicker sections
3. Produces less distortion.

Uses for Oxy-acetylene Welding

1. Joining thin sections of metal (less than 1/8")
2. Hard surfacing
3. Brazing
4. Bronze welding
5. Special design applications

On small jobs, the portability of oxy-acetylene equipment represents a significant advantage. Oxy-acetylene cylinders in small backpacks can be carried to locations where transporting electrical generating machines or providing great distances of cable to provide power for transformer welders would be impossible or impractical.

Oxy-acetylene welding is a useful approach in training novice welders to recognize the characteristics of molten metal that are not observable in the arc processes because of the flux shield. By practicing oxy-acetylene welding, the welder can learn to handle the molten pool (a critical skill in positional welding) and to recognize defects as they occur (porosity, slag holes, etc.).

Figure 8-35 illustrates the parts of the oxy-acetylene welding torch.

TYPES OF OXY-ACETYLENE FLAME

The variations in welding flames are obtained by altering the oxygen and acetylene ratio as it is supplied to the blowpipe

Neutral Flame The neutral flame (Figure 8-36) is obtained by an approximate one to one mixture of oxygen and acetylene The characteristics of the neutral flame are

1 Absence of sparks
2. Quiet flame
3. Temperature of approximately 6,000 F
4 Due to almost perfect combustion of both gases, the weld does not pick up either oxygen or acetylene which can cause serious defects in certain metals.

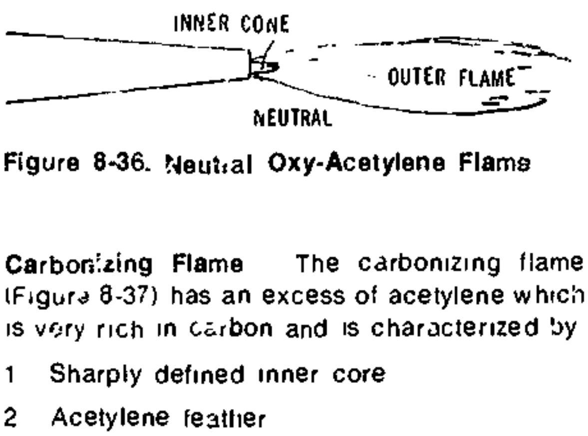


Figure 8-36. Neutral Oxy-Acetylene Flame

Carbonizing Flame The carbonizing flame (Figure 8-37) has an excess of acetylene which is very rich in carbon and is characterized by

1 Sharply defined inner core
2 Acetylene feather
3. Outer flame
4 Production of brittle welds in steel which tend to crack or shear (due to affinity which molten steel has for carbon)
5. Useful for hard surfacing on non-porous metals

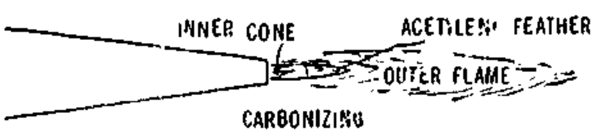


Figure 8-37. Carbonizing Oxy-acetylene Flame

Oxidizing Flame The oxidizing flame (Figure 8-38) is the least used of the three flames and is characterized by

1. Shorter flame
2. Sharper inner core
3. Temperature exceeds 6,000°F due to excess of oxygen
4. Weld quality often poor as a result of oxygen pick-up by most metals
5. Useful for brass and for braze welding

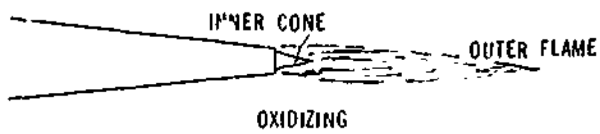


Figure 8-38. Oxidizing Oxy-Acetylene Flame

EQUIPMENT FOR OXY-ACETYLENE PROCEDURES

Figure 8-39 illustrates equipment for oxy-acetylene procedures.

Acetylene Cylinder Acetylene is stored in cylinders (never above 15 psi) packed with a porous substance filled with acetone. Acetone absorbs acetylene in a 20 1 volume ratio The acetylene is drawn off through a valve that releases maximum pressure after 1 1/2 turns. Safety fuse plugs are set into the bottom of the cylinder

Oxygen Cylinder Oxygen is supplied in heavy cylinders under 2200 psi (at 70 F) The valve is a high pressure mechanism with a rupture disc as a safety feature. When the cylinder is in use, the valve should be completely opened to prevent leakage of oxygen around the stem.

Regulators A regulator is a mechanism attached in the gas line between the cylinder and the gas conducting hose. It has the dual function of reducing high cylinder pressure to a lower working pressure and maintaining that desired working pressure at a constant level during the welding or cutting operation.

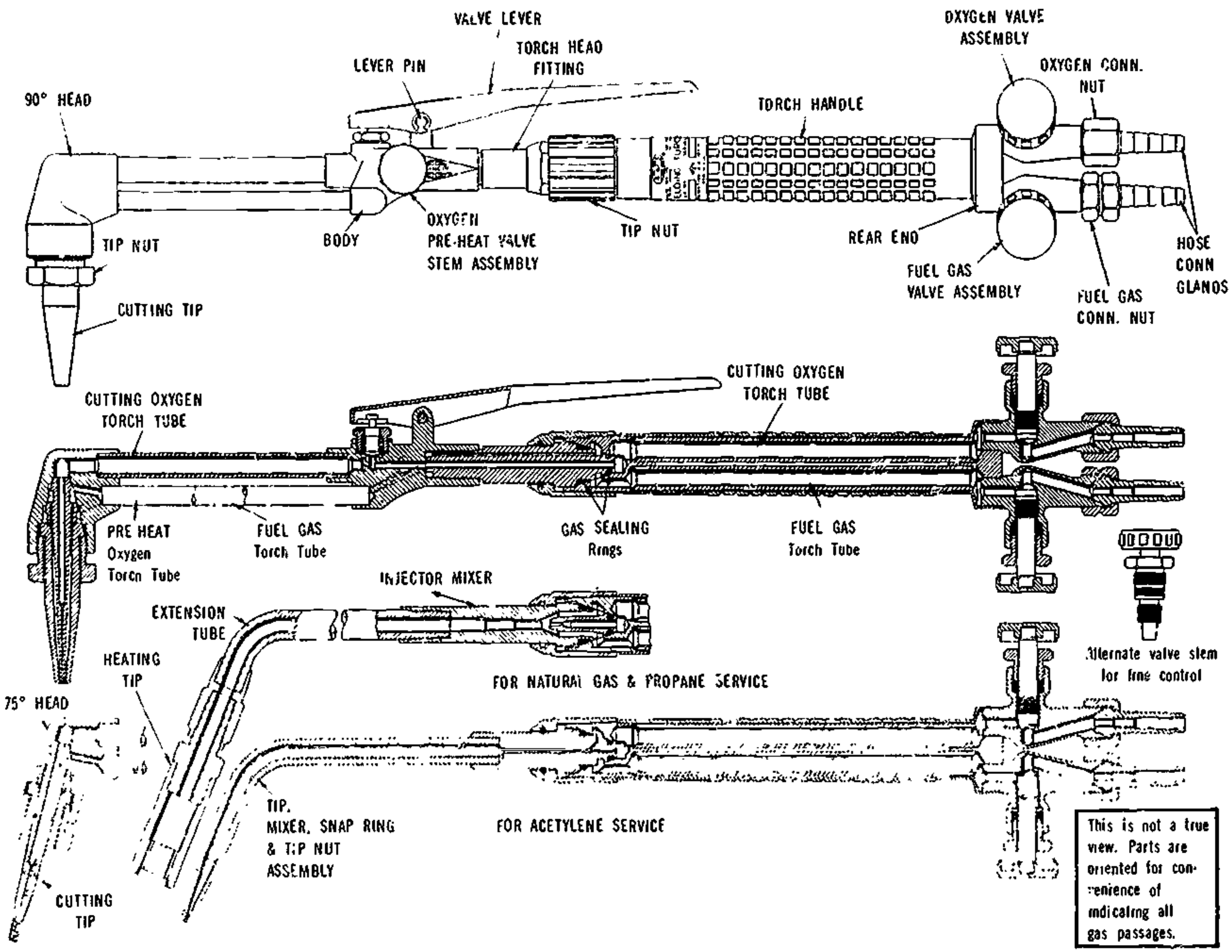


Figure 8-35. Parts of The Oxy-Acetylene Welding Torch

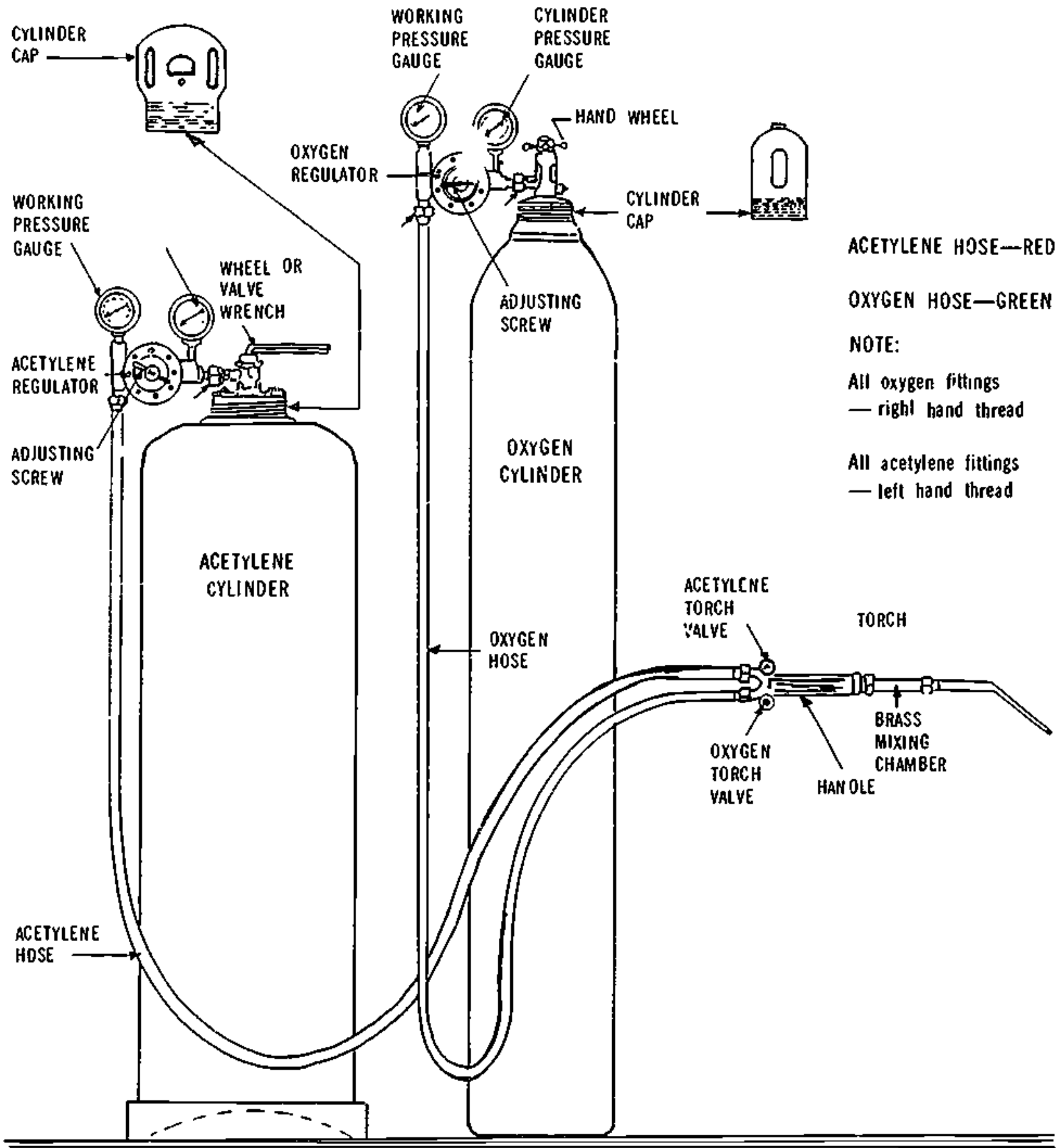


Figure 8-39. Schematic Representation of Equipment for Oxy-Acetylene Procedures

There are usually two gauges on the regulator one showing the working pressure at the tip, the other showing the pressure remaining in the cylinder

Hoses Hoses for gas cutting and welding are color-coded red for fuel gas and green for oxygen **Under no circumstances** must these hoses be interchanged. Hoses are supplied in standard sizes of 3/16", 1/4", 3/8" and 1/2". They are available as single line or double line (green oxygen hose jointed or moulded to red fuel hose).

A further safety feature identifying oxygen and fuel lines is noted in the fittings used oxygen nuts are smooth and have a right hand thread while fuel nuts are grooved and have a left hand thread.

Torches and Tips Design features of torches and tips are described below in the sections on flame cutting and welding

Torch lighter Oxy-acetylene torches should always be lit using a friction lighter. **never matches** or **burning paper.** Friction lighters ignite the torch with a spark rather than an open flame and are available as simple flint-and-steel types or pistol grip spark lighters.

Goggles Eye protection is required for oxy-acetylene procedures and is described in detail under "Safety Guidelines for Oxy-acetylene Procedures"

SETTING UP OXY-ACETYLENE EQUIPMENT

Step 1. Secure cylinders in an upright position.

Step 2. Crack cylinder valves to clean out dirt and water. Stand clear when first releasing valves.

Step 3. Attach regulators. Make certain that regulator adjusting screws are loose (in the turned out position).

Step 4. Attach hoses to regulators.

Step 5. Open cylinder valves slowly (again, stand clear when releasing valves):
Acetylene — 1 1/2 turns maximum. 1/2 turn normally sufficient
Oxygen — all the way

Step 6. Turn in regulator adjusting screw to blow out hoses; then turn out adjusting screw again.

Step 7. Attach torch handle.

Step 8. Attach proper size tip: select from torch manufacturer's chart.

Step 9. Set correct working pressures. Turn in the regulator adjusting screws until pressure shows on working pressure gauge.

Step 10. Test for leaks. Check supplier's manual for instructions.)

Step 11. Open acetylene needle valve on the torch handle 1/4 turn and ignite with spark lighter. Adjust for smokeless flame.

Step 12. Open oxygen needle valve on torch handle and adjust until desired flame is present.

Note: Acetylene is **always** turned on and off first.
Always use proper size wrench: **never** use pliers to make connections.

DISASSEMBLING OXY-ACETYLENE EQUIPMENT

When welding or cutting is to be stopped, close the blowpipe acetylene valve, then the blowpipe oxygen valve.

When the welding or cutting is to be stopped for a considerable period of time (as for a meal period or overnight), the cylinder valve should be closed and all gas pressures released from the regulators as follows:

Step 1. Close the oxygen cylinder valve.

Step 2. Open the blowpipe oxygen valve to release all pressure from the hose and regulator.

Step 3. Turn out the pressure-adjusting screw of the oxygen regulator.

Step 4. Close the blowpipe oxygen valve.

Step 5. Close the acetylene cylinder valve.

Step 6. Open the blowpipe acetylene valve to release all pressure from the hose and regulator.

Step 7. Turn out the pressure-adjusting screw of the acetylene regulator.

Step 8. Close the blowpipe acetylene valve.

SAFETY GUIDELINES FOR OXY-ACETYLENE PROCEDURES

Oxygen

1. Always call oxygen by its proper name.
2. Keep oil and greasy substances away from oxygen cylinder, valves, hoses and fittings since violent explosion may result if these petroleum products ignite.
3. Always use oxygen through an oxygen regulator, and, to avoid damaging the mechanism from a sudden burst of high pressure, open the valve slowly at first.
4. Faulty regulators should be tagged and returned to the supplier immediately, only the supplier can repair these gauges safely

Acetylene

1. Always call acetylene by its proper name; it is very misleading to refer to acetylene as "gas."

2. Storage precautions for cylinders:
   a. Store away from sources of heat.
   b. Do not store near combustible materials such as oil.
   c. Ensure that storage area is ventilated, protected and dry.
3. Handle cylinders carefully to prevent damage to fuse plugs, gauges, etc.
4. Use warm water only (never boiling water) to thaw an outlet valve that is "iced."
5. If a cylinder is leaking, remove it to well ventilated location, affix warning signs close by, tag it and arrange for return to supplier.
6. Open cylinder valve only 1 1/2 turns.
7. If acetylene consumption will exceed 1/7 of the rated capacity of the cylinder during one hour of use, use a manifold system.

Cylinders

1. Store cylinders in approved locations, protected from extremes of temperature, dampness, traffic. This area should not store other material or supplies.
2. When cylinders are not in use, replace valve protection caps.
3. Never use cylinders as rollers or supports even if empty.
4. Use a cylinder cart if possible; otherwise lash cylinders securely to a stationary object to maintain them in a vertical position.
5. Keep cylinders located some distance from electrical wiring, welding or cutting work.
6. Always close cylinder valves when work is finished.

Regulators

1. Never use oil on regulators.
2. If regulator is in need of repair (e.g. creeping), close cylinder valve and return regulator to supplier.
3. Ensure that the connection between the regulator and the cylinder is sufficiently tight to prevent any gas leakage.
4. When leaving the equipment unused for any period of time, always relieve the regulator adjusting screw to take the tension off the regulating spring.
5. **Never** use acetylene at more than 15 psi.

Hoses

1. Test hoses in water for leaks. Cut out damaged section and reconnect with a corresponding hose coupler.
2. **Never** repair hose with tape.

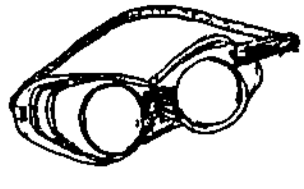
Eye Protection

1. Proper eye protection (face shields, safety goggles, etc.) must be worn for all work involving flying particles, e.g., grinding, chipping, drilling, slag removal or similar jobs. Figure 8-40 illustrates various types of protective eye wear.
2. Colored lenses of approved design must be worn when gas cutting or welding. When arc welding, the operator must use a shield or helmet that will protect both the eyes and the skin of the face and neck. Cover glasses should be changed in the goggles or welding helmets at frequent intervals to maintain clear vision.
3. How to select appropriate shade numbers:
   a. Clear lenses and filter lenses up to and including shade No. 2 may be used for welding.
   b. Shade No. 4 or 5 filter lenses are intended for cutting and oxy-acetylene welding.
   c. Shade No. 6 filter lenses are intended for oxy-acetylene cutting and medium acetylene welding and for arc welding up to 30 amperes.
   d. Shade No. 8 filter lenses are intended for heavy acetylene welding and arc cutting and welding exceeding 30 amperes but not exceeding 75.

UNDERSTANDING AND PREVENTING TORCH LINE EXPLOSIONS

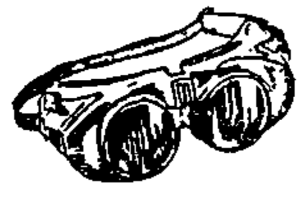
Flashback A flashback is a burning back of the preheat flames inside the equipment. The flames simply disappear, sometimes with a pop, as in the case of a backfire; however, the common flashback signals are:

1. Squealing or hissing noise from inside the blowpipe
2. Sparks coming out of the nozzle
3. Heavy black smoke coming out of the nozzle
4. Blowpipe handle heating up
5. Fire bursting through acetylene hose.



Heavy Impact Goggle

Protection from impact, dust, smoke, cinders and welding glare — May be worn with or without spectacles Not suitable for continuous close-up exposure to welding glare



Burner Goggle

Protection from light and sparks from burning torch, impact, dust cinders, and weld glare May be worn with or without spectacles

Welder Helper Spectacle

Proctection from welding glare Particularly suitable for continuous close-up exposure to welding operations.

General Purpose Spectac'e-Clear

Protection from impact, dust, cinders, and welding glare Not adequate for continuous close up exposure to welding operations

Note Also available in shaded lens and frames

General Purpose Spectacle-Shaded

Similar to General Purpose clear spectacle except shaded lens and frames Protection from sun glare Suitable for rivet heaters and affords some protection from welding glare

Cover-All Plastic Monogoggle-Clear

Protection from impact, dust, and cinders. Soft Vinyl frame readily adjusts to face so this is Particularly suitable for dust protection. May be worn with or without spectacles Does not protect from weld glare.

Note Also available in shaded lens and frames

Figure 8-40. Types of Protective Eye Wear

Flashbacks can cause serious damage to blowpipe, hose and regulators, and must be treated as emergencies.

Causes of Flashbacks:

1. Grossly unequal pressures can result in the higher pressure gas backing up into the lower pressure line. An explosion can occur if the pressure and mixture are right.
2. Mildly unequal pressures plus obstruction (such as tip blockage). Close both needle valves immediately and clean the tip.
3. Failure to purge each line individually before lighting the torch may cause a flashback due to the presence of an explosive mixture in one of the lines. this could result from bumping or dropping the torch, opening the needle valves slightly. Any obstruction of the tip increases the hazard.
4. Faulty manipulation of the valves such as lighting the torch with both needle valves open.

Burnbacks A burnback or pre-ignition is a steady combustion in the tip and mixer resulting in:

1. Black smoke, red sparks and screeching sound from the tip end
2. Torch becomes hot almost immediately.

In burnback the mixture of gases is too lean for proper combustion and the phenomenon differs from flashback in the following ways:

1. Combustion cannot take place without combustible material and supporting air or oxygen. In burnback, the combustion is continuous and therefore could not take place beyond the point of mixing providing the torch, seats, etc. are in good condition.
2. If the gases were mixed beyond the mixer, an explosion would result that would be classed as a flashback.

Causes of Burnback:

1. A hot tip
2. Tip orifices enlarged to a point where the mixer passages will not give an adequate flow of gases
3. Faulty mixer and torch body seats which allow mixing of gases before entering the mixer. Under these circumstances if pressure were sufficiently unequal to cause the high pressure gas to back up the lower pressure hose, a flashback could occur.

Prevention of Flashbacks and Burnbacks The best way to prevent flashbacks and burnbacks is to keep the gases apart:

1. Inspect valves of torch and regulator.
2. To prevent reverse flow in the lines, use a reverse flow check valve if available, and ensure that tips have clear, undamaged openings.

Emergency Response if Flashback or Burnback Occurs Close cylinder valves immediately — acetylene first

Inspection of Equipment Before Re-use

1. Inspect and clean torch tip.
2. Inspect hoses for burn damage, replace as necessary.

FLAME CUTTING

Flame cutting is accomplished by rapid oxidation or combustion of heated steel when a jet of pure oxygen from a cutting torch is directed against it. The cutting process is in two stages

Step 1. A small area of the metal is heated to the kindling temperature (approx. 1600 F.) using a preheating flame

Step 2. A jet of oxygen is directed against the preheated area.

FLAME CUTTING EQUIPMENT

1. Set of oxy-acetylene cylinders
2. Regulators (gauges)
3. Hoses
4. Cutting torch (manual or automatic)
5. Tips
6. Tip cleaners
7. Goggles

FLAME CUTTING TORCH

A cutting torch must be able to regulate and mix oxygen and fuel gas to produce the required flame for preheating the metal, and to direct the oxygen jet stream to complete the cut. Figure 8-41 illustrates parts of the cutting torch.

Manual Torches The oxygen is fed to the hand cutting torch by a single hose, as it enters the torch through the throttle valve, it is divided into two channels

1. To the mixer
2. To the valve controlling the cutting oxygen stream.

MIXERS

The function of a mixer is to meter gases into the mixing chamber. Oxygen and acetylene for preheat are mixed between the torch head and the handle. Two types of mixers are described.

Medium Pressure Mixer The two gases enter the torch at approximately equal pressures and are forwarded to the mixing chamber (Figure 8-42)

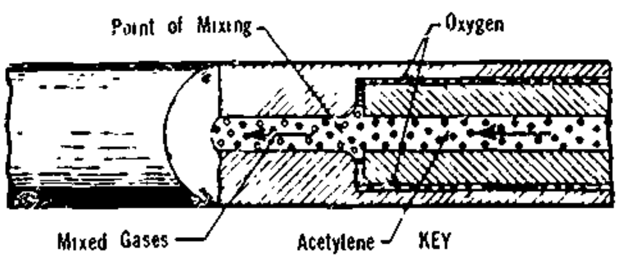


Figure 8-42. Medium Pressure Mixer

Injector Type Mixer Oxygen enters the torch at pressures of up to 60 psi, while fuel gas enters at pressures as low as 1 psi. The ratio of oxygen to fuel is maintained by the oxygen drawing fuel into the mixing chamber; the more oxygen passing through the opening, the more fuel is drawn in. The injector type (Figure 8-43) is used most frequently in shops where fuel gas is supplied at a low gas rate (5 psi or less).

CUTTING TORCH TIPS

Tips are interchangeable end pieces for cutting torches that contain openings for the preheating flame and for the cutting oxygen stream. Tips

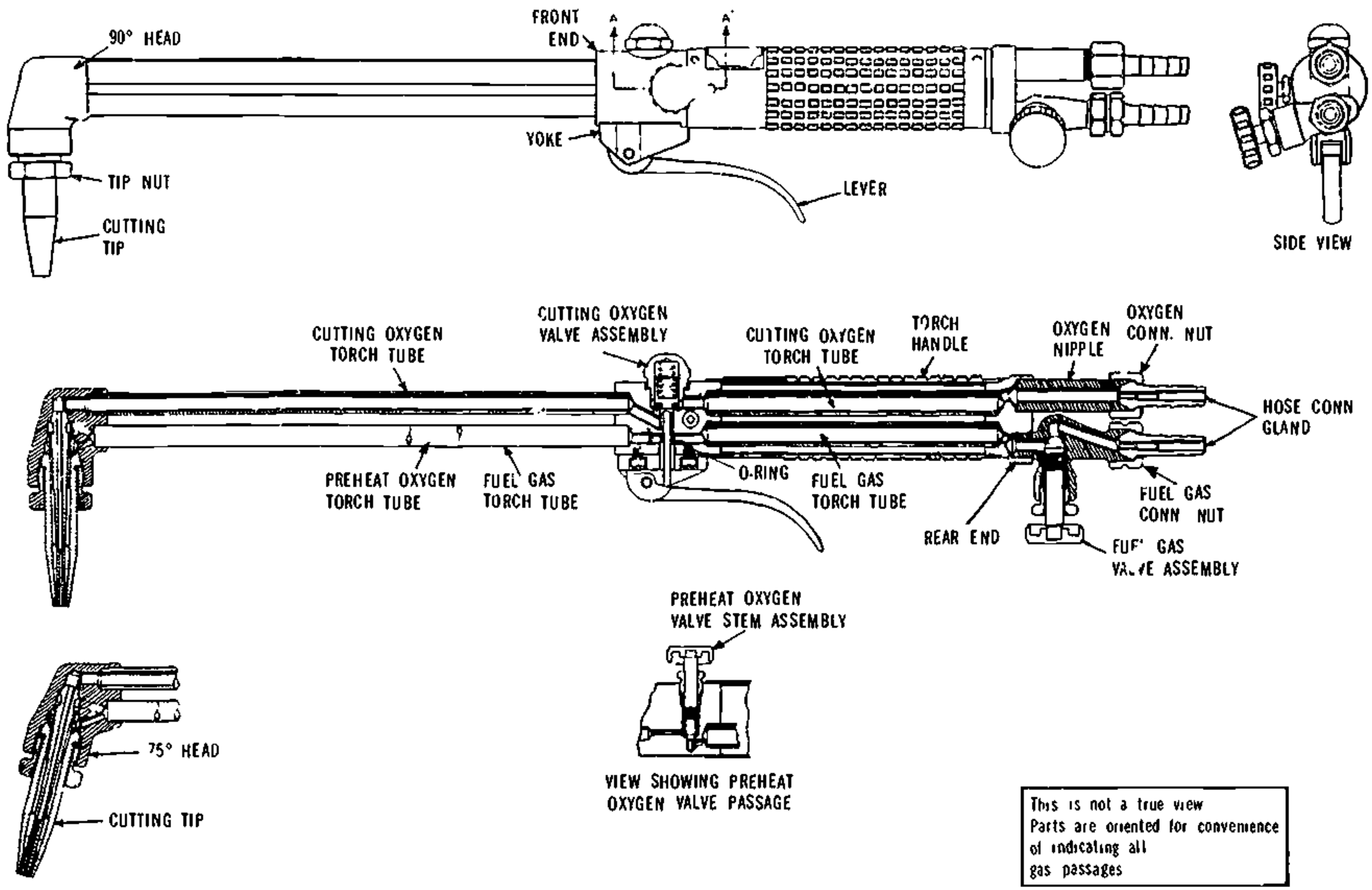


Figure 8-41. Parts of The Oxy-acetylene Cutting Torch

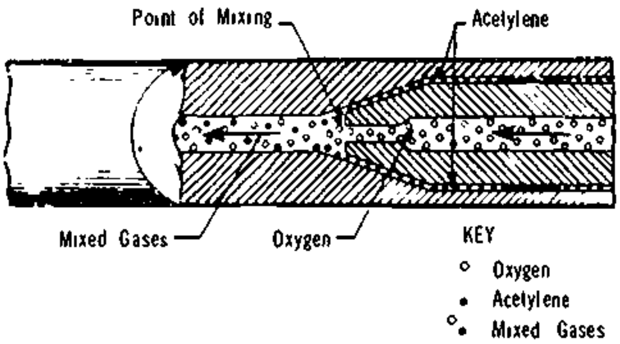


Figure 8-43 Injector Mixer

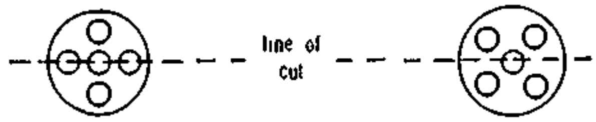


Figure 8-44. Adjustments of Cutting Tips to Alter Alignment of Preheat Openings

are supplied in various sizes and styles to meet different cutting requirements. Torch manufacturers supply their own range of tips, and charts are available that correlate the size of tip, material thickness, recommended pressures for acetylene and oxygen and anticipated consumption of oxygen and acetylene in cubic feet per hour (See Table 8-5).

Cutting tips can be adjusted to produce a desired line of cut as illustrated in Figure 8-44.

Care of Cutting Tips For satisfactory performance, the tips of cutting torches must be clean and in good condition, i.e., the face must be square to the axis of the tip and the holes free of any obstruction.

Cleaning Tip Openings Tip cleaner or drill sets (Figure 8-45) are available and identified by

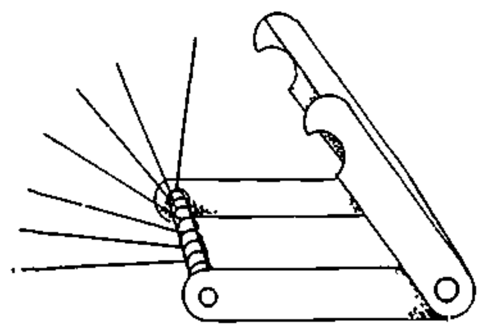


Figure 8-45.

TABLE 8-5. GAS PRESSURE FOR CUTTING WITH SUPER OR STANDARD CUTTING TORCHES AND WELDMASTER CUTTING ATTACHMENT

TIP NO	THICKNESS OF METAL INCHES	ACETYLENE PRESSURE LBS.	OXYGEN PRESSURE. LBS	ACETYLENE CONSUMPTION. CUBIC FEET PER HOUR	OXYGEN CONSUMPTION CUBIC FEET PER HOUR
L 00	1/8	4	10	9 5	35
L-0	1/4	4	15	9 5	40
L I	3/8	4	20	9 5	45
L-I	1/2	4	25	9.5	50
L-2	3/4	5	30	15.3	60
L-2	1	5	40	15.3	100
L-2	1-1/2	5	50	15.3	150
L-2	2	5	60	15 3	200
L-3	3	6	70	25.2	275
L 3	4	6	80	25 2	350
L 3	5	6	90	25 2	425
L-4	6	7	100	27 3	550
L-5	8	7	130	27 3	825
L-6	10	8	150	28.2	1000

NOTE: Consumption of gases given above was taken with flow indicator and estimated for continuous operation of the torch. These figures will seldom be reached in actual practice and are intended for estimating purposes only a number system. All tips, new or used, should have the openings cleaned with an appropriate cleaner before use.

Procedure

Step 1. Select cleaner needle one size smaller than opening. **Do not force larger cleaner needle into opening.**

Step 2. Open oxygen valve slightly to blow out any dirt.

Step 3. Up and down motion must be straight to prevent flaring the opening.

Note: Preheat holes and centre hole for cutting oxygen are all cleaned.

Drills are very brittle, and care must be taken not to apply excessive pressure nor bend them sideways, or they will break in the hole.

FLAME CUTTING PROCESSES

Cutting Thin Metals (Less than 3/16" Thick)

Step 1. Use the smallest cutting tip available.

Step 2. Reduce cutting oxygen pressure to 15 psi.

Step 3. Hold the torch at a very flat angle about 1 1/2" - 2" away from the surface of the metal (Figure 8-46).

Step 4. Complete the cut as quickly as possible to avoid undue melting of the metal.

An alternative technique (Figure 8-47) can be applied to overcome difficulties in following a straight line. Describe an arc while keeping the torch in the same relative position. Only relatively short cuts can be accomplished with this technique.

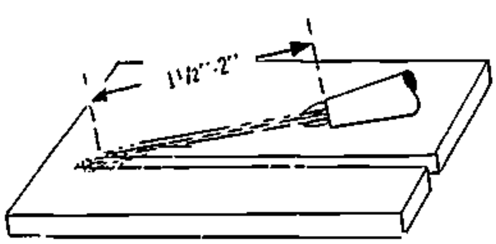


Figure 8-46. Cutting Thin Metals — Angle of Torch

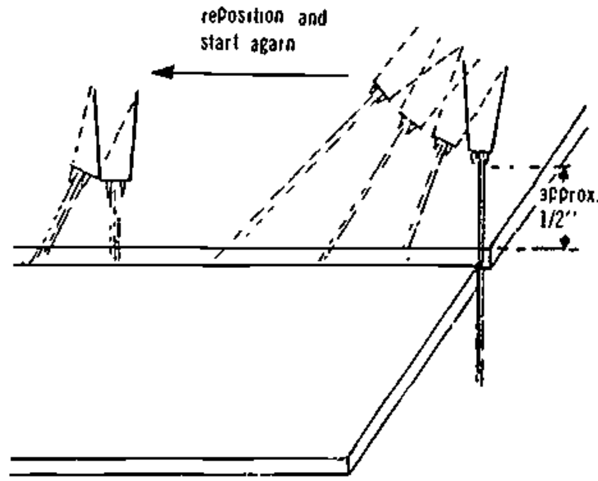


Figure 8-47. Cutting Thin Metals —Alternative Technique

Cutting Medium Thickness Metals (3/16" to 1 1/2")

Step 1. Hold the torch directly above the cutting line and approximately 1/4" to 1/2" from the metal (depending upon the length of the preheat flame).

Step 2. Release the cutting oxygen stream only when the metal has reached proper preheat temperature.

Step 3. Tilt the torch slightly so as to direct the tip toward the forward line of the cut.

Cutting Very Thick Metals (Up to 12")

Step 1. The tip should have a large number of preheat holes and a large centre opening.

Step 2. Hold the torch directly above the cutting line, beginning with the tip tilted opposite to the direction of travel. When the corner has been cut, hold the tip perpendicular to the work for the length of the cut and finally tilt toward the direction of travel to complete the cut through the terminal corner (Figure 8-48).

Cutting Rounds Hold the torch perpendicular to the work for preheating and then move it to a tangential position to begin the cut. To complete the cut, move the torch following the outline of the round (Figure 8-49).

Another method of starting the cut is to raise a chip in the metal with a chisel (or by welding a

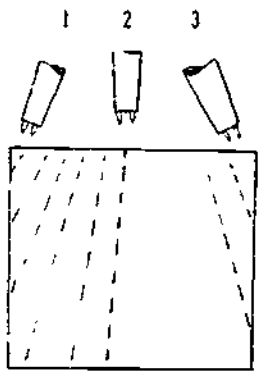


Figure 8-48. Cutting Thick Metals — Position of Tip

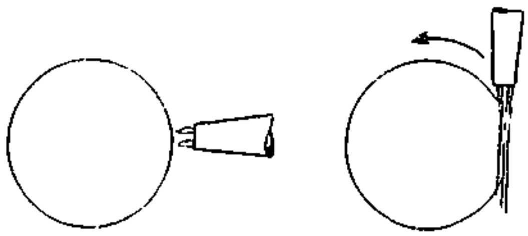


Figure 8-49. Cutting Rounds — Position of Torch

drop of metal on), and use this raised portion to begin the cut (Figure 8-50). To complete the cut, move the torch as shown in Figure 8-47.

Piercing Holes Through Metal Piercing holes requires a great deal of heat and therefore select a tip that is at least one size larger than that recommended for the thickness of the metal.

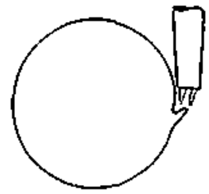


Figure 8-50. Cutting Rounds — Using Raised Chip

Hold the torch perpendicular to the work until preheating is achieved, and then turn the oxygen jet on very gradually. As the cutting oxygen is being fed, draw back the tip from the work just enough to ensure that the slag is not blown back into the tip openings (Figure 8-51).

MACHINE CUTTING

In manual cutting, the torch is advanced and controlled by the operator's hand; thus the quality of the cut largely depends upon the skill of the operator. In machine cutting, the torch is mechanically guided, with the following advantages:

1. Better workmanship
2. More accurate cuts
3. Better overall economy of production.

Stationary cutting machines (Figure 8-52) may be of the single torch or multi-torch design, and are usually equipped with magnetic or electronic tracing devices. The torch or torches mounted on the machine are guided by a

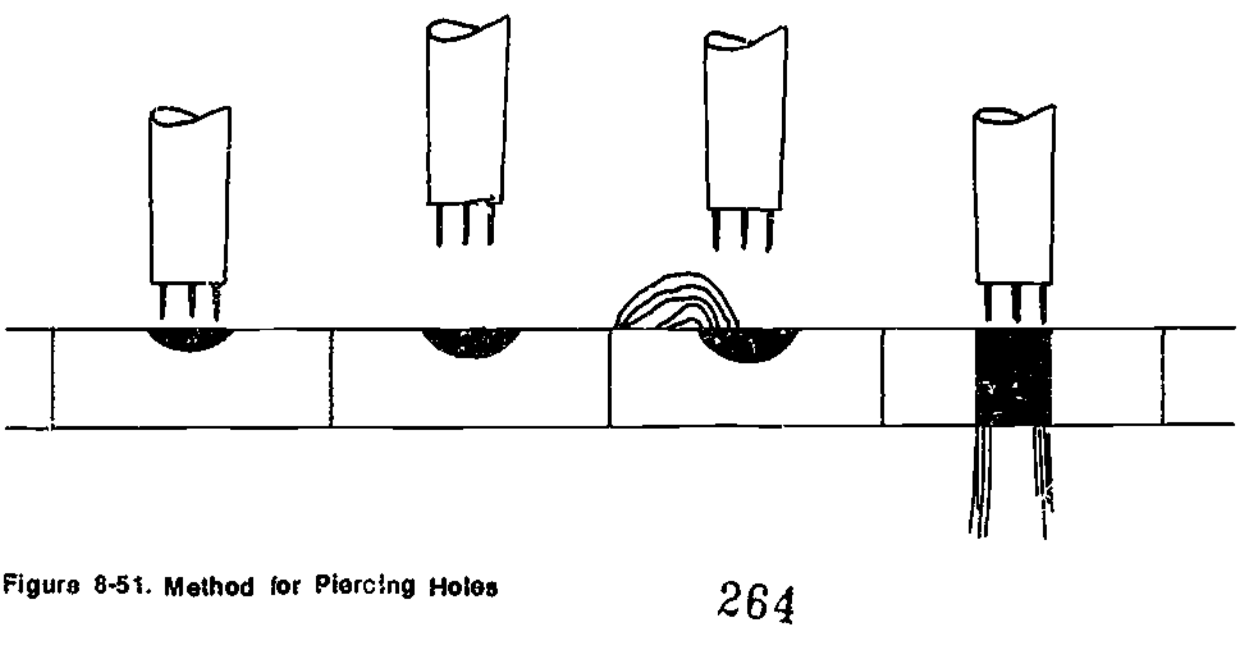


Figure 8-51. Method for Piercing Holes

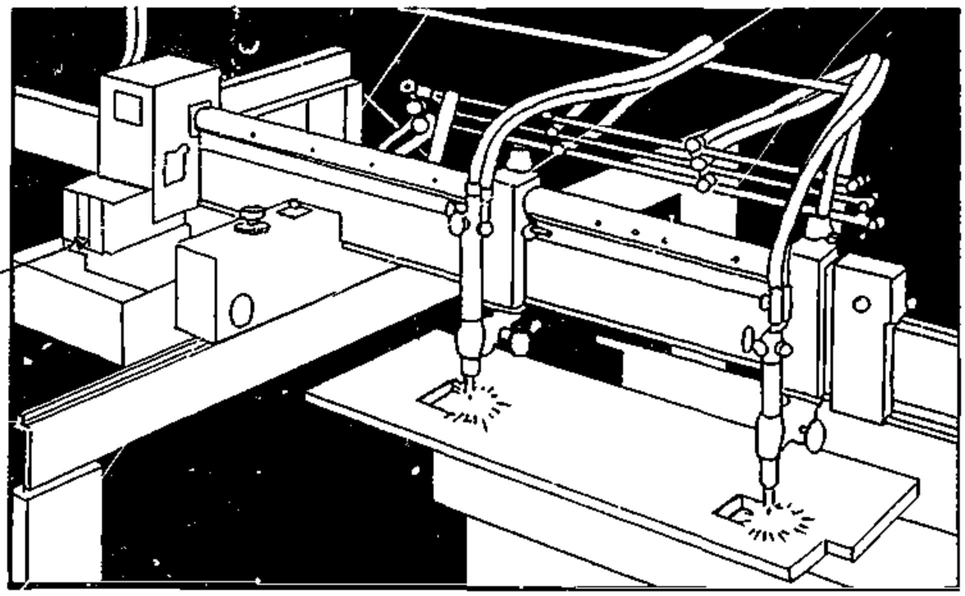


Figure 8-52. Stationary Cutting Machine

ma netic tracing wheel following a model or pattern, or an electronic tracer following a drawing.

Portable flame cutting machines (Figures 8-53 and 8-54) are powered by an electric motor or a gas turbine (oxygen) and may be guided along the line of cut by tracks or manually.

FACTORS AFFECTING QUALITY OF CUT

1. Size of cutting tip (opening)
2. Oxygen cutting pressure
3. Speed of travel
4. Material thickness
5. Type of material
6. Surface condition
7. Amount of preheat
8. Angle of cutting stream to surface
9. Condition of cutting stream opening
10. Condition of the end of cutting tip

COMMON FAULTS IN FLAME CUTTING

The specimen cuts in Figure 8-55 show the results of correct and incorrect adjustments of the cutting torch or cutting machine.

BRAZING AND BRAZE WELDING

Brazing is a method of welding in which two surfaces are bonded by heating to suitable temperatures above 800°F. and using a non-ferrous filler metal whose melting point is below that of the base metals. The filler is distributed between the closely fitted surfaces of the joint by capillary attraction.

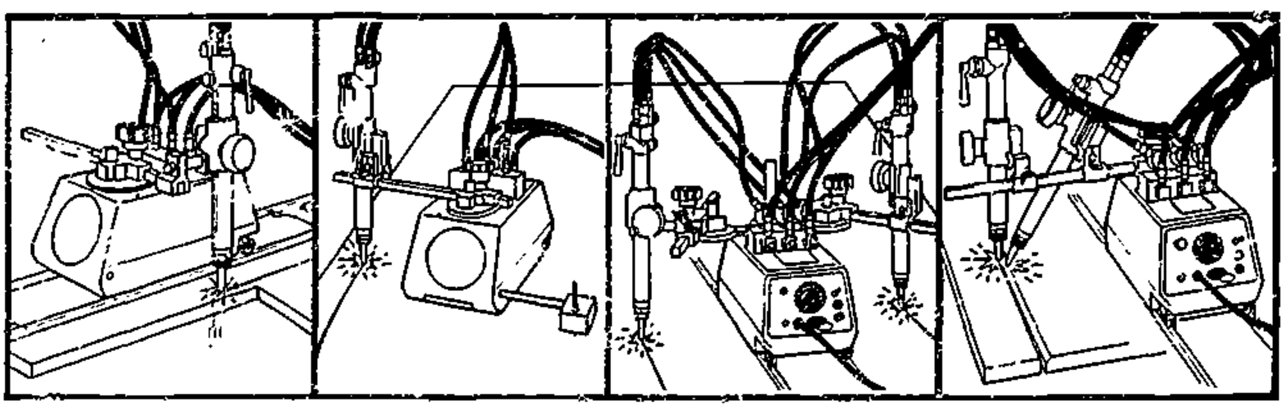


Figure 8-53. Portable Flame Cutting Machine on Tracks

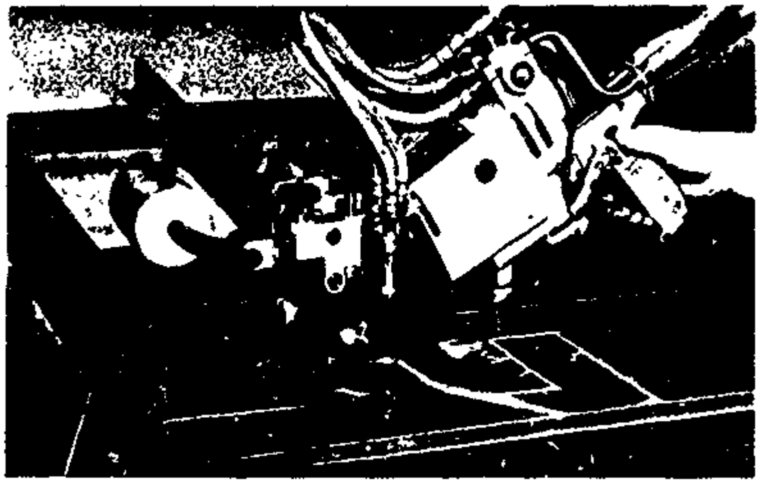
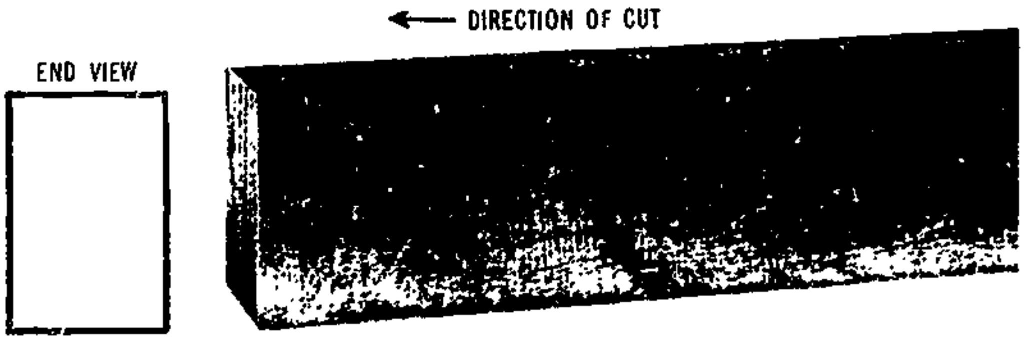
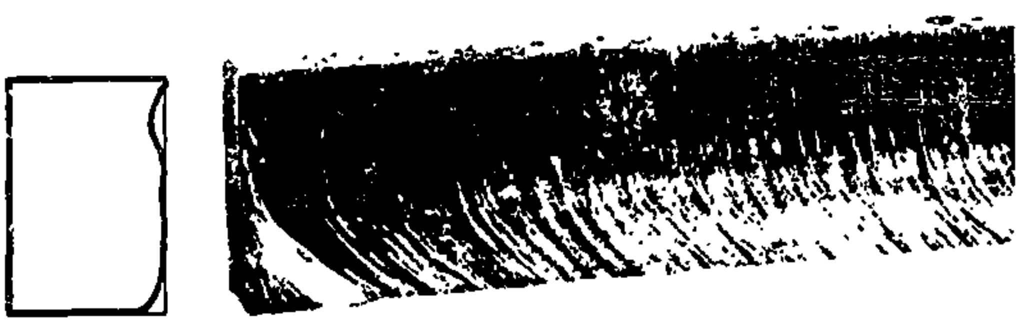


Figure 8-54. Manually Guided Portable Cutting Machine



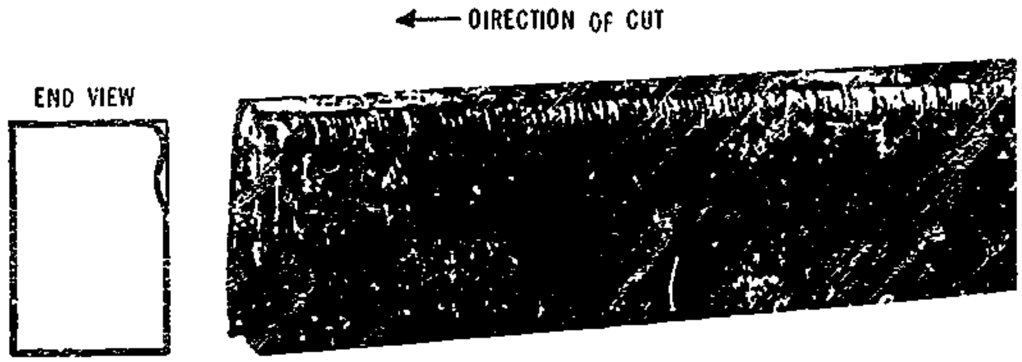
CORRECT ADJUSTMENTS— Top edge sharp. Cut surface smooth, draglines barely visible. Face of cut square. Oxide, if any, easily removed. Bottom edge sharp.

CUTTING SPEED TOO SLOW— Top edge melted and rounded. Face of cut irregular, with deep gouges. Bottom edge very rough and irregular. Possibly oxide tightly adhering to the bottom surface of the plate.



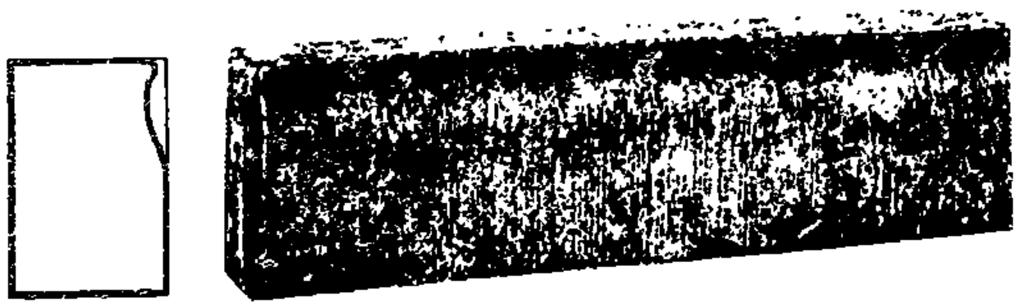
CUTTING SPEED TOO FAST— Top edge fairly sharp but with slight beading. Draglines have pronounced backward rake. Considerable undercutting just below top edge. Bottom edge rounded. Final corner uncut. (continued)

Figure 8-55. Common Faults in Flame Cutting



PREHEAT FLAMES TOO HIGH ABOVE THE WORK— Top edge badly melted and rounded over Slight undercutting just below top edge Face of cut otherwise square. Bottom edge sharp.

PREHEAT FLAMES TOO CLOSE TO THE WORK— Top edge slightly rounded Heavy beads along top edge. Face of cut smooth and square Bottom edge sharp. Could be considered a fairly good cut.



CUTTING OXYGEN PRESSURE TOO HIGH— Even bead entire length of top edge. Considerable undercutting below top edge Noticeable taper from top to bottom of cut. Face of cut smooth. Bottom edge sharp.

PREHEAT FLAMES TOO LONG— Top edge rounded over. Heavy bead entire length of top edge. Considerable taper from top to bottom of cut. Face of cut smooth, with draglines barely visible. Bottom edge sharp

Figure 8-55. Common Faults in Flame Cutting (continued)

Braze Welding is a method of welding whereby a groove, fillet, plug or slot weld is made using a non-ferrous filler metal having a melting point below that of the base metal, but above 800 F. The filler metal builds up in the joint and capillary attraction is not involved.

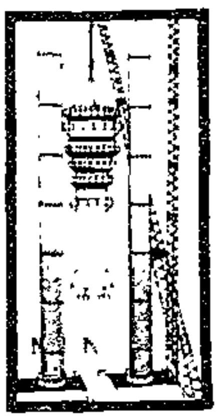
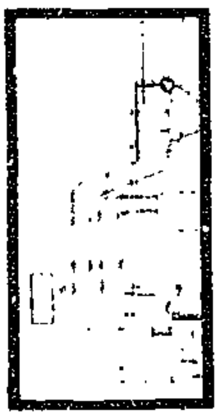
In both brazing and braze welding, metal parts are joined together without fusion of the base metal. The principal advantage of these processes is that the base metal is not melted: this avoids the problems inherent in overheating, especially in thin sections of steel and metals such as cast irons which are subject to cracking during and after fusion welding.

Although there are other types of brazing, only the process using bronze filler rods is discussed here.

PRINCIPLES OF BRAZING AND BRAZE WELDING

1. Base metal is not melted, but is heated to a cherry red heat (an approximation that experience will define more accurately).
2. A filler rod with a flux coating containing tin (if the rod is not pre-coated, an appropriate flux must be added) is applied to the heated surface.
3. The flame is applied to the base metal of the joint and the rod is "brushed" over the heated surface. When the rod melts and flows over the surface, the correct temperature has been reached.
4. The bonding action can be described as a two-stage process where initially the molten tin from the flux bonds to the base metal, and finally the melted bronze fuses to the "tinning."

Chapter 9
QUALITY CONTROL AND INSPECTION

INTRODUCTION

Quality control and inspection are a vital part of every project, large or small. The degree to which a quality control and inspection program is implemented depends upon the governing codes or the project's material specifications. Codes, standards and specifications are usually selected at the beginning of the design stage of each project and are used to determine safe stress levels of the various components and to ensure proper selection of materials for the applications. Some areas of the project may require more stringent quality control and inspection than others. These areas typically include critical welds on boilers, pressure vessels, penstocks, scroll cases, etc. The raw material must also be checked to verify that it has the proper chemical and physical properties required by the governing codes and material specifications. Dimensional tolerances on the raw material, machined parts, assembled units and the completed units also form part of a quality control and inspection program. All quality control and inspection personnel must be qualified and fully trained in the duties they perform. Purchasing personnel must also be part of the quality control program to ensure that all material and consumables they purchase meet required material specifications.

METHODS OF QUALITY CONTROL

Three main methods are used to assure quality control prior to or during a project. The quality control program will usually contain one or more of these methods: Non-Destructive Testing, Destructive Testing or Visual Inspection. The minimum amount of quality control required, using any of these methods, will be specified by the material specifications or governing codes. Additional quality control and inspection procedures may be specified by such certifying agencies as the British Columbia Boiler Inspection Branch, Canadian Welding Bureau, Atomic Energy of Canada or the owner.

ACCEPTANCE STANDARDS

The acceptance or rejection of materials, weldments, machined parts and finished components is generally made by an inspector of the quality control department or by an independent inspection company acceptable to the owner. The inspector accepts or rejects any element of the project in accord with the governing codes or material specifications that apply. Final disposition of non-conforming, unacceptable material, welds or finished components is usually left to the discretion of the engineer, after he has had an opportunity to review the quality control reports. Quality control and inspection personnel should keep a daily report of all inspections for inclusion in the final history docket of the project. Reports should contain sufficient information to identify fully the part being inspected, the stage of completion, the quality of workmanship and comments on any non-conformances relative to the established work procedure or drawings.

NON-DESTRUCTIVE TESTING

Non-destructive testing (NDT) is any method that can be used to examine an item for hidden flaws or discontinuities that may prove detrimental to the intended use of the finished item whereby **the test does not damage or alter the part in any way to affect its function**. The purpose of non-destructive testing is:

1. To determine quality without destroying or altering the properties of the item
2. To separate acceptable from unacceptable material
3. To assure a stock of usable material
4. To eliminate labour on defective materials
5. To indicate corrective manufacturing or fabricating processes.

The decision of when to use non-destructive testing, and the method to be used, is generally specified in a governing code or material specification, but may also be left to the discretion of the contractor and owner. Most non-destructive testing methods are complimentary and do not replace each other. Some methods are better used for detecting surface defects, while others are more applicable to detecting sub-surface defects. No single NDT method gives the best results for all possible defects or discontinuities that are likely to occur. However, usually one NDT method is best suited to detecting particular defect or discontinuity in any given item.

Four principal non-destructive testing methods are used in industry today

1 Radiographic Inspection
2 Ultrasonic Inspection
3 Magnetic Particle Inspection
4 Liquid Penetrant Inspection

Other less frequently used methods such as Eddy Current Inspection. Hardness Testing. Accoustic Emission Testing. Thermal Inspection. and Leak Testing will not be discussed in this manual

RADIOGRAPHIC TESTING

Radiographic testing (RT) is a non-destructive testing method for detecting hidden flaws by using electromagnetic radiation of short wavelengths such as X- or gamma-rays. to penetrate solid materials and be recorded on a photographic-type film This film. when exposed by X- or gamma-rays. and then processed. is called a radiograph. Typical weld and casting discontinuities that can be detected by radiography are incomplete penetration. lack of fusion. slag inclusions and slag lines. burn-through areas. undercut. porosity. gas and blow holes. sand inclusions. shrinkage areas. unfused chaplets and internal chills. Cracks and hot tears that are oriented in the plane of radiation can also be detected The radiograph's ability to show sizes and types of discontinuities depends upon the radiographic technique employed. Discontinuities generally appear as dark areas since they are voids. or as areas of less dense material. which allow more radiation through to expose the film to a higher degree. The radiographic technique employed must take into account the following

1 Type of material radiographed (e g . steel. aluminum)
2 Thickness of the area of interest
3 Variation in geometry
4 Type of weld or joint preparation (such as single-Vee butt. or fillet weld)
5 Extent of the inspection coverage
6 Acceptance standard that must specify the type of discontinuities not allowable. and the length or size of allowable discontinuities.

RADIOGRAPHIC EQUIPMENT

Five main items of equipment are necessary to produce a radiograph

1 Source of radiation
2 Radiography film and holders
3 Lead markers
4 Image quality indicators (penetrameters)
5 Darkroom facilities

Sources of Radiation Two principal sources of radiation are used in industrial radiography the X-ray machine and the gamma-ray radioisotope. X-ray machines produce X-radiation using electrical means They come in all sizes and degrees of portability. but are not generally as portable as gamma-ray equipment. The degree of penetration power (the ability of the X-ray beam to penetrate thicker material sections) and the intensity of the X-ray beam are usually variable within certain limits. The X-rays are produced in an X-ray tube by high speed electrons as they collide with a special target. The target is shaped to beam the X-rays in a suitable pattern or direction for use

Gamma-ray sources of radiation are obtained through the natural disintegration of radioactive isotopes The main isotopes used today are Iridium 192 and Cobalt 60; Both are man-made isotopes produced in nuclear reactors The penetrating ability of gamma-ray equipment is governed by the choice or selection of the radioisotope used. Iridium 192 is better suited for thinner steel thicknesses ranging from 1/2" - 3". while Cobalt 60 is best suited to thickness ranges from 1" - 7" of steel. The strength or corresponding intensity of a radioisotope is determined by the number of curies of radioactive material used to make it (A curie is "that amount of radioactive material which disintegrates at a specified rate ") Since gamma-ray sources are radioactive. they decay and have a finite useful life The source strength and useful life of any radioactive isotope can be determined by its "half life." The half life of a particular radioactive isotope is the time required for one-half of the original radioactive atoms to disintegrate. Therefore. by knowing the half life of the radioisotope and the original number of curies in that source. the source strength at any given time can be determined.

Radioisotopes are usually sealed in a stainless steel capsule. The handling and shielding of radioisotopes is usually accomplished through cable-drive mechanisms attached to the source capsule. or air-operated mechanisms that propel the capsule through special air hoses Radioisotopes are always stored in shielded lead or depleted uranium containers and are only exposed during exposure of a radiograph

Radiography Film and Holders Radiography film differs from photographic film in that it is usually of a much higher quality with finer grains and the negatives are usually coated on both sides The film comes in various sizes and speeds Film emulsions are formulated to be sensitive to X- and gamma-radiation Lower speed films employ very fine grains and therefore provide high contrast which is most likely to impart maximum sensitivity to small discontinuities in the object being radiographed Higher speed films employ larger, coarse, grains that provide less contrast and thus less sensitivity to small discontinuities Since radiography film is also light sensitive, it is placed in light-proof holders called cassettes to protect it when taken out of a darkroom environment Film cassettes can be flexible to allow good contact with contoured surfaces, or they may be rigid for flat surfaces

Lead Markers Radiographs should have permanent identification on them This can be accomplished through lead numbers or letters, which can be placed to produce a permanent image on the radiograph Lead is used since it is generally more dense than most of the materials being radiographed The lead markers appear as white images on the radiograph

Image Quality Indicators (Penetrameters) Penetrameters are used to indicate the degree of sensitivity the radiograph has achieved The penetrameter is usually a thin strip of material, similar to the material being radiographed, with three small holes drilled in it and a corresponding lead number attached Penetrameters come in various sizes and materials. The number on the penetrameter designates the penetrameter's thickness, generally in thousandths of an inch. The diameters of the three holes in the penetrameters are usually equivalent to one, two and four times the penetrameter's thickness. The selection of a penetrameter is usually based on 2% of the total thickness of the area of interest on the specimen being radiographed The number of holes that can be seen on the resulting radiograph indicates the sensitivity achieved

Darkroom Facilities The darkroom facilities required to process radiographic film are similar to those required to process any other black and white negative The chemicals used for processing are generally stronger than those used for ordinary negatives The finished radiographs are viewed on film viewers providing even, white illumination

RADIOGRAPHIC METHODS

The basic principle in making a radiograph involves placing a source of radiation on one side of the specimen, allowing the radiation to pass through the specimen and be projected onto a piece of radiographic film on the other side, thus exposing the film Lead markers and penetrameters are usually placed on the specimen as well so that their images may also be projected onto the film to identify the areas of interest and show the resulting sensitivity or quality of image attained. The time required to expose a film properly depends upon the distance from the source of radiation to the film, the thickness of the specimen, the relative speed of the film and the intensity of the radiation source. Exposure times using X-ray machines are obtained from charts specially prepared for each X-ray machine Exposure times using gamma-ray equipment are usually determined from special slide-rule calculators that take into account all the factors previously mentioned plus the type of radioisotope being used The surface condition of the area of interest in the specimen should be smooth enough to ensure that an uneven surface roughness such as weld splatter, undercut, porosity, arc-gouges or other nicks will not be mistaken for internal defects on the finished radiograph (See Figure 9-1)

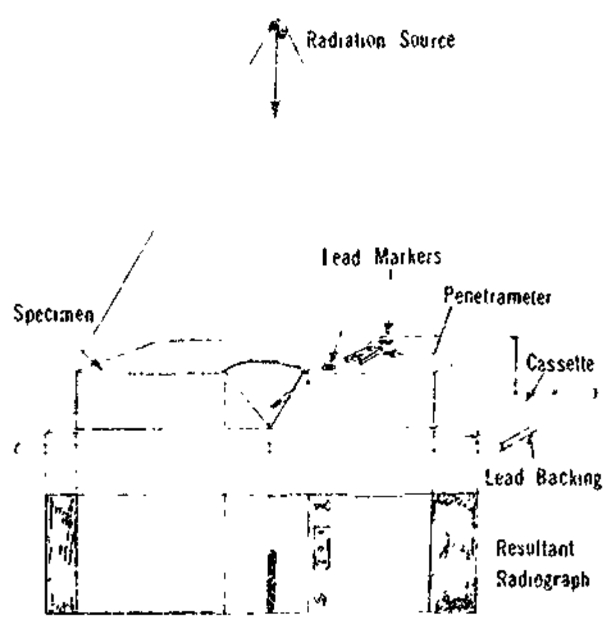


Figure 9-1. Basic Radiographic Principle

The following may be used as a guide in selecting elements for developing individual radiographic methods. If the radiographic inspection (Figures 9-2, 9-3) is being performed under the requirements of a code or customer specification, then most elements and procedures may already be set out.

Selection of Radiation Source The selection of the radiation source depends upon the specimen material, specimen thickness range and the degree of sensitivity required. X-ray machines are generally used for all aluminum and other light alloy materials and for steel thicknesses less than 1/4", however, it should be noted that X-ray machines may also be used for any material and thickness range within the capabilities of the individual X-ray machine. The penetrating power of the X-ray beam can be selected to give optimum results in most situations. It is generally recognized that X-rays, where practical, result in better definition and higher quality radiographs. X-ray machines are not as portable as gamma-ray equipment, since electrical power is required and their physical size makes them difficult to use in confined spaces; in addition, they take more time to set up for each exposure. The penetrating power of X-ray machines can vary through ranges from 1/8" aluminum to 20" steel. The use of gamma-ray equipment is generally more popular (especially in field conditions) because of its greater portability. Gamma-ray radiographs are usually restricted to use on heavier metals such as steel and copper. Iridium 192 radioisotope gives best results in the steel thickness range from 1/2" to 3". Cobalt 60 radioisotope is generally used for steel thicknesses from 1" to 7". Iridium is usually used where thickness in the areas of interest does not vary appreciably or where higher sensitivity is required. An additional consideration is the portability of the equipment. Cobalt 60 is less portable than Iridium 192 due to the heavily shielded container used to store the Cobalt 60 source which has a higher penetrating ability.

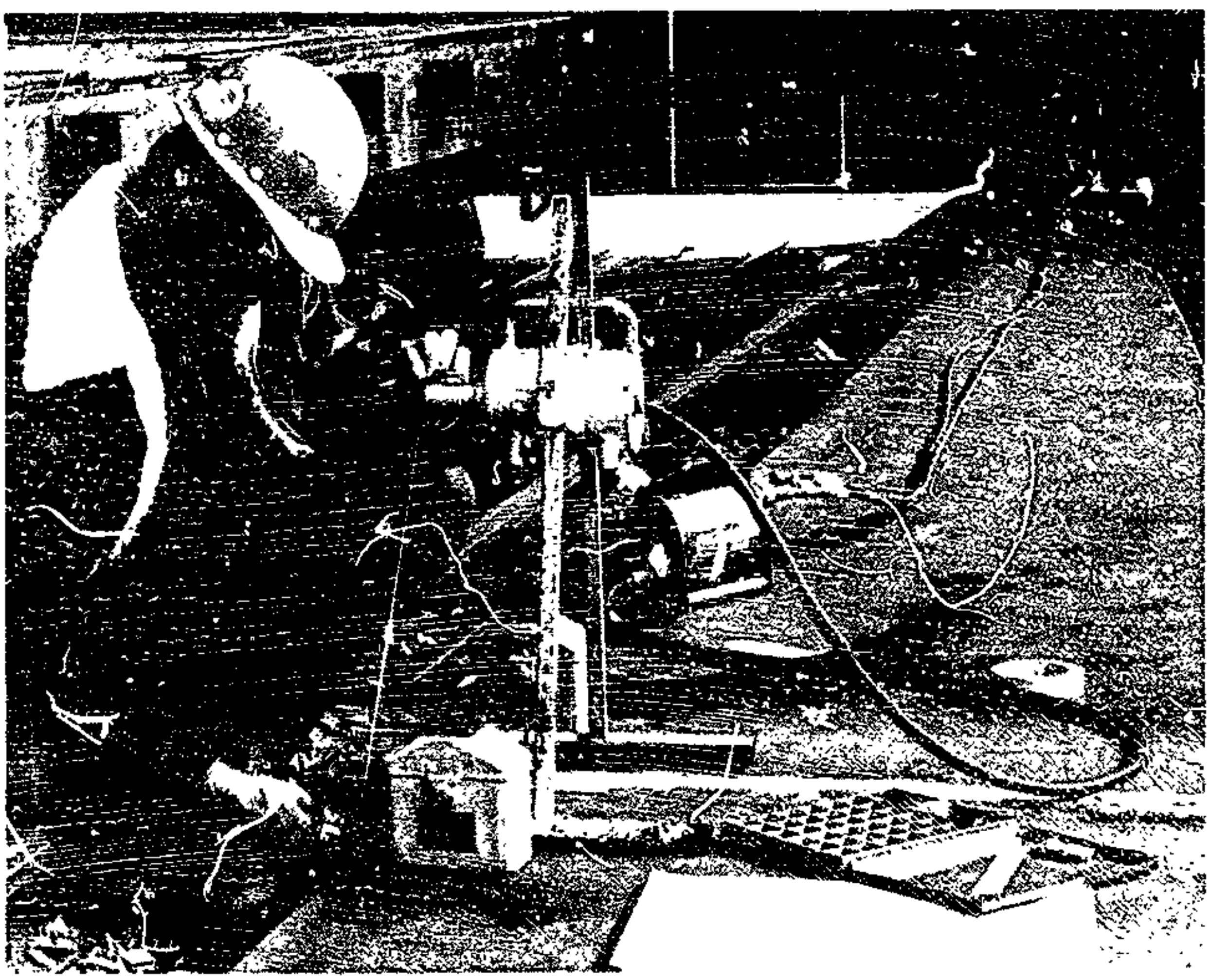


Figure 9-2. Weld Inspection Using Radiography (Gamma-Ray)

Selection of Source to Film Distance The source to film distance is usually based on the thickness of the area of interest. In most cases, the rule of thumb is that the source to ' distance should not be less than seven times the specimen thickness in the area of interest. The quality of t' radiograph is usually improved as the source t. film distance increases. This is not true, however, for the radiography of pipe welds with diameters greater than approximately 4"; in these cases, the source to film distance should be equal to the outside diameter of the pipe (for external shots) or the outside radius of the pipe (for internal panoramic shots). The length of the film to be exposed is also a factor in determining source to film distance, the distance must not be less than the length of the film being exposed, unless a panoramic set up is being used. In this case the source should be placed equidistant from the film.

Figure 9-3. Pipeline Weld Inspection Using Radiography (Gamma-Ray)

Selection of Film The selection of film should be based mainly on the sensitivity requirements as well as the nature and thickness of the specimen material Two or more different film types may be selected to cover different thickness ranges in one exposure The size of the film should be selected to ensure that the area of interest can be contained within a 1" border all around the film

Selection of Image Quality Indicators (Penetrameters) The selection of the penetrameter should be based on the penetrameter whose thickness equals approximately 2% of the thickness of the specimen in the area of interest. If this thickness varies appreciably, more than one penetrameter may be used The material of the penetrameter must be the same or very similar to the material specimen being radiographed. The size of the smallest hole that can be clearly seen on the penetrameter indicates the radiographic quality and sensitivity level attained. Penetrameters should be placed on the source side of the specimen whenever possible. If this is not possible, the penetrameter may be put on the film side, i e between the specimen and the film Penetrameters used for film-side placement may be one size smaller than that required for source-side placement

Selection of Identification Markers Identification markers should be selected to provide enough information on the radiograph to identify it from similar items and to indicate the location of the area of interest being radiographed.

RADIATION SAFETY PRECAUTIONS

Because of the nature of radiography, radiation hazards are always present. The greatest hazards are always associated with gamma-ray radiography, since the radiation source in X-ray radiography can be shut off simply by stopping the electrical power supply to the machine; in gamma-ray radiography, however, the radioisotope continues to emit gamma-rays until safely shielded Only fully trained and qualified personnel should be allowed to handle any radiation-producing equipment. Care should be taken that the radiation beam is pointed away from any personnel in the area. The area surrounding the radiography operation should be surveyed during the first exposure to ensure that radiation levels are not hazardous or above those allowed under Atomic Energy Control Board regulations Safe radiation level areas should be roped off an marked with conspicuous radiation warning signs (Figure 9-4). Radiography personnel should be monitored with individual radiation detectors and recorders as required by Atomic Energy Control Board Any accident involving an unshielded radioisotope requires immediate evacuation of all personnel from the area to a safe distance while the operator in charge establishes an emergency procedure for safe retrieval of the source

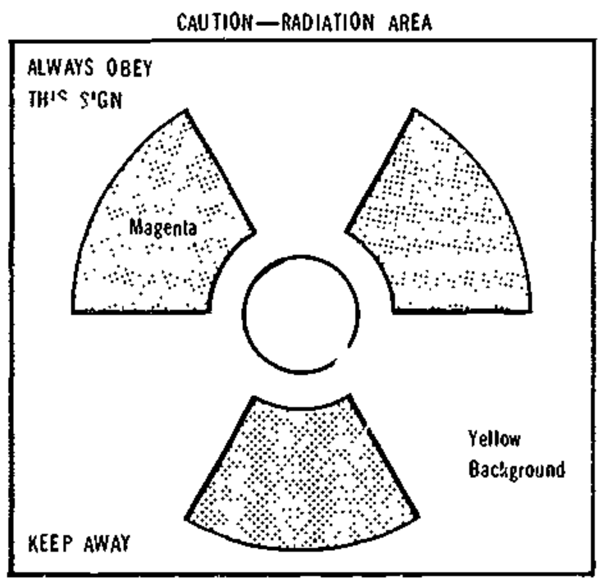


Figure 9-4. Radiation Warning Symbol

PERSONNEL QUALIFICATIONS

All personnel in charge of a radiography operation should be certified in accordance with the Canadian Government Specifications Board (CGSB) "Certification of Industrial Radiography Personnel." Personnel not certified in accordance with this specification may assist in the radiography operation but only under the direct supervision of a certified operator

ULTRASONIC TESTING

Ultrasonic testing (UT) is a method of non-destructive testing to locate hidden flaws in materials using ultrasonic sound waves to penetrate the materials, be reflected or distorted by internal discontinuities and be recorded as electronic signals on an oscilliscope-type ultrasonic machine The transmitted ultrasonic sound wave is produced by special transducers employing piezoelectric crystals that are made to vibrate at very high frequencies by high frequency electronic signals from the ultrasonic testing machine The returning ultrasonic sound waves are similarly reconverted into electronic signals by the piezoelectric crystals and transmitted to the ultrasonic testing machines for display on the oscilliscope-type screen The amplitude and position of pulses on the screen can be interpreted to show size and depth of discontinuities within the specimen Typical discontinuities that can be detected by ultrasonic inspection are incomplete penetration, lack of fusion slag inclusions, slag lines, burn-through areas undercut, porosity, gas and blow holes, sand inclusions, shrinkage areas, unfused chaplets, internal chills, cracks, hot tears and laminations The ability of ultrasonic inspection to show sizes and types of discontinuities depends on the ultrasonic technique employed which must take into account the following

1 Type of material inspected (i.e., steel aluminum)
2 Thickness of the area of interest
3 Variation in geometry
4 Type of weld or joint preparation (e g , single Vee-butt or fillet weld)
5 Extent of the inspection coverage
6 Acceptance standard specifying the type of unallowable discontinuities, and the length or size of allowable discontinuities.

The main application of ultrasonic testing is on weldments, castings, forgings, plates, rods, tubings and bars Thickness gauging and corrosion surveys form a large part of ultrasonic inspection work Some materials are not suitable for ultrasonic inspection because of grain structure and general inefficiency of sound transmission

ULTRASONIC EQUIPMENT

Four main items of equipment are necessary to perform an ultrasonic inspection.

1 Ultrasonic machines
2 Transducers
3 Calibration blocks
4 Couplant

Ultrasonic Machines Ultrasonic machines transmit and receive electronic signals to and from the transducers. The frequency, amplitude and gain (driving force) are governed by controls on the machine The received signals are processed and the results displayed on a meter, digital read-out or oscilliscope-type screen Ultrasonic machines generally operate in the frequency band from 5 to 20 megahertz The gain control is usually calibrated directly in decibels (dB) which allows accurate determination of flaw sizes

Transducers Transducers employ quartz or other piezoelectric crystals that vibrate at high frequencies when excited by voltage signals from the ultrasonic machines Conversely, if the transducers are vibrated by incoming high-frequency sound waves, they produce high-frequency voltage signals that are then received by the ultrasonic machines Some transducers are only designed to transmit signals, while others are designed to transmit and receive signals Transducers can be constructed to perform best at specific frequencies.

Transducers vary in size, but diameters ranging from 1/4" to 1" are most common. They can be constructed to sit flat on the specimen and produce straight or longitudinal sound waves, or can be angled by a wedge of plastic which results in shear or transverse waves in the specimen

Calibration Blocks Calibration blocks are used to calibrate the different systems of the ultrasonic machines, or check on the characteristics of the transducers or provide a reference sensitivity level for specific applications They come in many shapes and sizes. Calibration blocks should be made of the same, or accoustically similar, material as the specimen being examined.

Couplant A couplant is an interconnection medium used between the transducer and the specimen or calibration block. It allows the ultrasonic sound signals to be carried through the gap at the interface Couplants should have good accoustical properties, the ability to wet the surfaces involved evenly, and not detrimentally contaminate the part being inspected Typical couplants are water, oil grease, glycerin and cellulose paste.

ULTRASONIC METHODS

The basic principle in performing an ultrasonic inspection (Figure 9-5) is to pass ultrasonic sound waves of predetermined frequency and angles through a specimen, searching for hidden flaws from which the sound beam may be reflected and displayed on the ultrasonic, or distorted in a flaw indicated by a loss of signal. The specimen's material and basic geometry must be known to ensure accurate interpretation of any signals. The sound signal may be reflected from any interface such as a void, a crack, two pieces of metal pressed tightly together or even some weld zones where coarse grains in the metal's microstructure could cause significant reflectors. The surface of the specimen on which the transducer is to be moved must be smooth and free from any nicks, gouges or weld splatter that could interfere with the intimate coupling of the transducer to the specimen surface. The smoother the surface, the better the inspection. The following may be used as a guide in selecting the variables used in developing individual ultrasonic methods (if the

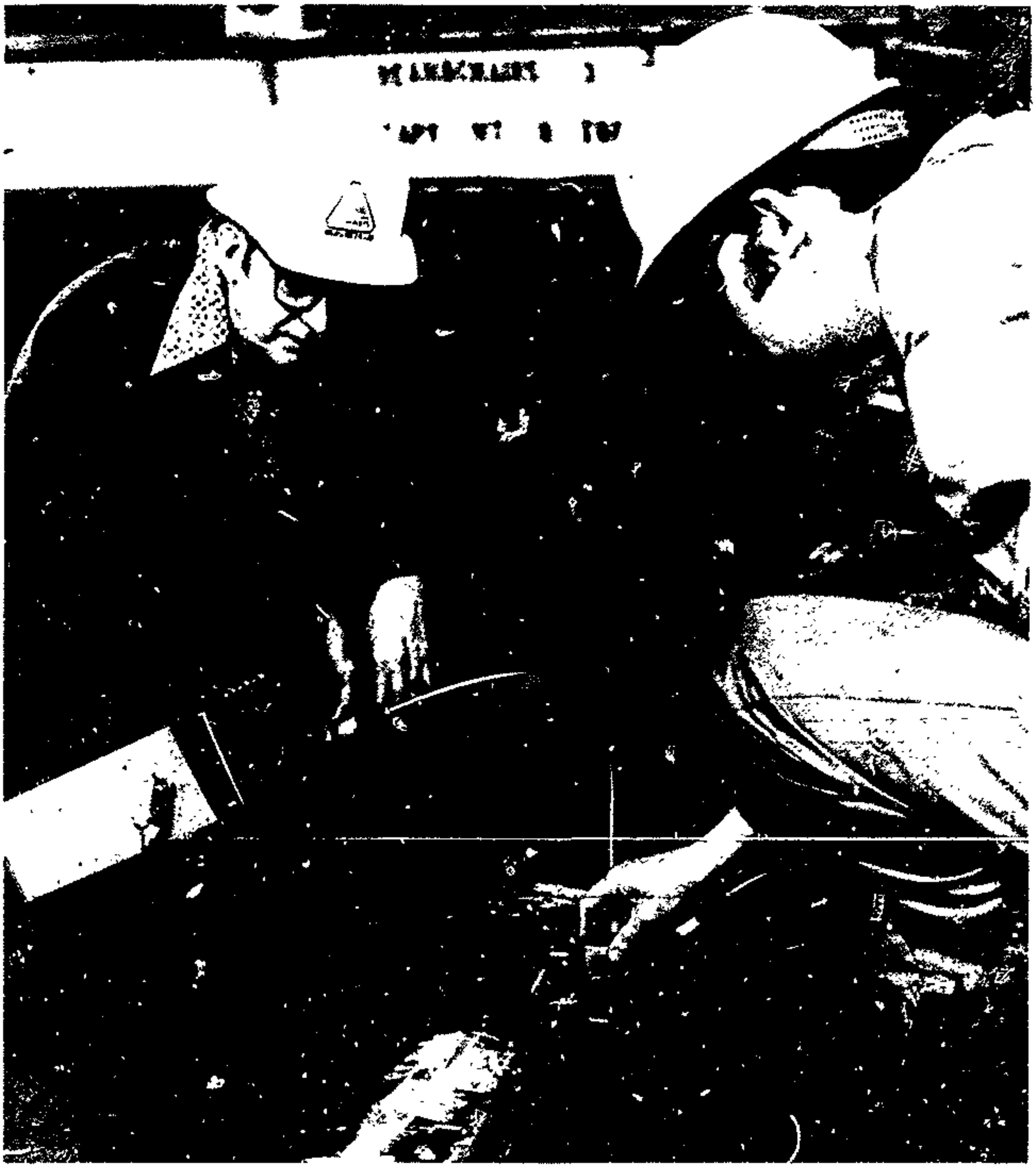


Figure 9-5. Weld Inspection Using Ultrasonics

ultrasonic inspection is being performed under the requirements of a code or customer specification. most of the variables discussed below may already be determined.

Selection of Ultrasonic Machines The selection of ultrasonic machines depends upon the frequency, gain (driving force) material range, desired read-out (oscilliscope screen, digital or meter) and the accuracy required for the inspection. Machines with calibrated gain control in decibels and the read-out on an oscilliscope screen are required for all code work. These machines are also used on all weld inspections. The digital and meter read-out machines are generally used in thickness determinations. They are not as accurate as the oscilliscope type since it may not always be possible to determine if the reading received is due to a true back reflection from the opposite surface of the specimen, or to some minor intermediate reflector that could be interpreted on an oscilliscope screen.

Selection of Transducers The selection of the transducer size and frequency is generally based on the specimen material. Frequencies of 5 — 5 megahertz are generally used on heavier metals such as steel and copper. while frequencies of 5 — 15 megahertz are generally used on lighter alloys such as aluminum and magnesium. The transducer size controls wthe width of the beam emitted from it. For thickness measurements. straight-beam transducers are always used (Figure 9-6). (The beam is passed into the material perpendicular to the entry surface.) For weld zones and other components. where defects are likely to occur in oblique planes with respect to the entry surface. a combination of straight-beam and angle-beam transducers may be used Angle-beam transducers generally vary from 40 — 70 with respect to a line drawn perpendicular to the entry surface. The particular angle chosen may be based on the weld preparation angle (to search for fusion defects along that face). or it may be based on a search for expected reflectors in a certain orientation in a casting (Figure 9-7) In many cases, one straight-beam examination and two or more angle-beam examinations may be conducted to ensure all possible orientations of reflectors be investigated

Selection of Calibration Technique The initial calibration technique is to calibrate the ultrasonic machine for sound-path distance This allows thickness to be read directly from the machine when performing a straight-beam examination. or it allows the distance from the transducer to the reflector to be determined in an angle-beam examination. Calibration blocks for thickness measurements are generally step-type wedges with parallel sides. The machine is calibrated to cover the expected thickness range of the specimen Calibration blocks for angle-beam examinations are generally designed to allow the sound-path distance to be calibrated as well as the sensitivity or the amplitude of the reflected peak from a desired acceptable size reflector to be established Sound-path distance calibration is performed first to establish an accurate scale on the oscilliscope screen. and then the sensitivity calibration is performed using the calibrated gain control (in decibels) to establish the desired sensitivity level. In some cases this level may have to be

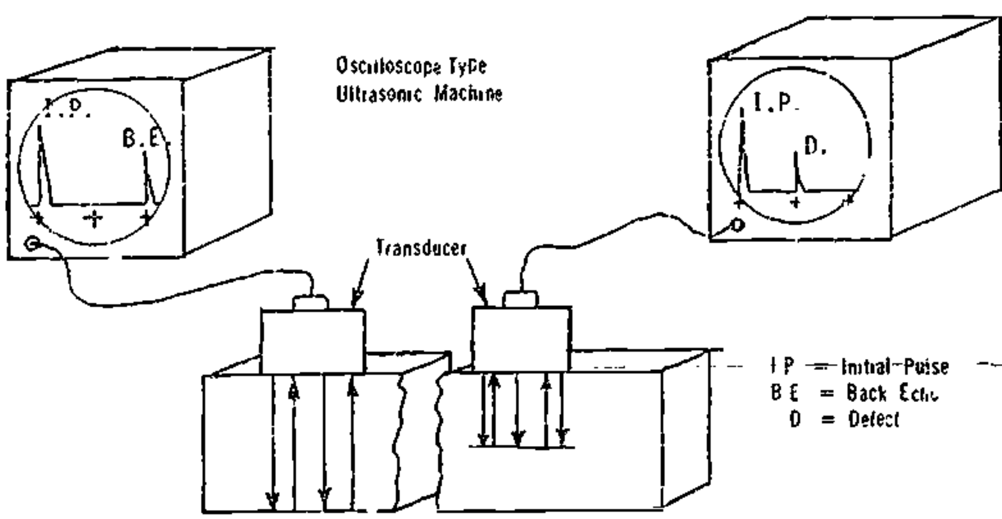


Figure 9-6. Straight Beam Ultrasonic Method

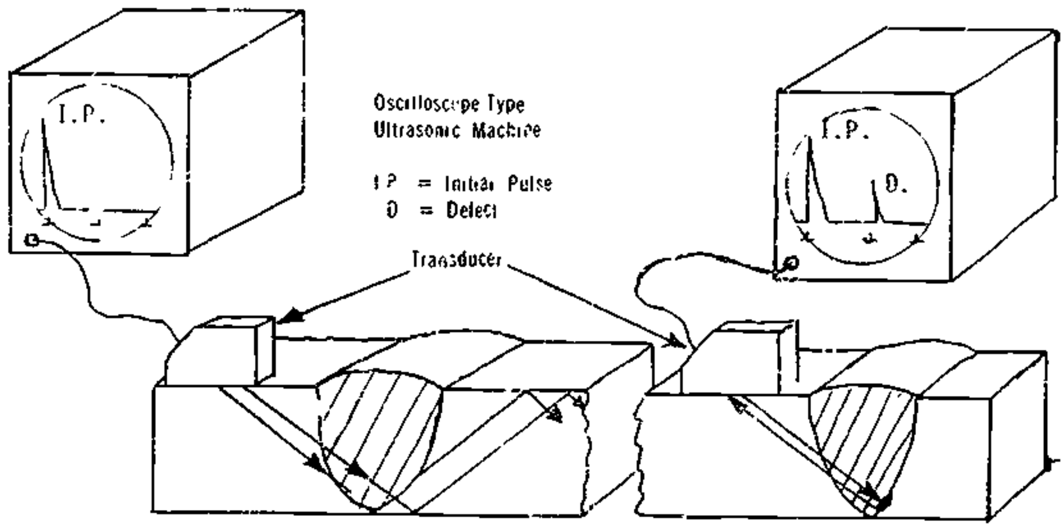


Figure 9-7. Angle Beam Ultrasonic Method

adjusted to allow or compensate for differences in the surface smoothness of the calibration block and the specimen itself

Selection of Couplant The selection of the couplant is generally based on the specimen's surface roughness, or the degree of contamination allowed on the specimen from the couplant The best couplant is one that would wet the surface most effectively and provide enough viscosity to prevent run-off during the examination It should be noted, however, that the higher the couplant's viscosity, in general, the higher the distortion of the ultrasonic sound signal This implies the need to weigh both concerns when choosing the most appropriate couplant for a particular test

PERSONNEL QUALIFICATIONS

All personnel performing ultrasonic inspection should be certified in accordance with the Canadian Government Specification Board (CGSB) Certification of Non-Destructive Testing Personnel — Ultrasonic Category"

MAGNETIC PARTICLE TESTING

Magnetic particle testing (MT) is a non-destructive method of inspecting ferro-magnetic materials for surface or slightly sub-surface flaws by using magnetic particles to form or outline discontinuities when under a magnetic field Typical weld or casting discontinuities that can be detected by magnetic particle inspection and are on or slightly under the surface are lack of fusion, slag inclusions and slag lines, undercut, porosity, shrinkage areas unfused chaplets, cracks, hot tears and laminations that extend to the edge of plates. Typical discontinuities detectable in forged and rolled products are stringers, non-metallic inclusions, cold laps and internal bursts that extend to the surface The ability of the magnetic particle inspection to show discontinuities depends upon applying the proper magnetic field strength and direction. The magnetic particle technique employed must take into account the size and shape of the specimen being inspected, and the acceptance standard specifying the type of unallowable discontinuities and the length and size of allowable discontinuities.

MAGNETIC PARTICLE EQUIPMENT

Two main types of equipment are required to perform a magnetic particle inspection magnetic particle machines (complete with assorted cables, prods, coils) and the indicating particles.

Magnetic Particle Machines Magnetic particle machines are low voltage, high current generators generally operating below 20 volts They have current capabilities as high as 3,000 amperes for portable machines and 10,000 or 20,000 amperes for stationary machines. Most machines are equipped with calibrated ammeters that read actual current flowing through the part being magnetized Machines that produce magnetism by passing a high current through the part use heavy cables and copper prods placed on the material at the point to be inspected. A magnetic field may also be produced by a coil carrying a high current which then induces the magnetism into the specimen. Electromagnetic yokes and permanent magnets similarly induce magnetism into the specimen. The current used to produce the magnetism in the part may be either alternating (AC) or direct current (DC).

Indicating Particles The indicating particles used are usually finely ground iron or steel filings. These are available in dry and wet forms. and are usually dyed red, black, grey or any other colour that would provide suitable colour contrast with the specimen background to highlight any indications.

Wet particles are also available in a flourescent yellow-green colour which fluoresces brilliantly under black light illumination. The wet fluorescent particle method is the most sensitive and can detect very fine surface cracks on smooth components

MAGNETIC PARTICLE METHODS

The basic principle in performing a magnetic particle inspection (Figure 9-8) is to magnetize the part or area of interest so that the magnetic lines of flux pass perpendicular to any suspected surface or sub-surface defects If any defects are present, the magnetic flux will leak out at these points and cause a reversal of the north and south poles of the local magnetic domain Areas where flux leakages occur will cause the indicating particles to clump or group and outline the defect exactly. Defects not oriented exactly perpendicular to the magnetic lines of flux may be shown, as long as they are more than 45° to the magnetic lines of flux. To ensure that the inspection covers all possible orientations of defects, two inspections are usually

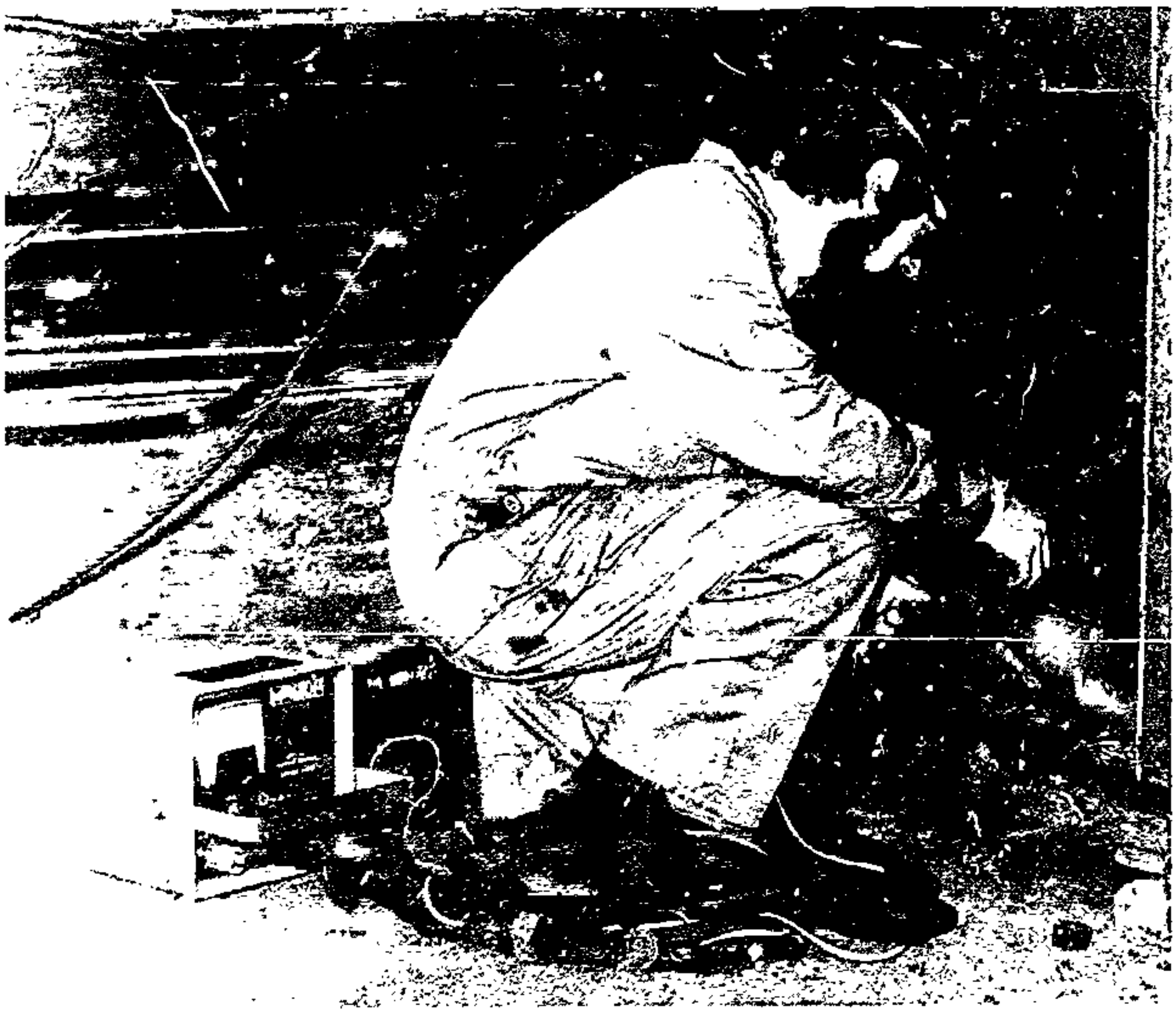


Figure 9-8. Weld Inspection Using Magnetic Particle (Prod Method)

carried out that produce a magnetic flux at approximately 90° to each other. This can generally be accomplished by rotating the test rods or electromagnetic yokes approximately 90° with respect to the previous inspection, or by using head and coil shots (see Figure 9-9).

Selection of Magnetic Particle Machines The selection of magnetic particle machines usually depends upon the current requirements for the size of the specimen being tested. When using test prods, current requirements are generally 100 amps per inch of prod spacing. Normal prod spacing is 6". Electromagnetic yokes are generally pre-set at the factory to provide adequate magnetic induction for the largest pole spacing allowed on the yoke. Wet bed magnetic particle machines employ only wet fluorescent particles under black light conditions. They are generally used to inspect tubular items such as shafts, bar stock and rings. The selection of the proper amount of current to use for magnetizing circular or cylindrical shafts is based on 1,000 amps per inch of diameter for head shots. Head shots produce circular magnetism that is used for detecting longitudinal-type defects. To find transverse-oriented defects in shafts and cylindrical components, a coil is used to produce longitudinal magnetism. The coil is made up of 5 to 10 turns of wire which induces the magnetic field into the component when the current is allowed to flow through the coil. The number of ampere-turns (NI) required to magnetize a cylindrical component is based on the formula

Number of Ampere-Turns (NI)

$$= \frac{45{,}000}{L/D}$$ (length to diameter ratio of the component)

To determine the actual current flowing through the coil (in amperes), divide the number of ampere-turns by the number of turns in the coil. The current used in any type of magnetic particle machine may be alternating (AC) or direct (DC). The direct current may be full-wave rectified or half-wave rectified. As a general rule, alternating current is better suited for surface defects, while direct current is better suited for sub-surface or deeper defects.

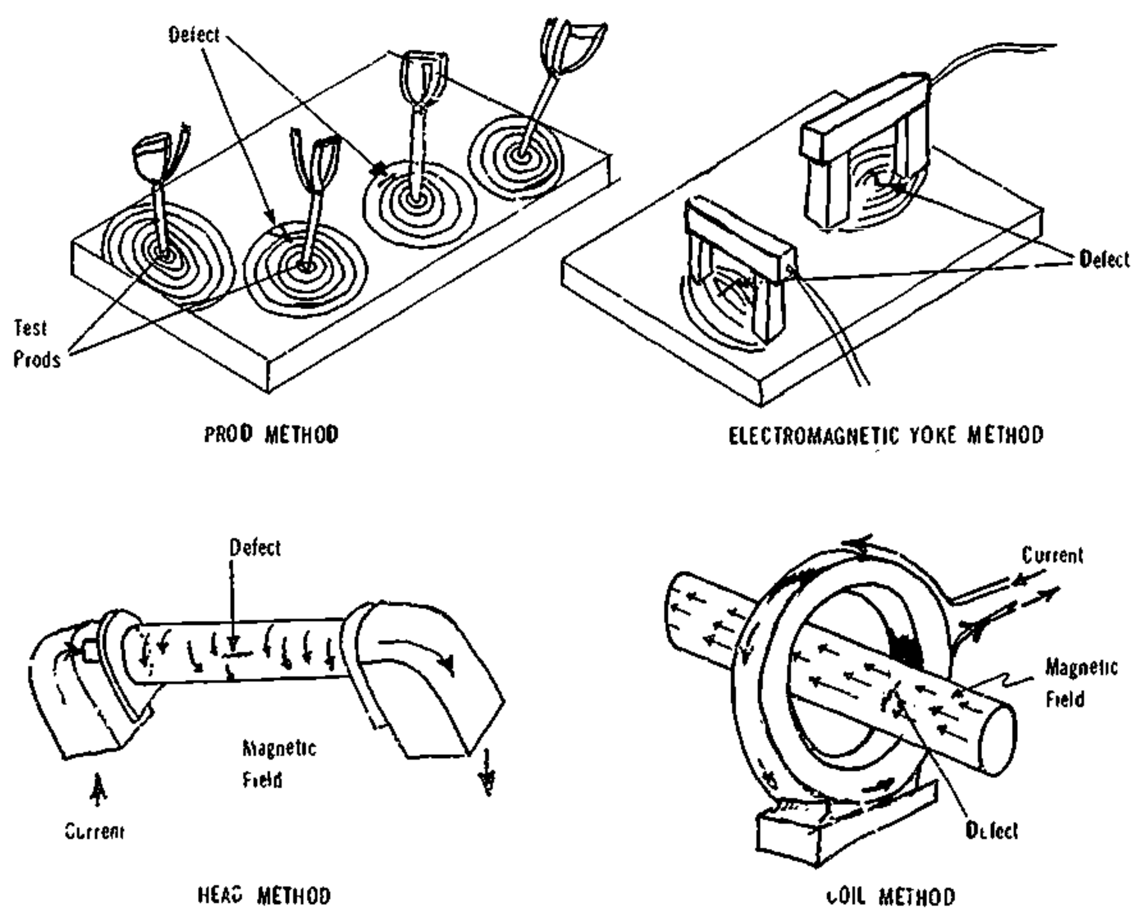


Figure 9-9. Magnetic Particle Methods

Selection of Indicating Particles Selecting the indicating particles is generally governed by the surface roughness of the part and the desired sensitivity to be achieved Rougher surfaces. such as as-welded and as-cast surfaces are better inspected with dry powder methods because wet powder methods sometimes allow the powder to collect in pockets that could mask indications Dry powder particles are mainly better suited for deeper indications as well Wet fluorescent particles are mixed in kerosene or light oil bath and provide the highest degree of sensitivity for small defects when used on smooth surfaces. The wet fluorescent particles may only be viewed under black light conditions. whereas the dry powder particles are usually selected with different colours to provide maximum contrast with the background of the specimen being inspected. The particles may be applied when the magnetizing current is turned on (continuous method) or they may be applied after the magnetizing current has been turned off (residual method) The residual method should be used only when it is apparent that the steel being magnetized has sufficient residual magnetism to allow indications to form

Demagnetization Demagnetization is sometimes necessary when the future intended use of the specimen or part is such that residual magnetism may be detrimental to the operation or further processing of the part Demagnetization may be accomplished by two methods

1. Subject the specimen to an alternating current magnetic field and withdraw it slowly as the field is maintained This allows the magnetic field to be diminished gradually
2. Reduce the alternating current magnetic field by reducing the current in steps gradually until it reaches zero

Proof of complete demagnetization can be checked by residual field strength indicators which are similar to a compass in operation

PERSONNEL QUALIFICATIONS

All personnel performing a magnetic particle inspection should be certified in accordance with the Canadian Government Specifications Board (CGSB; Certification of Non-Destructive Testing Personnel - Magnetic Particle Category

LIQUID (DYE) PENETRANT TESTING

Liquid penetrant testing (PT) is a non-destructive testing method of inspecting materials for surface discontinuities using liquid penetrants to penetrate small surface openings and remain in them thus allowing the discontinuities to be outlined with the colour of the dye. Typical surface discontinuities that can be detected by liquid penetrant inspection are cracks. hot tears. cold shuts. folds. inclusions. laps. laminations. porosity and fatigue cracks. The ability of the liquid penetrant inspection to show small discontinuities depends upon the liquid penetrant technique and the chemicals used.

LIQUID PENETRANT EQUIPMENT

Three main items of equipment or material are necessary to perform a liquid penetrant inspection

1. Penetrants
2. Emulsifiers
3. Developers.

Two principal categories of liquid penetrant chemicals are the colour contrast or visible group. and the fluorescent group Each category is further divided into three main groups

1. Water washable (excess penetrant may be removed with water)
2. Post-emulsifiable (penetrant can be removed by using emulsifiers. then washing with water)
3. Solvent removable (special solvents are required to remove excess penetrants)

LIQUID PENETRANT MATERIALS

Penetrants Penetrants are specifically formulated to provide a good wetting action on the surface of the specimen to provide a continuous and reasonably uniform coating that could migrate into small openings on the surface. Colour contrast penetrants are usually red. while fluorescent penetrants are yellow-green when viewed under ultraviolet (black) light

Emulsifiers and Removers Emulsifiers are liquids used to convert the excess oily penetrant on the surface of the specimen into a water-washable material The emulsifier must be matched for the type of penetrant system used. The emulsifier may be oil or water base Solvent removers (cleaners) are different from emulsifiers as they remove excess surface penetrant through direct solvent action The solvents dissolve the excess penetrants, thereby allowing them to be wiped clean

Developers Developers can be either wet or dry Dry developers consist of fine powder that is applied over the surface of the specimen after it has been cleaned of excess penetrant Wet developers consist of powder suspended in a liquid medium, these are almost always white to provide suitable colour contrast with the penetrant Developers effect a blotting action that tends to draw penetrant upward to the surface of the discontinuities to be more easily seen

LIQUID PENETRANT METHODS

The basic principle in any liquid penetrant inspection is to provide a clean surface upon which to apply the penetrant The penetrant is then applied evenly over the surface to be inspected and allowed to remain for a predetermined time so that it can enter tight surface defects The excess penetrant is then removed with the appropriate emulsifier or remover and, a developer is then applied that allows residual penetrant to come to the surface of the discontinuities for viewing during the final inspection (Figure 9-10)

Selection of Penetrant Materials The size and shape of the specimen to be examined and the degree of sensitivity required by the specifications determine the selection of penetrant materials Large size specimens normally require a water-washable penetrant system, this facilitates removal of the excess penetrant using water as a remover Complex shapes, where pooling of the chemicals is likely, may require a dry powder developer to ensure that the developer would not mask any possible indications The most sensitive penetrants are the fluorescent systems with post-emulsifiable (most sensitive), followed by solvent removable and water-washable It is not wise to use a penetrant system too sensitive for the inspection as specified. The extra sensitivity could result in many non-relevant indications that could hamper interpreting the test results Once the penetrant has been selected, the remaining chemicals required for the test (emulsifiers or removers, and developers) must follow the same family grouping and originate from the same manufacturer to ensure compatability between all the chemicals

Application of Penetrant Materials: All surfaces of the specimen must be thoroughly precleaned and completely dried before it is subjected to the liquid penetrant. All surface discontinuities must be free from oil, water or other contaminants to ensure that the penetrant can gain access to the cavities. After the precleaning and drying, apply the liquid penetrant in a suitable manner using brushes, cloths moistened with the liquid or aerosol dispensers, or the specimen may be immersed in a bath. Allow the penetrant film to remain on the specimen long enough to ensure maximum penetration of the liquid into any surface opening Next, remove the excess penetrant using the appropriate emulsifier, solvent remover or water, which is compatable with the penetrant Do not overclean the specimen surface, as it is possible to remove penetrant from the surface discontinuities, thus voiding the inspection results Apply the appropriate developer in an even, thin film over the surface

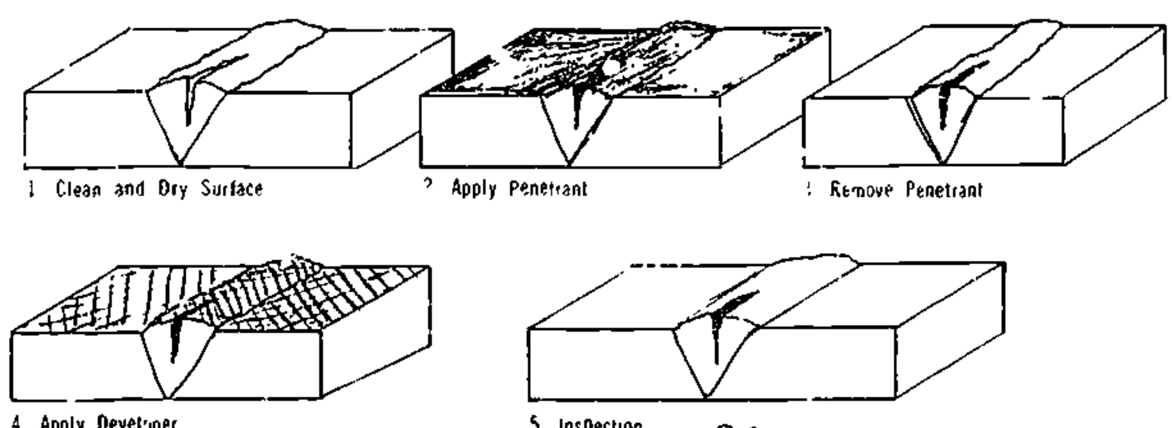


Figure 9-10. Basic Principle of Liquid Penetrant

of the specimen Do not apply the developer too thickly as it may mask some surface indications immediately examine the surface for indications as the blotting action of the developer is occurring For colour contrast penetrants, carry out the inspection under adequate white light, for fluorescent penetrants, carry out the inspection under black light conditions in a suitably darkened area The developer must be allowed to remain on the specimen for at least seven minutes for a final inspection at that time After final inspection, post-cleaning of the specimen may be specified to ensure that no undesirable contamination remains on the specimen The scope of liquid penetrant inspections may vary from a small inspection on a specimen using aerosol cans to a very large mass production line using vats of penetrant materials.

TABLE 9-1. SUMMARY OF NON-DESTRUCTIVE TESTING METHODS

	ADVANTAGES	DISADVANTAGES
Dye Penetrant	Can be very sensitive Fast, accurate No outside power Detection of haircracks in nearly all materials	Surface cracks only Clean, smooth surface required Outside power required for black light
Magnetic Particle	Quick to set up Fast in operation Portable Very sensitive	Defects at or near surface only Ferro-magnetic metals only Surface clean, dry, smooth No permanent record Source of power required
Ultrasonic	Generally quick to set up Portable Can be fast in operation Great depth and distance Internal haircracks and laminations Accurate depth of defects and material thickness	Reference standards usually needed Not all materials suitable (grain structure) Smooth surface required Not suitable for small, irregular objects
X-Rays	Higher sensitivity than gamma-ray Permanent records (films) Nearly all metals and materials Accurate for size and location of defects except in depth	Darkroom facilities needed Larger apparatus than gamma-ray Cooling duty cycle Difficult to position on complex objects No tight crack detection or cracks that are not parallel to the beam No determination of depth of defects Power source required
Gamma-Rays	Portable No power source required Deeper penetration for field use Permanent records (film) Nearly all metals and materials	Danger of radiation if accident occurs Darkroom facilities required Lower sensitivity than X-ray Replacement of isotope (half life)

PERSONNEL QUALIFICATIONS

All personnel performing liquid penetrant inspection should be certified in accordance with the Canadian Government Specifications Board (CGSB) "Certification of Non-Destructive Testing Personnel -- Liquid Penetrant Category"

SYMBOLS USED FOR NON-DESTRUCTIVE TESTING

The non-destructive testing symbols (Figure 9-11) are used to indicate to the technician or operator who will be performing the non-destructive inspection

1 Type of non-destructive test (NDT) to be employed
2 Part to be tested
3 Location to be tested
4 How many seams or spots to be tested
5. How long, etc.

These symbols will generally follow the same principle as regular welding symbols with the addition of particulars to non-destructive testing.

Type of Test	Symbol
Radiographic	RT
Magnetic Particle	MT
Penetrants	PT
Ultrasonic	UT

DESTRUCTIVE TESTING

Destructive testing is any method that can be used to determine the actual physical characteristics of a specimen by loading it until a failure occurs. The loading may be ac-

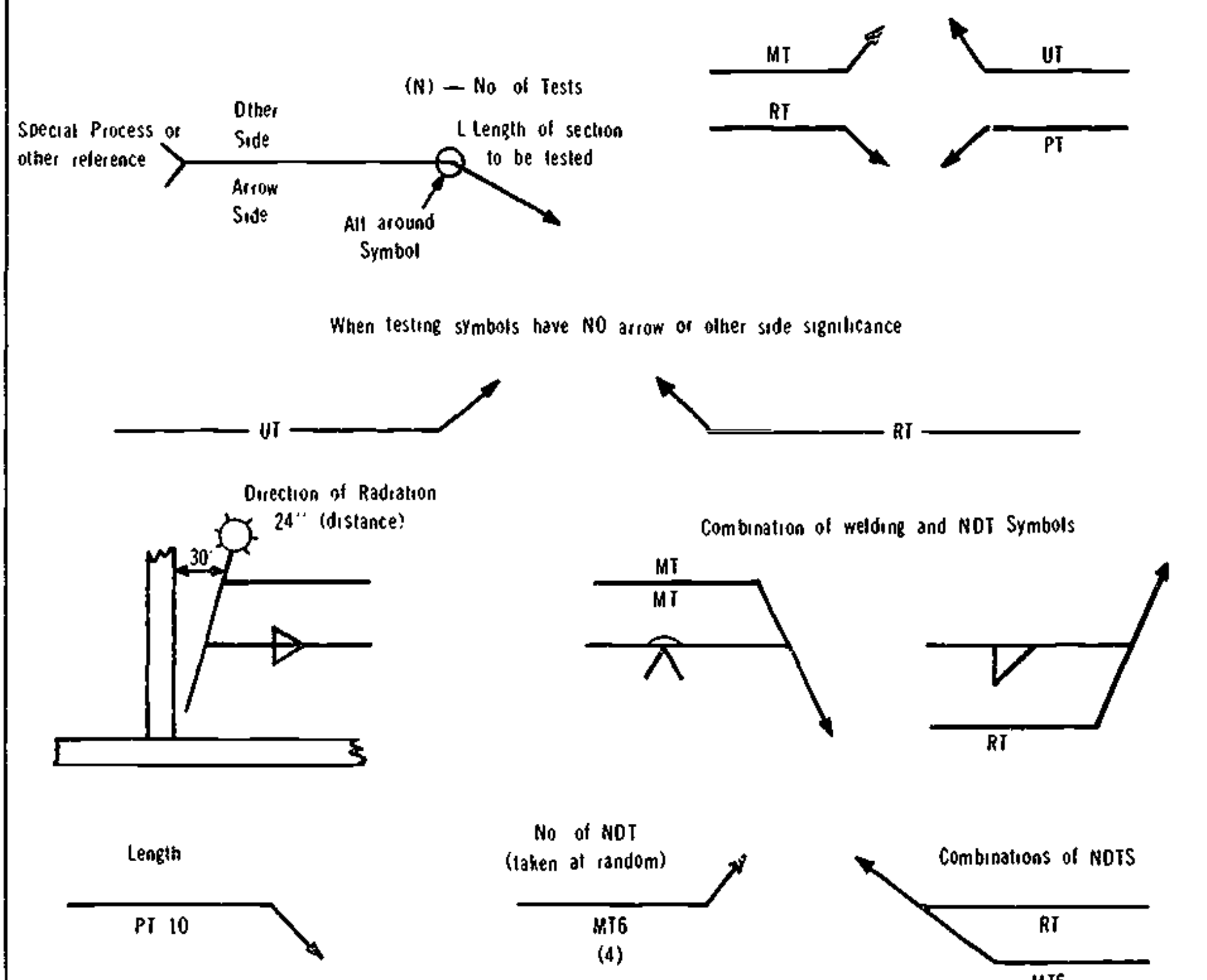


Figure 9-11. Non-Destructive Testing Symbols for Full Length NDT — no Length Dimension Needed

complished by stretching, bending, impact or compression forces that allow the specimen to exhibit any weaknesses or faults present as well as proving a minimum strength level There are several accepted destructive tests which specify dimensions and testing methods for each type of test specimen

Destructive tests are used to verify or prove the strength of base materials and welded joints on the test specimens. This can provide a level of quality assurance that the finished product, if fabricated from the same materials and welded in accordance with the same welding procedures, will have the same properties

TYPES OF DESTRUCTIVE TESTS

Guided Bend Test Cross sections are cut through the weld, and bent against the face or the root Side bends are, as the name implies bent (Figure 9-12) sideways This reveals lack of fusion, slag inclusions, porosity, cracks and brittle welds (coarse grain)

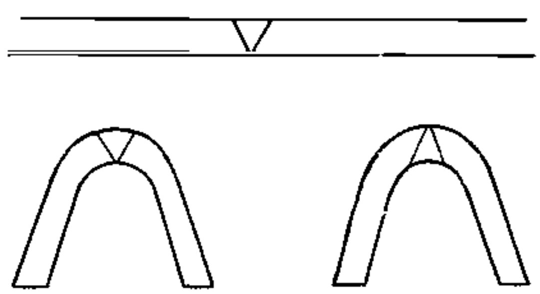


Figure 9-12. Guided Bend Test

Nick Break Test The specimen is cut in on the sides (and on the top) with a hacksaw, clamped in a vise with the hacksaw cut flush with the top of the jaws, and hammered back and forth until it breaks in the centre of the weld (Figure 9-13) In a nick break testing machine, the specimen is broken sideways. Slag inclusions, porosity, lack of fusion and brittle welds (coarse grain) can be readily seen.

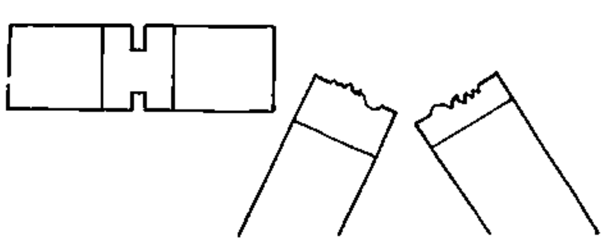


Figure 9-13. Nick Break Test

Impact Test (Charpy, Izod) This test is designed primarily to test the ability of metal or welds to resist sudden shock under various temperatures. The specimen is clamped in a machine and struck with a mechanical hammer The pressure exerted at the breaking point is recorded in foot-pounds (Figure 9-14)

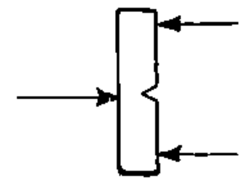


Figure 9-14. Charpy V-Notch

Tensile Test This test is designed primarily to determine the yield point and tensile strength of the metal. Specimen is secured in the machine and stretched until the metal breaks (Figure 9-15). To determine the tensile strength and yield point of the weld metal a specimen is prepared consisting of weld metal only. Weld specimens are prepared by leaving the reinforcement on and subjecting the whole coupon to the tensile test.

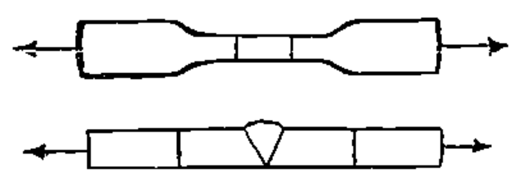


Figure 9-15. Reduced Section Tensile Test

Sectioning (Plug Test) A section or plug is cut out of the weld, polished and etched with an acid solution and inspected under a microscope

Metallographic Test

Metallographic Tests are carried out to determine:

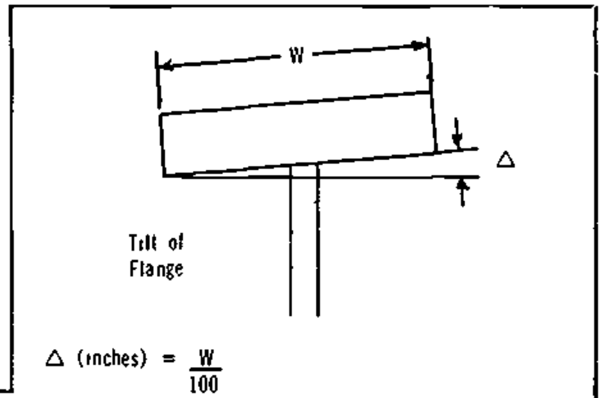
1 Number of weld passes
2 Grain structure in the weld and fusion zone
3 Distribution of non-metallic inclusions
4 Extent and structure of the heat-affected zone

Macro — Specimens are etched to bring out the structure and examined visually (unadided eye, or low magnification)

Micro — Specimens are prepared and etched for examination under the microscope at high magnifications.

QUALITY CONTROL OF STRUCTURAL SHAPES

Figures 9-16 to 9-18 depict the allowable tolerances during the manufacturing process of structural members to ensure quality control



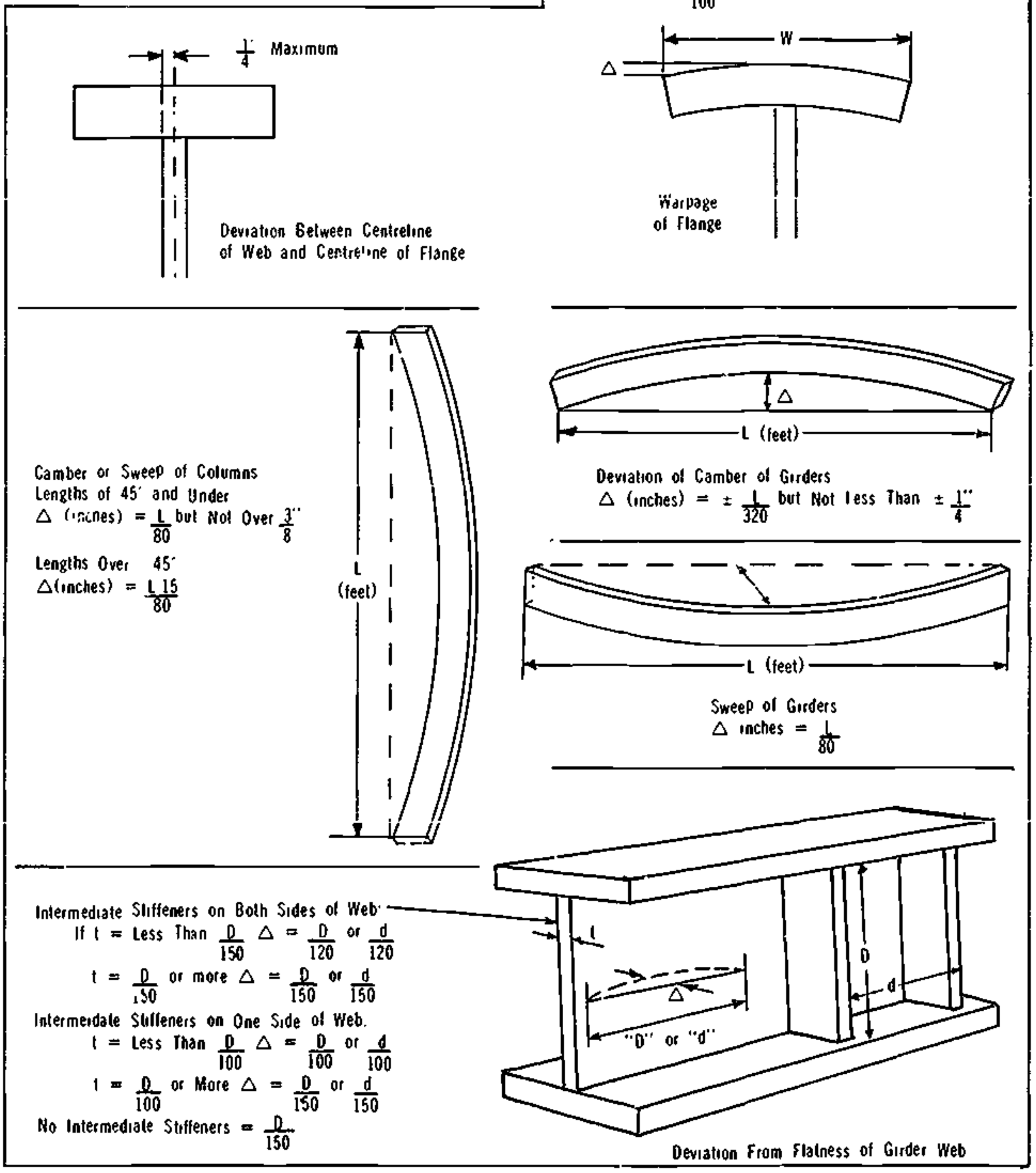
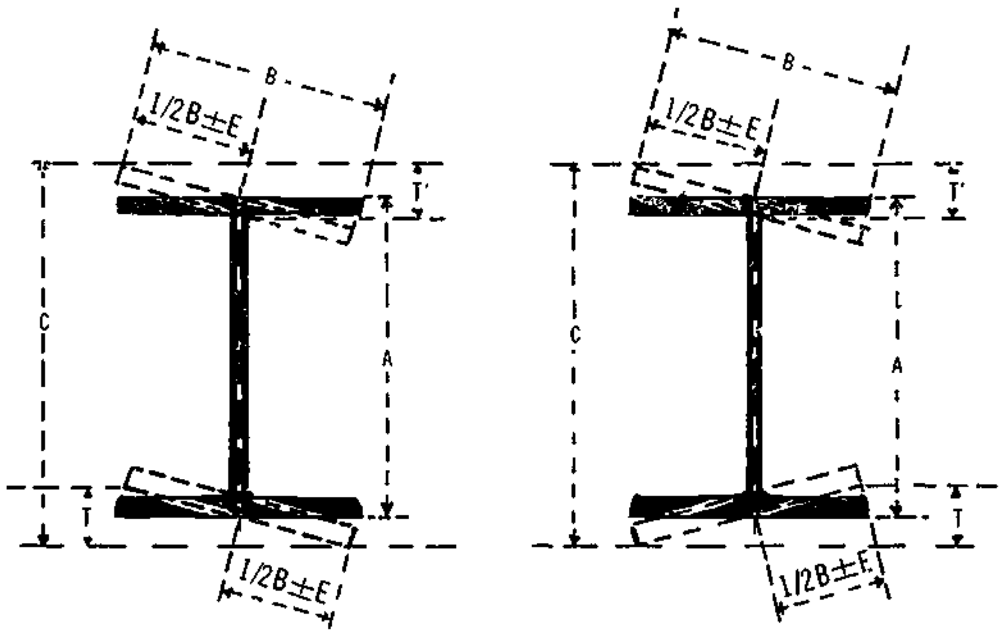


Figure 9-16. Dimensional Tolerances C.S.A. Welded Sections

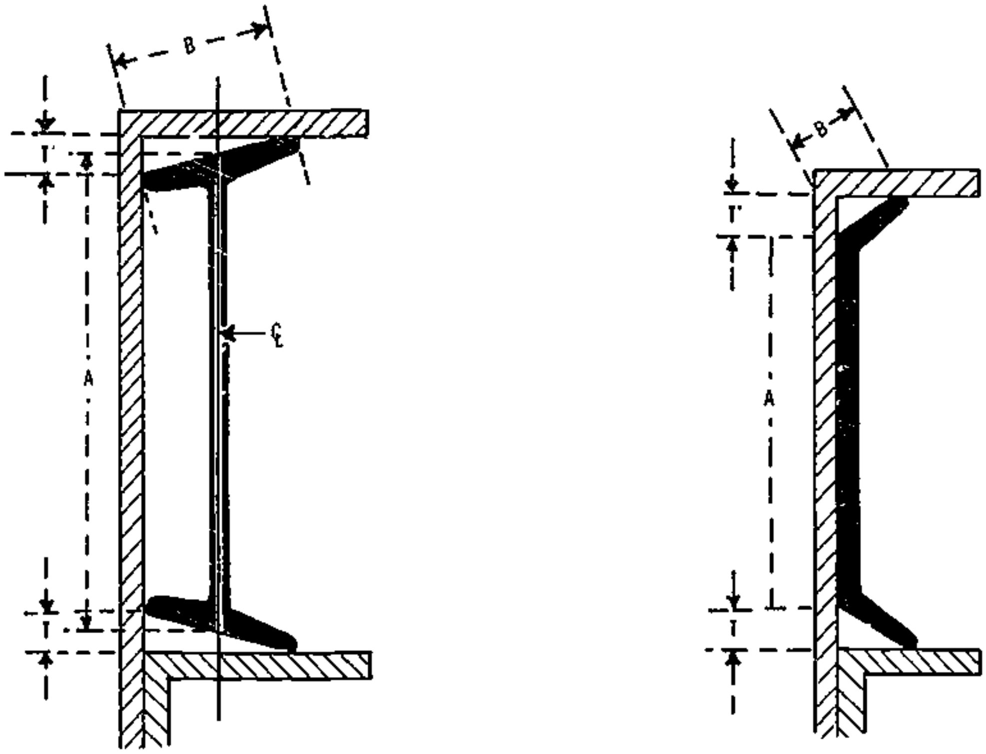


Section Nominal Size	A Depth		B Flange Width		T+T	E	C Max Depth at any Cross Sect
	Over Theor	Under Theor	Over Theor	Under Theor	Flanges Out Of Square	Web Off Centre	Over Theor Depth
Up to 12 incl	1/8	1/8	1/4	3/16	1/4 max	3/16 max	1/4
Over 12	1/8	1/8	1/4	3/16	1/4 max	3/16 max	1/4

OUT OF STRAIGHT Camber or sweep = 1/8 in x $\frac{\text{number of feet of total length}}{10}$

* Figure is 5 for sweep when flange width is less than 6 in

Figure 9-17. Rolling Tolerances, Inches



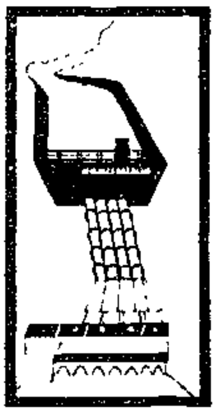
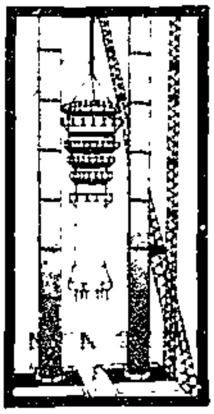
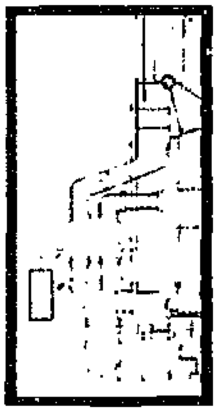
* (A) is measured at centre line of web for beams, and at back of web for channels

OUT OF STRAIGHT Camber = 1/8 in x $\frac{\text{number of feet of total length}}{5}$

Section	Nominal Size	A Depth*		B Flange Width		T + T Out Of Square Per In Of B, In
		Over Theor	Under Theor	Over Theor	Under Theor	
American Standard Beams	3 to 7, incl	3/32	1/16	1/8	1/8	1/32
	Over 7 to 14 incl	1/8	3/32	5/32	5/32	1/32
	Over 14 to 24, incl	3/16	1/8	3/16	3/16	1/32
Channels	3 to 7, incl	3/32	1/16	1/8	1/8	1/32
	Over 7 to 14, incl	1/8	3/32	1/8	5/32	1/32
	Over 14	3/16	1/8	1/8	3/16	1/32

Figure 9-18. Rolling Tolerances, Inches

Chapter 10
BOILERS

INTRODUCTION

Steam is one of man's dependable servants and more and more in the background, steam is doing more and more work for man. In an electrically heated home, steam may be seen only at the teakettle, but chances are that the electricity is generated by burning coal or gas and producing steam to turn the generator rotors in the electric power generating station. Even if the fuel is uranium and the heat supplied by nuclear fission, generating electricity is still first accomplished by generating steam.

In Canada and the U.S.A. the demand for electricity doubles every ten years. For the most part, water resources suitable for power generation are already in service. Except for standby and peak-load units, approximately 90% of the new electric capacity being installed uses steam. The use of steam for generating electric power is expanding in most countries of the world, the principal exceptions being countries where available water power resources are greater than power needs.

Steam propels many of the world's naval vessels and a high percentage of its water-borne commerce. It is used on a large scale in many industrial processes and is still much used for space heating.

Steam boilers today range in size from those required to heat a small-sized home to the very large ones used in electric power generating stations. Some single boilers recently or soon to be operating deliver approximately 10 million pounds of steam and consume more than 50 tons of coal per hour. In these large units, pressures range from 2,500 to about 4,000 psi and the steam is usually superheated to a temperature of 1000 F or higher. Modern steam boilers operate safely and dependably and remain in service for many years. Cleaning and repairs are usually required only at scheduled outage periods.

Today's boilers owe their dependability and safety to more than a hundred years of experience in the design, fabrication and operation of water-tube boilers. During this period the properties of steam and water have been accurately determined and tabulated for use by the designer. A new understanding of heat transfer, fluid flow and boiler circulation has been developed. Means have been devised for burning large quantities of fuel economically and safely and for disposing of the products and by-products of combustion. Steels and alloy materials now available are stronger and more consistent in their properties, and advanced methods are used for their fabrication and inspection. Finally, industry-wide codes and standards have been adopted to regulate the design, fabrication and inspection of pressure parts.

The nuclear steam supply system is a relatively recent development, representing a union of nuclear physics and the steam boiler industry. During the last twenty years a large number of nuclear steam supply systems have been placed in operation for naval propulsion and for generating electricity. Some of these units for the electric power industry are comparable in capacity to the largest fossil-fuelled boilers.

HISTORY OF STEAM GENERATION AND USE

The most common source of steam generation at the beginning of the 18th century was the "shell boiler," which was little more than a kettle. The next development was the fire-tube boiler, followed by the water-tube boiler. Further research and design over a period of years led to a modified version of the inclined water-tube boiler and the bent tube boiler, with improved fire boxes and lining. High pressure reheat boilers were developed subsequently. One of these, the universal pressure boiler, derived its name from its design capability for subcritical or supercritical operation and rapid load pick-up. Nuclear steam generation is the most sophisticated method developed yet to generate steam and power.

In the marine industry early boilers for naval and merchant vessels were refined to produce the dependable water-tube marine boilers used today.

Figures 10-1 to 10-17 illustrate some of the more prominent boilers in the history of steam generation.

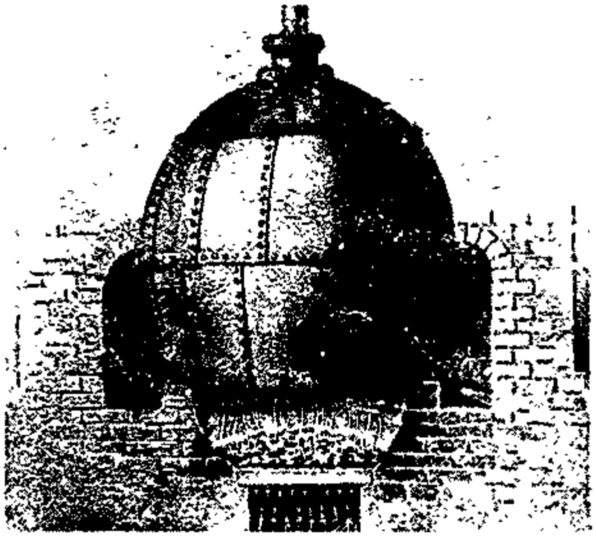


Figure 10-1. Haycock Boiler, 1720

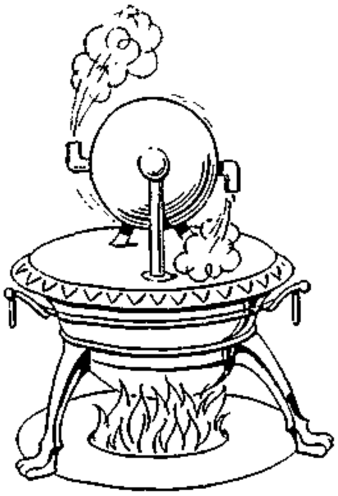


Figure 10-4. Hero's Engine (concept of Hero, 1st century AD)

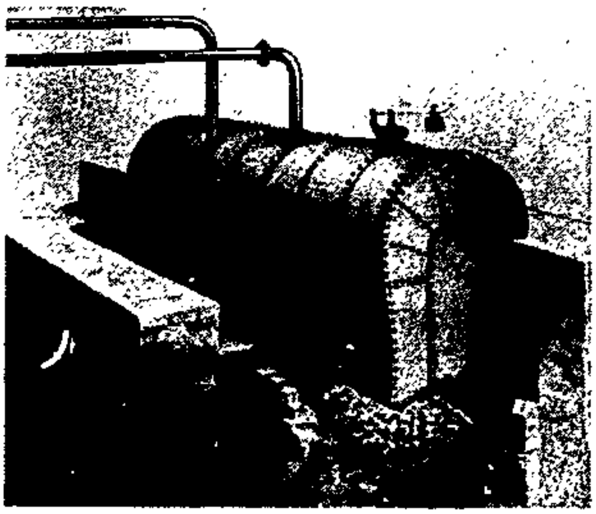


Figure 10-2. Waggon Boiler, 1769

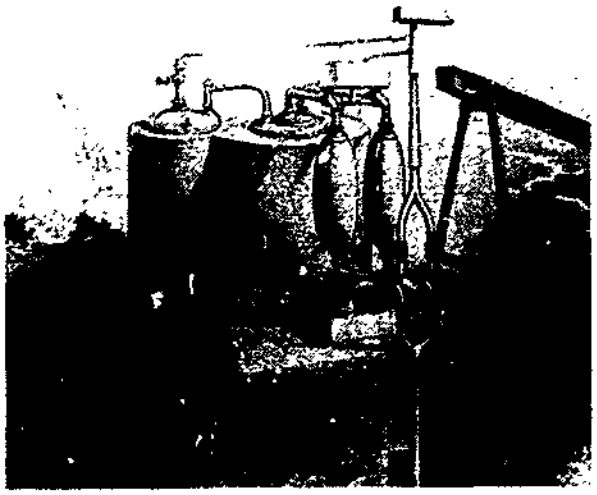


Figure 10-5. Savery's Engine, 1700

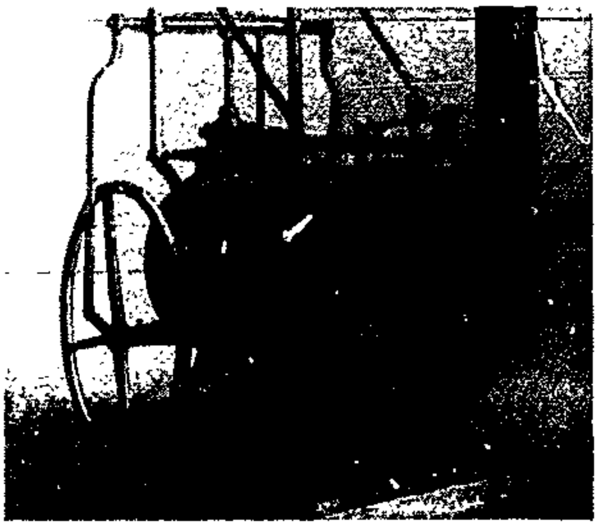


Figure 10-3. Trevithick Boiler, 1804

Figure 10-6. Newcomen's Engine 1711

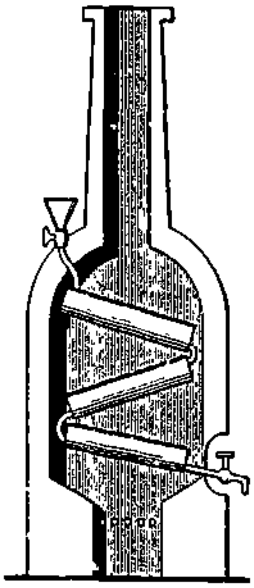


Figure 10-7. First Water-tube Boiler. Built and Patented by William Blakey in 1766.

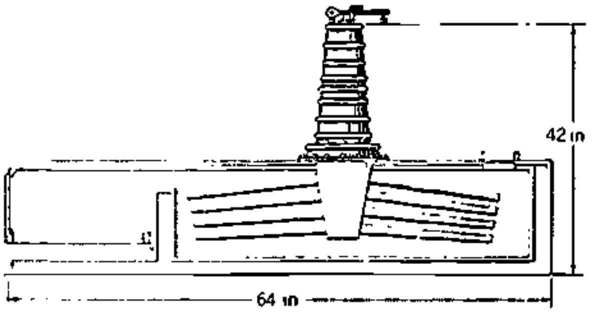


Figure 10-8. Water-tube Boiler of Small Tubes Connected at One End to a Reservoir. John Stevens, 1803.

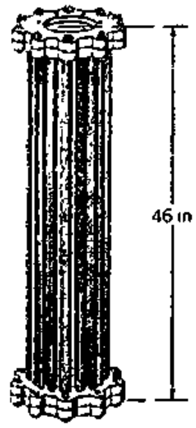


Figure 10-9. Water-tube Boiler with Tubes Connecting Water Chamber Below and Steam Chamber Above. John Cox Stevens, 1803.

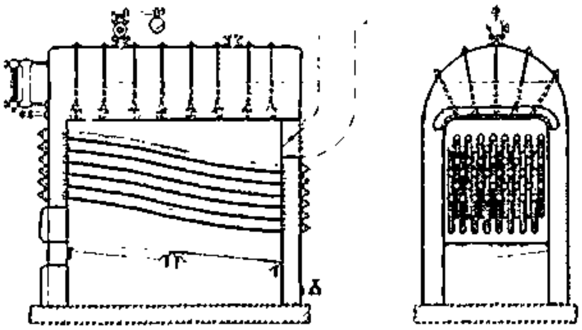


Figure 10-10. Inclined Water Tubes Connecting Front and Rear Water Spaces Complete Circuit with Steam Space Above. Stephen Wilcox, 1856.

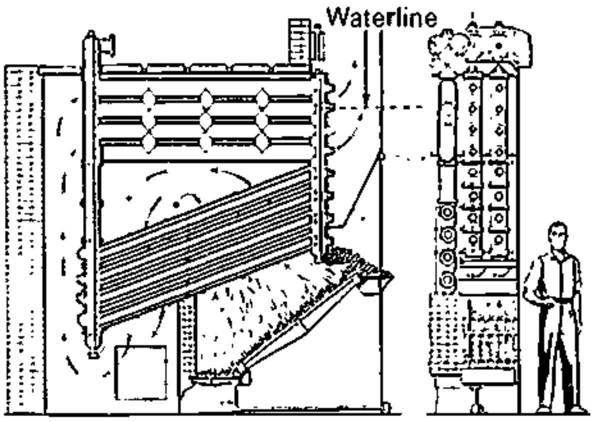


Figure 10-11. First Babcock & Wilcox Boiler, Patented in 1867.

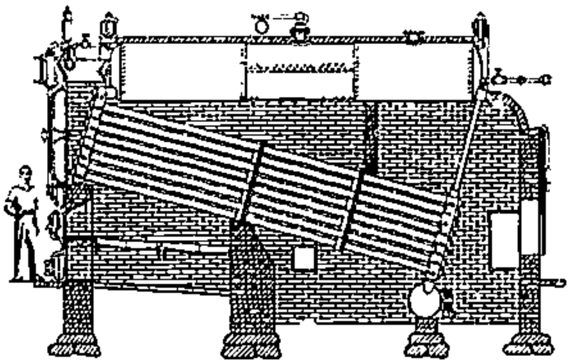


Figure 10-12. Babcock & Wilcox Boiler Developed in 1877

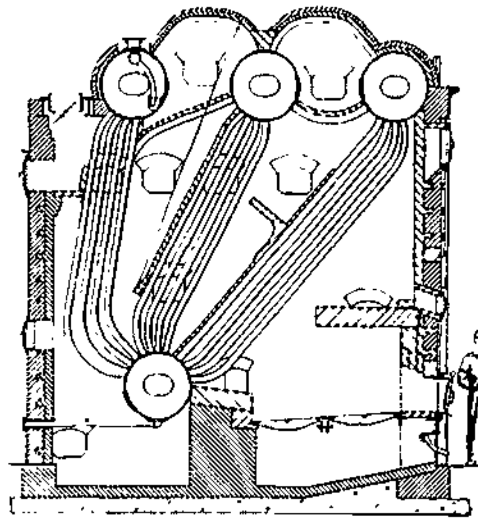


Figure 10-13. Early Stirling Boiler Arranged for Hand Firing, 1880

Figure 10-15. Integral-Furnace Boiler, 1933

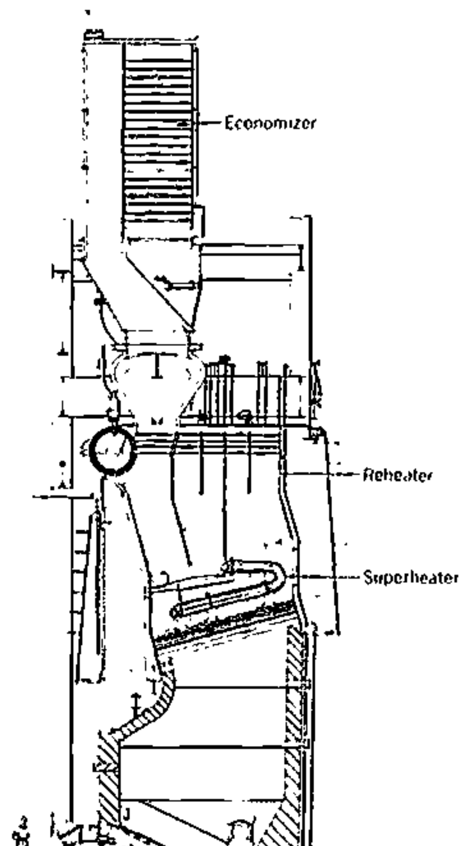


Figure 10-14. High Pressure Reheat Boiler, 1925

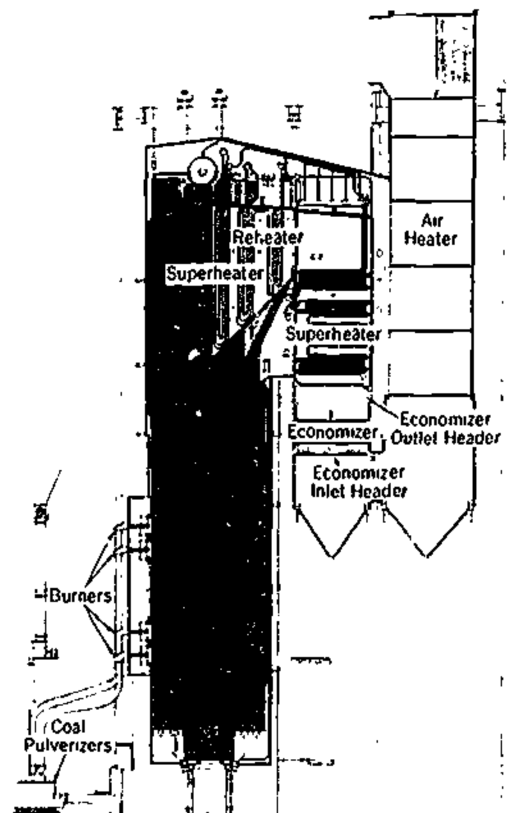


Figure 10-16. Radiant Boiler for 1650 psi and 1000°F Initial and Reheat Temperatures, 1940

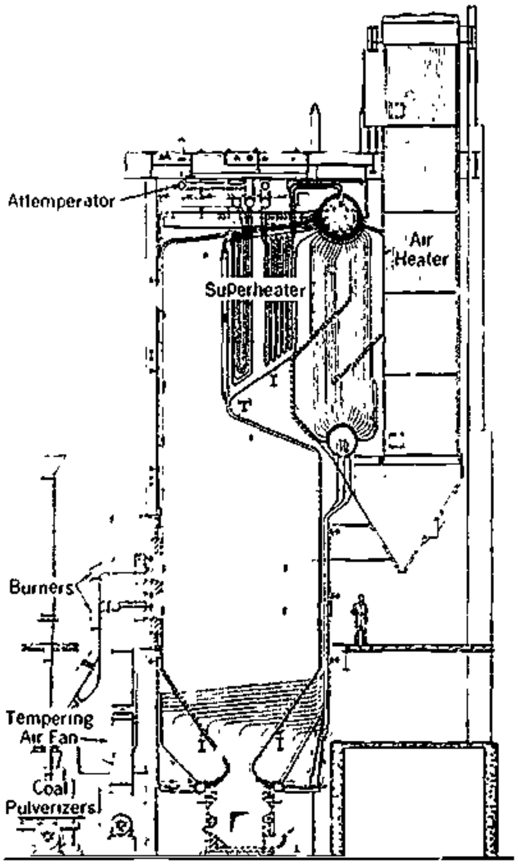


Figure 10-17. Stirling Boiler for 925 psi and 900°F. Steam Temperature

MODIFIED STEAM CYCLES

The continual quest for lower heat rates and, thus, higher cycle efficiency has involved modifications of the conventional steam cycle. One of these, using high-temperature, low-pressure mercury vapour to top a conventional steam cycle, dates back to the binary fluid mercury-steam unit placed in service at a New England utility in 1928. Binary fluid "topping" cycles are so named because the rejected heat of one fluid cycle is used to supply heat to another fluid operating in a lower temperature range. In the mercury-steam cycle, the mercury condenser also acts as the steam boiler

Other high efficiency cycles involve combinations of gas turbines and steam power, and direct thermal-to-electrical energy conversion. Direct-conversion systems under study for large power sizes include a magnetohydrodynamic (MHD) unit topping the conventional steam cycle and using conventional fuel or a char by-product from coal gasification or liquifaction. In spite of the many complex cycles devised to increase overall plant efficiency, the conventional steam cycle has, to date, proved to be the most economical.

The increasing use of high steam pressures and temperatures, reheaters, regenerative feedwater heaters, economizers and air heaters have led to improved efficiency in the modern steam power cycle. Many other developments have also progressively reduced the cost of equipment. The combined effect of these improvements, together with increased use of electricity, has substantially reduced power costs to the consumer (See Figure 10-18).

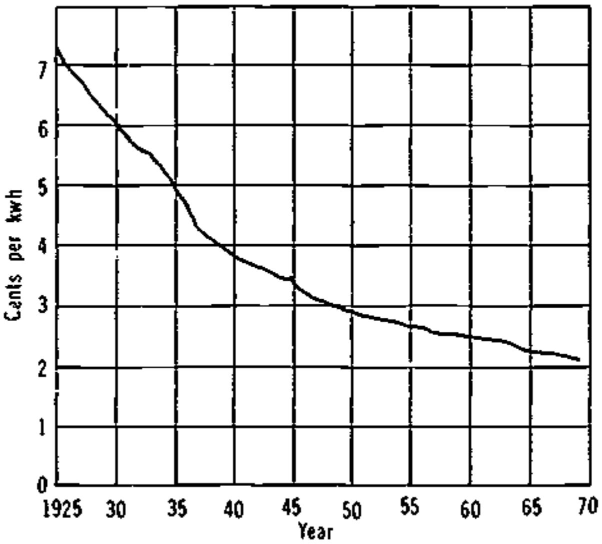


Figure 10-18. Average Cost of Residential Electricity to Consumer (Edison Electric Institute.)

MARINE BOILERS

The water-tube boiler was successfully applied to the propulsion of naval and merchant vessels in the 1890s. The subsequent development of marine boilers for naval and merchant ship propulsion has paralleled that for stationary use. Throughout the 20th century, dependable water-tube marine boilers have contributed greatly to the excellent performance of naval and merchant fleets.

NUCLEAR STEAM SUPPLY SYSTEMS

Since 1942, when Enrico Fermi demonstrated a controlled self-sustained fission reaction, nuclear energy has been recognized as an important heat source for power generation The first significant application of this new source for generating steam was the *USS Nautilus* prototype, operated at National Reactor Testing

Station in Idaho in the early 1950s This was followed by a number of installations for the propulsion of naval vessels.

The first electric utility installation was the 90-Mw unit (net capacity) at the Shippingport Atomic Power Station of the Duquesne Light Company. This plant, owned partly by Duquesne Light Company and partly by the U.S. Atomic Energy Commission, went into operation in 1957.

The Canadian nuclear power program was launched in 1954 when engineers from Canadian utilities and industries joined those of Atomic Energy of Canada Limited (AECL) to study the feasibility of commercial nuclear power stations in Canada This led to the construction at Ralphton, Ontario of Canada's first nuclear power station, which began to produce electricity in 1962, with 20 Mw capacity. This was followed by the construction of Canada's full scale prototype CANDU station, Douglas Point on Lake Huron This 200 Mw station produced its first electricity in 1967.

CANDU stands for Canadian Deuterium Uranium The Canadian nuclear power system has been under continuous development since the mid-1950s The main engineering feature that has contributed so greatly to the success of the CANDU PHW (pressurized heavy water) nuclear steam supply system is the use of the pressure tubes to accommodate the fuel bundles and primary circuit coolant. Other major power systems rely on a single large pressure vessel for containment.

In Canada the next development was Ontario Hydro's construction of one of the world's largest nuclear power stations at Pickering on Lake Ontario Pickering, which produced its first electricity in 1971, consists of four 500 Mw units.

The nuclear plant construction program in Ontario is continuing construction of the 3000 Mw Bruce generating station on the same site as the prototype Douglas Point unit that was started in 1969. The Pickering station is being doubled in size so that by the early 1980s eight 500 Mw units will be at one location. Ontario Hydro has plans for duplicating the Bruce plant and constructing another containing four 750 Mw units at Darlington on Lake Ontario.

In Quebec, a second nuclear plant is being built at Gentilly on the St. Lawrence River. The first was a 250 Mw prototype to explore the advantages of using boiling light water (BLW) as a coolant instead of heavy water. The second unit is a CANDU PHW rated 600 Mw, scheduled for operation in 1980. New Brunswick is also proceeding with the construction of its first nuclear development. The new Lepreau Station is to have two 600 Mw PHW units.

MATERIALS AND FABRICATION

Pressure parts for water-tube boilers were originally made of iron and later of steel. More recently, boiler drums and nuclear reactor vessels are fabricated from heavy steel plates and steel forgings joined by welding, with careful supervision and inspection. The development of the steam boiler has necessarily been concurrent with advances in metallurgy and progressive improvements in fabricating steel.

The cast iron generating tubes used in the first B & W boilers were later superceded by steel tubes. Shortly after 1900 B & W developed a commercial process for manufacturing hot-finished seamless boiler tubes, combining strength and reliability with reasonable cost. In the midst of the Second World War a mill was completed for the manufacture of tubes by the electric-resistance-welding process, and tubing produced by this method has subsequently been used in thousands of boilers. The cast iron tubes used for steam and water storage in the original B & W boiler (Figure 10-11) were soon followed by drums (Figure 10-12) and, in about 1888, drum construction was improved by changing from wrought iron to steel plates.

Prior to 1930 the standard method of joining boiler drum plates was riveting. This construction limited the thickness of drum plates to about $2\frac{3}{4}$ because no satisfactory method was known to secure a tight joint with rivets in thicker plates The only available alternative was to forge and machine a solid ingot into a drum, an extremely costly process. Boilers built prior to 1930 with pressures over 700 psi used the forged and machined drum.

The story behind the development of fusion welding is one of intensive search beginning in 1926. Welding techniques had to be improved in many respects, but equally, if not more important, an acceptable test procedure had to be found that would guarantee the drum without destroying it in the test. After extensive investigation of various testing methods, it was decided in 1929 to adapt the medical X-ray machine to production examination of welds By X-ray examination, together with physical tests of samples of the weld material, the soundness of the weld could be proved

During 1930 the United States Navy adopted a specification for constructing welded boiler drums for naval vessels, and, in that year, the first welded drums ever accepted by an engineering authority were a part of the B & W boilers installed in several cruisers. During 1930 as well the Boiler Code Committee of the American Society of Mechanical Engineers issued completed rules and specifications for the fusion welding of drums for power boilers, and in 1931 B & W shipped the first welded power boiler drum built under this code

The X-ray examination of welded drums and the rules promulgated for the qualification of welders and the control of welding operations were major first steps in the development of modern methods of quality control in the boiler industry.

Other important developments in materials include improved firebrick to withstand higher temperatures in boiler furnaces, alloy steels for superheaters and nuclear steam supply systems, special materials including the metal zirconium for nuclear fuel cladding tubes and alloys for control rods in nuclear reactors

The history of the boiler industry is the story of the search for more efficient and dependable steam generators Built into this history are fundamental concepts and basic inventions proved by experience to be sound. More recently introduced are the successful results of programmed research and development. This is the foundation on which today's research and development is building tomorrow's improved and larger fossil-fuelled boilers and nuclear steam supply systems.

BOILER MANUFACTURING

For many years, steam generating equipment built by reliable manufacturers in accordance with accepted codes, and properly operated has been recognized as dependable and safe. During the last twenty years, there has also been significant improvement in the quality of the materials employed, the control of fabrication processes and of inspection methods. Perhaps the greatest achievement of the boiler industry has been this improvement in the quality of its product accomplished through better inspection methods and quality control.

This improvement in quality has been necessarily achieved concurrently with rapid expansion in the size of steam generating units The majority of units, particularly in the larger industrial and utility applications, are specially designed to meet the user's requirements Most of the pieces, sub-assemblies and assemblies that make up the complete unit must be individually designed and shown on separate shop drawings. Thus, only a small segment of the manufacturing procedure could be classified as a quantity-production operation

Fabrication of the pressure and non-pressure parts and of auxiliary equipment for modern units involves a great variety of skills and unique manufacturing methods and metal-forming processes. Welding is used in the manufacture of almost every component produced and is especially important in the construction of boiler drums and pressure vessels Its development has facilitated fabrication of vessels of large size and great functional capability

FABRICATION OF FOSSIL-FUEL EQUIPMENT

DRUM FABRICATION

Figure 10-19 shows a large steam drum — 98' long and weighing 382 tons — for a utility boiler ready for shipment after shop fabrication The drum is composed of four cylindrical sections or courses and two hemispherically shaped heads

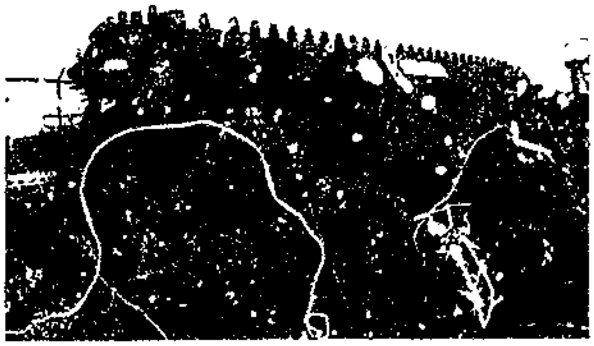


Figure 10-19. Steam Drum for an Electric Utility Boiler

The many large stubs and nozzles along the drum's length are connections to flow circuits for the steam generating and steam superheating surfaces of the boiler unit. Large nozzles along the bottom of the drum and the push-outs on the hemispherical head are connections from the drum to the downcomers, through which the water is carried to supply the various circuits in the generating system.

Fabrication of such a drum begins with the pressing of flat plate into half cylinders or the rolling of plate into full cylindrical shells. Figure 10-20 shows one of the larger presses used for this purpose, and Figure 10-21 a close-up of the pressing operation in the early stages. A plate-rolling operation in a set of vertical rolls (Figure 10-22). When short courses must be used because of material dimensions or heat-treatment requirements, the plate is rolled into a cylindrical course. For large drums, the normal procedure is to press plate into half-cylinders in lengths up to 42' and to form a course by welding two half-cylinders together longitudinally. The desired drum length is obtained by circumferentially joining courses as required. Long and circle seams in drums are made by the automatic submerged-arc-welding process.

Figure 10-20. Large Hydraulic Press for Forming Heavy Plate Into Half Cylinders for Pressure Vessels

Figure 10-21. Template Checking the Contour of a Drum Plate Being Formed Into an Half Cylinder

Drumheads are formed from flat plate by hot-pressing with suitable forming dies. Figure 10-23 illustrates this operation during its initial stages. Drumheads are attached to the completed cylinder by circumferential welds.

Automatic techniques are used for the greater part of the welding of a boiler drum. Figure 10-24 shows a double-submerged arc welding machine in operation on a longitudinal seam. The filler metal, in wire form, is continuously fed to the arc area, which is completely covered by a

Figure 10-22. Checking the Contour of a Cylindrical Section (Course) Rolled from Heavy Plate

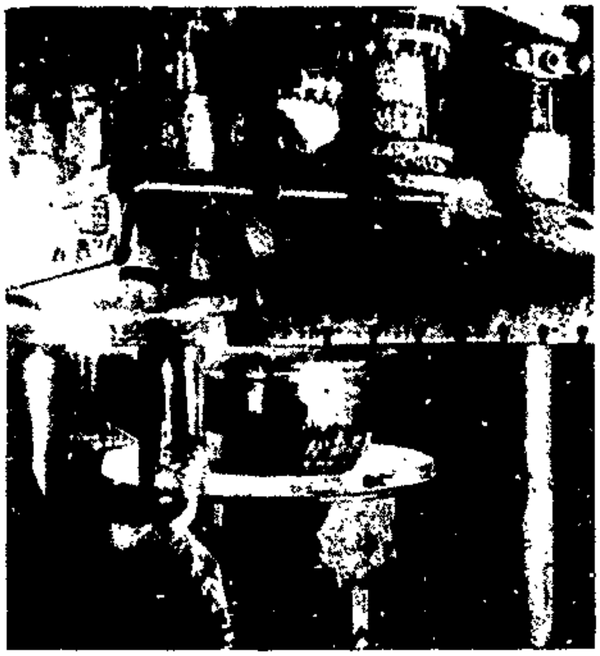


Figure 10-23. Hot Forming a Drumhead from Heavy Plate in an Hydraulic Press

granular flux to exclude air from the weld metal area. During the operation, the electrode carriage moves along the seam from one end to the other. Many passes may be required, depending on plate thickness, material specifications and the form of the welding groove.

For submerged-arc circumferential welds, the drum is mounted on a turning device and rotated while the welding head and the flux-applying equipment are stationary. Prior to and throughout all welding operations, a preheat is applied to the weld area to avoid detrimental stress conditions and metallurgical transformations. For some applications this preheat is maintained after welding until the vessel is stress relieved.

Figure 10-24. Welding Longitudinal Drum Seam with Double Submerged-Arc Machine

In recent years advances in engineering designs and the development of high-temperature alloys have required new welding techniques. What was formerly considered sound welding may be unsatisfactory for current applications. Old procedures had to be discarded and new ones developed, especially for welding stainless steels and high-nickel alloys. Thus today the use of the inert-gas-shielded tungsten-arc welding process (TIG) is often specified for welding the root pass where the job requires full root penetration and a uniform inside surface contour that will not interfere with fluid flow.

Nozzles and stubs are formed by hot forging from a solid billet. Larger connections may be integral with the heads, formed from rolled plate or made from pierced-and-drawn pipe. Attachments to the drum are made by hand welding with the manual shielded-metal-arc process using coated electrodes, by automatic welding with the submerged-arc process or by semi-automatic welding with the "flux-core" gas-shielded metal-arc method. This latter method, introduced about 1965, has been substituted in many applications for the slower manual metal-arc welding process. In the flux-core method, a continuous coil of fabricated electrode filler wire is fed through a hand-held gun that is directed at the joint to be welded. Slag-producing ingredients and alloying elements are contained inside a tubular sheath. Carbon-dioxide gas is introduced to shield the molten puddle from atmospheric contamination. This process has almost the same weld-deposition rate as the submerged-arc process sometimes used for nozzle welding. Its advantage lies in the portability of the equipment, the much lower setup time required and the decreased time span that can be realized by putting several welders to work on the same job. Other developments that will contribute significantly to the quality of the welded joint and appreciably increase the deposition rate of weld metal are currently nearing production stage.

Every drum fabricated must be subjected to a stress-relief heat treatment after all welding on it has been completed. In some cases several heat treatments are required during construction of high impact strength. Formed heavy plate is quenched in water to cool it rapidly from 1600° to 600 F. through the transformation range. This heat treatment is followed by normal stress-relief, which consists of heating to 1150° F., holding for one hour per inch of thickness and furnace cooling to 600° F.

Every inch of every longitudinal and circumferential weld in a drum, and numerous other welds, must be subjected to radiographic examination. For this purpose extensive X-ray equipment (Figure 10-25) of a wide range of power, from portable machine rates at 400,000 electron volts to the 12.8 MeV linear accelerator is provided. Supplementing the X-ray equipment are radioactive isotopes, such as Cobalt 60, used in various capsule sizes up to 2,500 curies. Other forms of non-destructive testing comprise dye penetrant methods for locating fine surface defects and magnetic particle testing for finding defects on or just slightly below the surface of the material. Reflectoscopic examination using ultrasonic vibrations has been adopted as standard testing procedure on all heavy plate for pressure vessels.

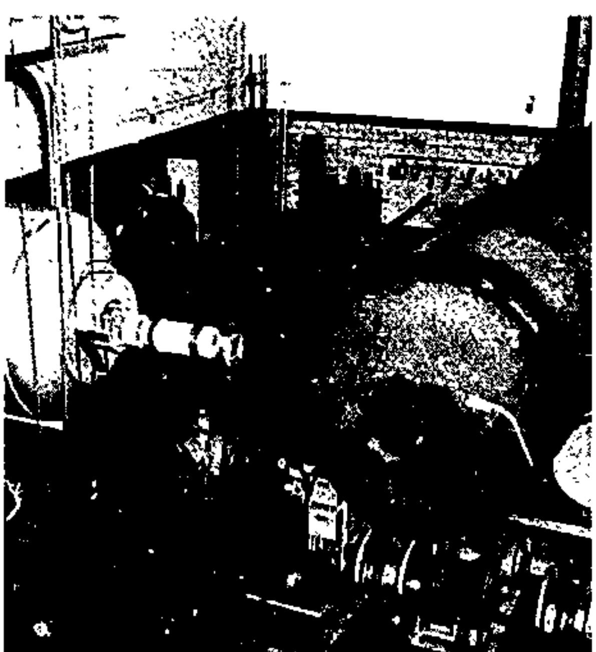


Figure 10-25. Registering 2 Million Volt X-Ray Machine on Circumferential Seam of Drum for Radiographic Examination of Weld. Film Cassette Positioned on Inner Surface.

Throughout the fabrication process of any pressure vessel, all work is conducted under the strictest surveillance of the company's quality control and quality assurance departments to assure compliance with the ASME Code, company standards, government standards and users' requirements. All materials used for pressure parts are certified as to specifications by wet chemical analysis and spectroscopy as well as by mechanical tests for tensile, bending and impact strengths.

After all welding of pressure parts has been completed and found satisfactory, the vessel is ready for the finishing operations. These include installation of minor attachments and the internals. Figure 10-26 shows the internal baffling arrangement for a large steam drum partially pre-assembled on the shop floor. This structure is later knocked down and reassembled inside the steam drum for shipment with the drum.

Figure 10-26. Partially Assembled Internal Baffling for a Steam Drum

HEADERS AS TERMINAL PRESSURE VESSELS

Headers are extensively used in modern steam boilers as a means for joining two or more boiler circuits. Headers are of smaller diameter (under about 24" ID) than drums and can be fabricated from seamless tubing, pipe or hollow forgings. Access to their interior is through handholes, whereas drums have manholes for ingress and egress. Figure 10-27 shows a superheater header nearing completed fabrication.

Many straight or bent tubes (stubs) and tee connections have been shop welded to the 20" OD,

Figure 10-27. Large Superheater Header of Low-Alloy Steel in the Final Stage of Fabrication

4½ thick. 50' long superheater header shown in Figure 10-28. All welds to pressure vessels are completed in the shop so that stress relieving of welds can be done quickly and economically under controlled conditions.

Complete facilities are available for the piercing and drawing of large-diameter heavy-wall pipe stock. This equipment consists of an 8,500 ton press (Figure 10-29) for initial piercing of the

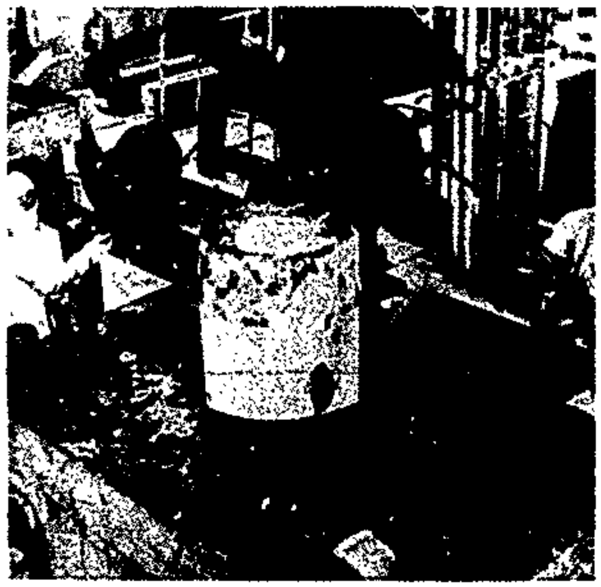


Figure 10-29. Cupped Forging Leaving Piercer Pot of Vertical Press, Ready for Drawing Into Pipe Stock

ingots, a 1,200 ton drawbench (Figure 10-30) for reducing outside diameters and wall thicknesses and extending the lengths of the pieces, a multiplicity of engine lathes for machining the outside and inside diameters of the produced pieces and numerous types of special test equipment for checking and controlling the quality of finished products.

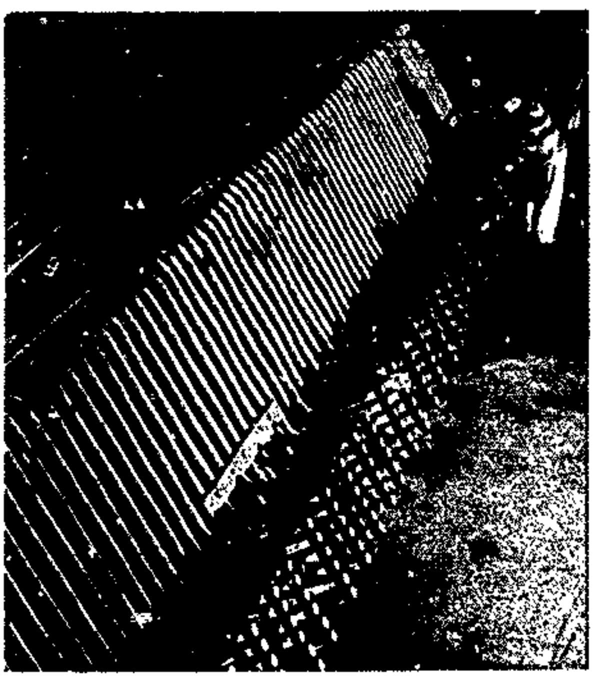


Figure 10-28. Bent Tubes (Stubs) and Tee Connections (Opposite Side) Shop-Attached to Large Superheater Header

Figure 10-30. Drawbench Converts 26,000 lb. Pierced Ingot Into Long Hollow Forging

Fabrication of a large header begins with circumferentially welding the required pieces of pierced-and-drawn hollow-forging stock by the automatic submerged-arc method to obtain the desired length. The ends of the header stock are then spun hot until closed (Figure 10-31). To absolute tightness after spinning, the centre portion of the closure is drilled out and replaced by a fusion-welded steel plug. For the larger headers, when the outside diameter exceeds the capacity of this spinning machine, the ends of the headers are closed by welding a forged hemispherical head made in an operation similar to that previously described for drumheads (Figure 10-30).

Completion of the header includes drilling and machining of tube and nozzle holes, fitting and welding the nozzles, stubs and other attahcments by manual and semi-automatic methods, heat treating, cleaning, and finishing operations, all conducted under strict quality control. Figures 10-32 — 10-33 illustrate some of these operations.

While the majority of headers today are circular in cross section, there are some applications where square headers are suitable. The fabrication process for these is similar to that described above, except that, prior to closing the ends, the header stock is changed to a square cross section by passing it at forging temperature through a set of rolls.

Figure 10-31. Header End Closed by Hot Spinning

Figure 10-32. Fusion Welding Nozzle Connections to a Large Header

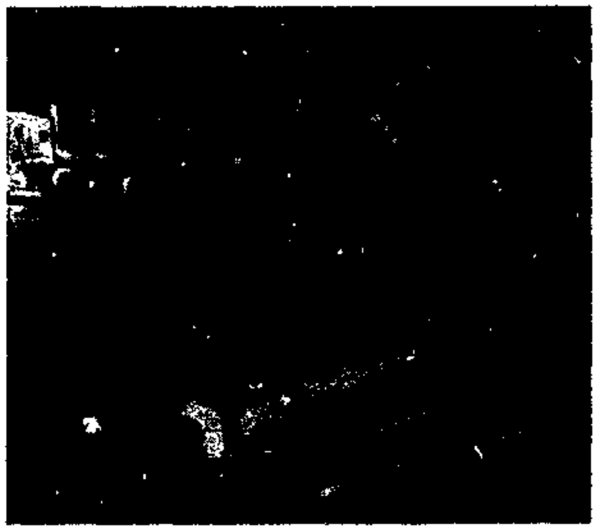


Figure 10-33. Shop Assembly of Two Connecting Headers

TUBES AS HEAT-ABSORBING SURFACES

Tubes, in an almost endless variety of arrangements, serve as the heat-absorbing surface and provide flow circuits in today's steam generating units. Tubes range from 1"-4 1/2 in diameter and may be plain or fitted with studs for extended surface, as in some furnace-wall tubes.

For larger units, past practice was to fabricate and ship each wall tube individually. This required a piece-by-piece field assembly during erection. Today, wall panels are generally assembled in the shop to expedite field erection. The latest design of panel walls is a "membrane" construction of furnace and setting walls.

This construction is shown for the major part of the pre-assembled wall section (Figure 10-34) where the space between wall tubes, from the top header down to the bottom, is closed with a metal filler piece continuously welded on both sides to the adjacent tubes. The result is a gas-tight metal wall surrounding the enclosed volume. A sectional view of a section of a membrane wall panel is shown in Figure 10-35.

This design eliminates the need for a pressure-tight casing and reduces the cost of field erection. Walls of this type can be assembled on a table in sections up to 10' wide and 90' long. The membrane is then welded to the tubes by the submerged-arc welding process, with a travelling head feeding a number of electrodes simultaneously. The machine for this operation is illustrated in Figure 10-36.

Wall panels may be bent to required radius and degree after assembly of panels, using a multiple die encompassing as many as 60 tubes. Figure 10-37 shows a membrane wall panel being bent in special multiple dies.

While wall-type surface is used for superheating, most convection superheaters use continuous tube sections. Figure 10-38 illustrates a typical section of the pendant type. Convection superheater platens are made from relatively short lengths of straight tubes that are first bent and then welded together to give the desired configuration. All bends are formed cold except the inside hairpin bend which must be made hot.

Close return bends are made by first upsetting a section of straight tube to increase its wall thickness at the location for the bend and then hot bending and sizing to the desired dimension. The prepared ends of the resulting "canes" are joined by an automatic butt-welder to form the section. In addition to forming the weld, this machine also heat treats the weld (Figure 10-39).

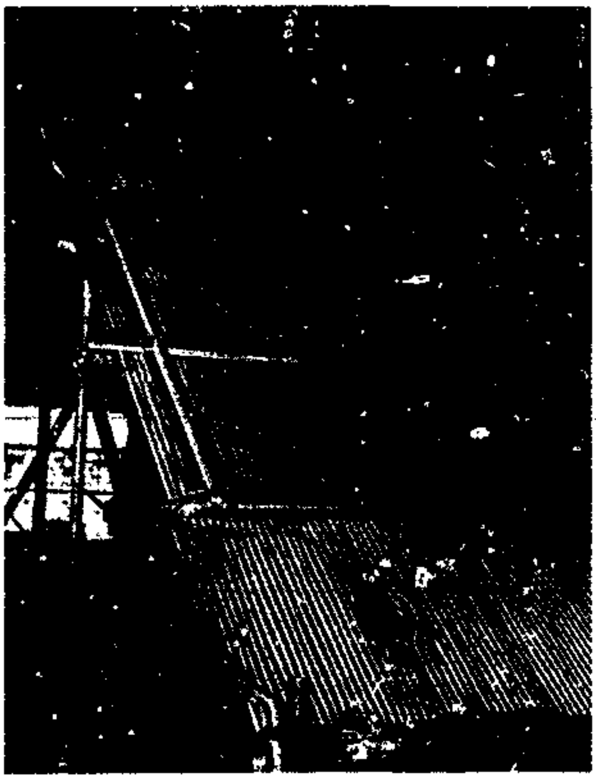


Figure 10-34. Membrane Wall Assembly of Steam Generating Surface

Figure 10-35. Section of Membrane Wall Panel

Figure 10-36. Welding Head for Welding Membrane Bar to Panel Wall Tubes

To complete the platen supporting lugs are fitted and welded into position. an hydrostatic test at one and one half times the design pressure is applied and the section ends are milled to exact lengths and bevelled for field assembly. Sections are then painted and prepared for shipment.

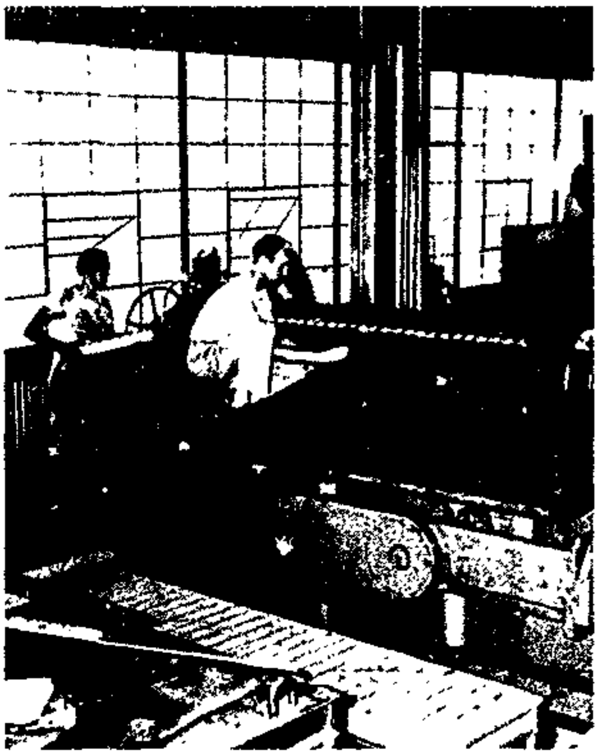


Figure 10-37. Bending a Membrane Wall Panel Between Special Multiple Dies

Figure 10-38. Pendant Superheater Platens Ready for Finishing Operations

Figure 19-39. Automatic Butt-Welding Machine for Making Continuous Tube Platens. Note Newly Made Weld and Other Welds in Completed Portion.

TUBE MANUFACTURING

Many thousand feet of steel and alloy tubes of suitable size, shape and material are required for a large steam generating unit. These tubes are used for steam generating surfaces including furnace walls and floors and in superheaters, reheaters, economizers and air heaters. Headers also might be classified as tubes, since the process of manufacture is similar, but the size range (9¾ -24") is beyond that ordinarily associated with tubes.

Two general types of tubes are manufactured: seamless and welded. Each has its proper application as dictated by users' specifications or technical details related to diameter, wall thickness and chemistry.

SEAMLESS TUBES

Seamless tubes, defined as tubes without weld or seam, are made by piercing from solid rounds of carbon or alloy steels. Most steel for seamless tubes is produced in electric furnaces. This steelmaking process is carefully monitored and controlled at every step and produces steel quality consistent with application requirements.

Tubes for boiler application are furnished either hot finished or cold-drawn, depending on size, tolerance and desired finish.

Metallurgically, the two are similar; the difference is mainly in surface finish and the permissible tolerance in dimensions. To obtain a smooth, even surface and close tolerances, stainless steel tubing is generally finished by cold-drawing only. This process also permits control of grain size in final heat treatment which is important in high temperature application of austenitic stainless steels. The production of seamless tubes requires special tools, careful control of heating and exactness in procedure.

CENTRING AND HEATING

To ensure accurate centring of the piercer point in relation to the piercing rolls, the hot-rolled conditioned tube-round or machine-turned round (if of stainless steel) is provided with a concentric "starting hole." This shallow hole may be produced by a centring machine that drills the cold tube-round prior to heating or by a punch that indents the end of the hot round just prior to piercing. In some stainless steels a small diameter hole may be drilled through the billet's entire length to ease the load in the piercing mill and preserve the piercer point.

The round, ranging in length from about 40"-144" and from 2¹/₄"-8³/₄" diameter, is then heated in a rotary-hearth furnace.

PIERCING

Piercing is done in especially designed machines. The round is gripped between the surfaces of two revolving rolls that rotate in the same direction. Each roll is directly driven by its own motor. By the rapid rotation and kneading action of the rolls, set at the proper angle, the round, somewhat reduced in diameter, moves forward helically over the piercing point held firmly in position (Figure 10-40). After piercing, the bar is withdrawn from the inside of the tube and the rough pierced hollow may be reheated in a suitable furnace to the correct temperature for rolling.

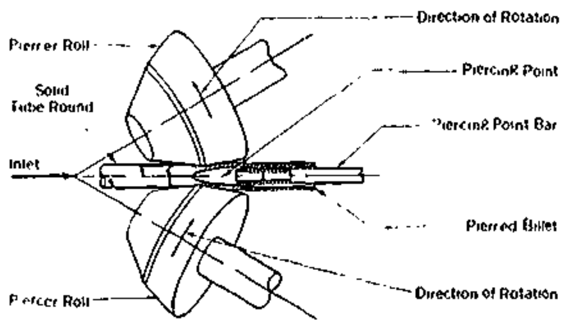


Figure 10-40. Piercing Operation (Diagrammatic) B & W's Cone-Type Piercing Mills

ROLLING

The function of the rolling mill is to lengthen the tube and reduce the wall thickness to the approximate dimensions required. A ram forces the tube into the grooves of the rolls, the rotation of which carries it forward over a plug and bar, working the metal between the grooved surfaces of the rolls and the plug (Figure 10-41). Two to six passes with change of plugs may be requried in rolling stainless steel tubes. To make the wall uniform and avoid ribs or overfills, the tube is turned 90 after each pass through the mill.

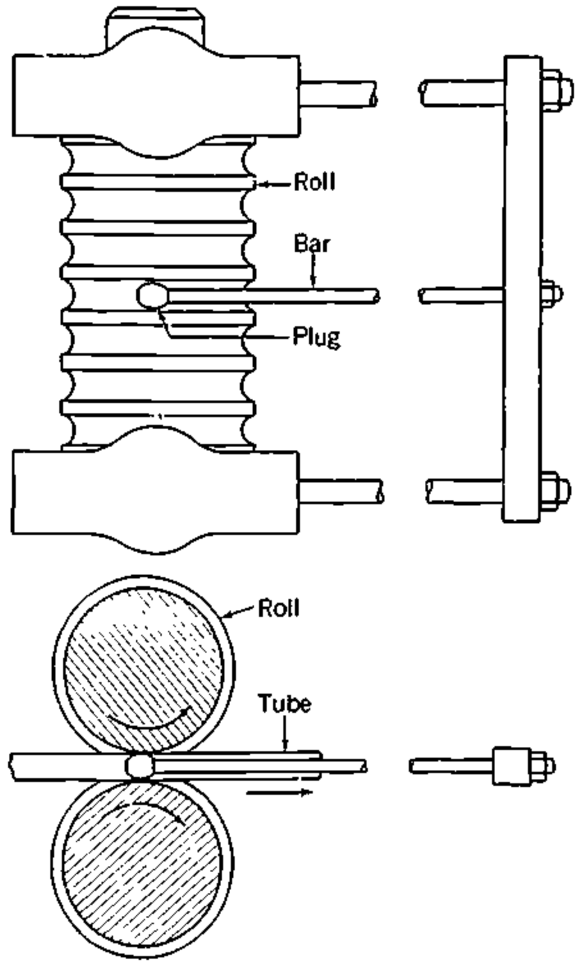


Figure 10-41. Rolling Operation (Diagrammatic) in Tube-Rolling Mill

REELING AND SIZING

After rolling, the tube is in a semi-finished condition, that is, it has required wall thickness and approximate diameter but a relatively rough surface. Directly after rolling and while the tube is still hot, it is conveyed to a reeling machine (Figure 10-42) where it is forced helically over a smooth mandrel, or "reeler plug," supported by a thrust bar on the outlet side of the mill. Rolling over this plug removes light overfills and scratches and the tube is smoothed and burnished. The tube is also rounded and expanded slightly in diameter, but the wall thickness remains approximately constant, or, depending on the pressure applied, is slightly reduced. After reeling, the tube is taken to a sizing mill.

The function of the sizing mill is to hot-size the tube to its proper diameter. Its main elements are several sets of roll stands with single-grooved rolls set in tandem. After sizing, the tube is annealed or otherwise heat treated, if required, and then straightened, cut to length, hydrostatically tested and submitted for final inspection. Appropriate samples are secured for tensile, hardness and deformation tests, and the length gauge and diameter of the tubes are measured.

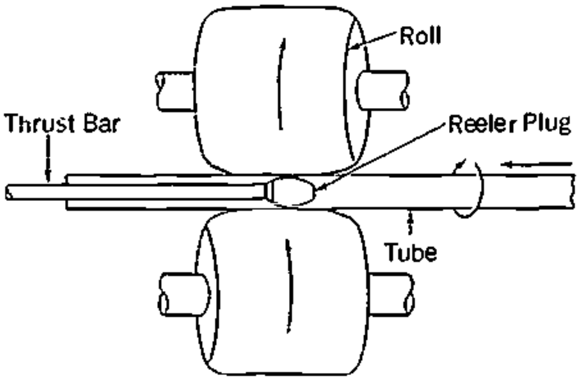


Figure 10-42. Diagrammatic Sketch of Reeling Operation

COLD-DRAWING

Tubes requiring finer finish, closer dimensional tolerances or smaller sizes than can be obtained by the hot-finish process are cold-drawn. The cold-drawing process is used after hot finishing brings the tube close to the desired size.

Cold-drawing is done on a drawbench fitted at its centre with a heavy steel holder for the die through which the tube is drawn. The arrangement of the drawbench, tube die and mandrel is illustrated diagrammatically in Figure 10-43. Tubes may be cold-drawn one or more times to obtain desired dimensions. They are usually pickled and lubricated before each cold-

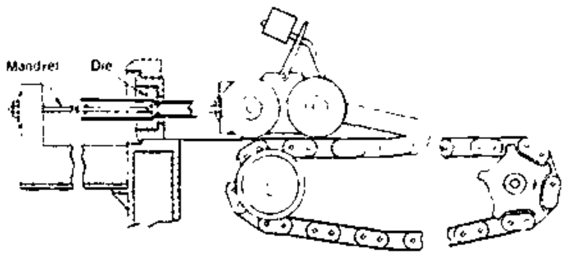


Figure 10-43. Drawbench for Producing Close-Tolerance Fine-Surface-Finish Cold-Drawn Tubes

drawing operation, and in most cases annealing is also required.

After cold-drawing, tubes are given appropriate heat treatment according to specific analysis and specification. Tubes are then descaled, straightened (Figure 10-44), cut to length, tested and examined as required by the American Society for Testing and Materials (ASTM) and other applicable specifications.

Tubing can be made with special shapes such as square, rectangular or airfoil design. It can also be made with helical ribs on the inside or longitudinal ribs on the outside. Such tubes are generally shaped on the hot mill or by extrusion, in each case followed by cold-finishing.

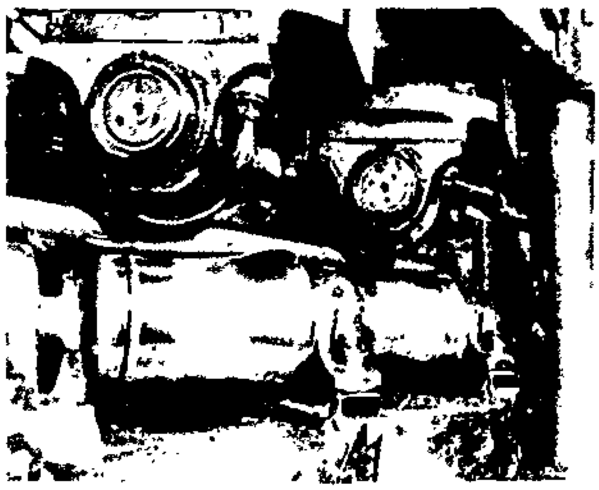


Figure 10-44. Straightening Operation for Finished Tubes

EXTRUSION PROCESS FOR SEAMLESS TUBES

The Ugine-Sejournel hot-extrusion process is used for the manufacture of certain sizes and types of tubes, especially those made from refractory alloys that are difficult to pierce in a rotary piercing operation. A hollow billet, with glass lubrication, is confined in a container between the ram of a press and the extrusion die. A mandrel extending from the ram passes through the billet and the die. As the ram moves forward, the metal is squeezed out between the die and the mandrel.

With present facilities it is possible to produce, by extrusion, tube hollows ranging in size from 1 1/2 -5 3/4 outside diameter and from 0.160"-1 000" wall thickness. Extrusion product lengths vary from 20' for heavy wall products to 60' for lighter products. After the hot-extrusion process is finished, cold-drawing is used to bring the product to the desired size.

ELECTRIC-RESISTANCE-WELDED TUBES

Electric-resistance-welded (ERW) steel tubing is made by forming a flat strip into tubular shape and welding the edges together in an electric-resistance-welding machine.

ERW carbon-steel tubing, rather than seamless tubing, is widely used in stationary and marine boilers. It offers smoother surfaces, more uniform wall thickness and less eccentricity Because of softness and uniformity, welded tubes are easily installed. ERW tubing is commonly produced in sizes from 3/4 -4", diameter and to minimum wall thickness from 0.028-0.220".

Pressure tubing produced by electric-resistance welding is mainly of carbon steel, and both rimmed and killed steel strip are used Rimmed steel is used extensively in the lower carbon grades because of its excellent welding characteristics. However, if the additional cost is justified and the specifications require killed steel, it poses no problem in the manufacture of ERW tubes

Hot-rolled strip, in coils, is used for most tubing produced by this method. The first operation consists of running the strip through a scale breaker under tension onto a re-coiler. After recoiling, following the scale-breaking operation, the coil is backspun to open the individual wraps. The coil is then pickled, rinsed and conveyed to the cold-rolling and sizing mill.

Cold-rolling is applied to the hot-rolled strip to smooth its surface and obtain a uniform dimension. Control of thickness is obtained by use of a beta-ray gauge having Strontium 90 as the radioactive source.

After cold-rolling, the strip is re-coiled and the coil fed into a leveler for flattening. The ends are then cut square and butt welded to the ends of the preceding and following coils to form an "endless" strip. Width and thickness within close limits are essential for welding of acceptable quality. Freshly slit or shaved edges are used to eliminate rust and assure strong, sound welds.

The strip is folded into an open-tube form in a forming mill preparatory to welding. In the resistance welder, high frequency current (450,000 cycles per sec.) is fed into the surface of the strip through silver-tungsten-carbide sliding contacts, positioned on both sides of the seam just before the edges are brought together. The inside flashes (or upsets) formed during welding are trimmed to a specified height, and the outside flashes cut off. These operations are continuous as the tubing emerges from the welding mill (Figure 10-45).

Next, the tubing is accurately sized and straightened in a three-pass mill. As the tubing emerges from the sizing mill, it is cut to required lengths. All transverse welds at coil ends are cut out and the tubes are then normalized in a controlled-atmosphere furnace to produce a uniform metallurgical structure throughout. During this heat treatment the tubes receive a rust-retardant oxide finish.

The tubes emerging from the normalizing furnace are conveyed through rotary straighteners (Figure 10-45) to the cutoff machines where each tube is cut to the required length. Coupons cut from the ends of tubes are mechanically tested according to specifications. Once coupon is flattened with the weld at the flattened edge, another is expanded, and, if required, a third is crushed longitudinally. To pass the acceptance test, coupons must not crack or split in the tube metal or open at the weld. After normalizing, the tubes may be cold-drawn to produce intermediate sizes or smaller diameters.

QUALITY AND METALLURGICAL CONTROL

Steel used in manufacturing pressure tubing, either seamless or welded, is carefully inspected to verify that the material is of the desired quality. In process control, checks are made as required to assure product quality

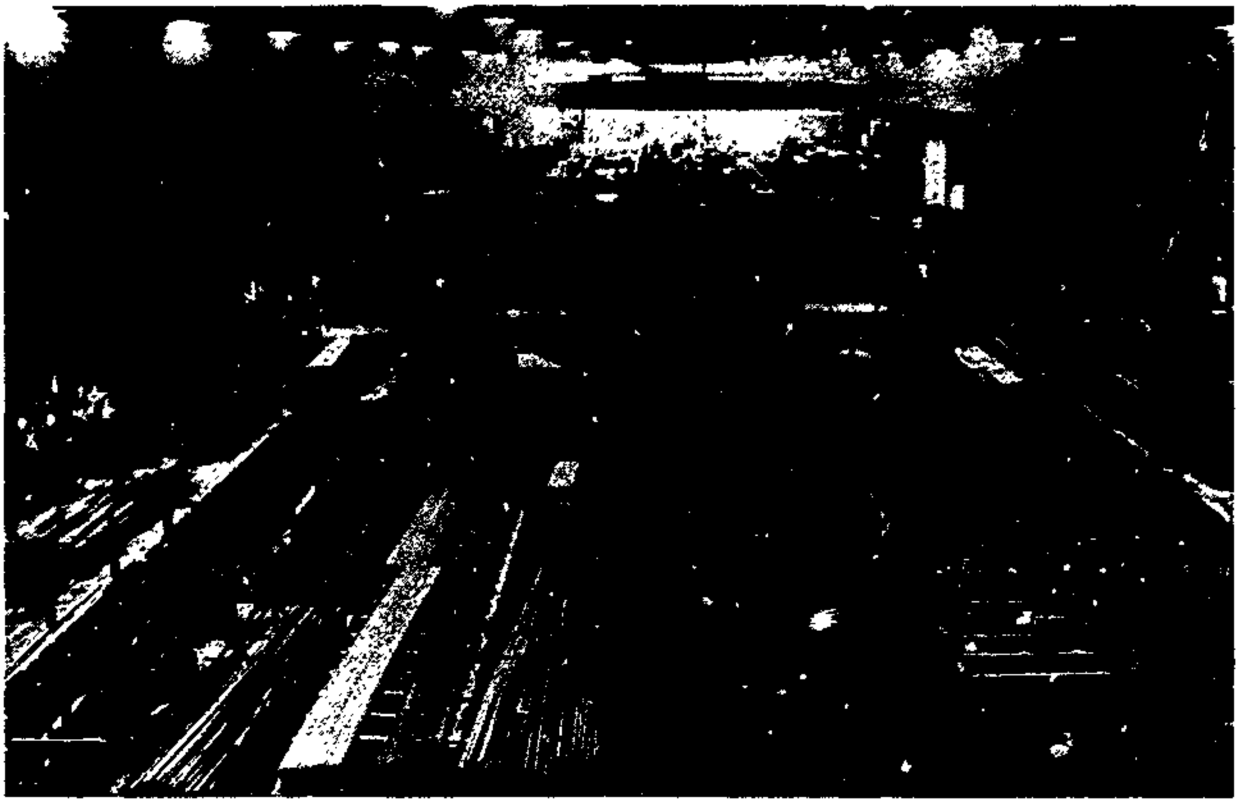


Figure 10-45. B & W Electric-Resistance-Welded-Tube Mill for Continuous Tube-Length Production

Immersed ultrasonic testing is used to inspect the weld of electric-resistance-welded tubing. Imperfections in the weld cause deviations in the normal pattern, alerting mill operators to the possibility of unacceptable material. Non-destructive testing is also used in producing seamless tubing to supplement routine inspection where necessary to assure product quality.

For most applications, tubes are inspected and tested in accordance with ASTM (American Society for Testing Materials) specifications. All pressure tubes are subjected to either an hydrostatic pressure test or a non-destructive electric test of their entire length and periphery. Final inspection includes, for example, measurement of dimensions, visual examination and, in the case of welded tubing, a check of bead-trim height.

BOILER MAINTENANCE

The capability of steam generating equipment to operate safely and remain in operation in accordance with plans and schedules is of prime importance. The maintenance of equipment in condition to assure this capability has come to be known as "preventive maintenance." Preventive maintenance includes a policy of operating equipment properly and within its range of capability. It includes maintaining equipment clean and in prime operating condition. This is verified by instrumentation and in-service observations. Preventive maintenance also includes regularly scheduled outages to make inspections that cannot be made during operation and to perform necessary repairs.

REPAIRS TO FOSSIL-FUEL EQUIPMENT

Repairs to steam generating equipment must meet exacting requirements. This is not surprising in view of the rigid requirements for design, fabrication and field erection of steam generating equipment. Three resources — experienced supervision, skilled manpower and adequate tooling — are necessary for effective repairs. In some situations, the manufacturer's assistance is required particularly when engineering design, metallurgy, welding technology and special tool development are involved. The manufacturer's construction capabilities can often reduce the minimum down-time required to accomplish maintenance and repairs.

Performance monitoring and inspection establish the nature and amount of repair and adjustment to equipment required to return the unit to dependable operation The equipment manufacturer can recommend, guide or carry out the work, but the final decision on what will be an acceptable, dependable repair rests with the operating company and insurance or provincial inspectors.

REPLACEMENT OF SECTIONS OF TUBES

A section of failed tube must be replaced by a qualified journeyman. The length of the replaced section should be a minimum of 12". Usual practice is to cut out the defective section with an oxy-acetylene torch. Care must be taken to prevent slag from entering the tube. The ends are scarfed by grinding with special tools. The use of backing rings is generally recommended when sections are welded into existing tubes. However, where the backing ring is not used, as in high-heat-input zones of high pressure boilers, the space between tube ends should be a minimum and the first bead of the weld metal should be run with a 3/32" diameter electrode. The tungsten-inert-gas process is recommended for the root pass (Figure 10-46). This is a gas-arc-welding process, which uses an inert gas to protect the weld zone from the atmosphere. If the tube to be replaced is of alloy material, the boiler manufacturer should be consulted for procedures and welding techniques.

Figure 10-46. Tungsten Inert Gas (TIG) Welding

SEAL WELDING

Seal welds are used under some conditions for fluid tightness. Structural strength must be secured by some other means such as an expanded joint.

In new construction the ASME Code permits the elimination of the "flare" or "bell" on tubes to be seal welded, provided the throat of the seal weld is not less than 3/16" nor more than 3/8". This applies to a seal weld either inside or outside the drum or header. For repair work the appropriate code permits seal welding and differentiates between inside and outside seal welding as follows:

1. Tubes may be seal welded inside provided no single bead has a throat thickness in excess of 3/16", and the throat thickness of a multi-pass weld does not exceed 3/8".
2. Tubes may be seal welded outside provided the tube has been expanded and flared to 1/8" over the size of the tube hole, and provided that neither the width nor the thickness of the weld exceeds 1/4"

The codes require that tubes be re-expanded after seal welding. The re-expanding should be done lightly and the seal weld examined for cracks after the operation is completed

BUILDING-UP CORRODED SURFACES AND REPAIRING CRACKED LIGMENTS

Repairs included in these two categories vary considerably and can be extremely complex. Each individual case should be reviewed with the boiler manufacturer, operator and authorized inspector to establish acceptable procedures.

REMOVING TUBES AND FITTINGS FROM DRUMS AND HEADERS

Occasionally tubes must be removed and replaced because of damage or defects or because the boiler is to be dismantled and relocated. There are various ways to remove tubes, depending on whether they are to be salvaged, wholly or in part, or scrapped.

EXPANDED TUBES

With light-gauge tubes it is often possible to cold-crimp both ends of the tubes to loosen them in the seats and then drive or "jack" the tubes out.

When the tubes are too heavy for cold-crimping, the two-stage heating method may be used. Heat is applied to the inside of the tube end with a torch first for a short period — not long enough for it to be transferred to the tube sheet. When the tube end cools, the joint will have loosened enough so that the second heat will not be readily transferred to the tube sheet. The tube end can then be heated sufficiently for crimping and the tube can be pushed out of its seat.

If neither method is applicable, the tubes are usually cut off close to the outside of the shell, and the stubs are later removed in a separate operation. To remove light tube stubs, it is advisable to cut grooves about 3/4" apart with a round-nose chisel. When the tongue (the metal between the two grooves) is knocked free, the stub can be collapsed and removed (Figure 10-47).

When a heavy gauge tube must be replaced and the expanded end is a good joint, it is better not to disturb the expanded end provided there is outside access to the tube. It is simpler to cut off the tube at a convenient distance from the drum and join the stub end to the new tube with a ring weld. However, if there is no access for such a repair, the cutting can be done from inside the drum by careful use of a cutting torch. The tongues can be prepared without damage to the seat with the grooving tool. When it is impossible or inadvisable to use a torch, a hand-operated cutter may be used (Figure 10-48).

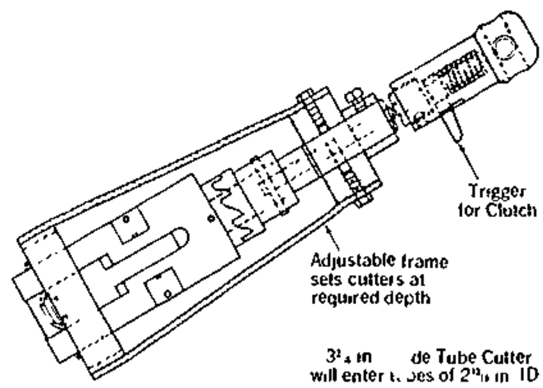


Figure 10-48. Hand Operated Inside-Tube Cutters

SEAL WELDED TUBES

Seal welds are removed from tubes by using tools or cutters such as that illustrated in Figure 10-49. This tool will remove seal welds from 2½ OD tubes inside headers, and can also be used to cut off excess stock from 2½, 3" and 3¼ OD tubes.

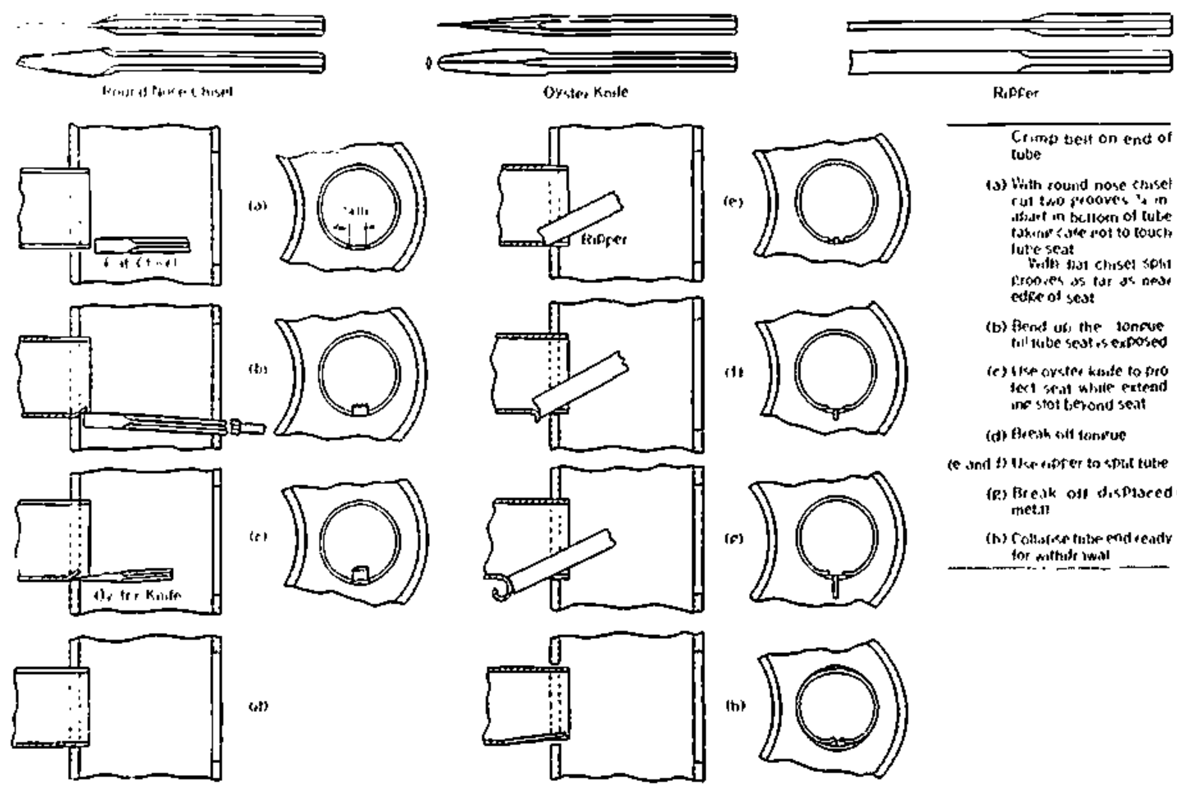


Figure 10-47. Method of Removing Tube from Header

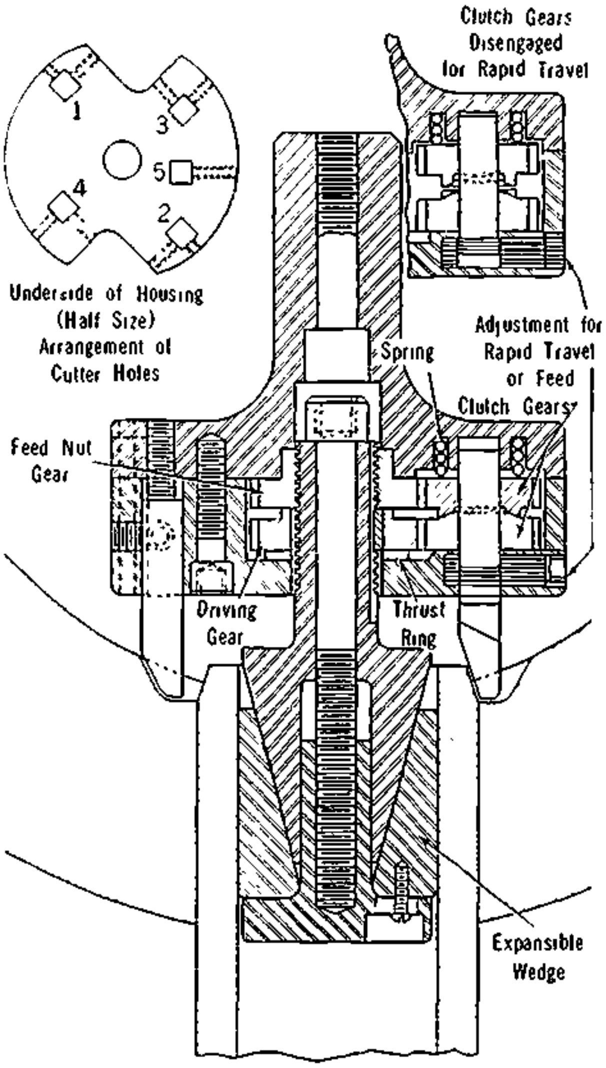


Figure 10-49. Tool for Removing Weld from Inside Seal-Welded Tube

Figure 10-50 illustrates another type of cutter used for removing the seal weld of small-diameter (marine superheater) tubes. The pilot and cutter assembly is placed in the tube and driven through a universal joint and extension by an air motor located outside the header. After removing the seal welds, the tubes and tube stubs may be removed as described above.

REMOVING SEAL-WELDED HANDHOLE FITTINGS

In the course of repair and maintenance it is often necessary to remove one or two seal-welded handhole fittings The most practical way to do this, when no alloy material is involved, is to remove the seal weld with a cutting torch. Considerable care is required to prevent damage to the header in this process. Alternatively, the seal weld can be removed by grinding or chipping.

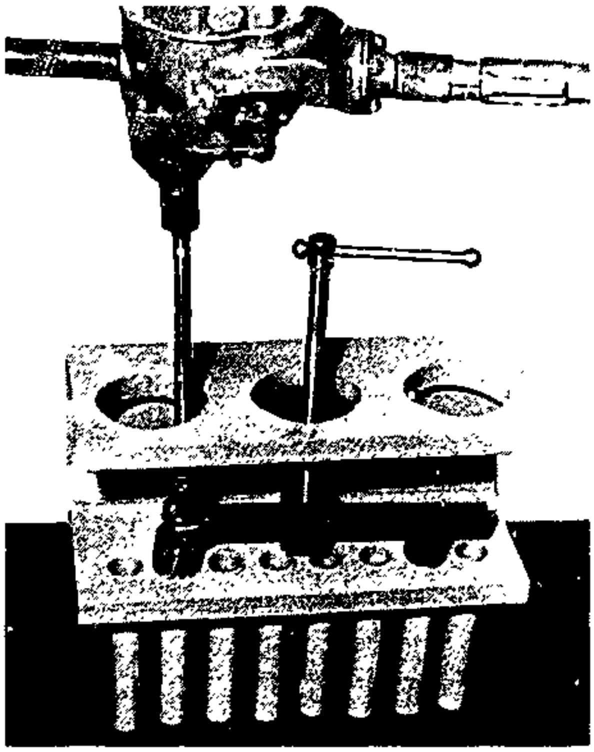


Figure 10-50. Cutter for Removing Seal Welds of Small-Diameter Tubes

While these methods are slower, they do not present the hazard involved in the burning process, and alloy materials can be handled without damage.

If a great number of fittings are to be removed from alloy headers, it may be advantageous to use special tools (Figure 10-51). This type of cutting tool is used outside the header to remove seal welds from 3¼, 4" and 4½ expanded-type cup caps blind nipples and welded-type handhole plugs.

REPAIRS TO STUD SURFACES

During the construction, repair and maintenance of boilers it is sometimes necessary to replace or provide additional welded studs on tubes and ductwork for attaching insulation, casings, doors or refractories. In most applications the Nelson Stud Welder may be used (Figure 10-52). This apparatus consists of a welding machine, a weld-timer and a welding gun The surface to which the stud is to be welded should be dirt free, but it is not necessary to remove paint or mill scale. The stud locations should be laid out accurately and the gun held in position to assure the stud will be square with the plane of the wall or surface. The operator must not permit the gun to slip while making the weld The Nelson Stud

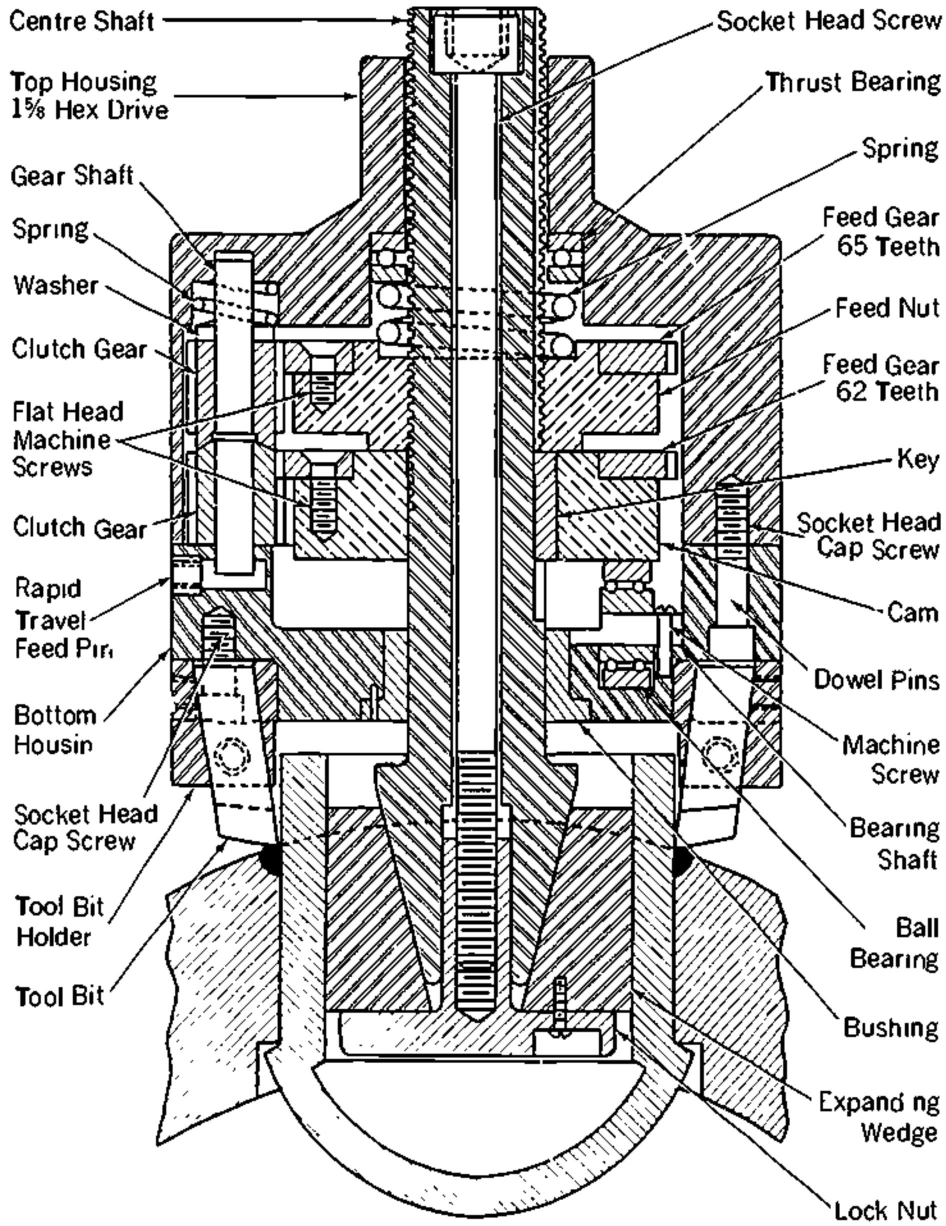


Figure 10-51. Tool for Removal of Seal Welds From Cup Caps and Blind Nipples

Figure 10-52. Applying Self-Welding Studs for Refractory Application

Welder is not recommended for tubes less than 0.125" thick. Hand welded studs should be used for these.

CARE OF IDLE EQUIPMENT—FOSSIL FUELS

To minimize the possibility of corrosion, boilers to be held out of service must be carefully prepared for the idle period and closely watched during the outage.

PROTECTION OF INTERNAL SURFACES—DRY STORAGE

When a boiler is to be idle for a considerable length of time and only a brief period will be allowed tc prepare it to return to service, the dry-storage method is recommended In this method the unit is emptied, thoroughly clean internally and externally, dried and then closed tight to exclude both moisture and air Trays of lime, silica gel or another moisture absorbent may be placed in the drums to draw off the moisture in the air trapped by closing-up the boiler. To ensure against overflow of corrosive liquid after moisture has been absorbed, the pans should not be more than three-quarters full of dry absorbent. Particular care must be taken to prevent water, steam or air leakage into the unit. Periodic inspections should be made to assure no corrosive action is occurring and to replenish absorbent as required.

The same general method of preparing the boiler for out-of-service periods should be followed for the superheater, economizer and reheater sections.

PROTECTION OF INTERNAL SURFACES—WET STORAGE

Where boilers go into standby service but must be available for immediate operation, they should be steamed in service, so that boiler water conditions may be stabilized and oxygen bubbles cleared from the boiler surfaces The boiler should be brought down in rating slowly, and the water level raised as high in the glass as is consistent with safe operation while still unloading some steam to the line. The hydrate alkalinity should be built up to a minimum of 400 ppm. Sodium sulfite (100 ppm) aids in preventing oxygen corrosion.

When the pressure, as indicated by the boiler vent, has almost disappeared but before a vacuum occurs as a result of cooling off, water should be slowly fed to the boiler until it is completely full and the superheater is filled by the spill-over This makeup water must be deaerated The drain on the boiler side of the main stream stop valve shoulo be wide open so that any water getting past the no-return valve will not accumulate on the boiler side of the stop valve Filling should be continued until a pressure of at least 10 psi is achieved against the no-return valve. Close watch should be kept to avoid building any undue pressure against the no-return valve from leaking feedwater valves

Boiler connections should be checked for leakage, and frequent boiler-water samples should be taken and analyzed. If the analysis indicates that hydrate alkalinity has dropped below 250 ppm, the water in the drum should be lowered to normal operating level, chemicals injected to bring the hydrate alkalinity back to 400 ppm, the boiler steamed sufficiently to circulate the added chemicals and the process of wet storage completed as described above Even with these precautions, the possibility of corrosion must not be underestimated, and no boiler should be held in wet storage without emptying for periodic inspection.

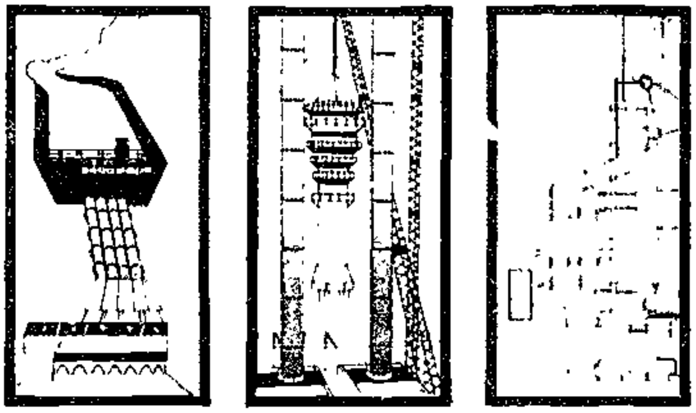
PROTECTING IDLE SUPERHEATERS AND REHEATERS

During out-of-service periods superheaters, except when the complete wet-storage method is used, should always be kept dry and closed from contact with the air. Reheaters should be cared for in the same manner as superheaters except that the wet-storage method is never used. No unit should be wet-stored when there is any probability of a temperature drop to the freezing point.

PROTECTING EXTERNAL SURFACES

The external surfaces of all pressure parts and other metallic surfaces should be completely cleaned of all ash and soot deposits. Other ash, cinder or fuel accumulations, such as on the grates, furnace floors, shelf baffles and in the cinder hoppers, should be removed The settings should then be closed and kept closed Inspection should be made regularly to guard against sweating and corrosion of the external surfaces of the pressure parts, particularly when the wet-storage method is used In such cases it may be necessary to use coke stoves or similar heating devices at convenient points to keep all metal surfaces above the dew point, particularly during protracted spells of damp weather accompanied by rising temperatures

Chapter 11
DUST COLLECTION SYSTEMS



INTRODUCTION

In addition to the legal requirements, there are many instances, particularly in the pulp, chemical and mining industries, where efficient separation of valuable dusts is an economic necessity.

This chapter surveys the factors affecting the selection and particular application of equipment for separating dust from gases. It does not deal with problems peculiar to handling radioactive dusts, where separating dust from the pneumatic handling of powered material has to be considered.

This chapter's aim is to present the basic principles and types of installation of gas cleaning equipment. The types of dust collection equipment this chapter includes are:

1. Cyclones
2. Washers
3. Scrubbers
4. Bag Filter Systems
5. Precipitators

Reference to certain types of equipment that may be associated with particular manufacturers or suppliers does not imply that satisfactory equipment of a similar nature cannot be obtained from other sources or is not being developed elsewhere.

DRY CYCLONES

The cyclone is a simple type of dust collector, designed to replace the force of gravity by a centrifugal force that causes the particles to move out of the gas stream and be collected. The centrifugal force impressed on the particles is affected by their density, and the efficiency of the cyclone by the difference in the density of the dust and gas.

Even under the influence of gravity, dust particles above a certain limiting size will settle out of a gas stream if enough time is allowed and the density of the particles is greater than the density of the gas (e.g., simple settling chambers).

The centrifugal force is obtained by designing the cyclone to spin the gas at a high velocity. The dust particles above a certain size in the spinning gas migrate under the influence of the centrifugal force toward the peripheral boundry of the equipment and subsequently to the dust discharge point.

Two main types of equipment, both generally termed cyclones, employ the above principle. 1) the straight-through cyclone and 2) the reverse-flow cyclone.

STRAIGHT-THROUGH CYCLONE

In the straight-through cyclone (Figure 11-1) the gas is made to spin by a fixed multi-bladed propeller mounted in a circular duct. Dust particles migrate to the walls of the duct under the action of the centrifugal forces created. A short distance from the propeller, the first duct ends and the gas passes through a second duct of slightly smaller diameter. The dust particles pass through the small annulus between the two concentric ducts.

This form of dust collector is frequently combined with a reverse-flow cyclone. In this case, a fan is usually installed to include a small gas flow through the annulus. This small gas flow, which contains the bulk of the dust, is fed to the reserve-flow cyclone, where the dust is separated.

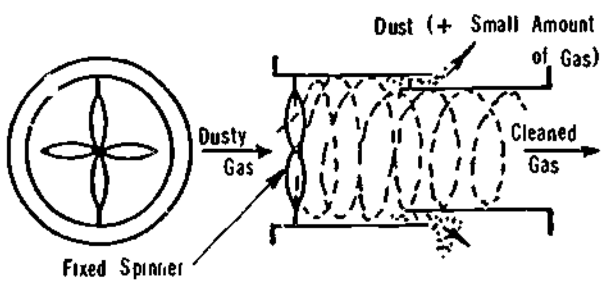


Figure 11-1. Straight-Through Cyclone

REVERSE-FLOW CYCLONE

In the reverse-flow cyclone (Figure 11-2) the gas is made to spin by introducing it tangentially to the top of a cylinder. The entry velocity and the cylinder diameter are chosen to give the desired centrifugal force. (High velocities and small cylinder diameters lead to high centrifugal for-

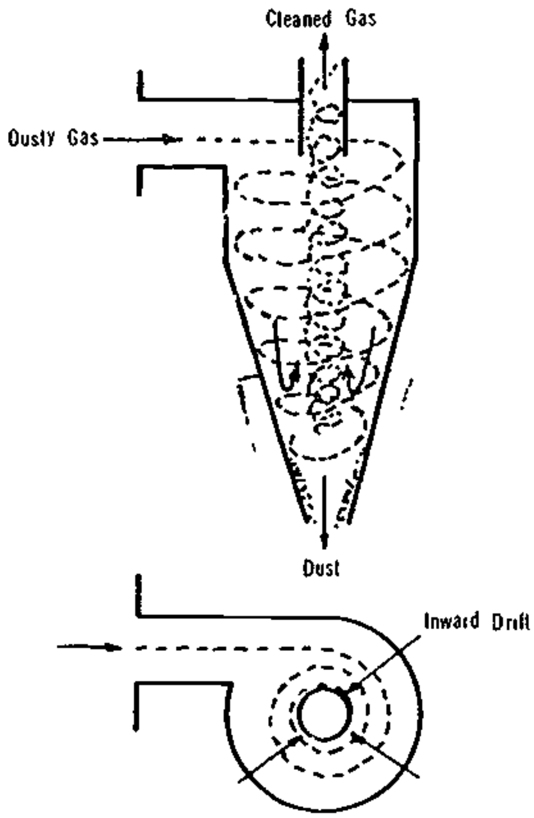
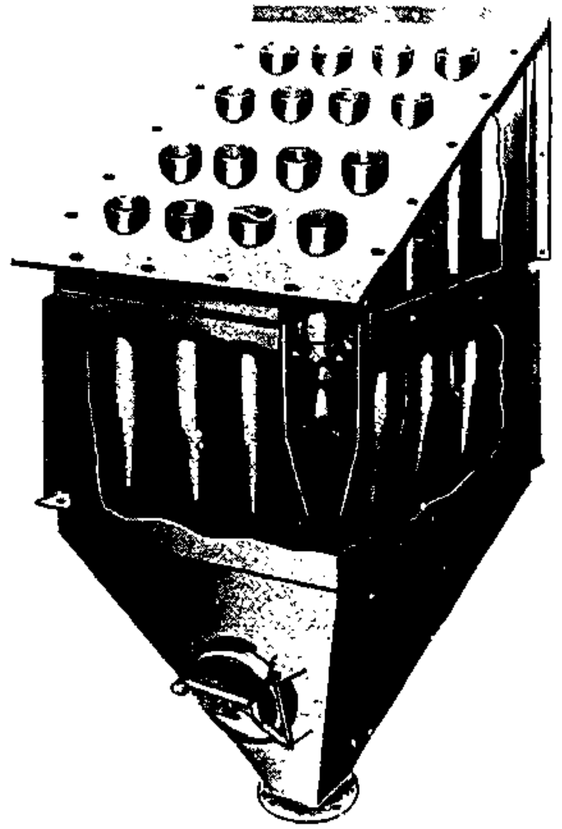


Figure 11-2. Reverse-Flow Cyclone



HOW THE MULTICLONE COLLECTOR WORKS

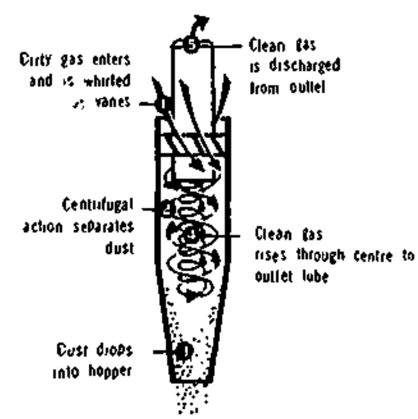


Figure 11-3. Multiclone Mechanical Dust Collector

ces.) The dust particles move toward the cylinder wall and then toward the apex of the inverted cone, fitted to the base of the cylinder. The dust particles are rejected at the apex of the inverted cone, and the gas spirals upward toward the gas outlet at the top of the cyclone. The movement of the gas is thus reversed in the cyclone.

The precise flow pattern of the gas passing through the cyclone is complex, but since the gas is introduced at the wall and removed at the centre, a general movement of gas occurs in this direction. The effect is sometimes called the "inward drift."

MULTICLONE DUST COLLECTORS

Although cyclonic dust collectors were common in the 19th century, they were usually several feet in diameter and useful only for collecting coarse material such as sawdust, shavings, chaff and similar matter. Not until the 1930s did Western Precipitation patent and first market a practical inexpensive multiple cyclone with the individual cyclones or "tubes" less than 30.48 cm. (11.9 inches) in diameter, operating in parallel. This was the Multiclone (Figure 11-3).

Reducing the diameter of the cyclones increases their collection efficiency to the point where many industrial dusts can be collected. Such decreased size, of course, reduces the gas-flow capacity, thus requiring numerous tubes in parallel and also increasing the cost. The best balance between efficiency, capacity and cost occurs usually for tubes about 30.48 cm (11.9 inches) in diameter. Larger tubes are offered for heavy concentrations of some dusts which tend to cling to the tubes; such dusts sometimes plug smaller tubes. Sizes as small as 15.2 cm (5.9 inches) are offered for the highest efficiencies attainable for industrial dusts by cyclones, but their cost is greater.

Multiclone dust collectors with larger tubes — 61 cm (23.8 inches) in diameter — are widely used in the cement industry becuase cement dust tends to clin to surfaces and therefore sometimes clogs cyclones with smaller tubes These are also used for coal drying operations

An involute type of multiclone that imparts a spin to the gas by properly shaping the inlet scoops, instead of using vanes, is also available. This model is used in cement plants and in metallurgical industries, wherever dusts are more adhesive than usual Special collectors best suited to individual needs, including cyclone collectors as large as 1.8 m. (5.9 feet) or more in diameter, are also available.

Cyclones with special inlet scrolls to lower gas turbulence aerodynamically are available. As a result dust laden gases enter the collector and leave it with the lowest possible pressure drop — this means lower fan power and lower operating costs (Figure 11-4).

These cyclones have a computer designed barrel and cone to increase the revolutions taken by the gas stream which in turn forces more dust particles to drop out. Efficiency is thus improved.

FRACTIONATING COLLECTORS

Fractionating collectors separate the ash they collect into two fractions — coarse and fine. The coarse ash, particles from spreader-stroke-fired boilers, usually contain a considerable amount of combustible coke-like material. That ash may be returned for re-use as a low grade fuel instead of being wasted as in an ordinary ash collector. The fractionating collectors send only the fine fraction of the ash to the disposal system.

These models essentially consist of two Multiclone collectors, a large primary one which collects coarse ash and a small Multiclone which collects fine ash (Figure 11-5).

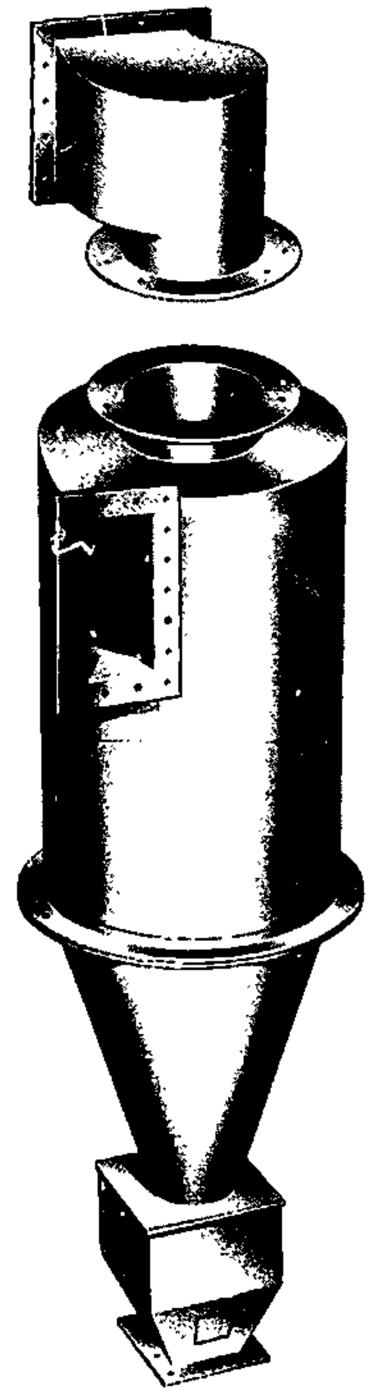


Figure 11-4. Special Inlet Scrolls Cyclone

WET WASHERS (SCRUBBERS)

The success of a wet washer depends on whether airborne particles can be wetted and retained in the circulating water Problems involved in methods of wet dust collection include:

1. Supply and disposal of water
2. Recovery and disposal of collected solids
3. Cleaning the tanks and pipes of sludge
4. Corrosion and erosion.

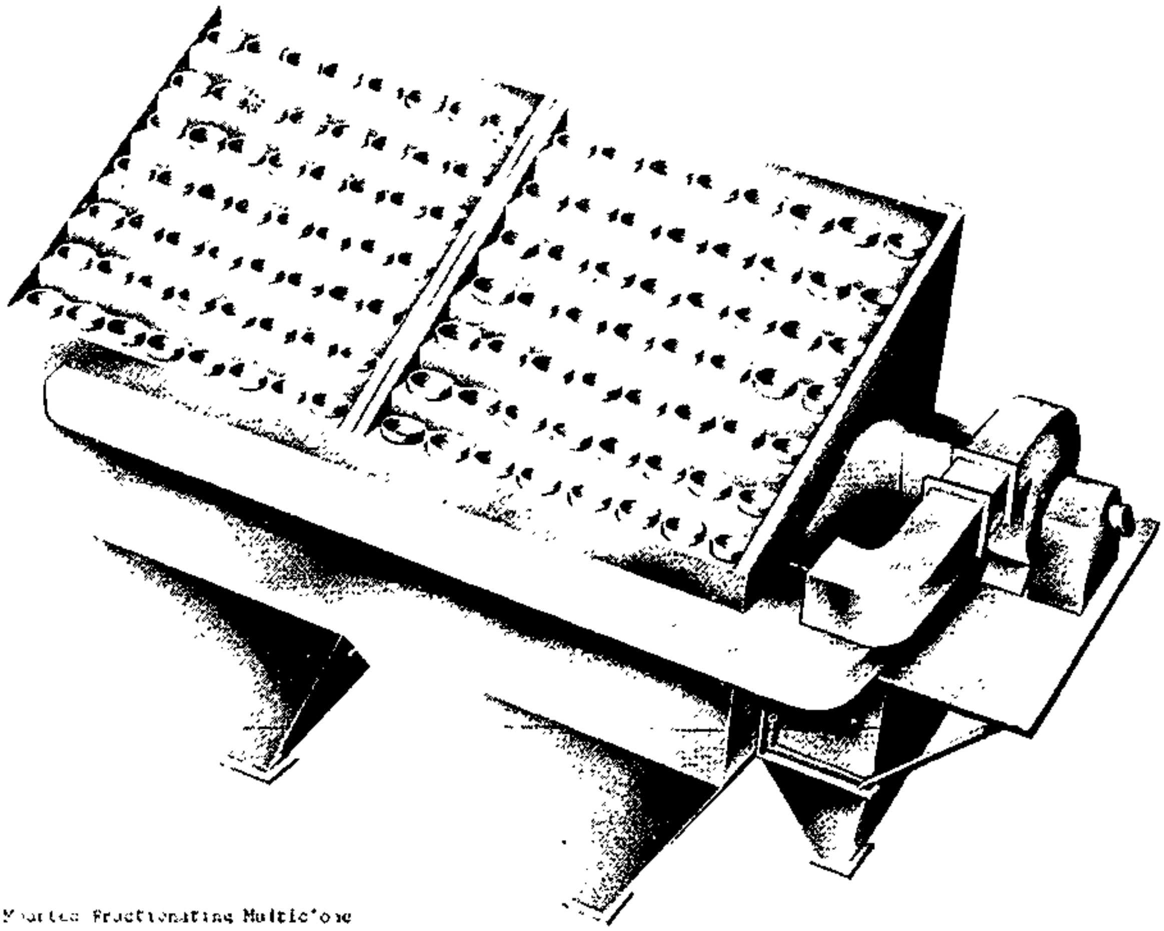


Figure 11-5. Fractionating Collectors

Wet collectors also behave as effective humidifiers and coolers, although these secondary processes are not controllable within close limits However, the cooling of effluent gases can produce acid dew point and air pollution problems. Under favourable conditions, wet washers can give dust collection efficiencies compatible with bag filters and electrostatic precipitators.

The process of collecting dust by means of wet washers depends on the affinity of the material to be collected for the liquid used. This is normally water, sometimes with the addition of a wetting agent.

Wet scrubbers may be subdivided into two main classifications 1) low pressure-drop types and 2) high pressure-drop, high efficiency types.

LOW PRESSURE-DROP SCRUBBERS

Spray Chambers Gas is passed through a series of water sprays directed into the gas stream. Sets of zig-zag elimination plates are provided at the gas outlet, and often inserted between each set of sprays. The water jet scrubber illustrated in Figure 11-6 is a modified version of a spray chamber.

Cyclone Spray Chambers Cyclone spray chambers combine liquid scrubbing with cyclonic action. In the type illustrated in Figure 11-7 the dust-laden gas is given a whirling motion, as in a cyclone, and water is sprayed radially across the gas stream. In the spray chamber illustrated in Figure 11-8 the gas stream is rotated and liquid dispersion obtained by a series of guide-vanes or impingement plates.

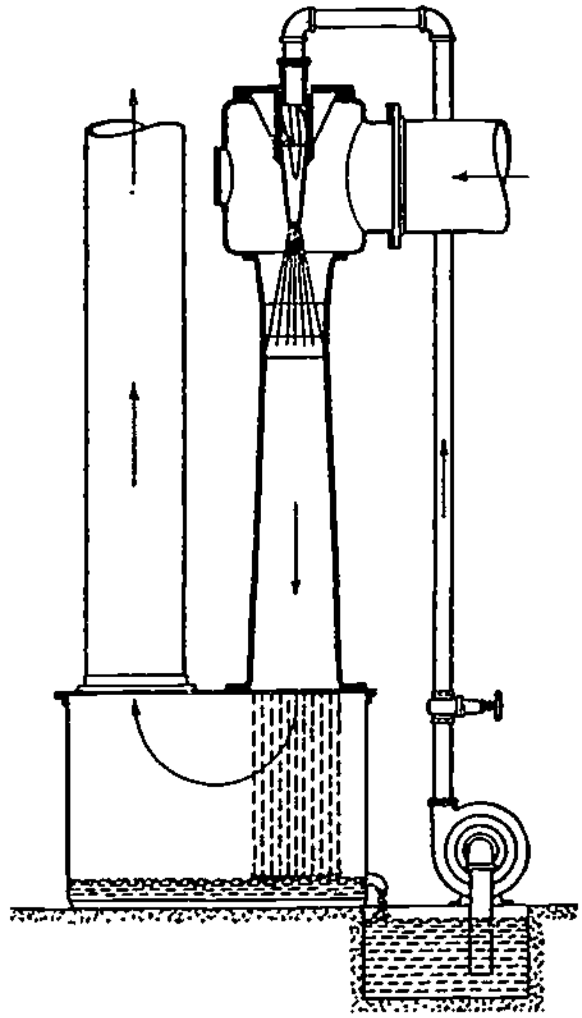


Figure 11-6. Water Jet Scrubber

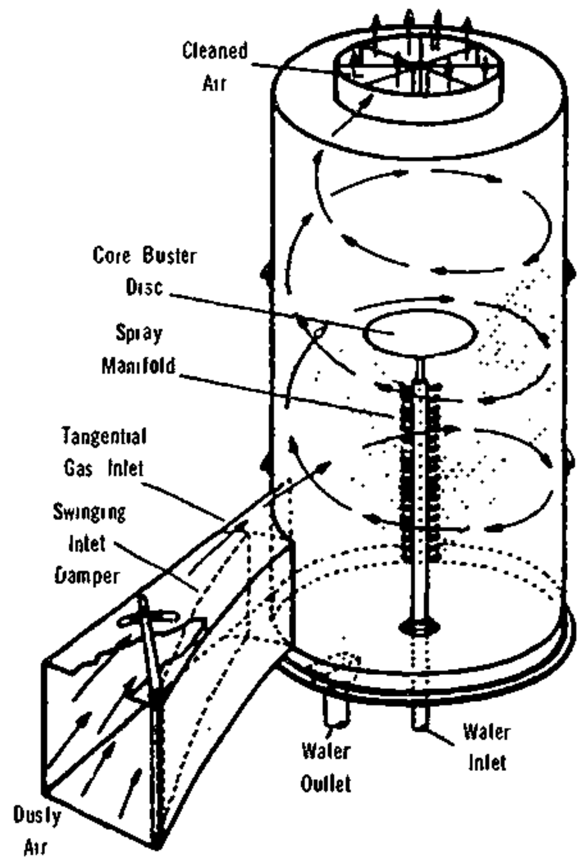


Figure 11-7. Cyclone Spray Chamber

Wet Impingement Scrubbers Dust-laden air is wetted and then cleaned by passing through a series of spray zones and an impingement process. Figure 11-9 shows a typical self-cleaning wet collector. Immediately on entering the collector, the gas is divided into two main longitudinal streams to descend to the initial collection-induced spray section. As it passes through this section, the gas is finely divided, wetted and partially cleaned because of the relative positions of the spray plates and the settling tank water-level. The partially cleaned gas then passes through a froth floor section, where the highest proportion of dust is removed. The gas is further divided in this section as it passes once again through a controlled depth of water at a lower pre-determined speed than in the pre-collection stage. The gas finally passes through water eliminator plates located above the froth floor. The plant's collection efficiency can be varied by simple adjustment of the automatically-maintained water level.

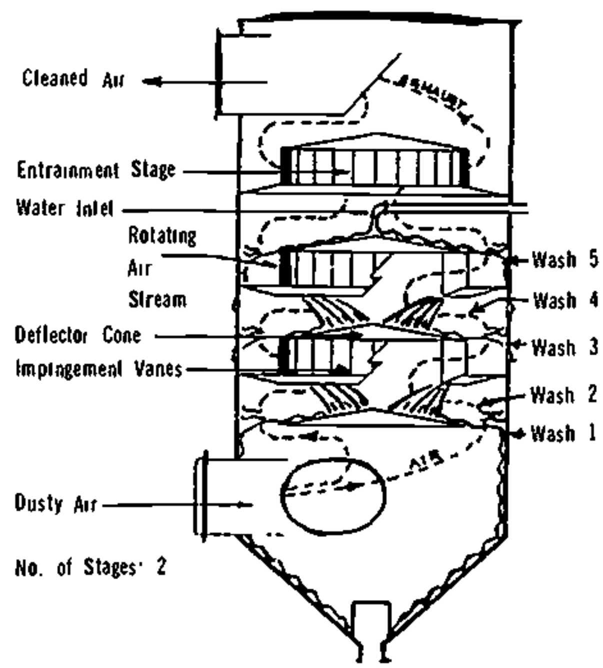


Figure 11-8. Cyclone Spray Chamber

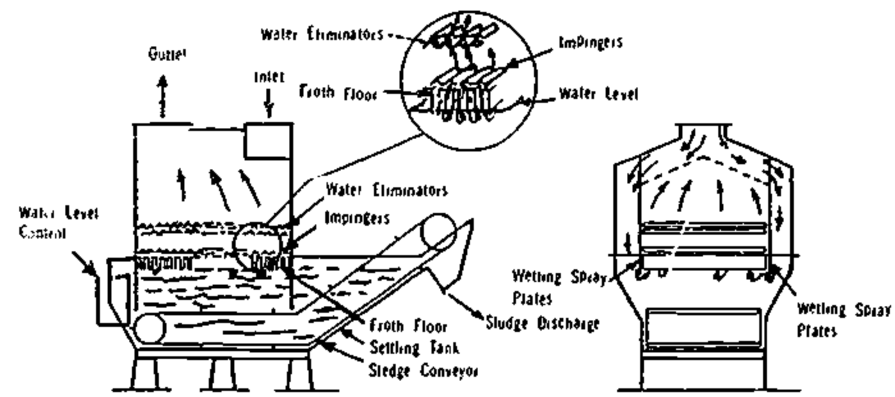


Figure 11-9. Self-Cleaning Wet Collector

The collected dust settles to the bottom of the tank and is removed by mechanical conveyor in the form of a sludge A time control enables the conveyor to be run at pre-set intervals. and sludge quantities up to a rate of about one ton per hour can be removed.

Turbulaire Scrubbers Turbulaire scrubbers impinge dirty gas into a pool of water. They are often used after other types of dust collectors to clean whatever pollutants may have escaped the first collector. However. they can be used to clean most gases without a pre-cleaner and can be used on very hot applications. They can be fitted with quench sprays for gas cooling at the inlet side.

With the exception of fan and motor turbulaire scrubbers have:

1 No moving parts
2. No spray nozzles
3. Low water requirements
4 Simple design
5 Low maintenance.

Various modifications of the design are available as shown in Figures 11-10 to 11-12. The configuration may vary according to space requirements. The scrubbers can also be made from or lined with many different materials including wood. brick. lead. plastic. steel and fiberglass-reinforced plastic.

Wet Cyclones Gas and particles enter the cone of a cyclone tangentially at approximately the same speed and move downward together. The particles are submitted to the separating force of centrifugal action and to the viscous drag of gas flowing toward the outlet duct. If the centrifugal forces are predominant. the particles move to the shell of the cyclone where they become subject to the vertical downward velocity component and are collected. If viscous drag predominates. the particles move toward the centre of the cyclone and are carried away to the exhaust outlet by the gases.

The cause of low performance. experienced particularly with fine particles. can be counteracted by irrigating the inside walls of the cyclone. The water entrains the dust moving vertically downward and transports it into the hopper before it is swept away by the viscous gas streams

HIGH PRESSURE-DROP. HIGH EFFICIENCY SCRUBBERS

Venturi Scrubbers Dust-or-fume-laden gases are directed to the flooded venturi by the fully wetted cone and throat surfaces. The scrubbing liquid partially cools and starts to clean the gases. while protecting the throat against thermal shock and abrasion.

At elocities from 61 m. (200 feet) to 152.4 m. (500 feet) per second in the flooded venturi. the gases created a very fine. dense. turbulent mist of scrubbing liquid. Fumes and sub-micron particles are continuously entrapped by these droplets. as the gas-mist stream is ducted through one turn before tangential injection into the main separator chamber. Here. the droplets with their dust fume loads are centrifugally collected against the sides of the chamber and precipitated to the sump. The cleaned gases circle up through the outlet to the stack. The sludge is then drawn off to settling tanks or centrifuge of other reprocessors. The scrubbing liquid is re-cycled at the appropriate level of clarity and necessary losses are made up (Figure 11-13).

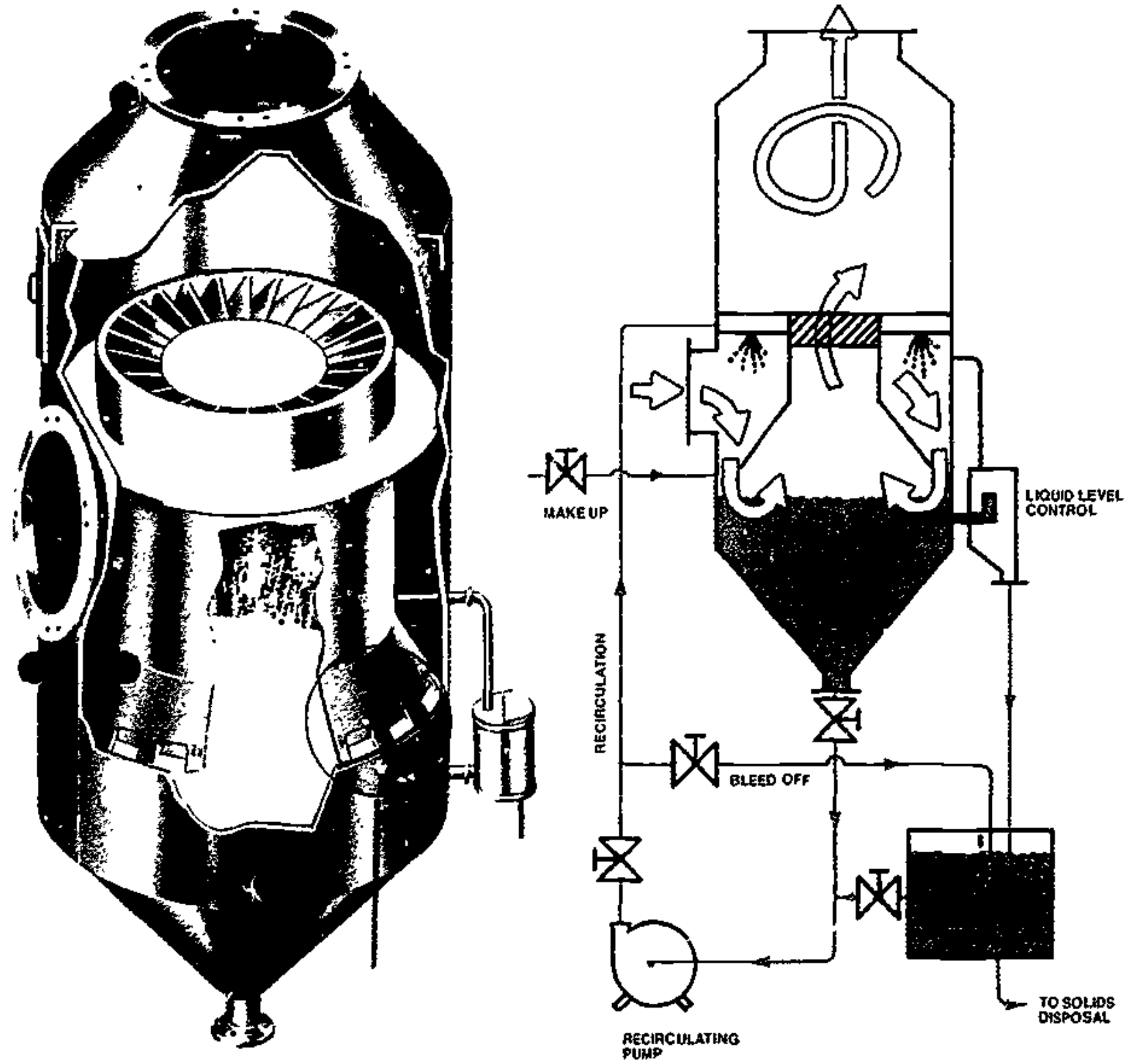


Figure 11-10. Type D Turbulaire Scrubber

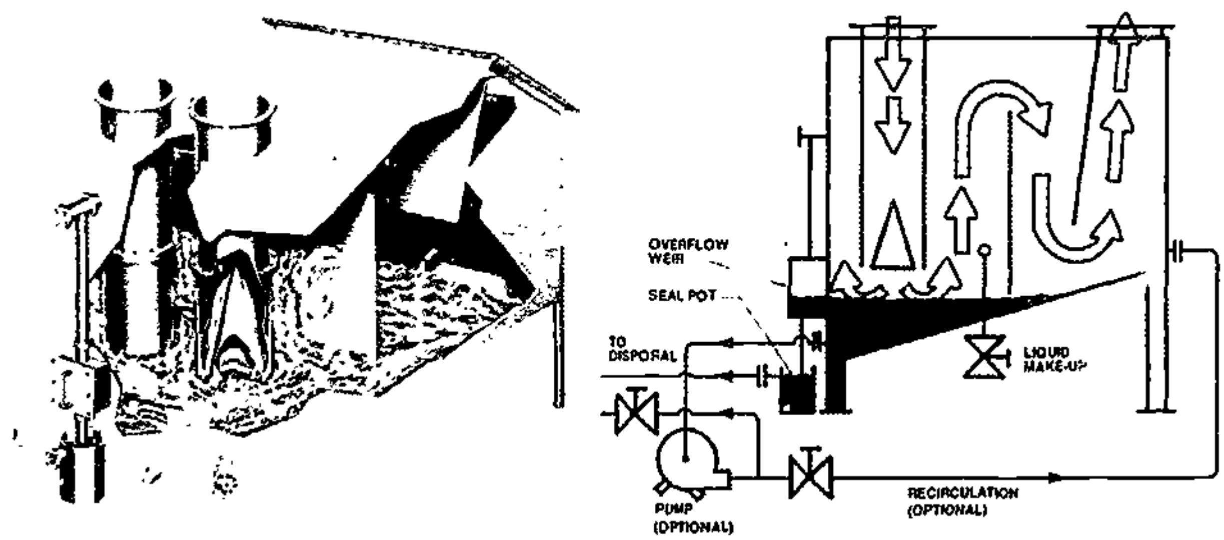


Figure 11-11. Type T Turbulaire Scrubber

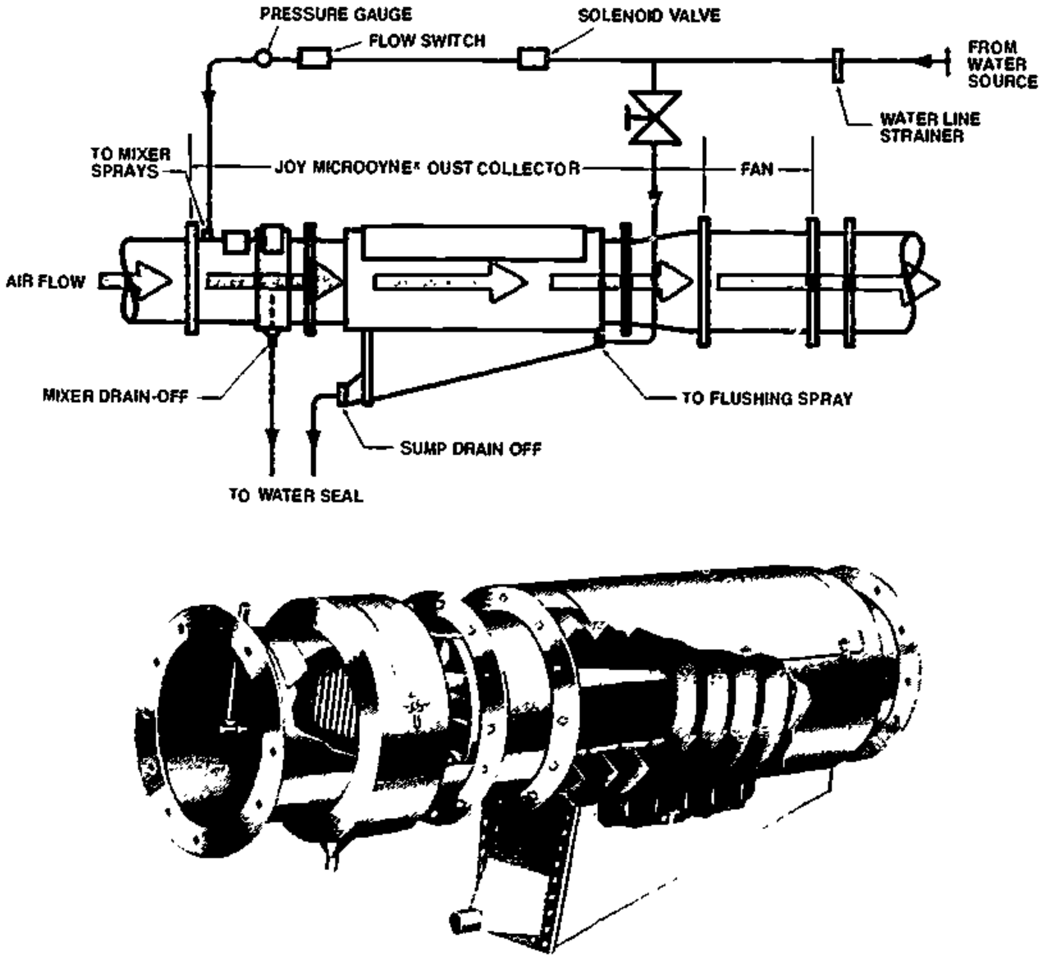


Figure 11-12. Type JM Turbulaire Scrubber

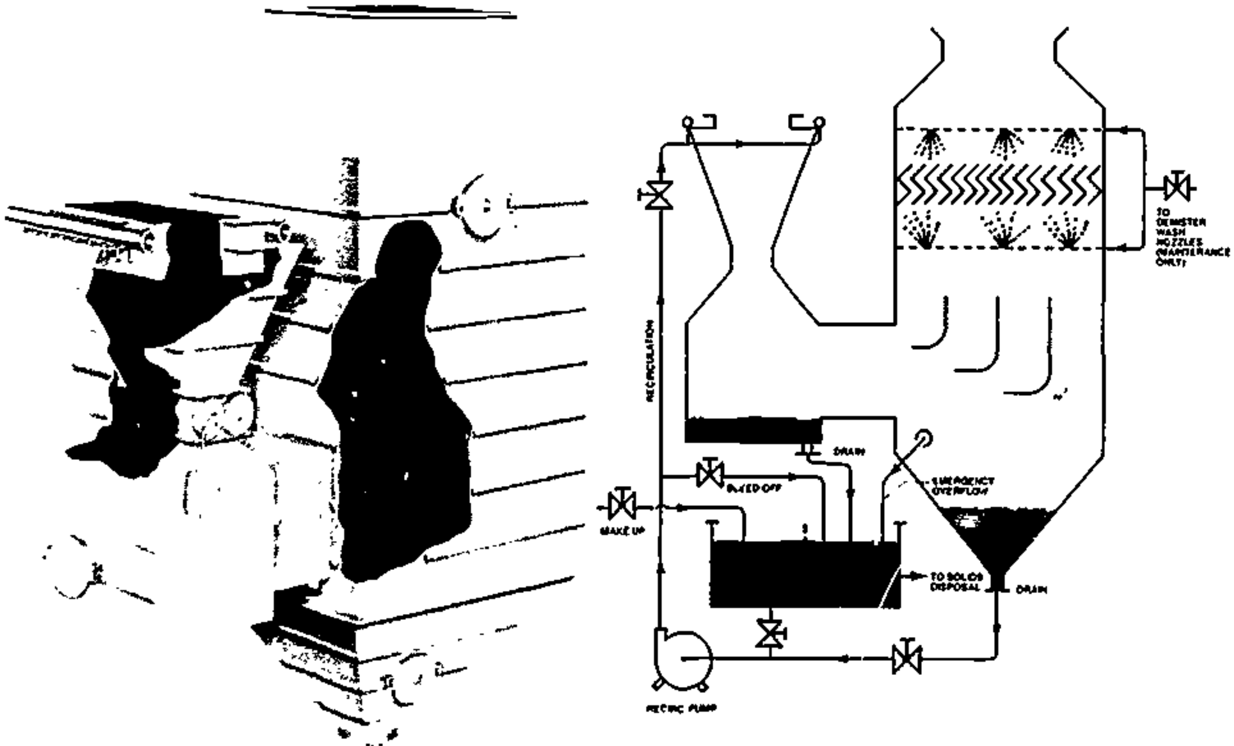


Figure 11-13. Venturi Scrubber with Baffle Plate Separator Chamber

Self-Induced Spray Scrubber The self-induced spray scrubber (Figure 11-14) operates by causing the gases to be drawn under baffles, partly submerged in water, thus generating a dense spray. This section is followed by a wetted wall and finally a spray elimination section. These scrubbers give a good performance even with dusts as fine as 2.5 microns.

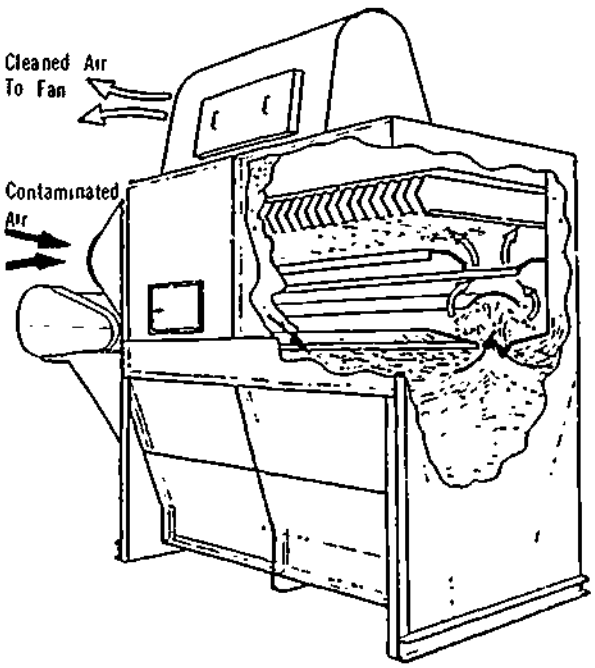


Figure 11-14. Self-Induced Spray Scrubber

BAG FILTERS

Everyone who has used a vacuum cleaner for rugs has used cloth bags as dust filters Cloth bag filters have been used to collect industrial dusts for many years, but their application has been quite limited because cloth made of cotton or other textile will not withstand the high temperatures common to most industrial gas streams.

The advent of glass fibres and glass cloth only partly responded to this problem, because early filters of glass cloth wore out when shaken or flexed to clean them. Eventually, methods were developed for suitably impregnating the glass cloth with silicone binders so as to leave a slick, smooth finish allowing the cloth bags to be cleaned without excessive shaking. The silicone prevents the glass fibres from abrading each other. These greatly improved, long wearing filter bags, 99.9% effecient and durable, even at gas temperatures up to 316 C., are used in the modern Therm-O-Flex (Figure 11-15) by Western Precipitation. These filters are cleaned by periodically collapsing the bags on an automatic cycle.

There are three mechanisms by which a bag filter removes dust from a gas stream, depending on the size of the particles:

1. Large particles will not pass through the mesh of the filter and are sieved out.
2. Medium-sized particles are caught by impingement on the filter fibres.
3. Small particles (which behave in some ways like gas molecules) diffuse and are usually the most important, for, where large particles are present in any quantity, it is usual to remove them by means of a settling chamber built into the filter unit, or by a low pressure-drop cyclone, thus reducing the load of the actual bags.

The Pulseflo filter (Figure 11-16) is available in a wide variety of sizes in either cylindrical or rectangular modular types. The cylindrical models are recommended for relatively small volumes and for larger volumes to 100,00 CFM or more the rectangular modular type is used.

The Pulseflo is a continuous, automatic filter dust collector using an exclusive patented air injector to clean each fibre as necessary. The WP injector uses a short burst of compressed air through a venturi nozzle to create a "pulse" wave down the bag which causes collected dust on the outside to drop off. Cleaning takes only a fraction of a second and dust filtering is virtually continuous. Compressed air requirements are unusually light. As the injector never enters the bag, the entire surface of the filter can be used for cleaning (unlike similar collectors). The Pulseflo is furnished with bags made of the appropriate fabric for the application — cotton, dacron, orlon, nylon, nomex, wool, teflon or a variety of others in temperatures up to 232°C.

PRACTICAL CONSIDERATIONS

Bag filters vary in size from small units, controlling isolated dust sources, to large industrial installations capable of handling millions of cubic feet of gas per hour. The filter unit may consist of either tubular bags or envelopes The bags may be from 12.7 cm (5 inches) to 76 2 cm (29.7 inches) in diameter and from .601 m. (2 feet) to 9.14 m. (30 feet) long. The actual filter units are suspended with the open ends at-

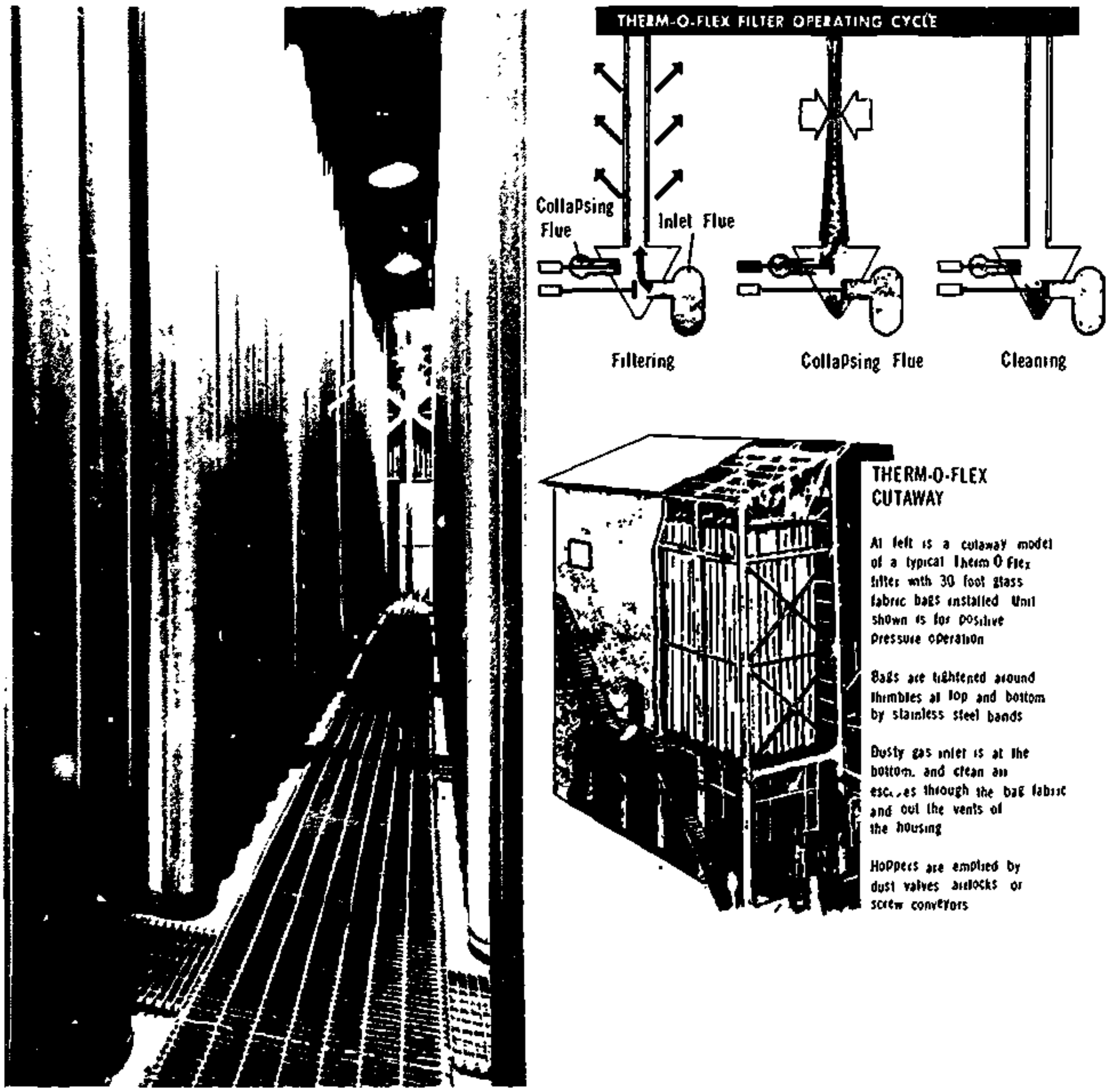


Figure 11-15. Therm-O-Flex Filter

tached to an inlet manifold, either at the top or bottom of the housing or both. The lower manifold also forms the receiving hopper for the dust. Depending on design, the gas can flow inwards through an envelope.

Dust accumulation on the fabric slowly increases the pressure-drop, until the maximum allowable resistance is reached, when it is necessary to dislodge the layers of dust into the collecting hopper. However, for reasons of economy, the pressure-drop should be kept to a minimum, and it is desirable, therefore, that as much dust as possible, compatible with the desired efficiency, be removed at regular intervals. Note that mechanical shaking may not remove compressible dusts, and in these cases, pneumatic cleaning is recommended, if a bag filter is selected for this duty.

METHODS OF BAG CLEANING

The dust collecting efficiency of a bag filter installation increases with the amount of dust deposited in the fabric. This increase in efficiency is associated with the rise in resistance to gas flow and, therefore, an increase in running costs. In addition, a large accumulation of dust in a fabric can damage the fibres and therefore impair its filtration properties.

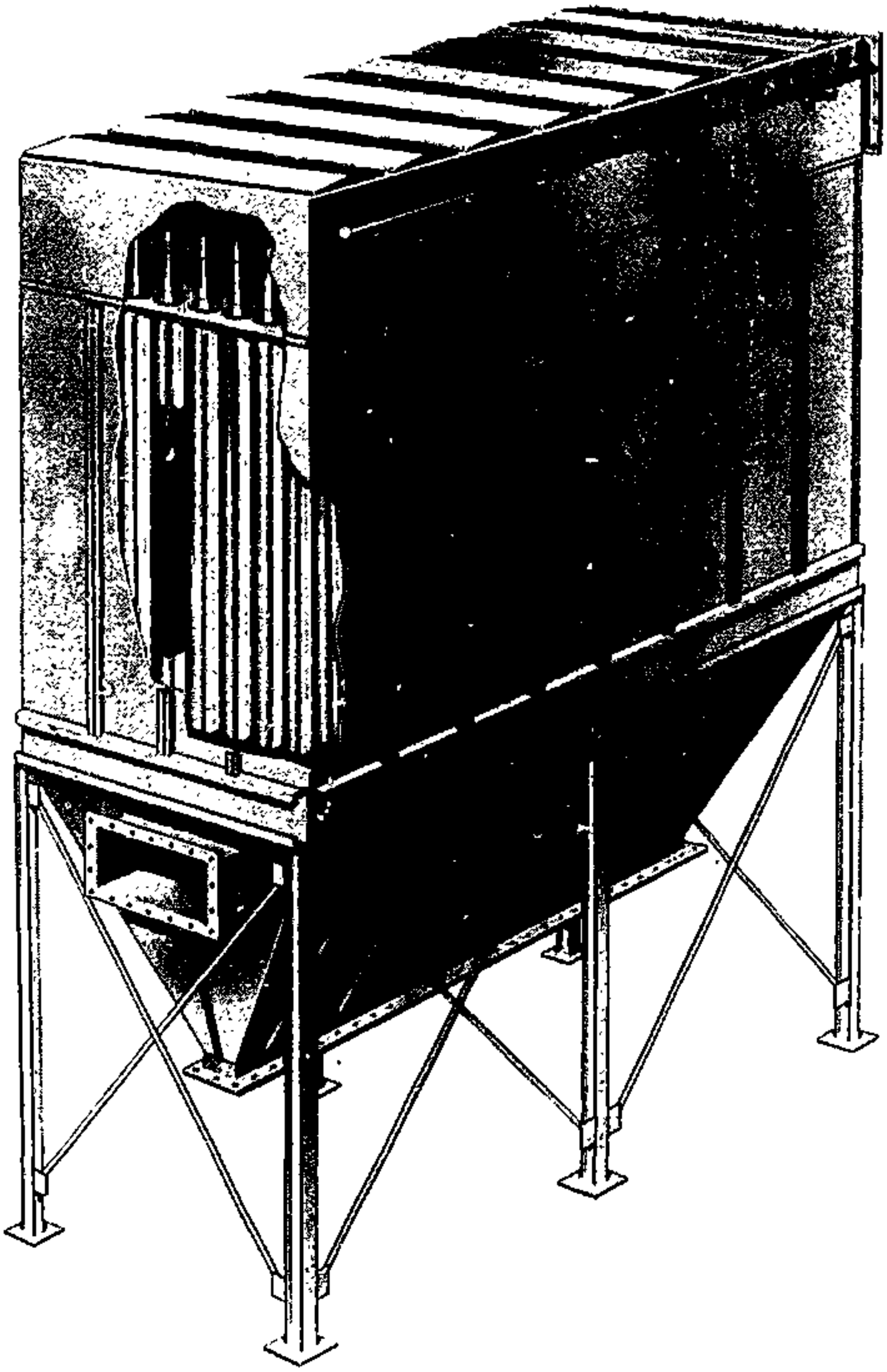


Figure 11-15. Pulseflo Filter

Bag cleaning systems are generally designed to keep resistance within pre-determined maximum and minimum limits. The method used should operate regularly and clean effectively without causing mechanical damage to the bags or allowing dust to escape by re-entrainment. Bags can be cleaned by two main methods: 1) mechanical shaking or 2) pneumatic dislodgement of the dust.

Mechanical shaking is carried out by two main actions:

1. The bags are directly shaken with a rocking or vertical motion, so that dust cannot adhere to the flexing fabric and falls into the hopper
2. If a frame is used to support a bank of tubular or envelope bags, the dust can be dislodged from a complete bank at once by rapping or vibrating this frame (Figure 11-17).

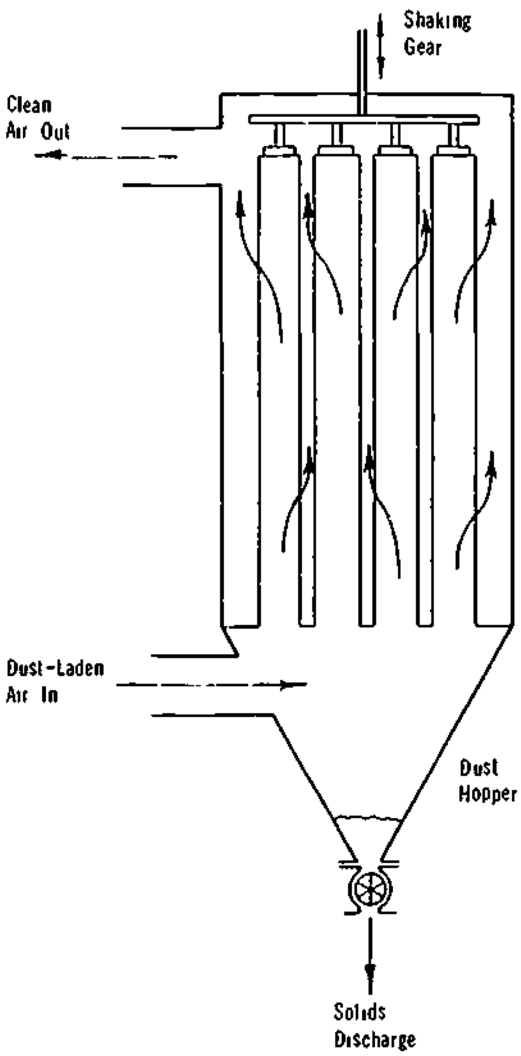


Figure 11-17. Mechanical Shaking

In **pneumatic cleaning**, the cleaning action depends on reversing the flow of gas through the fabric. This produces a partial or local collapse of the bags and flexing of the fabric. Pneumatic cleaning is accomplished by two main types of action:

1. **Reverse Gas Flow** The total gas flow to a section of bags is reversed. To apply this method to continuous operation, the filters are divided into a number of sections that are cleaned in sequence. Dampers divert the main gas flow from a section being cleaned to the rest of the filter.
2. **Reverse Jet Cleaning, Internal High-Pressure Jet** This is accomplished by means of sequence opening and closing of dampers in the various main gas flows, and the associated high-pressure jets shown in Figure 11-18. The entire surface of the bags can be continuously clean.

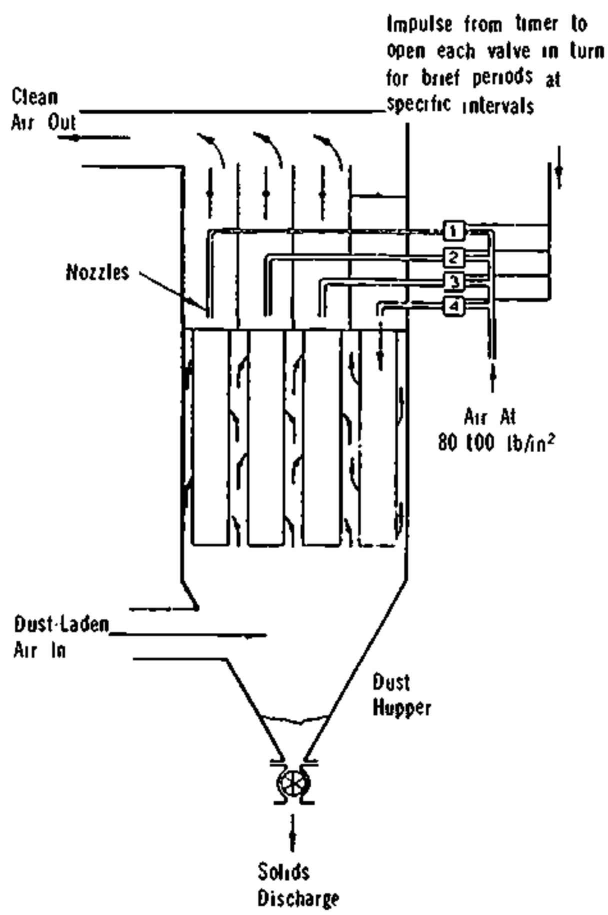


Figure 11-18. Bag Filter with Reverse High-Pressure Jet

The gas flow is reversed over a small area of the fabric by a blow ring or hood that continuously traverses the length of the bag (Figure 11-19). The bags are designed to be slightly larger than the blow rings, so some flexing of the fabric occurs to assist in dislodging the dust.

Some authorities consider that flexing the bags can distort the weave of woven fabrics and allow some dust-slip to occur. It has also been reported that dust can build up above and below the rings and subject the complete circumference of the bags to wear by abrasion

High-pressure jet or ring cleaning methods appear to require very clean dry air for blowing through the jets, gas from the clean side of the bag filters is not considered satisfactory. The running costs of reverse jet cleaning can therefore be high

Regardless of the action used, it is essential in designing large filter plants to arrange for automatic cleaning of the bags at regular intervals

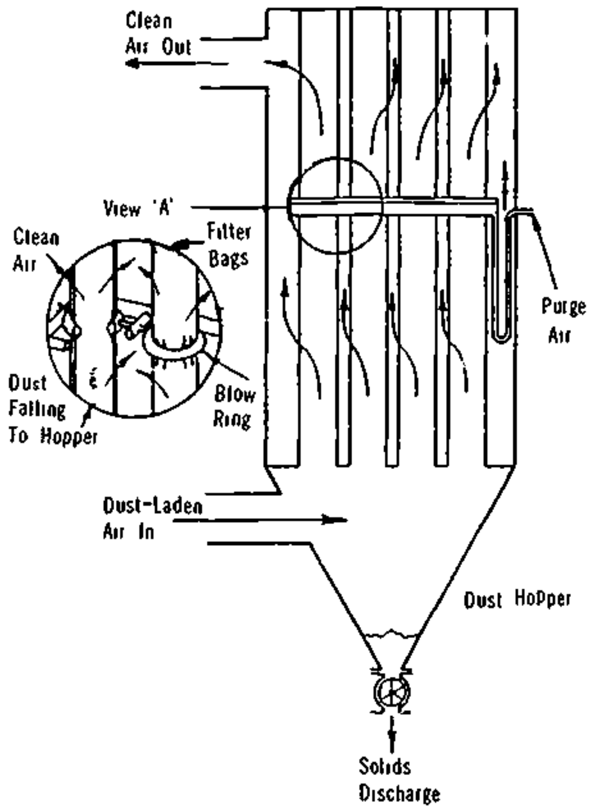


Figure 11-19. Reverse Jet Cleaning, Using Traversing Ring

ELECTROSTATIC PRECIPITATORS

In the early 19th century, in Leipzig, M. Hohlfeld inserted a high-voltage electrode in a metal pipe containing smoke and observed that it was precipitated to the walls. The operation of electrostatic precipitators was found to require a supply of direct-current electricity for connecting to the electrodes. This was not commercially available at the time of M. Hohlfeld's experiments and development was therefore delayed. By 1912, independent work by Sir Oliver Lodge in Britain, G.F. Cottrell in America and Moeller in Germany, resulted in reliable and economical methods of producing high voltage from direct current supplies, and from then onwards, commercially successful electrostactic precipitators were commissioned Units capable of treating gas volumes of up to two million cubic feet per minute with dust collection efficiencies in excess of 99.0%, can now be offered for many industrial applications

TUBULAR ELECTRODE PRECIPITATORS

Since a radial field is obtained from a round wire suspended axially in a tube, early designers considered that the optimum theoretical design would be obtained from banks of tubular electrodes closely nested together, (Figure 11-20). Experience has shown, however, that tubular precipitators suffer from a number of practical limitations.

However, tubular precipitators are used for cleaning blast-furnace gas so that it may be used for fuel, or for acid mist precipitation as well as other applications. Sometimes, the interior surface of the tubes is continuously flushed with water. In the case of the acid mist precipitator (Figure 11-21) the acid runs down the tube walls by gravity and the discharge electrodes consist of wires along the tube axis.

CONCENTRIC ELECTRODE PRECIPITATORS

Instead of installing tubes in nests, they can be arranged in a number of comparatively large concentric tubes (Figure 11-20). In this design, the negative discharge wires are located in a series of annular gas passes formed between the positive plates.

The disadvantages of tubular electrode precipitators also apply to concentric ring types. They are sometimes used for detarring or acid mist applications, where no mechanical rapping of the plates is required. The tar or acid is deposited on the plates from which it gravitates into the hoppers as a liquid

PLATE ELECTRODE PRECIPITATORS

Precipitators incorporating passes between parallel plates (Figure 11-20) have been found to provide the most desirable proportions for the efficient and economical treatment of large gas volumes.

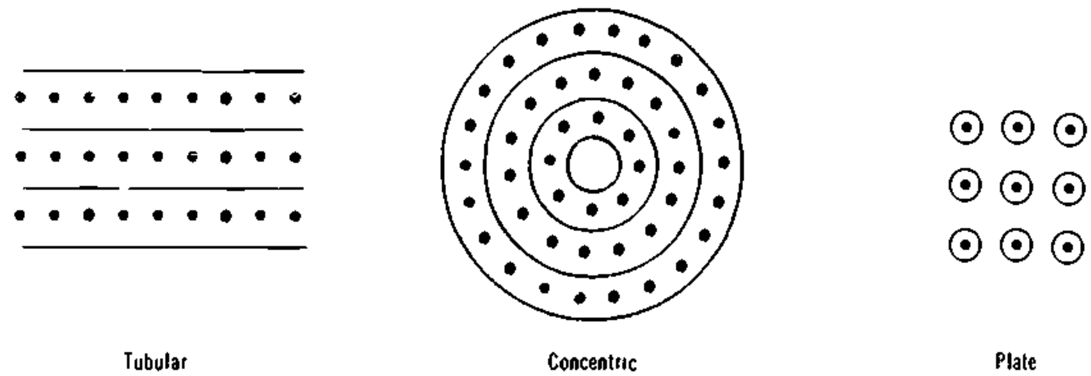


Figure 11-20. The Three Main Arrangements of Precipitator Electrodes

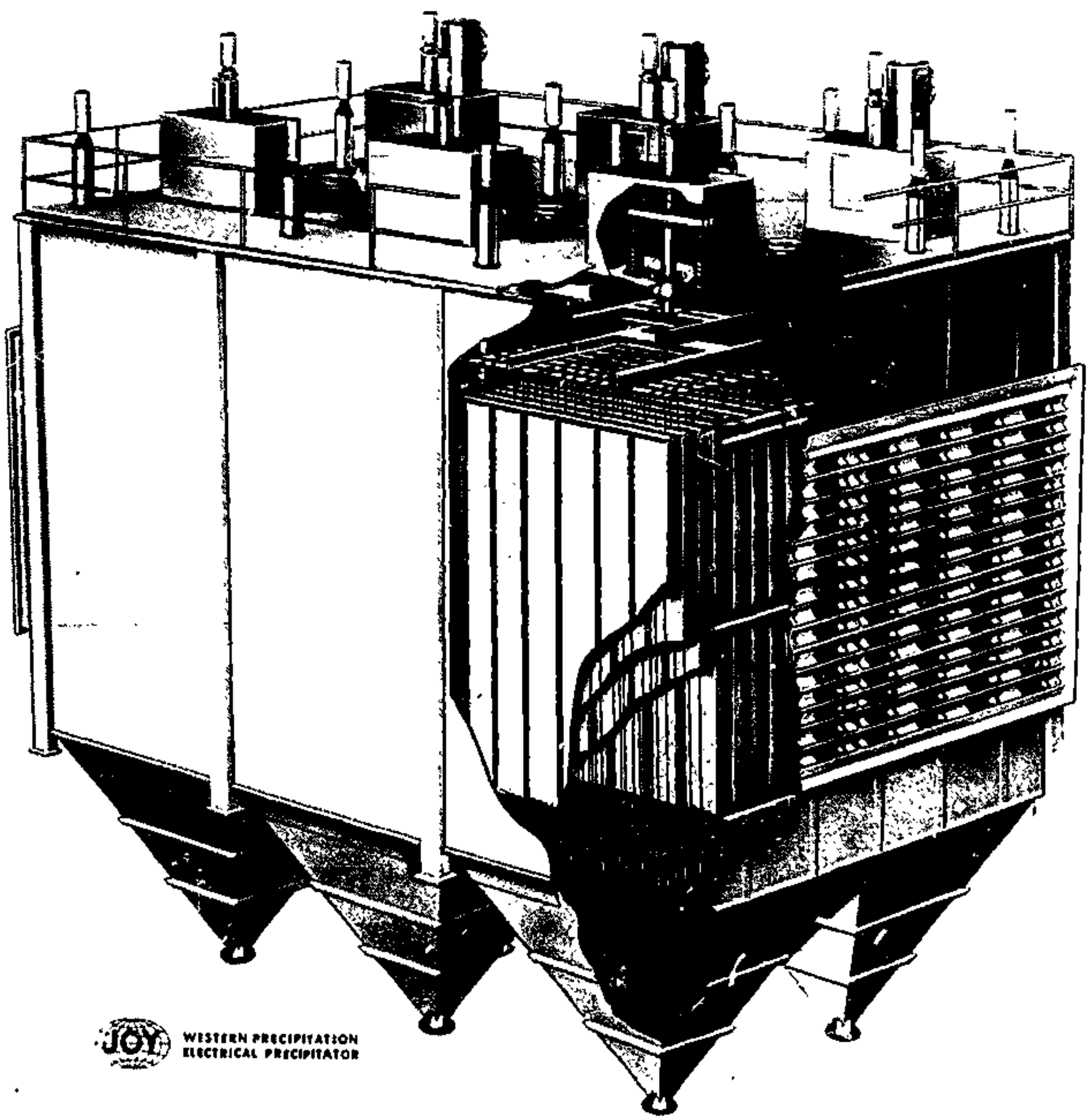


Figure 11-21. Acid Mist Precipitator

Studies show that a radial field is not produced by a wire between flat plates, but one that is enlongated, so that a similar area of electrode surface is affected by the same field intensity in both tubular and plate types

The process of collecting dust and fumes by eletrostatic precipitation,consists of applying an electrical force that will move the particles transversely across the gas stream and deposit them on the collection electrodes. The speed at which the particles move is usually termed the "migration velocity." Dry electrodes are periodically rapped, and the dust falls into storage hoppers or into a continuous disposal system Alternatively, the electrodes can be irrigated, and the dust washed down into the hoppers as slurry

In consequence, electrostatic precipitators will operate satisfactorily only if adequate attention is given to these four processes involved in their operation

1 The electrical charging of the particles
2 Migration velocity of the dust particles to the collecting electrodes
3 Cleaning the electrodes
4 Removal of the collected dust

Electrostatic precipitators for industrial applications are made in three main types, distinguished by the shape and arrangement of the collecting electrodes:

1 Tubular Electrode
2 Concentric Electrode
3. Plate Electrode

The advantage of parallel plate electrode systems can be exploited by a designer without noticeable loss of electrical efficiency. The electrodes take the form of a number of long plates mounted vertically in parallel rows, and located some 25.4 cm (9.9 inches) to 30.48 cm (11.9 inches) apart. The discharge wires are suspended in the passes midway between the rows at (ideally) similar intervals. The gas flows horizontally through the passes.

Modern applications frequently require a precipitator to be subdivided in series into two or more self-contained separate parts termed banks, fields or stages, when considered in relation to the electrical equipment. This is particularly important when very high efficiencies have to be obtained for long periods, such as in the collection of sub-micron dust in the metallurgical industry.

Plate electrode precipitators (Figure 11-21) have the advantage that they can be constructed with the banks arranged in series, end to end, so that the gas flows directly through one bank and into the next The dust is removed from the plates by a system of rappers Sufficient dust can also collect on the discharge wires to interfere significantly with the plant's electrical operation Therefore, these wires also must be kept clean

WET ELECTROSTATIC PRECIPITATORS

The main differences between wet and dry electrostatic precipitators is that the dust-bearing

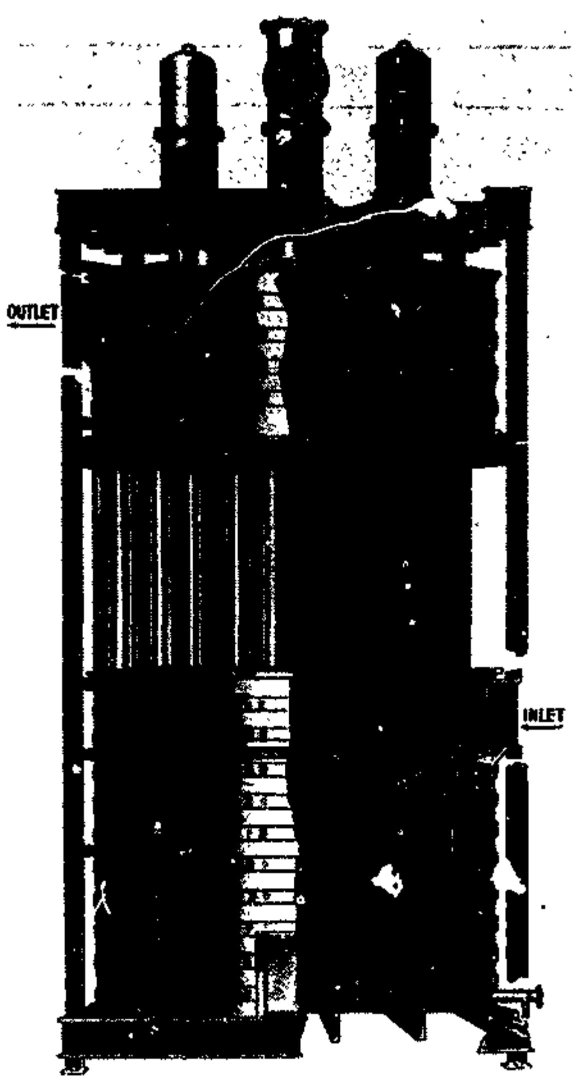


Figure 11-21. Plate Electrode Precipitator

gas is treated wet, and the collected dust is washed off the collecting and discharge electrodes as slurry.

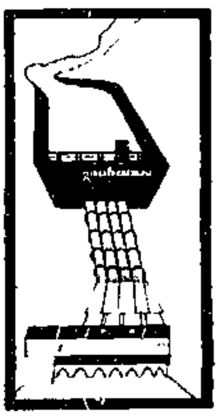
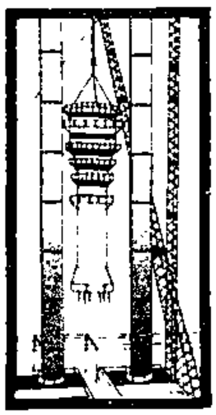
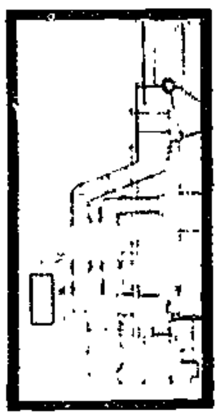
There are two main types of wet precipitator:

1 Intermittently flushed — the unit is switched off and the dust is washed down into the hopper.

2 Continuous irrigation and washing of the dust down into the hoppers.

The advantage of irrigated electrostatic precipitators is that re-entrainment of the dust is eliminated. This is particularly important when the dust is very fine and particularly clean gas is required

Chapter 12
TANKS AND STACKS

TANKS

There are a number of principles and guidelines to be applied in constructing field erected tanks (Figure 12-1). The areas discussed in this chapter follow the stages of construction in sequence.

GRADES (TANK FOUNDATIONS)

The foundation on which a tank rests is usually described as grade. Many different types of grades may be encountered and before erection begins the grade should be inspected for its ability to support the tank and its contents. The report filed with the customer and the erector should include the grade's size, level and bearing capacity.

Most grades will be slightly crowned by 2"-4" in the smaller diameters, and 4"-8" in the larger diameters. Where the grade has an excessive pitch or crown special problems are presented such as:

1. Length of columns for structural supports
2. Location of sleeves for pipe supports on double deck floating roofs
3. Attachments for drain lines on floating roofs.

Another type of grade has a concave shape where the "floor" slopes to the centre. In this case, the design of the bottom and structural supports are appropriately modified by locating a sump at or near the centre with a draw-off pipe.

Sloping bottoms are sometimes used where one side of the grade is higher than the other. In this instance the first ring is designed to accommodate the slope, and if structural steel is required, similar design adaptations are applied.

The importance of having an even grade at all times during the erection of a welded tank cannot be overemphasized. If the grade is uneven the tank is out of round, and any seams welded out of round will remain so. If any doubt exists

Figure 12-1. Large Tank Farm Under Construction

about the grade level during erection of the tank shell, it must be checked repeatedly and levelled when required. Using points 5'-8' apart on the circumference or outer edge, the grade must be level to within 1/4" plus or minus

Solid Concrete Pad A solid concrete pad is a base made of reinforced concrete with suitable footings built in some cases on wood or concrete pilings. One or two inches of sand or asphalt are usually applied on top of the concrete to serve as a cushion and keep out moisture. The pad is generally sealed around the edge with a form of mastic compound. Offsets are provided for sumps or drains in the bottom (Figure 12-2)

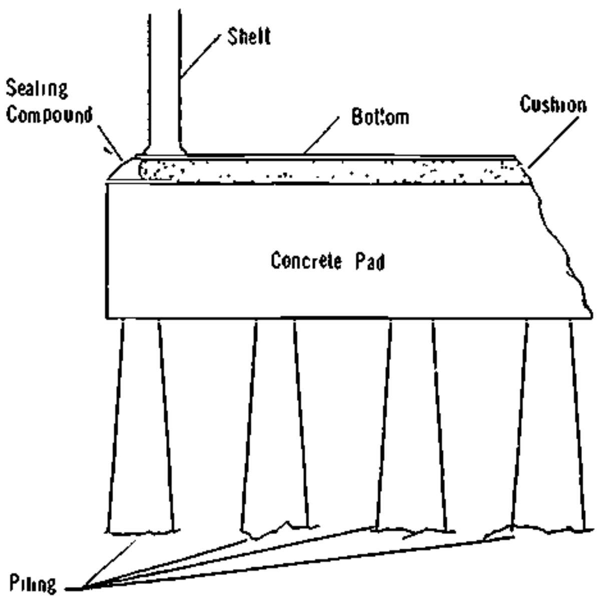


Figure 12-2. Concrete Pad for Tank Floor Support

Concrete Ring An alternative method of building a grade is to pour a ring of reinforced concrete usually 2'-3' wide (depending on tank size) with suitable footings. The centre is filled with sand or layers of crushed rock and sand. These should be tamped and packed by watering heavily. The fill should extend about 1"-2" (based on how well the material is packed) above the concrete ring so that when settlement occurs, the bottom plates will not bear over the sharp edge of the concrete ring. This type of grade is generally sealed off around the edges in the same manner as solid concrete pads (Figure 12-3).

Built Up Grade A built up grade is made by levelling off the existing soil, sometimes cutting

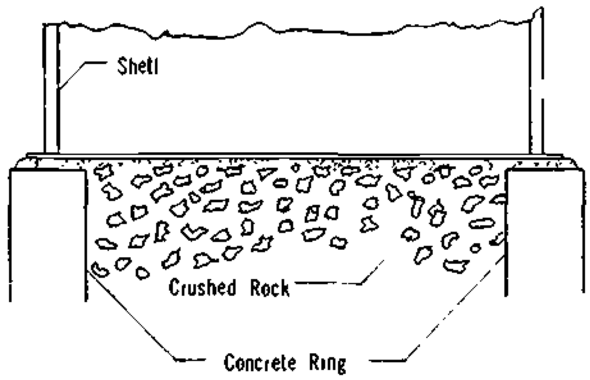


Figure 12-3. Concrete Ring Grade

down below grade level. The recess is filled with crushed rock that is tamped or rolled and covered with about 2" of sand as a cushion. The crushed rock should extend approximately 3'-5' (depending on height) beyond the outer edge of the tank bottom to ensure the tank will be supported in the event of any erosion. No seal is required around the edges, since this grade drains very easily and does not permit water to run under the bottom. This grade has proved to be very functional (Figure 12-4).

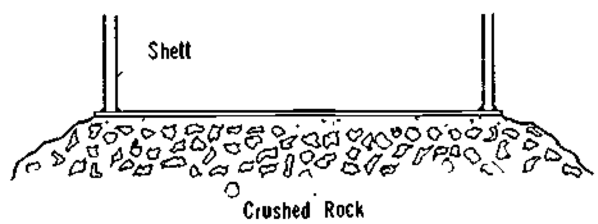


Figure 12-4. Built Up Grade

Soil Grade Developing a soil grade consists of levelling, cutting down and filling, using soil fill present at the location.

Where the grade involves levelling only, no trouble should be encountered; it is good practice to apply a 2" sand cushion to eliminate moisture at this point.

Where cutting and/or filling has been done, it is necessary to investigate how the grade was constructed and filled. If soil was cut from one-half of the grade to fill the other half, the filled in area should be applied in thin layers and tamped or rolled, then watered. This prevents uneven settlement causing stress to the tank shell. If the tank area was prepared by filling only, the nature of the site must be checked Grades constructed on old municipal dumps are definitely

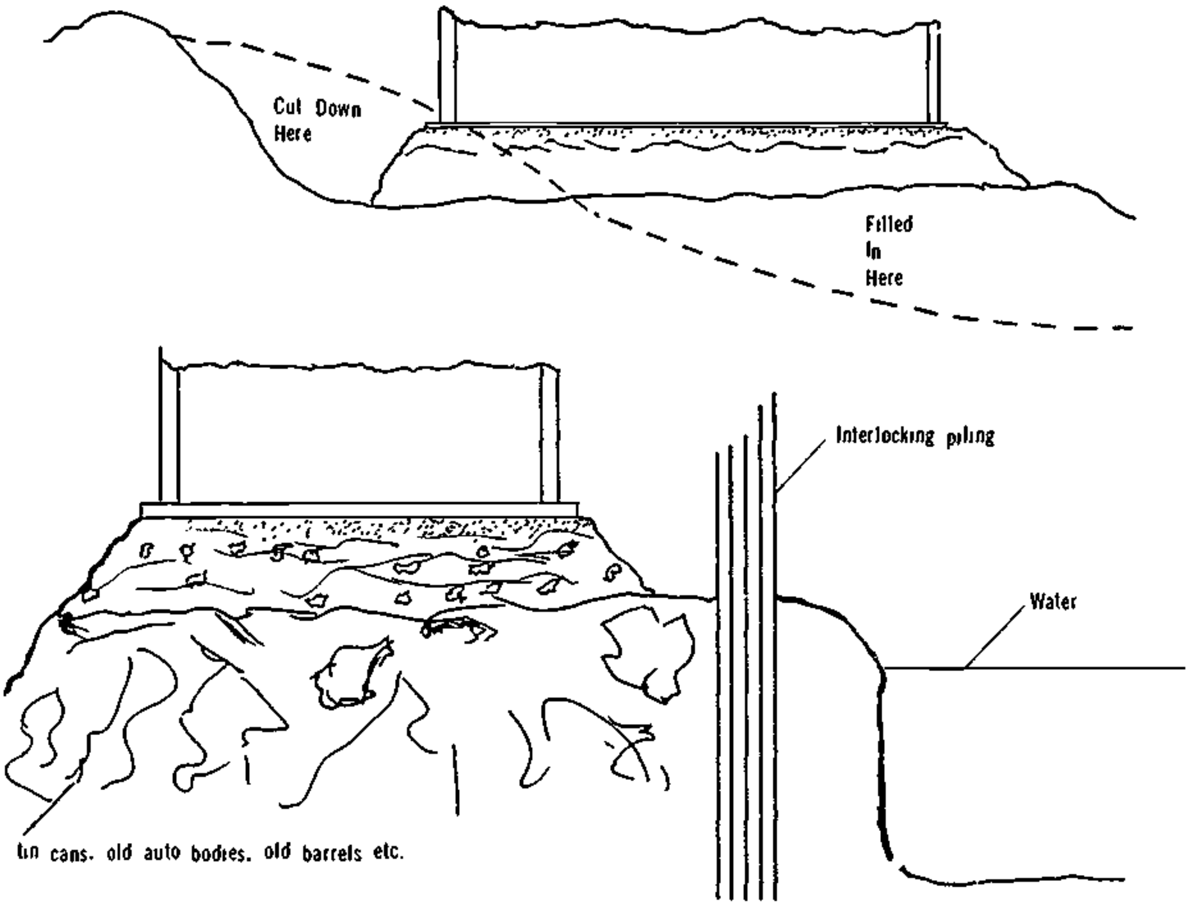


Figure 12-5. Soil Grade

inferior; swampy areas are not suitable unless pilings are driven: locations near streams or other bodies of water will fail unless provisions are made to hold back the water (Figure 12-5).

Grillage and Beams Acid tanks are frequently placed on wood or steel grillage: sometimes solid concrete pads are used with troughs extending under the seams at specified intervals. Each variation is designed for the particular job. Bottom plates are usually heavier to provide support between points of bearing on the grillage (Figure 12-6).

FINDING THE CENTRE OF THE GRADE

Before any bottom plates are laid, the centre of the grade must be determined. A stake may have been left to mark the centre, but generally the exact centre will have to be located using the following procedure:

Step 1. Measure the diameter of the grade.

Step 2. Divide by two to determine the radius.

Step 3. Hold one end of a line or tape at some point on the outer edge and scribe an arc near the centre.

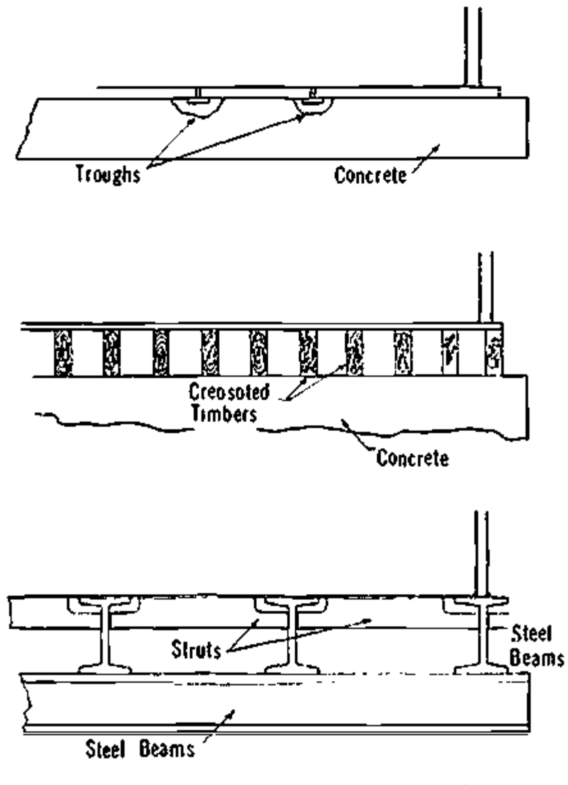


Figure 12-6. Three Types of Acid Tank Supports

Step 4 Hold the tape at two other points on the perimeter, 120 apart, and again scribe arcs near the centre.

Where the three arcs intersect is the exact centre (Figure 12-7).

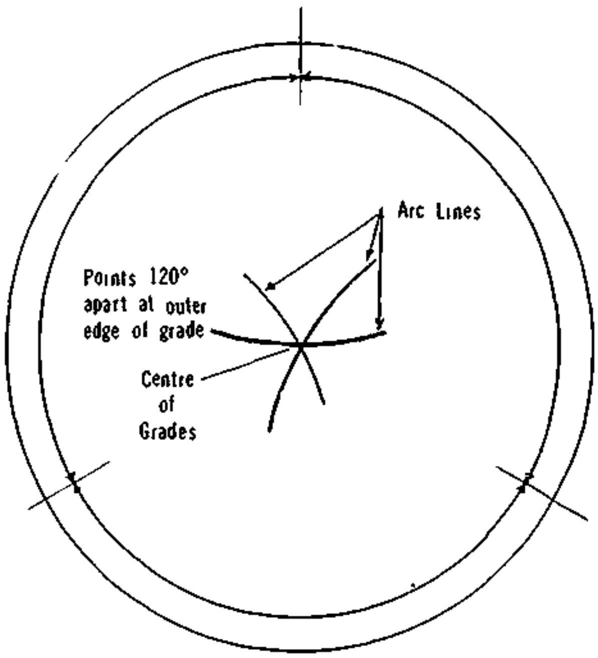


Figure 12-7. Tank Centre Location

BOTTOMS

The following procedure for "laying out" bottoms for tanks and vessels is only one of many design types Specific service conditions dictate design variations from one project to another. Some companies insist the outer plates be fabricated in the form of a ring (annulus ring), because experience has shown that a stress point has created cracking where the shell meets the lapped bottom plates. Other companies require laps to be shingled to allow drainage away from them New materials have also dictated changes in procedure, and with certain types of steel it is no longer permissible to hammer the edge of the lapped plates.

Laying Bottoms — Flat Lap Weld

Start laying the tank bottom at the centre. When the design has a centre course, mark off on the grade one-half of the plate width and one-half of the plate length from the centre. Hold the centre plate to these marks. Where the design has a plate course on each side of the centre line with one plate in the centre, mark the centre of the plate on one side and lay on the centre mark of the grade. In each case, re-check to confirm the first plate is laid correctly (Figure 12-8).

Continue to lay the balance of the plates in line with this first plate to establish the "first course." Use a chalk line or tape line to ensure the plate is laid in a straight line.

The minimum lap is 1¼". Weld a welding rod at the centre of the grade (on the plate) and hook the end of a tape over it. When the sketch plates are laid, hold each side of the circumference to the exact overall diameter of the bottom as set out in the drawing. The sketch plates are

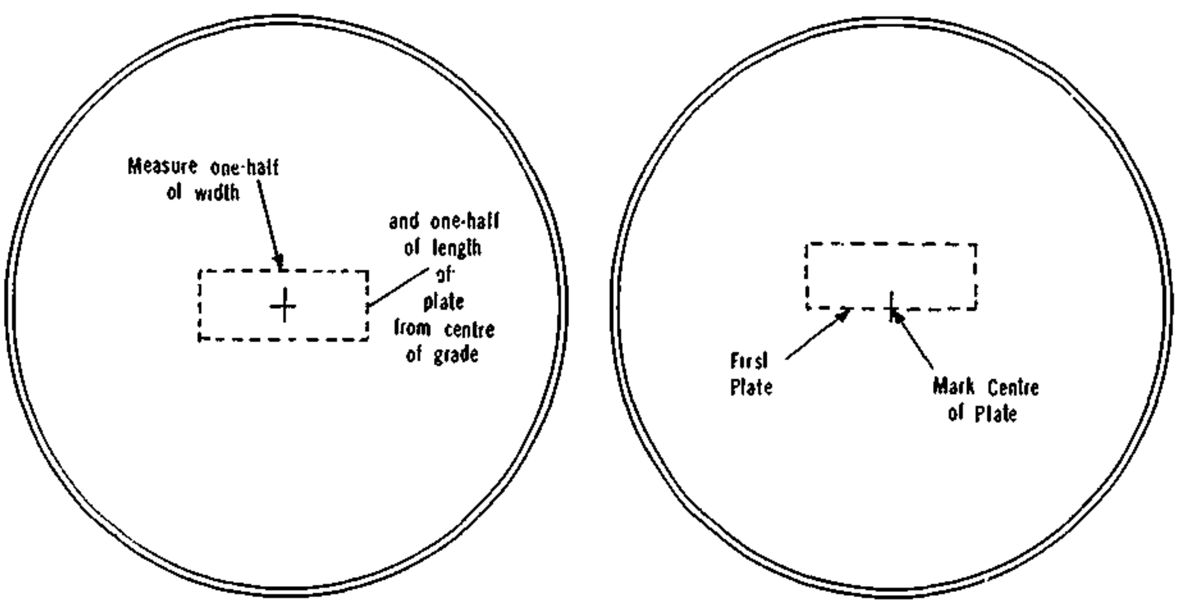


Figure 12-8. Two Methods of Laying Centre Plate

trimmed to describe the acutual outer circumference of the tank bottom.

American Petroleum Institute specifications require that a minimum of 1" of bottom plate extend beyond the outside edge of the fillet weld. The customer may request more than a 1" extension, however, this will be noted on the drawing

Continue to lay the balance of the plates in the same manner. Tack sketch plates only enough to hold them in position. These tacks must be broken after corner welds are made. Tack square plates on each side at the centre **only** (Figure 12-9).

Procedure for Flushing (Joggling) Lapped Plates on Circumference

Weld the outer ends of the sketch plates together as follows. (On plate thicknesses up to and including 1/4 , the plate must be lap welded using E-6010 electrodes.)

Step 1. Remove all foreign matter from between the lapped plates.

Step 2 Fit-up tightly with a clip or pin and tack weld on the end and 8" from the end.

Step 3. Hammer the edge of the lapped plate down until the gap between the plates is closed.

Step 4 Weld one stringer pass from the corner of the joint for 8" and weld across the end of the lapped plates (Figure 12-10).

Step 5 Run a second pass to make 8" of full fillet weld (Figure 12-10).

Step 6 Place a suitable back-up bar underneath the under lapped plate and hammer down with a mall until the surface of both plates is flush (Figure 12-10).

Step 7. Check the break-down for cracks in the weld. If cracks are visible, the weld must be chipped out and rewelded.

FIRST RINGS

Laying Out the First Ring Using the welding rod tacked to the centre of the bottom to hold the tape line, scribe a circle on the bottom to the exact inside diameter of the tank. Make allowance on measurements to include the diameter of the weld rod.

Scribe the full circle if the position of the vertical seams is not known: as in laying out the chord marks these intersect the circle at the vertical seam positions. When the location of the vertical seams is known, scribe short sections of the circle at the approximate vertical seam positions, and mark the balance of the circumference at intervals of 2'.

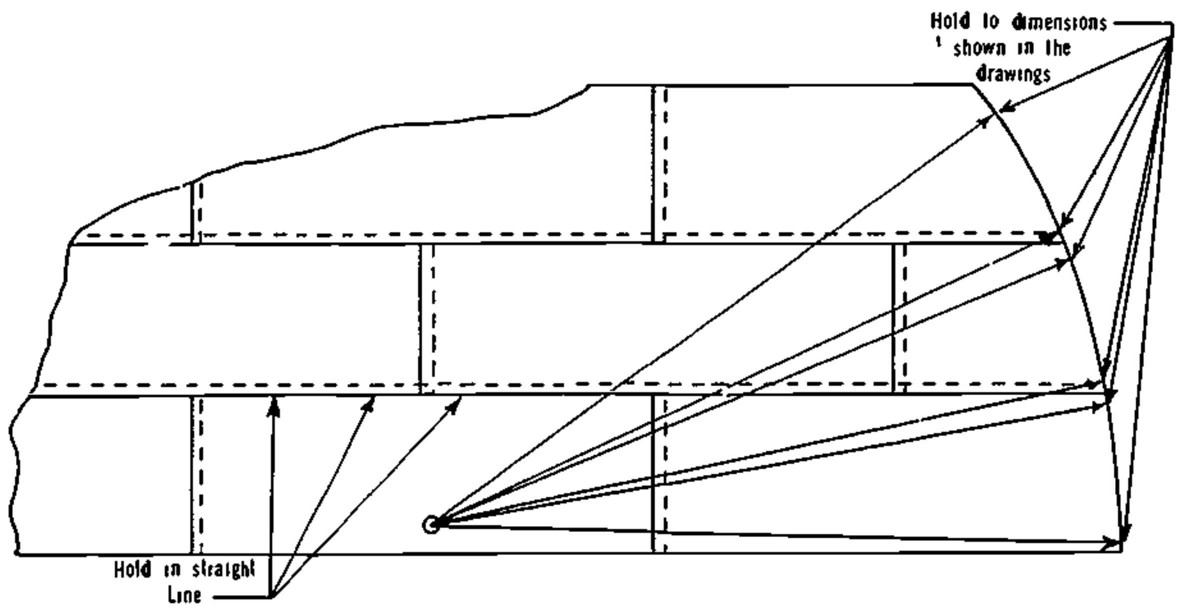


Figure 12-9. Aligning Floor and Sketch Plates

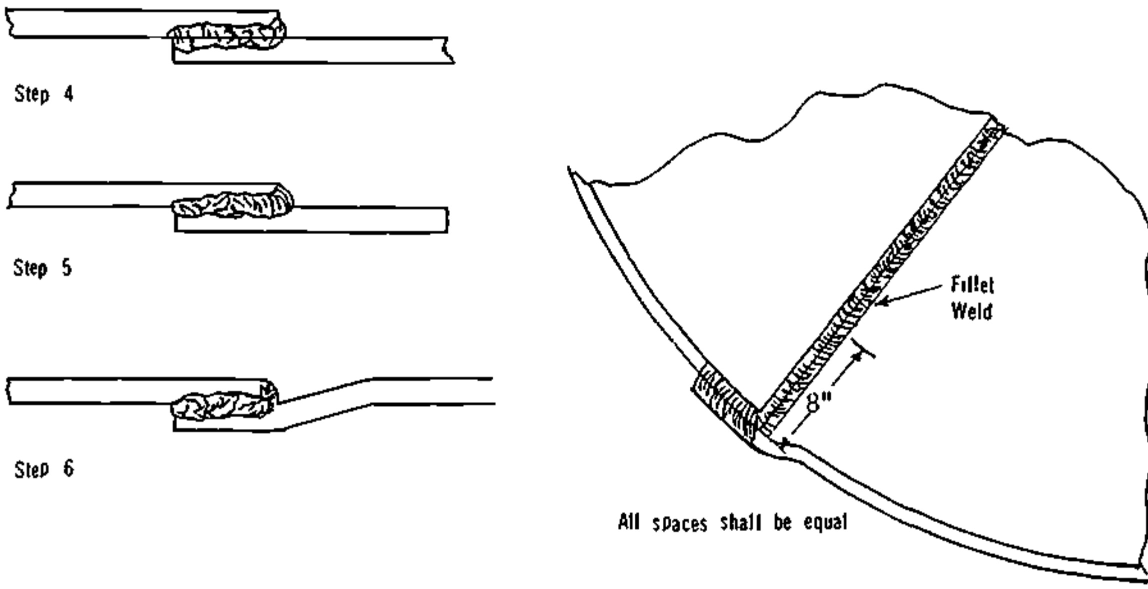


Figure 12-10. Flushing (Joggling) Block Plates at Circumference of Tank

Determine each plate's position on this circle by taking chord dimensions shown on the drawing and marking off the position of each vertical seam on the bottom. These marks must be made accurately. thus the scribed circle must be accurate If in making these chord marks the last position measured is over or under. change all previous marks so that all spaces are equal. This is particularly important on floating roof tanks and expansion roof tanks. When chord marks have been properly laid out. mark permenently with a centre punch (Figure 12-11).

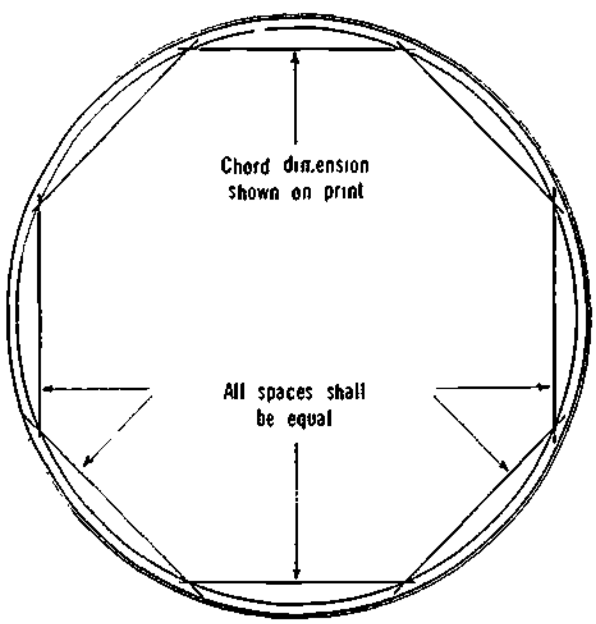


Figure 12-11. Establishing Chord Marks

Setting Up the First Ring Having "laid out" locations. the first ring plates may be set up. The usual procedure is to start with the sheet having the manhole cut-out in it. However. this is not absolutely necessary since each plate s location nas been previously determined with respect to the location of the shell manhole cut-out.

Place the first plate in its approximate position. Set one end on a chord mark at the circle and tack securely to the bottom at this point. Push the other end of the plate to its chord mark less the spacing required (if 1/8". 1/8" back from the mark: if 3/16". back 3/16" from the mark). Adjust the balance of the plate to somewhere near the scribed circle. In all cases it will be necessary to hold out beyond the scribed circle. since plate lengths are figured without spacing. Adding the spacing makes the diameter greater. With this end in proper position. tack securely to the bottom. Adjust the balance of the plate to the scribed circle and tack (Figure 12-12).

Fit up the next sheet. using stiffener channels to hold it in position. Place spacers in the vertical seams: three to five are required. depending on the width of the plate. Hold to the .proper spacing. Place the balance of the plate in approximate position. adjusting the end of the plate to the chord mark minus the the vertical seam spacing and slightly out beyond the scribed circle line. Tack a flat bar or blank nut on the edge at this point to hold the position (Figure 12-13).

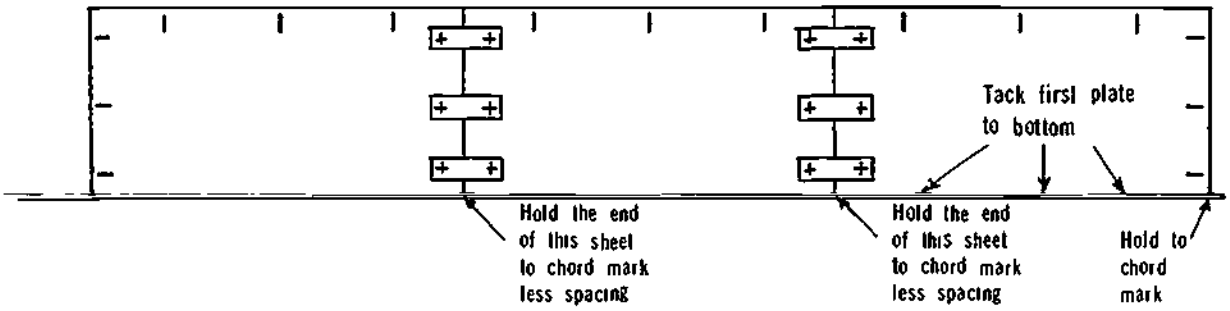


Figure 12-12. Holding Plates to Chord Marks and Tacking

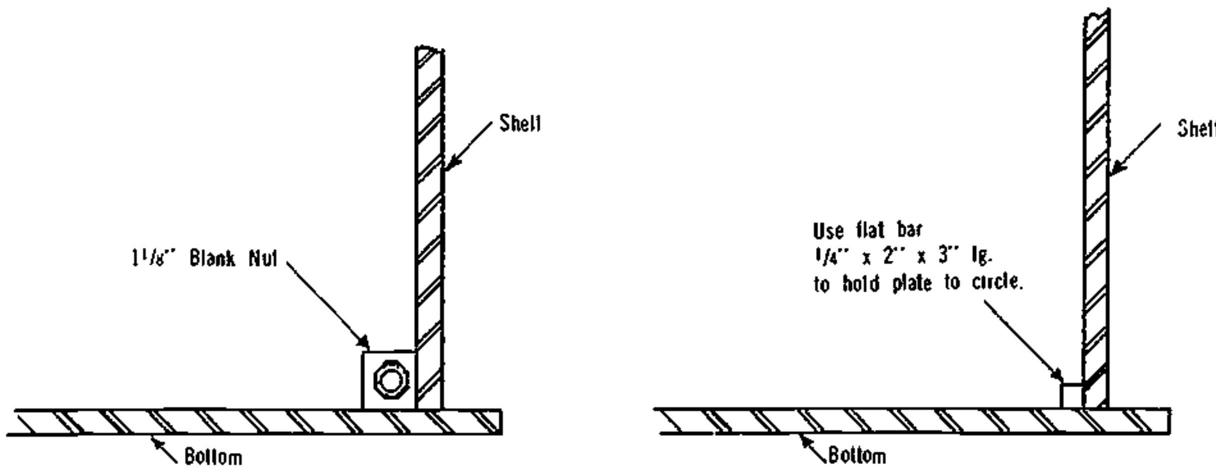


Figure 12-13. Fitting Shell to Circumference

Continue to fit up the balance of the plates in the same manner. Hold plates to exact position. If the plate is over or under the chord mark an excessive distance, check plate lengths. If too long or too short, adjust the chord mark to correspond. Do not cut off the end of the plate as another plate may compensate for the discrepancy. Hold the top of all plates in the first ring even.

When the last plate is placed in position it should fit perfectly. If the assembly has run over or under the chord marks, readjust all the plates so the tub has the same diameter at all points.

Before welding on the first ring vertical seams, check the tub for level. If there is considerable variation in elevation, some seams may peak out and some may bow in — they must not be welded in this position. Level the tub to within 1/4" plus or minus at the outer edge. The better method is to cut down high spots rather than fill in low spots, since filled in areas will be soft and are likely to settle resulting in the tub or tank becoming out of round again. This is a particularly important step.

WELDING THE FIRST RING

First Ring Vertical Seams Weld the first ring vertical seams. Note that after welding and shrinkage the diameter has become smaller, resulting in the plates being drawn closer to the scribed circumference line.

Bottom to First Ring Vertical seams having been welded, the first ring can be tacked to the bottom. Tacking must be on the inside only. Pull the bottom tight to the first ring. If it is necessary to hold plates in or out of the scribed line, confirm that this dimension is the same all around. This will ensure a round tank. The edge distance from the first ring to the outside edge of the bottom will also be uniform around the perimeter.

After tacking is completed, weld the first ring to the bottom, **outside first**. This rule must be observed because:

1. Welding the outside first has a tendency to tip the sketch plates down instead of up, resulting in a more level bottom.
2. In some instances it will be necessary to chip out the tacks after the outside weld has been made.

Weld the first ring to the bottom on the inside next If the tacks must be removed, they must be chipped out first

Welding Bottoms Unless the correct procedure for fitting and welding bottoms is followed, the bottom will not be level and the following serious problems will result.

1 If the bottom is not level or is buckled, complete water drainage to sump areas will not occur

2 Temporary supports for floating roof structures must rest on the bottom If the bottom is not level, the supports cannot provide required uniform elevation.

On small and medium bottoms, weld the first ring to the bottom before welding on the bottom itself On large bottoms it is permissible to weld on the square plates before making the corner weld, leaving loose all sketch plates that attach to the first ring.

As stated above, tack all bottom squares in the centre of the plate on each side only. This is sufficient to hold the bottom in place while it is being laid. The reason for this is that in the subsequent tacking of bottom plates prior to welding, the welder can work out any excess of plate toward the ends without breaking tacks, since breaking tacks is usually overlooked. It is important to examine the entire bottom and pull up all low places to level.

Figure 12-14 shows the bottom divided into two sections with the heavy lines describing the seams to be welded last Tack and weld all cross seams as Mark 1 Fit and tack all long seams as Mark 2 starting at the centre of the tank and working toward the sketch plates on each side of the bottom. Weld all long seams starting at the centre of the tank, using the back step method to work out to the sketch plates at each side. If the first ring has not been welded to the bottom on the inside and outside, **do not tack and weld the sketch plates to the remainder of the bottom.** They must be left loose to permit shrinkage. Weld centre long seam starting at the centre and working toward the sketch plates at each side. Weld all sketch plates together with the exception of the seams indicated by the heavy lines; all other bottom seams should be completed. Weld sketch plate to the bottom using the back step method. Do not have welders working close together on these final seams.

SCAFFOLD BRACKET CLIPS

The importance of welding scaffold clips competently cannot be overemphasized. Only the best welders should be assigned this job.

If at all possible, scaffold clips should be welded on the plate while it is still flat on the ground. Of course this can only apply to the top-side or inside of the plate.

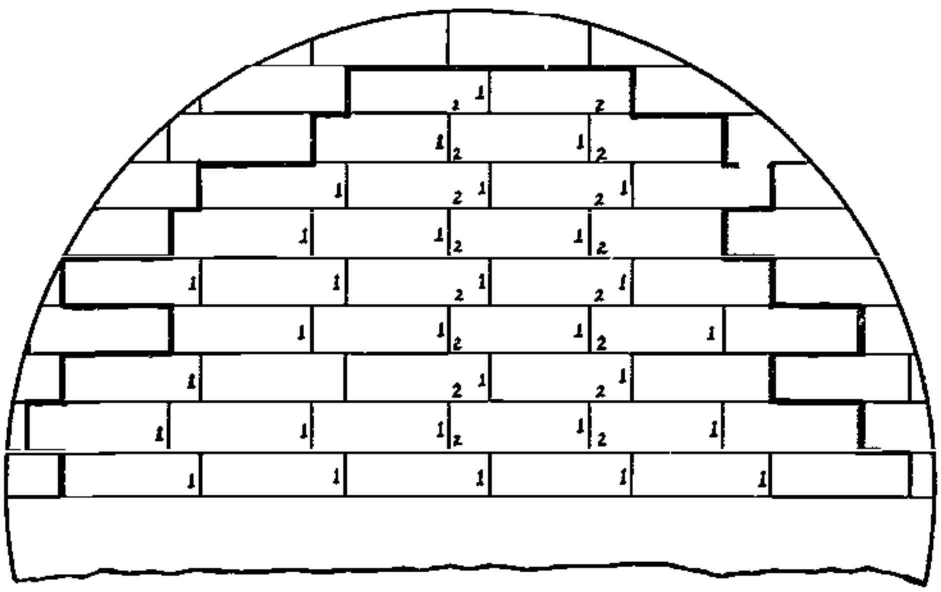


Figure 12-14. Welding Sequence of Tank Bottom

When the clip is to be welded on the plate after it is in position, ensure that the welder is sufficiently elevated to see his work clearly. Ensure he is standing on a secure support and that the work is protected from the wind.

The following procedure is the only accpetable method of welding scaffold clips (Figure 12-15)

Step 1. Place the clip in position and weld for a distance of 1½" on both ends of the top side of the clip

Step 2 Weld clips in position using 5/32 E-6010 electrode, making a full fillet.

Step 3 After being used twice clips should be trimmed back to the parent metal to obtain a full fillet.

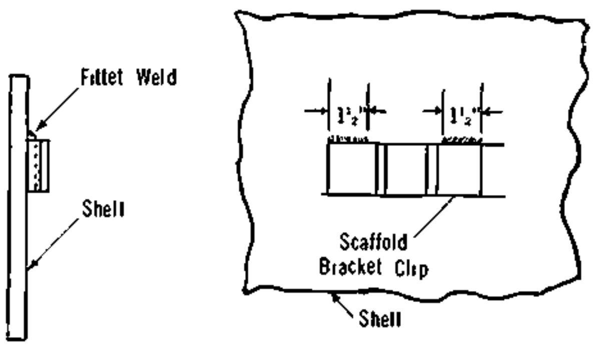


Figure 12-15. Scaffold Bracket Clip Welding

Caution: Never weld a clip on while riveting, caulking or chipping is being done in the immediate vicinity. Machines used for these processes set up vibrations in the metal which cause hot weld metal to crack.

SHELL PLATE

Laying Out Shell Plate

At this point in the project, the following have been completed:

1. The tub has been set up and levelled
2. The first ring vertical seams have been welded.
3. The first ring has been welded to the bottom
4. The bottom has been welded.
5. The scaffold has been set up on the first ring.

Since each shell plate has a definite location for placement, the exact position for setting up each plate must be marked on the ring below.

Usual specifications require vertical seams to be staggered one-third of plate length (Figure 12-16). The location of each vertical seam is determined by measuring on the outside of the shell from the first ring vertical seam one-third of the plate length. Measuring and marking must be accurate, since 1/8" over or under creates problems.

Measure for position all vertical seams by this method. **Do not** attempt to take the full length of the plate and mark the positions as you will always be over or under at the last position Mark with a chisel on the top edge of the plate so the marks will be permanent.

Laying Out Key Plate Lugs It is both functional and expedient to weld key plate lugs on the plate while it lies flat on the ground before being set up in position, a better quality weld can be achieved, and the weld has time to cool completely before being used.

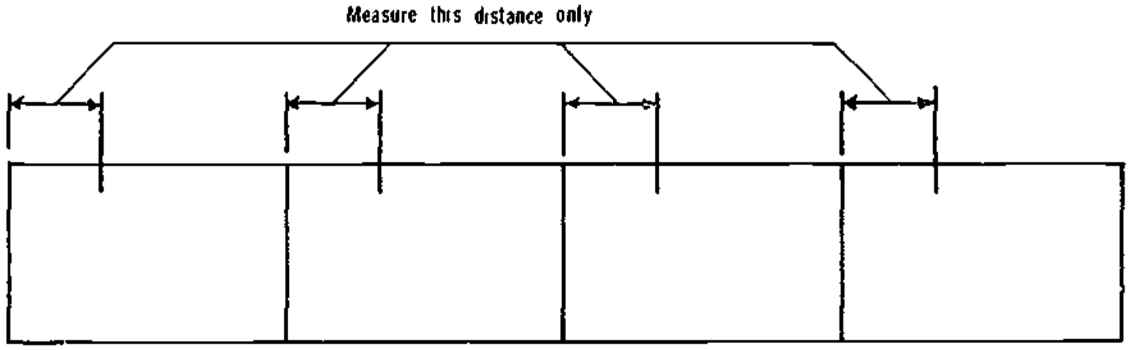


Figure 12-16. Succeeding Ring Alignment

In most cases, laying out the position of the lugs requires only a tape or rule If a large number of plates are involved, a template of steel banding or rods can be used Place all lugs on the inside of the sheets, which is the top side when laid on the ground

On 6' plates, 12 lugs are required, 3 lugs on each side at each end On 8' plates, 16 lugs are required 4 on each side at each end (Figure 12-17)

Setting Up Shell Plates Using a gin pole and shell trolleys, or in some cases a crawler or mobile crane, raise the plates and move to location on the shell Place the end of the plate exactly on the position marked for the vertical seam Insert a spacer and drive a wedge to hold the plate in alignment at the horizontal seam. Fit the balance of the plate with spacers and wedges, insert spacers at about 18" intervals on the horizontal seams.

When the plate is in position, check the end of the plate fit-up last to determine its position with regard to the marks for the position of the vertical seam The first end of the plate fit must be on the mark **less the spacing required.** Thus the first end of the next plate fitted with the spacer in the seam will be exactly on the mark.

If the plate is not in the proper position, push or pull it into position as required. A pushpull jack can be used for this task. Note that in 99% of the cases, it will be necessary to **push** the plates into position since shrinkage of the welds in the vertical seams of the ring below shortens the shell's circumference. Shrinkage of each vertical seam amounts to approximately 1/8" across the weld.

At **no time** fit shell plates to the horizontal seam with an excessive amount of gap left in the vertical seam to be pulled together later with key plates. Always adjust the spacing at the vertical seam **first** once the plate is moved into position, then fit up the horizontal seam. Pulling the vertical seams together after the horizontal has been keyed up produces a flat spot adjacent to the vertical seam, since there is sufficient friction in the keys to hold the greater length of plate in position, and only a small section of the plate adjacent to the vertical moves. This very important feature of the procedure must be followed to produce a shell free of peaks and flat spots

Whenever any plate is an excessive distance over or under the mark, check it for length by measuring with tape on the outside. An excess or shortage of plate up to 1/4" in length in one or two plates, or 1/8" in all the plates, can be made up by slacking off on the keys and pushing or pulling into position. This results in temporary misalignment of the horizontal seam. Horizontal seams can be easily fitted into proper position after the vertical seams are welded (Figure 12-18).

If all plates in the ring are 3/16" or more over their proper length, the amounts in excess of 1/8" must be permitted to run over the marks.

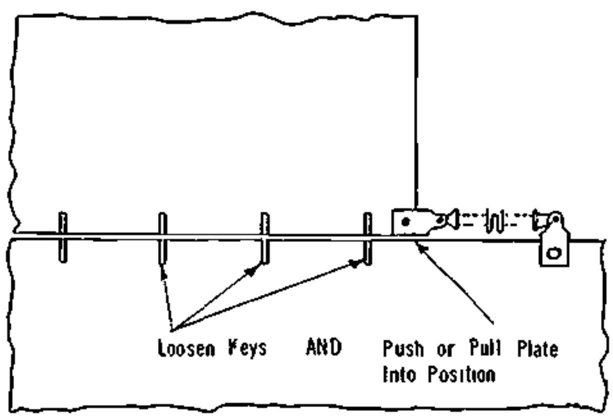


Figure 12-18. Positioning Plate

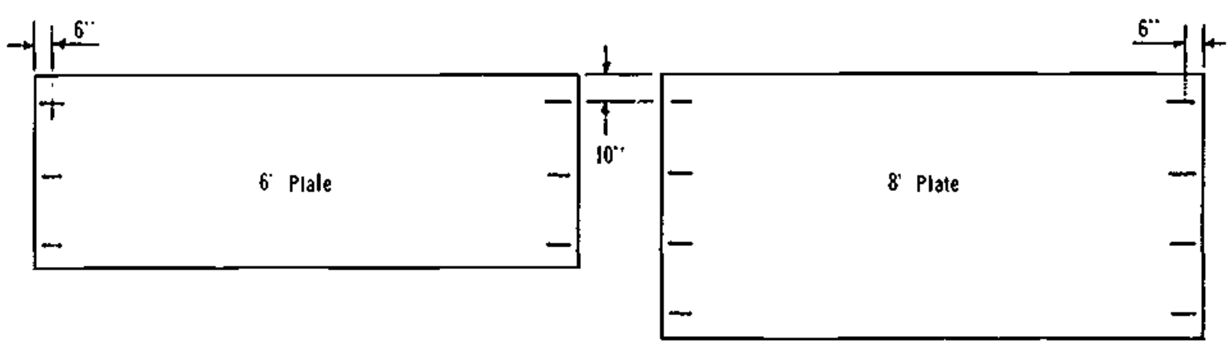


Figure 12-17. Key Plate Lug Layout

Each plate will be over the mark by the required amount determined by measurement, plus the accumulation of the overage on plates previously set up. Cut the last plate to suit the space remaining.

In the event the plates are short, reverse the procedure. On the last piece of plate installed, a new piece of plate will be required to make up the shortage. This new piece of plate must not be less than one-third of plate length.

The above problems will arise only in rare cases, so **before** any decision is made, a thorough check is required. If either complication does occur, the marks for positions of vertical seams on the ring above will have to be laid out to compensate for the odd lengths of plate Remember that a ring on which vertical seams have been welded is always smaller than a ring on which the vertical seams have only been fitted

Fitting Vertical Seams Vertical seams may be fitted for welding as soon as two sheets are hung, or may be fitted after the complete ring is set up

Select the proper spacer for the seam; remember that vertical seams usually require a different spacing than horizontal seams. The spacing of the joint is entirely determined by the design. The ability to weld the seam properly depends on the correct spacing in the seam. The difference between 1/8" and 3/16" either way is significant if a competent joint is to be achieved. Accuracy is critical.

Place three to five spacers in the vertical seam with one at each end approximately 6" in from the end. Distribute the balance evenly in the seam. Using a push-pull jack, pull the plates against the spacers. Do not continue pulling after the plate has come in contact with the spacer, as this will sometimes bend the plate. **It is important** to adjust the gap in the full length of the seam before tacking to prevent the seams from becoming bowed (Figure 12-19).

The tack welds are to be made on the inside of the tank since vertical seams are always welded on the outside first.

After fitting and tacking on the vertical seam **release the key plate wedges momentarily, then tighten them only enough to bring the vertical seams to touch the key plate.** Do not pull the plate flat against the channel. This peaks the

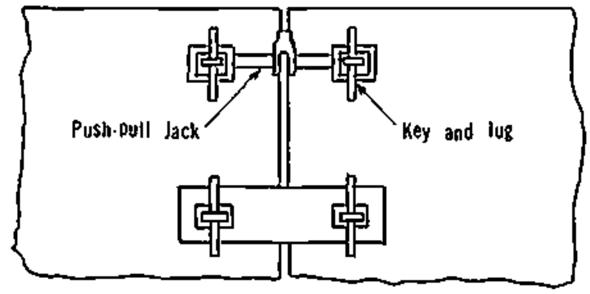


Figure 12-19. Vertical Seam Alignment

verticals in to help eliminate distortion from welding.

Spacers may now be cut off and backed out, providing sufficient tacks have been welded in the seams to hold them in alignment. The vertical seams are now ready to weld.

Shell verticals are subject to primary stress due to weight or pressure of the tank contents. Thus these joints must have **ONE HUNDRED PERCENT PENETRATION** WELDS. To assure 100% penetration in the verticals, it is necessary after welding the outside joint to back-gouge the weld with an Arcair torch or a chipping tool, gouging down to solid weld metal before finishing the joint.

Fitting Horizontal Seams Horizontals must **not** be tacked or welded until **all** verticals, which are to be joined in both courses, have been completely welded inside and outside

Hold horizontal seams in alignment with spacers and wedges of the prescribed thickness placed approximately 18" apart. Spacers are to remain in the seams until tacked. Pull horizontal seams together with stiffener key plates only When properly installed on sheets of average length, they will be located each 8' or 9' apart. This spacing is all that is required to hold the plates in position tight against the spacers Spacing shown is minimum and whenever plate widths are not the same, do not remove the spacers at the wide plate to adjust an excessive gap on the narrow plate Also, when excessive spacing exists in the seam due to this, do not attempt to pull the spacing together, as a buckle will develop on each side of this area. Where the difference in plate width exists, the maximum spacing will start at the vertical seam and gradually taper to a normal spacing in about a 5' or 6' length of the seam, depending upon the amount of difference in width. A great difference in width will ha ɔ a longer tapered area than a lesser difference in width. **AGAIN, DO NOT ATTEMPT TO PULL ANY EXCESSIVE SPACING TOGETHER IN A SHORT AREA.**

Seams must be tacked on approximately 6"-9" centres As spacers are inserted in seams on about 18" centres. the tacks can be made directly adjacent to spacers and half way between spacers This is done so that when spacers are cut off and backed out. there will be no misalignment in the seam.

Where misalignment occurs. push or pull it into position with lugs and keys or with tapered spring leaves inserted into the gap. Misalignment must not be more than 20% of the thickness of the upper plate with a maximum of 1/8" (A projection of only 1/16" is permissible for plates less than 5/16" thick.)

Tack welds should not exceed 1" in length. The amperage on the welding machine should be set high enough so that a concave. well fused tack weld can be made. which can easily be covered when welding the seam Use E-6010 electrode for tacking.

Welding Horizontal Seams One hundred percent penetration is required on all horizontal seams. For best results weld on the inside of the shell first. as the seam has more resistance to distortion outwardly than inwardly After the inside has been welded. this weld will contribute stiffness to resist inward shrinking action of the outside weld Also. in some cases. the seam outside can be finished in one pass. This usually has a better appearance than a weld made in several passes.

DOOR SHEETS

Whenever large amounts of bulky materials such as structural supports. floating roof plates and parts are to be placed inside the tank shell after it is erected an opening is provided in the shell to facilitate moving these materials inside. These openings. described as "door sheets," consist of a part of one shell plate. On cone and expansion roof tanks. the door sheet will be one-third of the first ring shell plate (Figure 12-20). On floating roof tanks. it will be one-fourth or one-half of the second ring plate (Figure 12-21) Door sheets may be placed at any point. however. they should be located so that material can be moved directly into the tank from storage or unloading

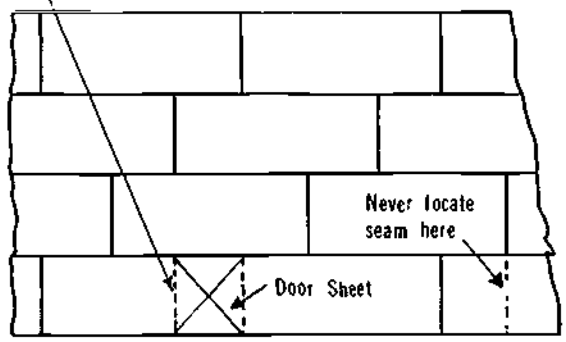


Figure 12-20. Door Sheet in 1st Ring

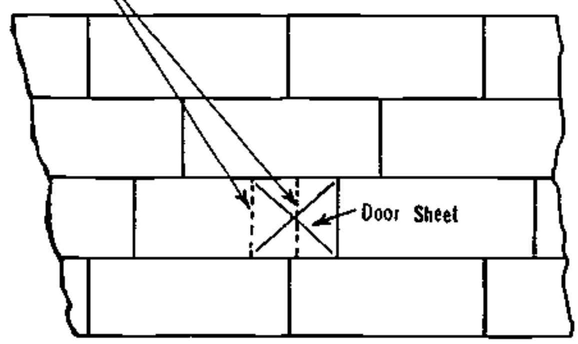


Figure 12-21. Door Sheet in 2nd Ring

Fitting Up Door Sheets Since door sheets are part of one plate. an additional vertical seam is made in the ring if a door sheet is installed. This additional seam requires different treatment than the others. Fit up this **extra** seam **without** spacing. this provides for shrinkage when the vertical seams are welded. If this extra seam is spaced like the balance of the vertical seams. an excessive gap will result when the door sheet is fit up prior to welding in place. The above applies only to the extra seams made by the door sheet Thus. on the initial fit-up. since there are two vertical seams. one must be fit up with spacers and one without (Figure 12-22).

In all cases. door sheets must be fitted into position and left in until the ring above has been hung. the vertical seams welded on the ring above and the horizontal above and below either tacked or welded. This tacking or welding of horizontal seams must stop at least 5' from each vertical seam of the door sheet. This provides for the required spacing of the horizontal seam without loss due to shrinkage of weld metal. It also ensures that flat spots will not develop in

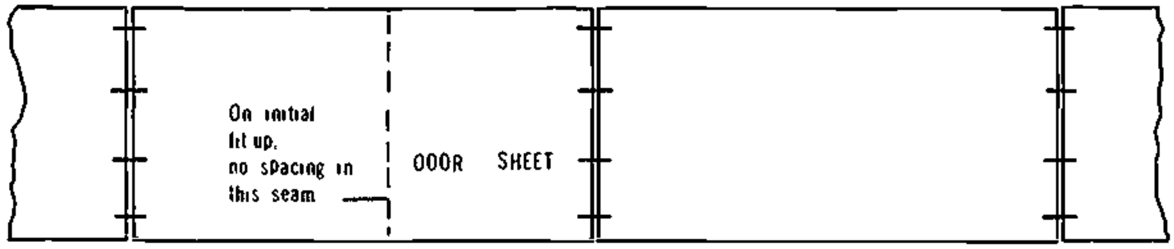


Figure 12-22. Fitting First or Second Ring Door Sheets

the door sheet area due to shrinkage of the horizontal weld. Before removal, suitably mark the door sheet so that it can be replaced as in the initial installation.

After erection of the structural supports or the floating roof, the door sheet must be replaced It is important to replace it exactly as in the initial installation. Place spacers in accordance with the spacing required. Since in the initial fit-up, there was no spacing in one seam, the spacing of this seam will cause the sheet to be out beyond the proper horizontal alignment Leave it that way until the vertical seams are welded Do not attempt to pull into horizontal alignment.

This horizontal misalignment will be approximately 1 — 1¼" at the centre of the plate, tapering to correct alignment at the vertical seam. An excess of misalignment is better than too little, since the vertical seam welding shortens the circumference If sufficient extra length is not provided, a flat spot will develop in this area

Weld vertical seams following the designated procedure Weld both seams **in and out** before aligning and tacking the horizontal seam to allow maximum movement to occur. Permit the plate to cool before tacking up the horizontal seam. Place spacers in the horizontal seam and pull into alignment, ensuring that spacing of the seam is exactly as required If the horizontal seam has not been welded to within 5' of each vertical seam of the door sheet, no difficulty should be experienced in getting the proper spacing Tack the seams to hold in correct alignment.

Weld the horizontal seams following the designated procedure for horizontal seams. In the case of a door sheet in the first ring, weld the door sheet to the bottom, as the first ring plates are welded to the bottom.

PRECAUTIONS TO TAKE UNDER GUSTY WIND CONDITIONS

Note: When erecting tankage at locations where there is a possibility of high speed or gusty wind conditions one or preferably a combination of the following precautions are recommended to prevent the tank shell from "blowing in" collapsing. These precautions should be followed until the roof rafters are all in place and secure.

1. Use short sections of channel iron (4'-5' long) and key plates centered vertically across the horizontal joints attaching two or three, spaced evenly, as each shell plate is erected.
2. Use staging clamps at each staging bracket to make the staging rigid, thereby effectively making the staging into a wind girder.
3. Stitch weld long sections of angle or channel iron (stiffners) vertically inside the tank shell; these must rest on the floor of the tank. (Three or more, evenly spaced, per shell plate length.)
4. Use guylines on the outside of the tank shell. Tack weld the hook of each guyline to shell and anchor the guyline correctly.

STRUCTURAL ROOF SUPPORT

When the tank shell is completely erected, the structural roof supports can be set up. The top angle may or may not have been installed by this time, however, when the top angle has been installed, it must **not** be welded until the structural roof supports are completely installed. This ensures that the top of the tank shell does not become too rigid to permit rounding it up.

Care must be exercised when unloading, handling and setting up the structural supports Remember that structural members that are bent will not support the required load. Any parts accidentally bent must be **straightened or replaced** before being erected.

All structural members are fabricated with holes for holding together as well as for fitting up. The length of the members and the location of all holes are designed for the specific diameter, height and pitch of the roof When structural members do not fit, either the tank shell is out of round due to uneven foundation, or an excessive crown in the grade is causing the supporting columns to be too long.

When the tank shell is out of round, some rafters will be too long and an equal number too short **Do not** attempt to pull or push the shell into shape at the top with the rafters. Instead place a heavy jack or jacks at the low spots at the base of the tank shell (directly below the location where the rafters are too short) and jack up the shell until short rafters can be made. Before removing the jacks, tamp the grade material well under the tank shell to provide support.

If jacks are not available, the high spots on the grade may be cut down (directly below the location where the rafters are too long). Remove only a small amount of grade material at a time so the shell does not settle too far. Remove only enough grade material so that the rafters may be fit up. In either case, whether the grade is built up or cut down, after the short or long rafters are made up, the balance will fit into place properly without any additional movement of the shell. As stated, **do not attempt to round up the shell with rafters. Always level the tank shell at the base first and the rafters will fall into place.**

If all the rafters that do not fit are too short, it indicates an excessive crown in the grade (assuming the structural supports have been properly designed and fabricated). This makes an excessive pitch in the roof, thereby creating a greater distance from the edge of the tank shell to the top of the centre column. Determine the amount of crown and pitch to the grade with a chalk line, and cut the corresponding amount off the lower ends of the supporting columns. A 2"-4" crown on a small diameter tank, or a 4"-8" crown on a large diameter tank will not require shortening of columns as this amount is easily taken up by movement in the holes of the rafter clips.

The completed structural assembly must have bolts in all holes that provide for them. When rafters do not "make up," do not weld them in that position. Sufficient allowance for any minor out-of-roundness is provided for in the holes in the rafter clips and lugs. Approach any more out-of-roundness than this by levelling the tank shell at the base. If a fabrication error has been made in the shop, corrections must be made in the field before the members are erected in place.

Install rafter clips before assembling structural supports. The exact location must be laid out on the shell before installing, as **all spaces must be equal.** Also place clips at the proper elevation so that the top edge of the rafters are flush with the top of the top angle. Rafter clips must be continuously welded on both sides in the uphill position. (Use 5/32 E-6010 electrodes.)

As the method of installing structural roof supports differs significantly on various diameter tanks, the descriptions will be set out individually for small, medium and large tanks.

Small Diameter Tanks (approx. 60') Small diameter tanks have only one supporting column located in the centre.

Procedure:

Step 1. Place the centre column inside the tank alongside the inside scaffold adjacent to the gin pole (Figure 12-23).

Step 2. Bolt on three rafters, each approximately 90° apart. The outer end

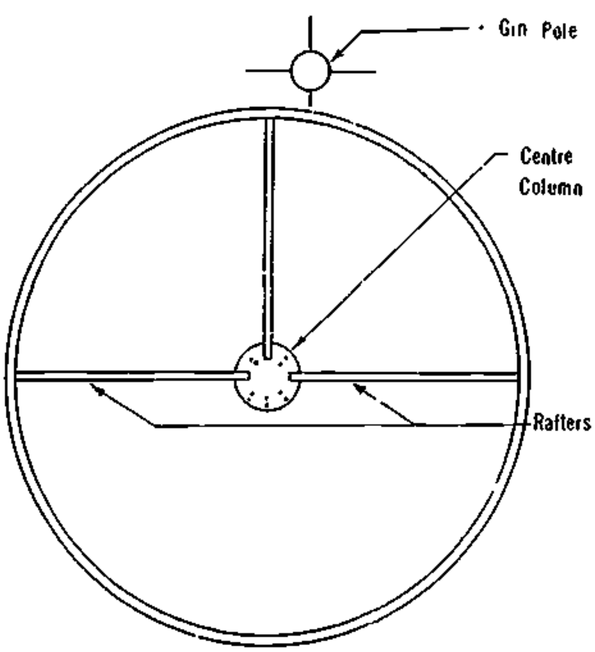


Figure 12-23. Erection of Centre Pole and Roof Support Rafters

of two rafters will lie across the edge of the shell, while the outer end of the third rafter is located at the gin pole and needs to be held up with the load line until bolted in place.

Step 3. Secure the load line on the rafter clip at the centre column. Move the entire assembly out toward the centre of the tank, slacking off on the load line at the hoist at the same time. Move the lower end of the column out toward the centre of the tank with a suitable bar

Step 4. Bolt the three rafters to the respective lugs on the shell.

Step 5 Install the balance of the rafters by sliding the inner end out toward the centre column cap plate on the rafters previously erected.

Medium Diameter Tanks (approx. 60'-90') Medium diameter tanks have supports with one row of circle beams. Three different methods may be used to erect roof supports for tanks in this group; the method is determined by the equipment available.

Gin Pole Method

Step 1 Set up a standard 6" or 8" pipe gin pole inside the tank, and locate the four guylines to the top angle with each line 90 apart.

Step 2 Locate the gin pole adjacent to the centre of the position where the first support unit (two columns and a circle beam) will be erected.

Step 3. Assemble the first support unit on the bottom of the tank. Raise into position and lash to the gin pole. Tie the guylines to the top angle each way to prevent the assembly from falling to one side.

Step 4. Using the load line on the gin pole, erect and secure the first rafter. Using the first rafter as a support, slide the remaining rafters of that unit into position. Rafters on this section must point directly to the centre of the tank; the completed assembly will otherwise be spiralled and not correctly aligned.

Step 5. Move the gin pole to the next position locating it about one quarter of the circle beam length away from the final position of the column in the second support unit (one column and a circle beam).

Step 6. Assemble the second support unit. Apply a sling on the circle beam approximately one quarter of the circle beam length from the column. This will balance the assembly and reduce the bending strain at the joint.

Step 7. Raise this unit into position and bolt to the adjacent circle beam. Install the rafters on this section by sliding them out on the rafters already erected.

Step 8. Complete the erection of the remaining circle beams and rafters by this method.

Step 9. Set up the centre column using the gin pole in its last location. Install three rafters at 90° to each other between the centre column and the circle beams. Install the remaining rafters.

Centre Pole Method

Step 1. Assemble two columns and their adjoining circle beam (first support unit) on the bottom of the tank. Ensure that the circle beam is close to the shell, as the unit is to be raised by the gin pole which, for this method, is located outside but near the tank shell (Figure 12-24).

Step 2. Raise the unit using the gin pole. When erect, the unit should be temporarily lashed to the inside scaffold. At this time bolt two or three rafters to the circle beam, and extend out to the sides two or three guylines to stabilize the unit.

Step 3. Move the assembly to its proper location by "barring" the bases of the columns (moving them in small stages using a crowbar as a lever. The unit is stabilized during this process by feeding the attached rafters out from the top angle. When the support unit is located, secure the guylines and install the remaining rafters on this section.

Step 4. Using a tugger or chain fall with the line through a block attached to the top of the circle beam, erect the cen-

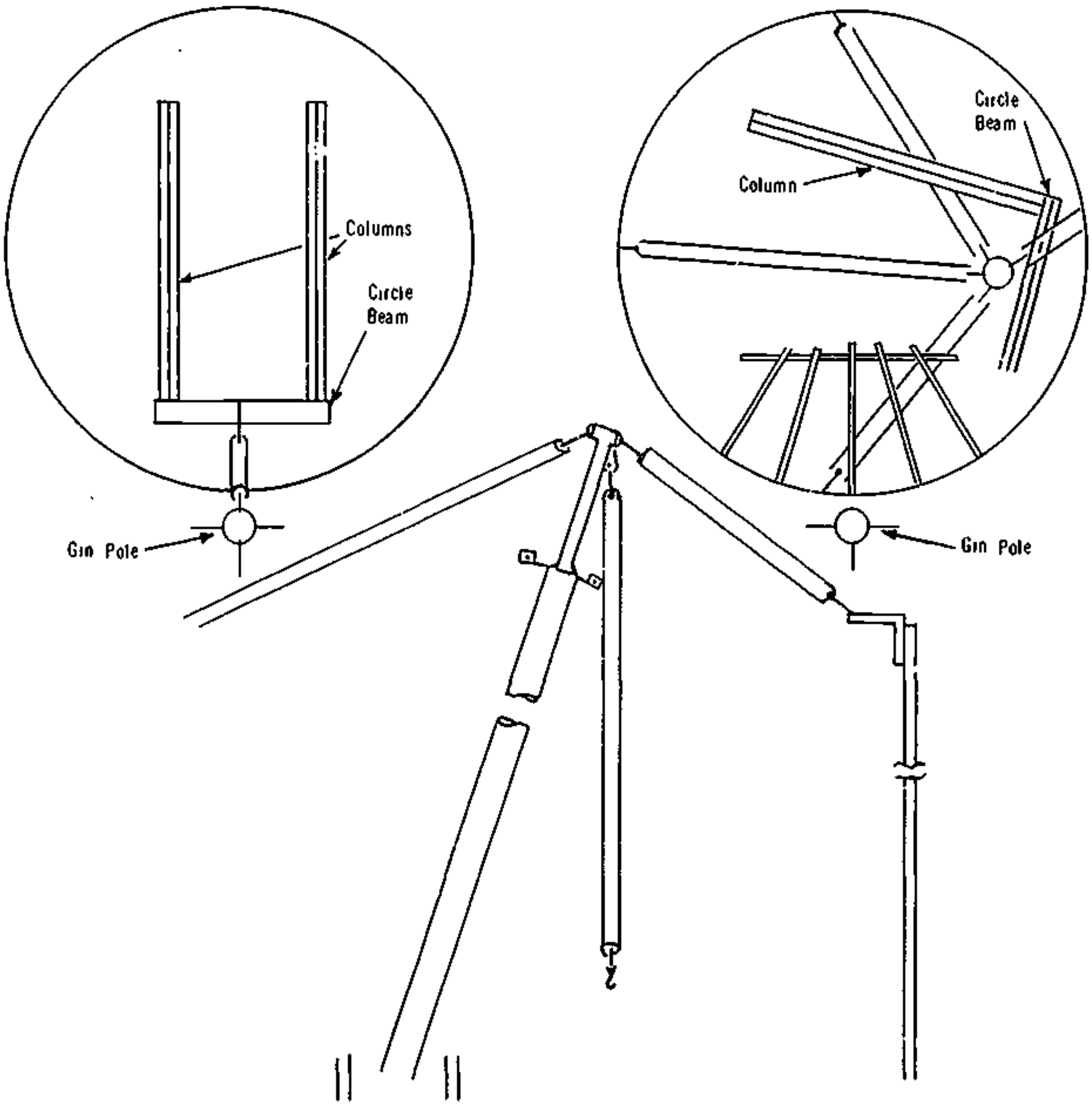


Figure 12-24. Circle Beam Erection Using Centre Pole as Lifting Device

tre pole alongside the first support unit. Attach a 12' section of 6" pipe on the cap plate of the centre column. At the top end of this centre pole extension, install the pipe cap from the gin pole complete with four sets of rope falls extended 90° apart. Weld a lifting lug directly below the cap of the centre pole extension, and suspend from it the load line sheave with a line in place.

Step 5 Using the "barring" technique, move the centre pole to the centre of the tank and hold it in position by nesting base between four lugs welded to the tank bottom. The centre pole can now function as a gin pole to erect the next support unit and subsequent support units into position. As each unit is erected, install all rafters section by section. Continue until the circle is complete.

Step 6 With the centre pole askew, bolt two or three rafters to the centre pole cap plate. Using the rope falls, being the centre pole to an erect position. Bolt the rafters in place to the appropriate circle beams. Install the remaining rafters. Remove the centre pole extension pipe from the cap plate when the roof plate has been laid to the half way point.

Structural Buggy Method When equipment for the structural buggy method is available at the site, this method is optional, since one of the other methods may be more expedient. Considerable expense is involved in erecting and dismantling a structural buggy, and only when expansion roofs of medium diameter are being installed can the method by used to any advantage. Also, when snow and ice are present on the bottom the structural buggy is very difficult to move. As the structural buggy method is required on large diameter tanks, the method is explained under that heading (Figure 12-25).

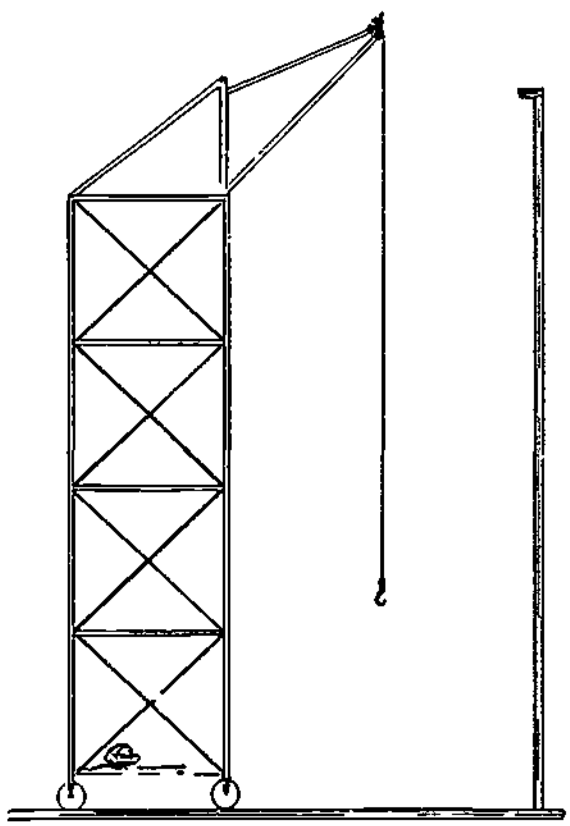


Figure 12-25. Structural Buggy

Large Diameter Tanks (Greater than 90') Large diameter tanks have supports with two or more circles of supporting beams and columns.

Structural Buggy Method It is assumed that the erection of a structural buggy is understood and that one has been erected for this project.

Procedure:

Step 1. Place the buggy midway between the two column location and to one side of the circle beam location. The side referred to is the side nearest the centre of the tank.

Step 2. Raise the columns with the boom and lash to the buggy wings.

Step 3. Remove the load line from the boom and place it in the sheave at the top of the mast. Raise the circle beam and bolt to the columns.

Step 4. Replace the load line in the boom sheave and erect rafters to the circle beam and shell. Ensure the rafters align radially to the centre of the tank, then hold this assembly in place with rope guylines (Figure 12-26).

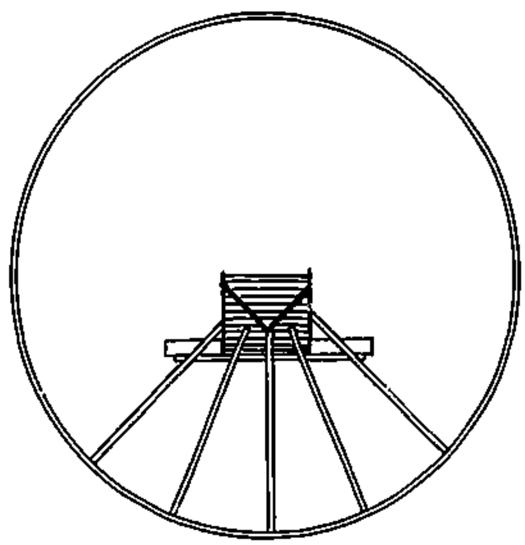


Figure 12-26. Primary Circle Beam Erection

Step 5. Move the buggy to the next location, centre it as on the previous location. Raise the column and lash to the wing. Raise the circle beam and bolt it to the columns and together. Erect the rafters and bolt to the circle beam and shell lugs (Figure 12-27).

Step 6. If the rafters do not fit without excessive pushing or pulling, **do not attempt to fit them in place.** This will only bend the circle beam. Either leave them loose until later or level the shell at the base.

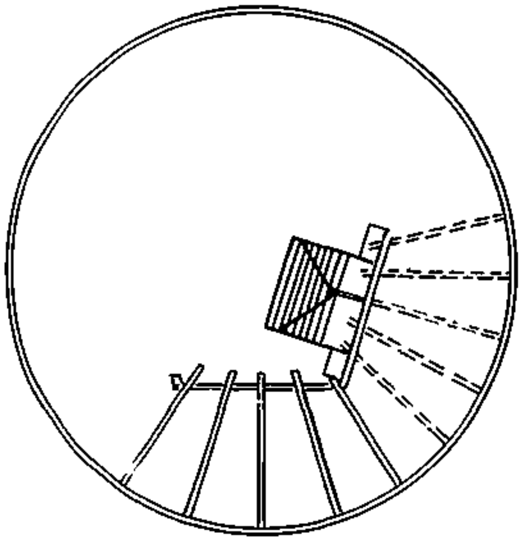


Figure 12-27. Succeeding Circle Beam Erection

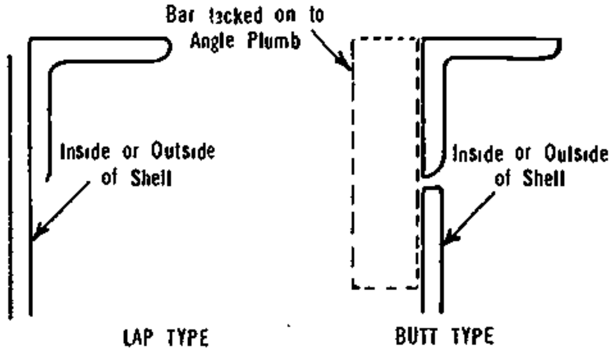


Figure 12-28. Two Methods of Placing Top Angle

Step 7 Do not tighten the bolts in the rafters as erection progresses; tighten them when erection is completed.

Step 8 Continue erecting the balance of the structural supports by the same method, finishing at the centre.

Step 9 Exercise care when using the structural buggy. Do not attempt to pick up a load at a great distance from the base of the buggy; place beams and columns near the base of the buggy for erection. Do not push or pull the wheels over large obstructions on the bottom since the shafts may break and cause the buggy to tip over.

TOP ANGLE

Laying Out Top Angles Check the drawings to determine the exact position of the angle on the shell In most cases a variation in the height of the angle occurs if installed above the shell. In addition, angles are sometimes installed by lap-welding and sometimes by butt-welding. They must be installed **exactly as shown**, since the overall height of the shell depends upon how the top angles are placed (Figure 12-28). Top angles may be installed either before or after the structural roof supports are erected

FITTING UP

There is only one accepted method to install a lap top angle.

Procedure:

Step 1. Set up the first bar of angle in its proper location and tack. The location of the end should be immediately adjacent to the rafter clip.

Step 2. Set the second bar of angle end to end with the first bar. Hold a minimum of 1/4" spacing. Sight along the angle for proper radius and level, then tack together. Weld on a heavy pass on both legs of the angle, then tack the angle to the shell.

Step 3. Continue to weld and fit the balance of bars of angle by the same method.

A top angle to be installed by butt welding to the top of the shell can be installed without welding the butt ends **provided** it is set up on spacers with keys and not tacked to the shell. Weld the butt ends next and then tack the angle to the shell. If a butt-welded top angle is to be tacked as it is fitted, use the same procedure as described for a lap type.

Butt-welded angles must be installed and held plumb with the shell during welding; they must not cock in or out Heavy bars welded on the edge across the shell and angle may be required to hold the angle plumb at all points during welding (Figure 12-29). Spacing of butt-welded angle to the shell must conform to drawing specifications.

ROOFS

After structural roof supports are completely fit up, top angle butts welded and top angle to shell overhead tacked or welded, the roof plates may be laid.

The drawing will indicate where to start laying the roof plates. Lap the plates on the top angle as required by the dimensions on the drawing.

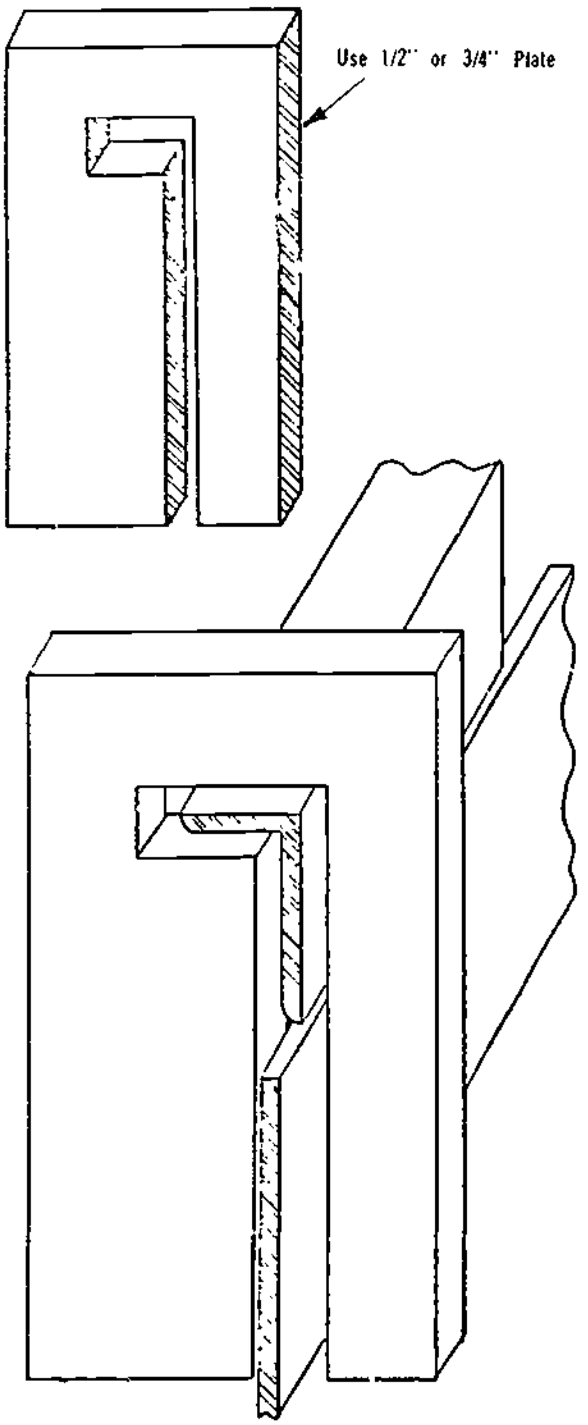


Figure 12-29. Top Angle Dog Used for Holding Butt-Welded Top Angle

Lay the sketch plates at the ends of the courses first. Lay square plates by starting at the ends of the courses and working toward centre. It is advisable to use plenty of false rafters to hold the plates level. Lap plates as required, holding **straight lines** on each course. Tack sketch plates lightly so that the tacks can be broken later.

Continue laying roof plates by this method until half the roof has been laid. On small diameter tanks, laying the second half of the roof follows directly, proceeding with the courses from the centre toward the opposite side, except that plates are lapped underneath so the seams will shed water. On large diameter roofs, lay a number of square plates side by side toward the opposite side of the roof to serve as a runway for the roofing buggy. Measure from the edge of the centre course on each end of the centre course around the outside of the shell to a point 90° of circumference distant. This point is the centre of the first course as the plates are laid on the opposite side (Figure 12-30).

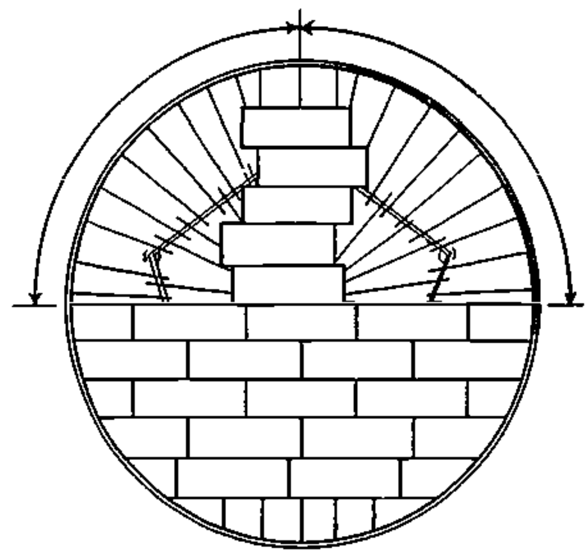


Figure 12-30. Method of Laying Roof Plates

FITTINGS

Shell Manways and Nozzles The specifications for locating fittings are set out in the drawings. It is important in erecting shell plates to ensure that vertical seams are properly placed so that fittings will not be located on or too close to the seams.

Double check the layout of fittings before cutting any openings; holes cut in the wrong place must be patched at considerable cost and they produce an inferior finish to the tank

Drawings of fittings show the size of cut-out to be made in the shell. The specifications must be followed precisely An opening too large requires a larger reinforcing pad as well as an excessive amount of weld metal Conversely, an opening too small will not permit the required size fillet weld to be made on the inside, resulting in inadequate strength of the joint. Double fillet welds of the specified size are necessary to reinforce the opening competently.

Openings or cut-outs over 2" in diameter must have reinforcing pads (double plate) which must be double welded: welds both inside and out.

Since numerous types of fittings are assigned to various locations and installed by different methods, each will be explained and illustrated separately.

COUPLING OR PIPE, 2" OR LESS

Installed in the Shell of the Tank

Step 1 Cut the size hole indicated on the drawing.

Step 2. Insert coupling or pipe as shown.

Step 3. Weld inside and out with the size of fillet shown on the drawing.

Step 4. Never insert a coupling half way in, as the shrinkage caused by the welding will not permit a full thread to be made when a pipe or fitting is screwed in (Figure 12-31).

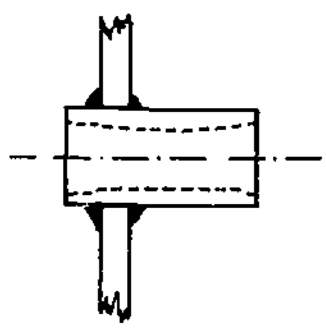


Figure 12-31. Tank Shell Fitting

Installed in the Roof or Bottom

Step 1. As roofs and bottoms of flat bottom storage tanks are not stressed, couplings or pipe may be installed and welded on one side only.

Step 2. Cut the size of opening as required for the method used.

Step 3. Install and w~ld as shown (Figure 12-32)

NOZZLES OVER 2" DIAMETER WITH REINFORCING PAD

Nozzles with Shop Welded Reinforcing Pad

Step 1. Cut the exact size circular hole as required.

Step 2. Insert the nozzle in the shell and centre in the hole.

Step 3. Pull the pad to the shell with dogs and wedges. Tack weld the nozzle to the shell on the inside of the tank only; the pad to the shell **must be left** loose.

Step 4. Weld the inside of the nozzle to the shell first (5/32" diameter electrodes must be used). When the face of the weld becomes greater than 1/2", each layer of weld metal must be peened so as to relieve the shrinkage stresses. Final wash passes need not be peened.

Step 5. Allow the inside weld to cool; then tack and weld the pad to the shell outside (Figure 12-33)

Nozzles with Reinforcing Pads Unwelded

Step 1. Cut the exact size of hole as required

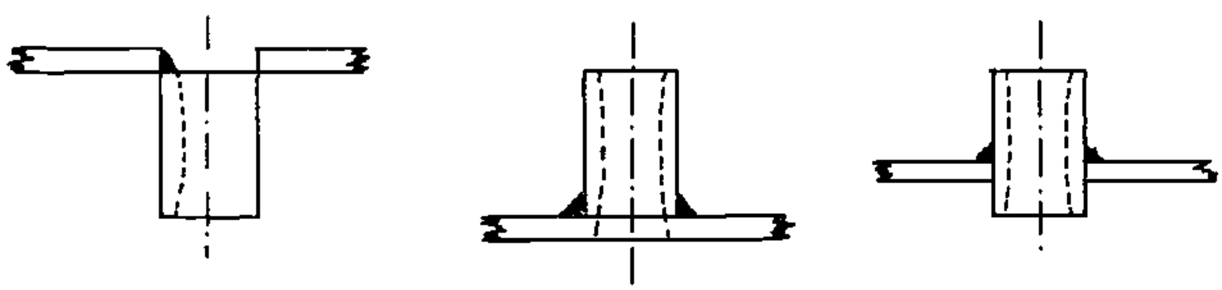


Figure 12-32. Floor or Roof Fitting Installation Procedure

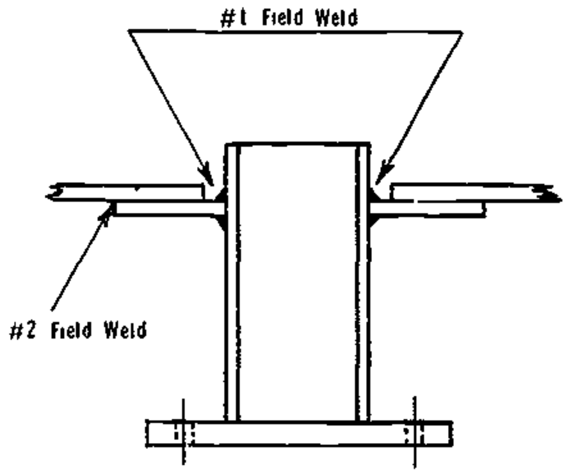


Figure 12-33. Tank Shell Fitting with Welded Reinforcing

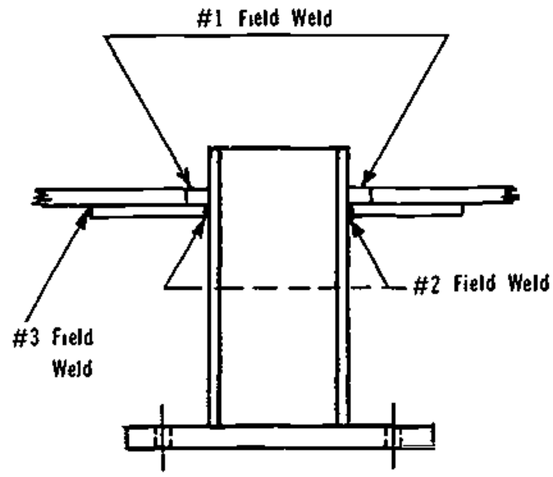


Figure 12-34. Tank Shell Fitting with Unwelded Reinforcing Pad

Step 2. Install the reinforcing pad to the shell with clips and wedges. Ensure the pad is centred over the cut-out in the shell. Tack the pad to the shell on the **inside only**; hold to the shell outside with clips. Tacking on the pad to the shell outside is not permitted.

Step 3. Insert the nozzle through the shell and tack in place either inside or outside. Holes in the flange must straddle the horizontal centre line. Align the nozzle radially with the centre line of the tank or an alternative reference if required.

Step 4. Weld the nozzle and the pad to the shell **on the inside first**. Weld the nozzle to the pad on the outside next. Weld the reinforcing pad to the shell last. Only 5/32" diameter electrodes are to be used on uphill passes (Figure 12-34).

Welding Where nozzles fit through the shell without reinforcing pads, the holes through the shell must be cut the same size as the outside diameter of the pipe. Full fillet welds of the size specified on the drawing are to be made inside and out.

Where reinforcing pads are used, they must fit tightly to the shell at all points. Where pads do not fit tightly, an increase in the size of weld will be required to compensate for the gap.

Welding Procedure for Plate of Varying Thicknesses Figure 12-35 illustrates the required welding procedures for plate having thicknesses greater than and less than 5/16".

Welding Sequence for Manway Fittings with Reinforcing Plate

1. Welds 1 and 2 as shown in Figure 12-36 are completed in the shop.
2. Weld 3 inside the shell is to be completed in sequence as shown from A to D.
3. Weld 4 (reinforcing plate to shell) must follow in sequence as shown from A to M.

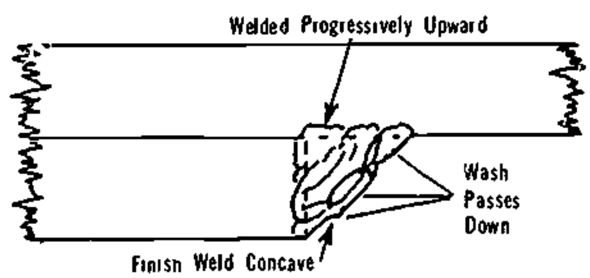
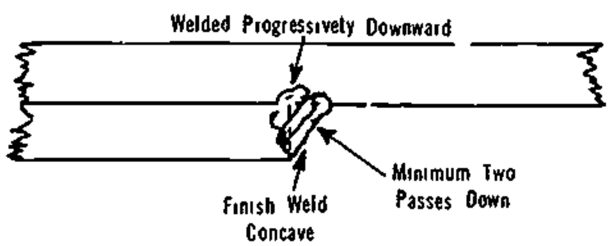
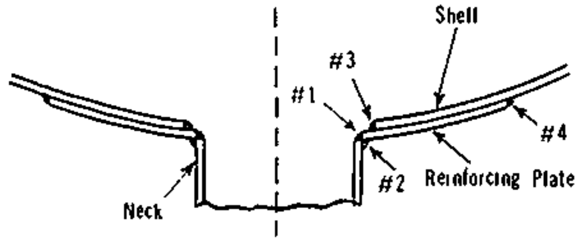


PLATE THICKNESS OVER 5/16"



UP TO AND INCLUDING 5/16" PLATE

Figure 19-35. Welding Procedures



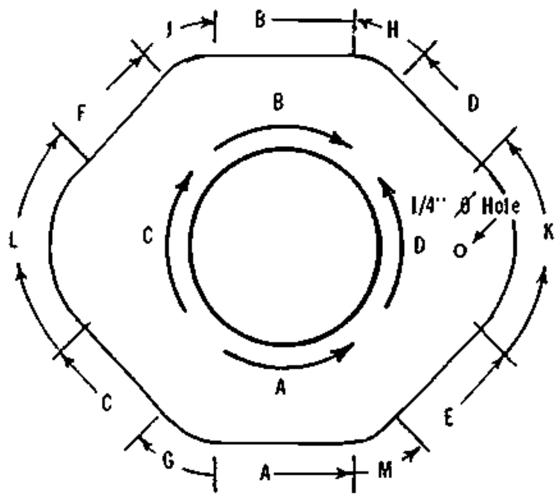


Figure 12-36. Welding Sequence for Manway Fittings with Reinforcing Plate

Note: 1 Weld sizes are specified on customer drawings.

2 Welding electrodes to be used are: E-6010, E-6011, E-7016 and should not exceed 3/16" in diameter.

Patching In many cases in field erection a fitting or other appurtenance may have to be relocated after it has been welded in place. The procedure generally followed for this begins with burning the old fitting out of the shell plate. A circular patch is then rewelded in its place. It is very important that the repaired area not be distorted in any way and that the design strength of the shell not be compromised. Both these considerations depend upon the competence of the welding on the patch.

The following welding procedure should be followed in cases where field repairs are required on a tank shell:

Step 1. Grind circular opening in the shell plate to clean metal, and remove any notches caused by the cutting torch. Grind a double bevel around the inside of the opening at this stage.

Step 2. Pre-set the plate to be inserted in the opening to a contour slightly in excess of the tank shell contour.

Step 3. Bevel the plate to match the bevel on the opening.

Step 4. Tack the plate in position with a gap of 1/16" all around the plate; the gap must not exceed 1/8"

Step 5. Weld as shown in Figure 12-37 using E-6010 electrode; clean the slag after each pass.

Step 6. Drill a 1" diameter hole in the centre of the circular plate.

Step 7. Examine the repair for any inward or outward distortion. If inward distortion is present, complete welding on the outside, using a similar procedure as for the root pass; if distortion is outward, complete welding on the inside using a back step procedure.

Step 8. Allow the stresses set up by the welding to be relieved spontaneously by means of the drilled hole; when the area has cooled to approximately 200°F., fill the hole using extreme care to eliminate any slag from the weld.

Step 9. Grind all excess weld metal flush to the shell surface, and eliminate any undercut that may occur.

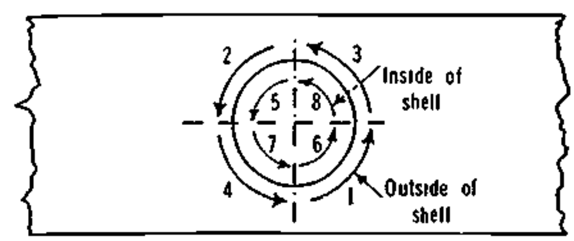


Figure 12-37. Patching Tank Shell

TESTING

Bottom Upon completion of the welding on the tank bottom, apply the following testing method: The joints are subjected to air pressure or vacuum, using soap suds, linseed oil or other suitable material for detecting leaks.

Shell Upon completion of the entire tank, and before any external oil piping (or other content material) has been connected to the tank, test the shell by one of the following methods.

Method 1. If water is available for testing, fill the tank with water, with frequent inspections during the filling operation. For tanks with tight roofs, the filling height must be 2" above the top leg of the top angle. For open-top tanks, the filling height must be the top of the top angle or the bottom of any overflow that limits the filling height.

Method 2. If sufficient water to fill the tank is not available, the test may be accomplished by:

a. painting all joints on the inside with a highly penetrating oil, such as automobile-spring oil; examine the outside joints carefully for leakage.

b. applying internal air pressure or external vacuum as specified for the roof test; examine the outside of the joints carefully for leakage.

c. any combination of the methods outlined in a and b.

Roof. Upon completion, the tank roof is to be tested by applying an internal air pressure or external vacuum to the seams, using soap suds, linseed oil or other suitable material for detecting leaks. The internal pressure must not exceed the weight of the roof plates.

GENERAL CONSIDERATIONS

This chapter has outlined the method used to build structurally sound and neat appearing field erected tanks, although no mention has been made of the final dressing and cleaning up. The latter consists of making a thorough inspection of the bottoms, shells, structural roofs and fittings to confirm that no omissions have occurred. Inspections are to be conducted as follows.

Bottoms

1. Inspect bottom seams for unwelded areas, undersize welds, improper welds at the laps and undercutting.
2. Chip (or grind) off all burrs or lugs. Inspect for undercut at these locations and reweld where necessary.
3. Sweep clean the entire bottom and inspect for indentations where brackets or channels have fallen. The plate may be ruptured at these points, requiring patching.

Bottom to First Ring

1. Clean off slag on fillet weld inside and outside.
2. Inspect for undersize weld, undercut and unwelded areas.

Shells

1. All scaffold lugs are to be removed unless the customer requests otherwise. Any burrs left after removing lugs must be chipped off. Where there is undercut on the shell plate, fill it in with weld metal. If weld metal protrudes excessively beyond the plate surface at these points, it must be chipped off.
2. Where fitting lugs have been removed, the burrs must be chipped off and any undercut rewelded.
3. Vertical and horizontal seam welds must be inspected for undercut, reinforcement and surface porosity. There is to be no undercut on vertical seams. Undercut on horizontal seam welds must not exceed specified limits. Reinforcement on welds may be slightly over flush with the plate, but must not exceed 1/16". Any surface porosity on welds must be chipped off and rewelded.

Structural Supports

1. All bolts must be in erection holes and drawn up tight.
2. Columns must stand plumb and be secured by lugs welded to the bottom only.
3. Column bases must be installed so that the ends of the columns are a minimum of 1" off the bottom.

Roof

1. Roof seam welds must be full size fillet, with no excessive convexity. There is to be no undercut. Welds at laps must be full size.
2. All burrs or lugs must be chipped off roof plates.
3. Examine closely to ensure that no unwelded areas remain on the roof to angle and roof seams.

Fittings

1. Welds on fittings must be of proper size. Fillet welds are to be slightly concave with no undercut.

2 Holes in flanges on nozzles must straddle vertical or horizontal centre lines.

3 The faces of flanges on roof nozzles where pressure or vacuum valves are installed must be installed level.

4. Stairways and railings must have their true shape and be welded in accordance with requirements.

FLOATING ROOFS FOR LIQUID STORAGE

Floating roofs are used in liquid storage tank construction for primarily two reasons.

1 To reduce pollution by limiting the escape of fumes into the atmosphere.

2 To reduce loss of product from evaporation.

Floating roofs may be constructed of aluminum, mild steel or any combination of steel alloys.

Although there are variations in floating roof construction, all include the basic design components of synthetic or natural material seals, adjustable legs and drains.

TYPES OF FLOATING ROOFS

Hard Top Floater Hard top floating roofs designed to be constructed inside existing tanks with conventional roofs, are common in the petroleum and chemical industry (Figure 12-38). The construction is all-welded and vapour-tight, which, in combination with seals of polyurethane or similar material, effectively prevents vapour loss.

Hard top floating roofs are virtually maintenance-free, since no snow or ice removal are required and service life of the inner roof and seals is extended by virtue of being protected from the weather. Erecting a floating roof within an existing tank requires little or no modification of the tank structure beyond cutting slots for ventilation and overflow and welding shields above them.

Pontoon Floater The pontoon floating roof tank provides vapour-saving, anti-corrosive storage since the single deck roof floats directly on the stored liquid, 100% contact is maintained to prevent corrosion by entrapped vapours (Figure 12-39).

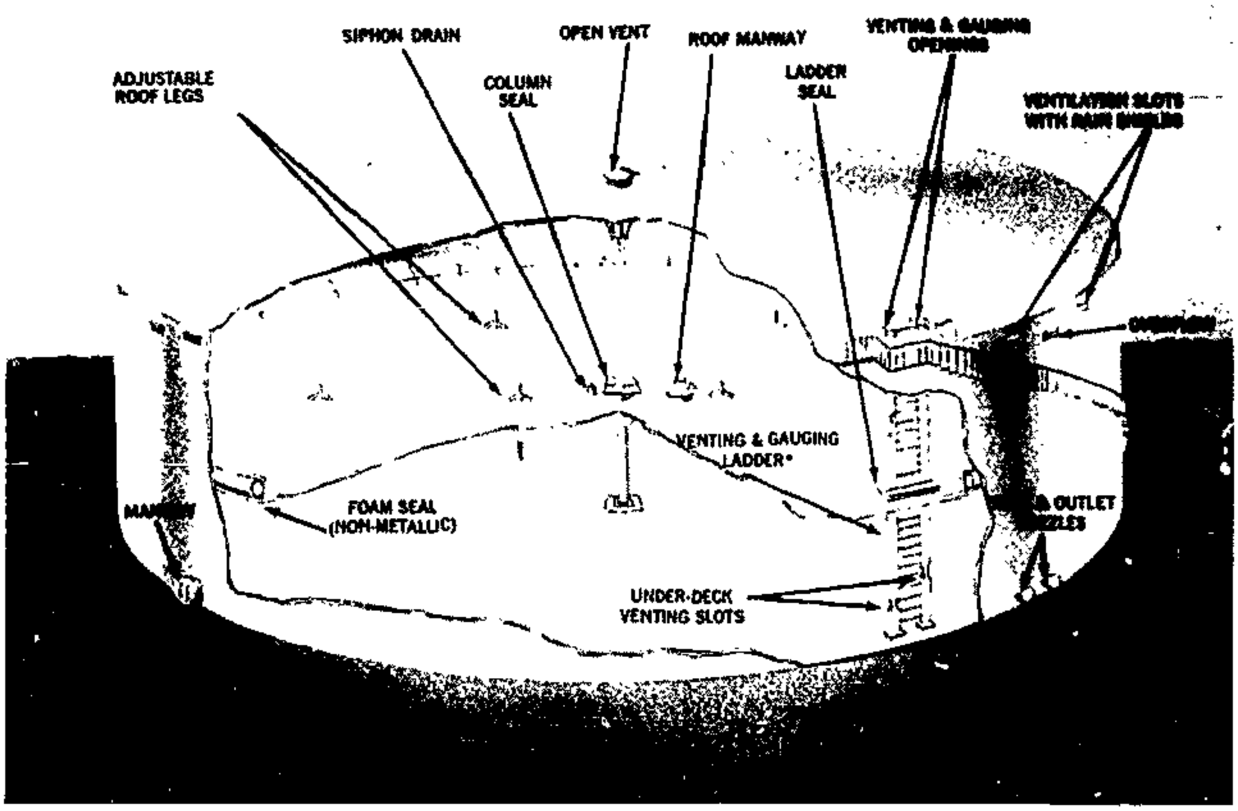


Figure 12-38. Hard Top Floating Roof

The roof is supported by peripheral pontoons covering approximately 25% of the deck area. The welded construction is strong, stable and fire-resistant. The large pontoons have built-in stiffeners that provide maximum rigidity. Heavy rainfall is drawn off by a central sump and hose drain to the outside perimeters of the tank. The space between the roof and the shell of the tank. The space between the roof and the shell of the tank is closed with polyurethane foam or similar seal.

Double-Deck Floater Double-deck floating roof tanks have proved successful in protecting volatile products against evaporation The double deck is designed for buoyancy and strength, and insulates the product against rising temperatures; the roof floats directly on the stored product to prevent vapour loss (Figure 12-40). The upper deck of the roof is sloped to the centre sump for efficient drainage, and only deep snowfalls create a need for attention. As with the pontoon floater, the space between the roof and the shell of the tank is closed with a choice of seals.

DRY STORAGE CONTAINERS

Dry storage tanks (Figure 12-41), bins and hoppers are constructed in various shapes and sizes and may be erected at various elevations using struct ' supports. In general, the techniques used in erecting liquid storage tanks are applied in erecting dry storage units although some specific characteristics of dry storage are reflected in the construction procedures.

Features of Dry Storage Tank Construction

1. Depending on the customer's requirements, the base (usually concrete) of a dry storage tank or bin may be the actual floor of the unit.
2. Depending on its function, the top of a dry storage unit may be open, or partially or completely closed; the roof may be constructed of wood, concrete or steel.
3. The function of the completed unit may require inclusion of a dust-tight seal of polyurethane foam or similar material at the base and/or at the top of the container.

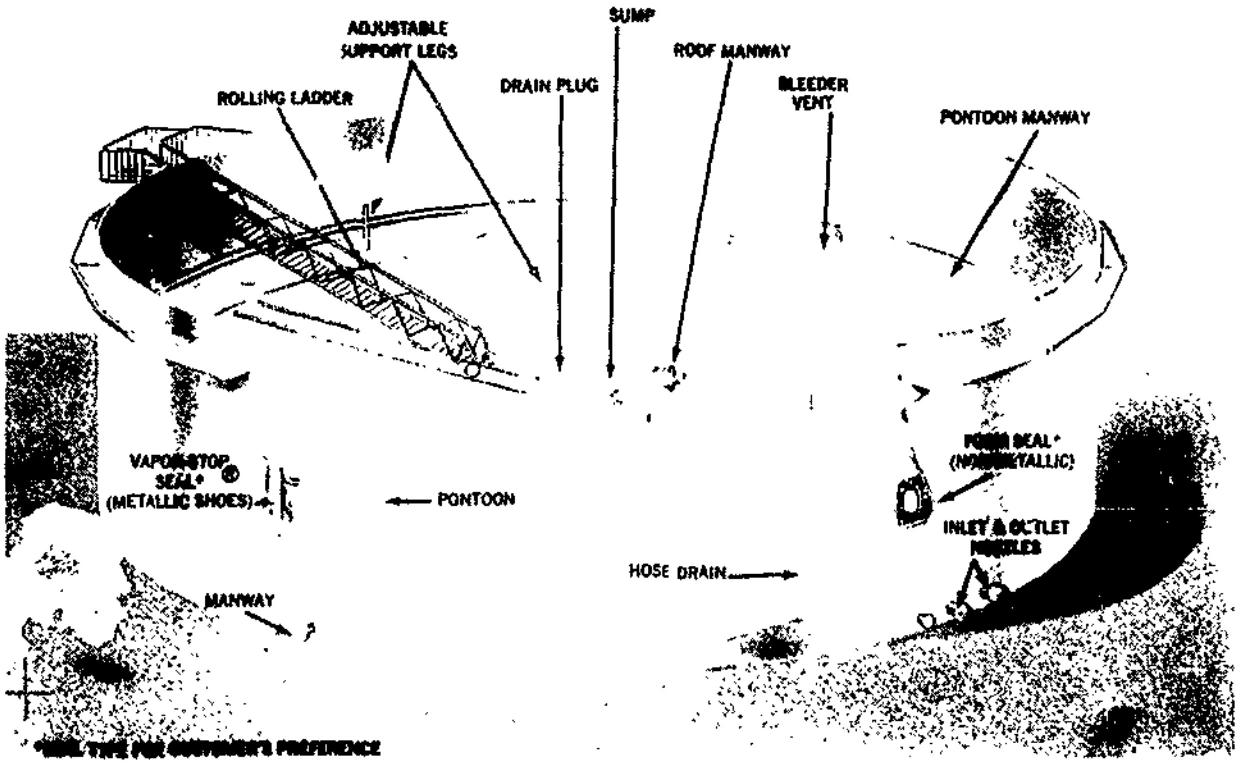


Figure 12-39. Pontoon Floater

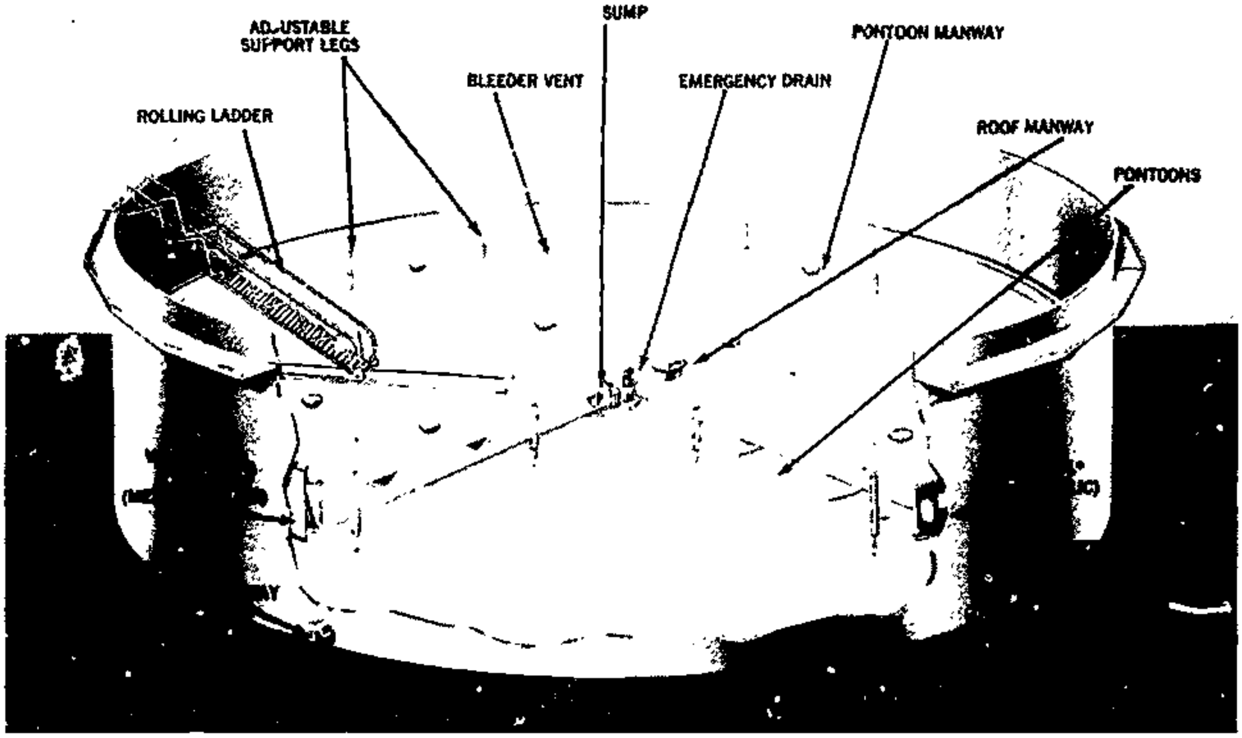


Figure 12-40. Double Deck Floater

4 Dry storage design requirements are based upon the effective direction of stress which is vertical.

5 Bins and hoppers, depending upon customer specifications, may have inverted pyramid, oval or cone bottoms, cone or inverted pyramid bottoms may be hard surfaced or have wear plates attached.

6 Although requirements are less critical for dry storage units than for liquid storage, all welding must conform to appropriate codes and specifications.

7 In many cases dry storage units are constructed with self-supporting roofs offering the following advantages:

- Roof slope conforms to the angle of repose of the product to be stored.
- Maximum capacity from a tank of a given diameter can be achieved.
- No interior columns impede efficient removal of the product.

STACKS

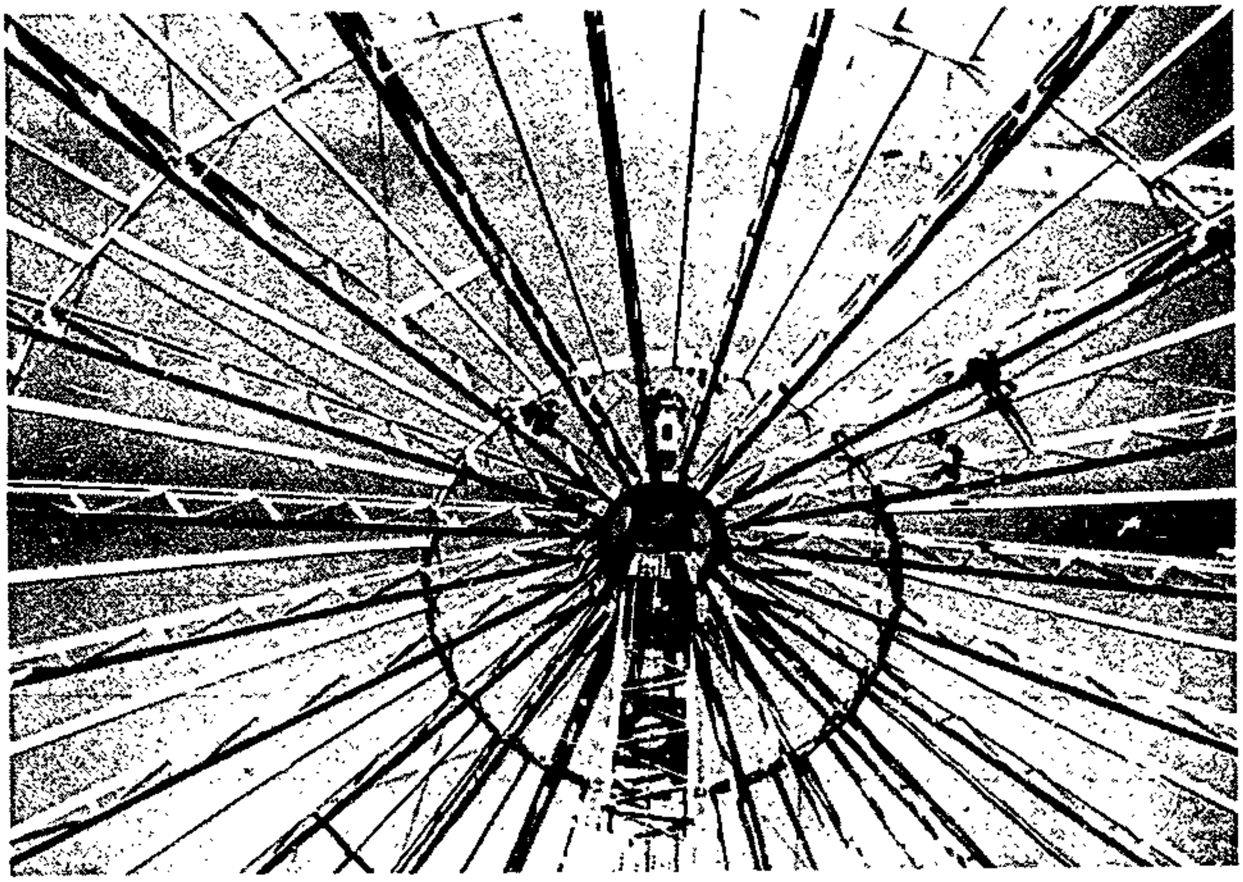
Stacks could be described as power plant exhaust systems that serve to emit gases into the atmosphere at a safe elevation to mix with and be diluted by the upper air. A stack is essentially a vertical conduit that forces gases out by creating a draft due to the difference in density between the exhaust gases and the atmosphere. Stacks may be made of brick, steel or fibreglass; in some cases a brick or concrete chimney is built around a steel liner.

The choice of erection method for a stack is dictated by the following considerations: 1) the required height of the stack and 2) existing site conditions, particularly with respect to adjacent structures.

ERECTION METHODS FOR STACKS

Stacks are erected in sections supplied to the jobsite as shop fabricated units, either full round sections or half-round sections. The height of a stack erected in sections is limited only by the vertical reach and capacity of the crane. The sections are placed on top of each other, one at a time; each section is plumbed, fitted and welded before the next section is welded. Sections are plumbed using a transit and a plumb bob.

The most common technique of fitting stack sections is illustrated in Figure 12-42. The slotted



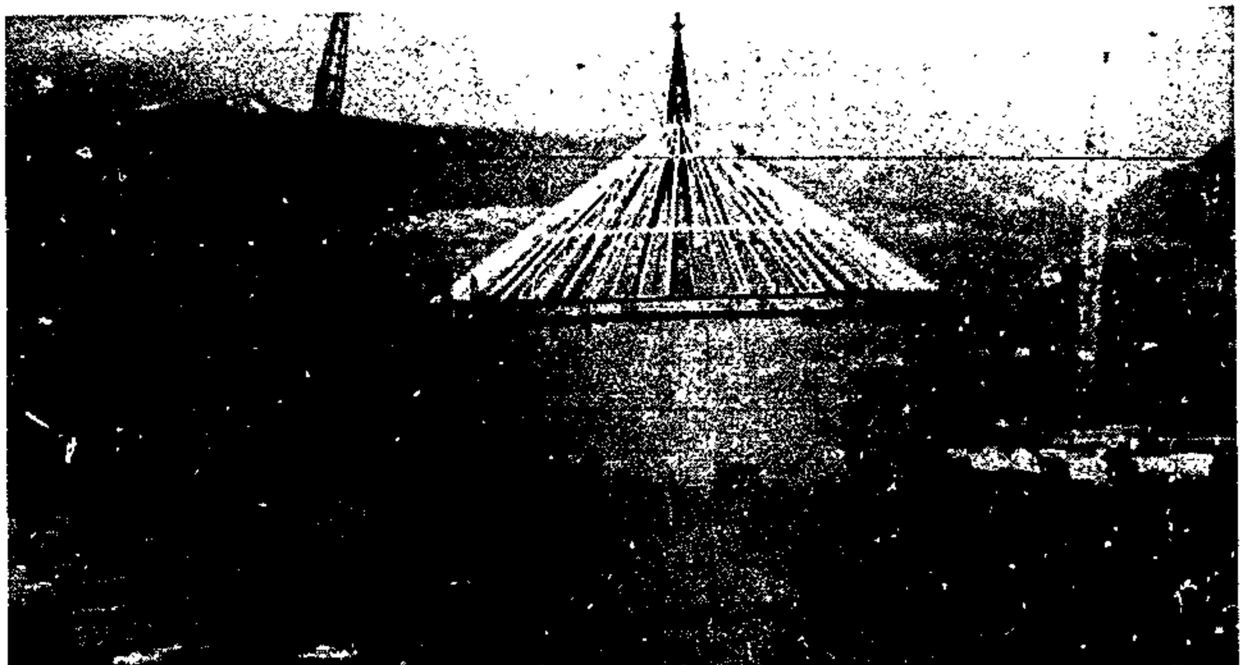


Figure 12-41. Dry Storage Containers

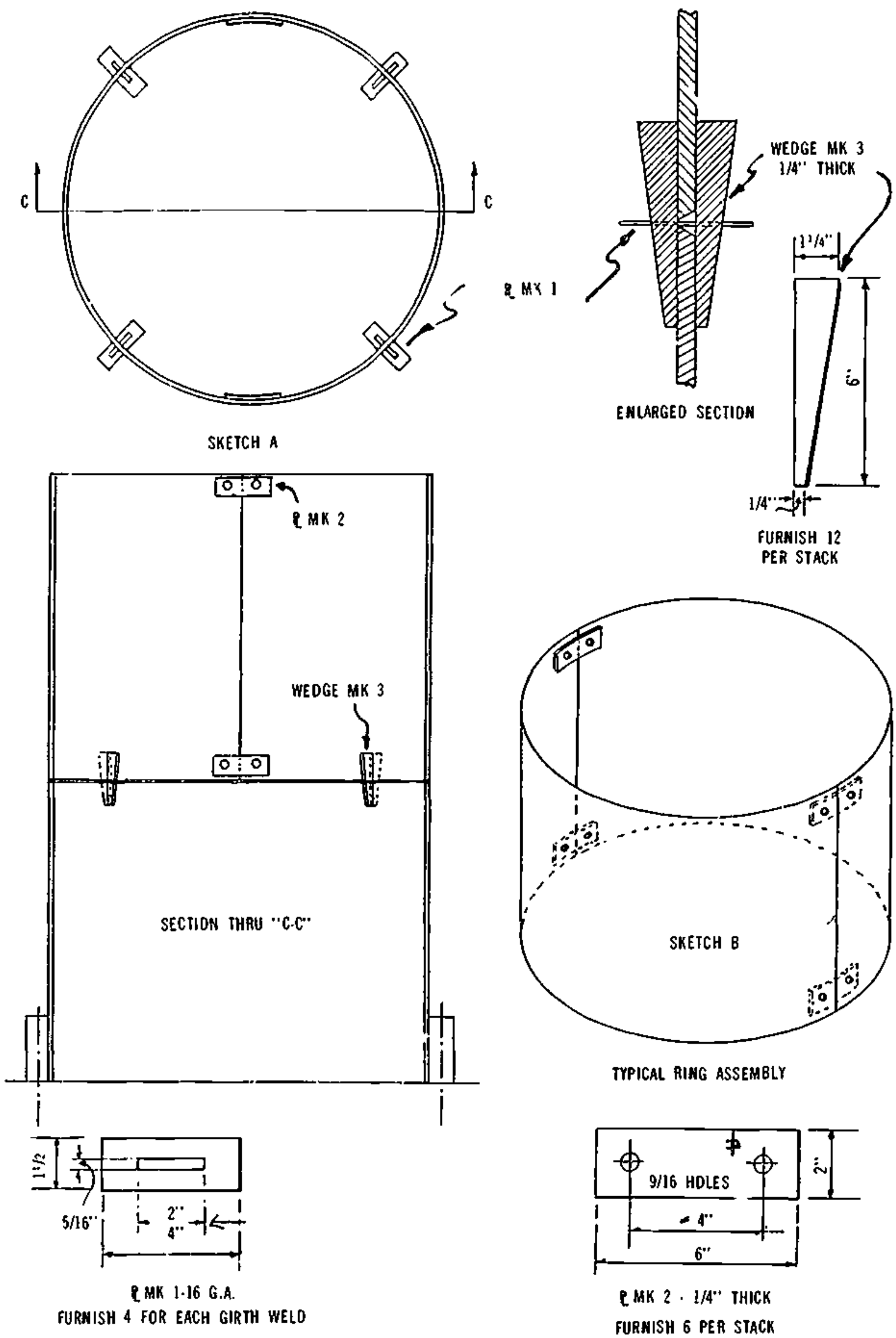


Figure 12-42. Stack Section Fitting

plates (MK 1) and the wedges (MK 3) are used to bring the newly placed section into alignment. Tack bars (MK 2) provide a temporary means of holding two half sections together prior to welding.

Full-Round Stack Sections There are a number of techniques for erecting full-round stack sections, but only the three most common are described here.

1. Often the prefabricated full round sections are hoisted into position one on top of the other. Once in position, each section is plumbed and fitted before the girth welds are done and the next section lifted. Sections are plumbed using a transit and a plumb bob. Figure 12-43 shows a stack being erected by this method; the upper section is being raised by a tandem hoisting arrangement consisting of a gin pole situated on the highest point of the boiler structure and a crane on the ground. Figure 12-44 shows another stack under construction; the section in the foreground is the top section being raised into a vertical position in preparation for hoisting.

   Figure 12-45 shows the main line of the crane about to lift the section into place on top of the completed lower section of the stack. Figure 12-46 shows the lower section of the stack ready for the top section to be hoisted into place. Note that the lower levels of staging have been removed. A mobile crane was used in this sequence to effect the lift.
2. In some cases, the whole stack except for platforms and ladders, is assembled on the ground and erected as a completed unit. This method can be used only within a limited range of heights and within the capabilities of the crane.
3. Another common method of erecting stacks from prefabricated whole round sections is used when site conditions present access problems. This technique involves jacking up the completed portions of the stack and guiding the next section into place under the raised portion.

Half-Round Stack Sections When the stack sections have been supplied as half-rounds, the erection of each section involves vertical as well as horizontal (girth) welds. Figure 12-47 illustrates one method of erecting half-round

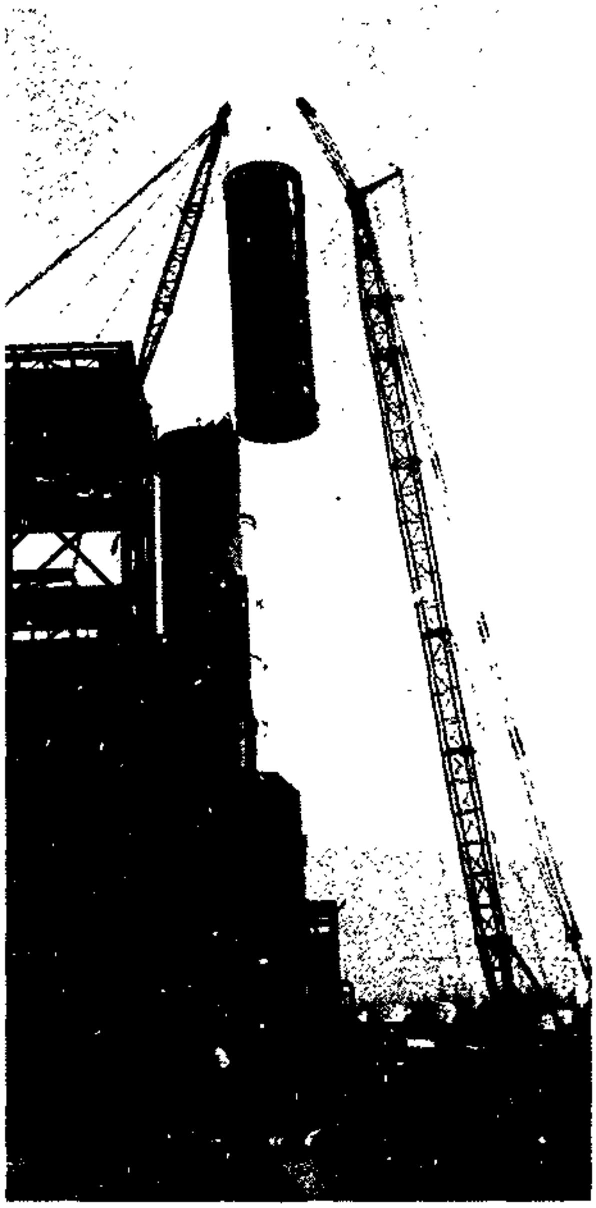


Figure 12-43. Tandem Hoisting Stack Erection

sections; in this procedure a floating type of inside staging is used which is supported by two light chain falls used with bridles to provide four points of suspension. Four small rope falls can be used as an alternative. The advantage of this arrangement is that during the transition, when only one half ring is in place, the stage is supportable on one side only; this causes the stage to lean to one side and jam against the stack so that it is perfectly safe.

Another method of supporting an inside stage (a simple platform consisting of 2" x 12" planks laid across and nailed to 4" x 4" struts) is to weld angle clips to the inside of the stack at each elevation. These angle clips should be

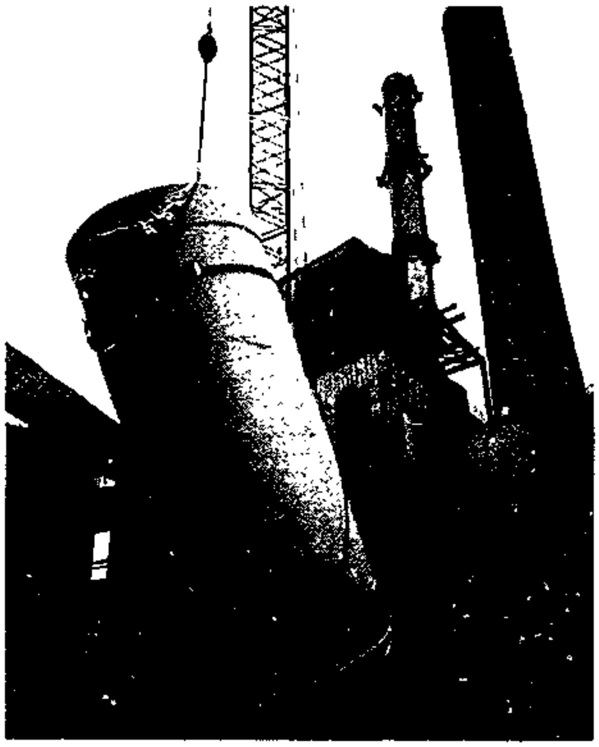


Figure 12-44. Standing Up Stack Section Using Two Hooks

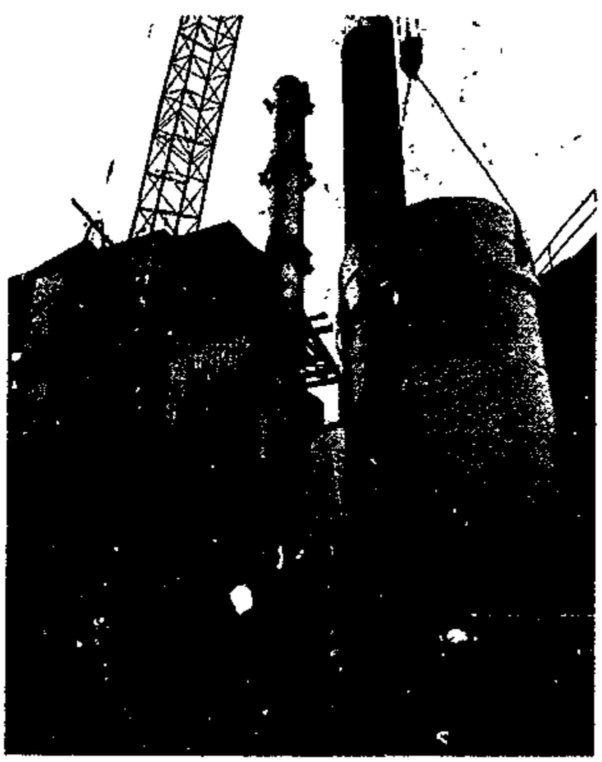


Figure 12-45. Stack Section Ready For Lifting

Figure 12-46. Lower Stack Section

welded on one side only to facilitate removal since they will be knocked off for re-use when work at that elevation is completed. Sufficient staging materials (angle clips and lumber) for two platforms are necessary, so that when one is in position the other can be assembled at the next elevation. When the work moves up to the new elevation the lower platform is dismantled simply by removing the wood and bending the angle clips until the weld breaks.

Figure 12-47 also shows the field-constructed gin pole resting on the platform and against the stack; it is prevented from slipping sideways by wooden cleats nailed to the platform. The guylines of the gin pole are fastened to the stack as shown. After the first half of a section has been raised, placed and secured with sufficient tack welds, use the gin pole to raise the stack cage to the top of the new half section. At this point move the gin pole to its new position (at the same elevation) for raising the other half of the section.

When the floating platform is to be raised to its next elevation, move up the guys on the gin pole one at a time to their new fastening points. The bottom of the gin pole is moved around 90° with its upper end leaning against the top edge of the stack in the approximate direction required to lift the first half of the next section. One of the chain falls supporting the platform is slacked off and unhooked so that the lug from which it is

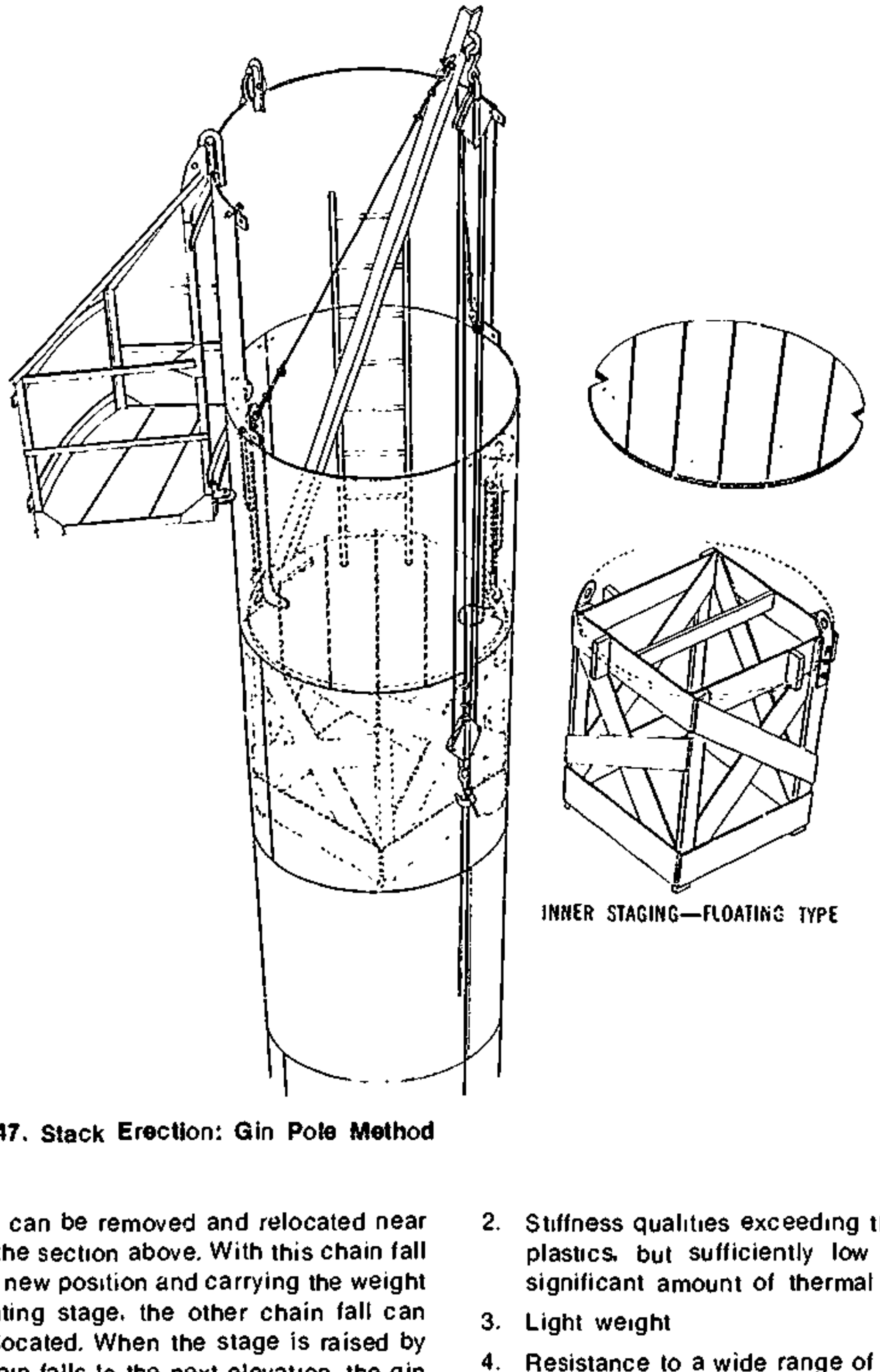


Figure 12-47. Stack Erection: Gin Pole Method

suspended can be removed and relocated near the top of the section above. With this chain fall hung in its new position and carrying the weight of the floating stage, the other chain fall can also be relocated. When the stage is raised by the two chain falls to the next elevation, the gin pole will rise up with it until the guys are taut.

FIBREGLASS REINFORCED POLYESTER

Fibreglass reinforced polyester (FRP) has a growing range of applications in construction due to its unique properties and characteristics:

1. High mechanical strength
2. Stiffness qualities exceeding those of other plastics, but sufficiently low to absorb a significant amount of thermal stress
3. Light weight
4. Resistance to a wide range of chemical environments
5. Ease of fabrication and erection.

FRP is primarily used in process industries for the following structures:

1. Ventilation equipment such as ducting and hoods
2. Breechings and plenum chambers in considerable size ranges and operating temperature levels

3 Stacks and stack liners

4 Process vessels (scrubbers, cooling towers, etc.)

5 Vertical and horizontal tanks in a wide range of dimensions.

STRUCTURE

FRP used in construction is a complex combination of fibreglass and polymerized unsaturated polyester resin in which the properties of the product can vary widely depending upon the type, amount and arrangement of the reinforcing fibreglass particles. In the manufacture of FRP, three components are required.

1 The unsaturated polyester resins as the base of the combination; the functions of this material are:

- Providing form to the product
- Distributing operating stresses within the product
- Providing chemical and thermal stability
- Rendering the product fire-resistant.

2 The fibreglass reinforcing material which gives the product strength and stiffness The quantity of fibres and the manner in which they lie in the polyester base determine these characteristics.

3. The coupling agent that mediates the cohesion of the fibreglass within the polyester base material. The functions of the coupling agent within the FRP product are:

- To help focus stresses toward the fibreglass reinforcement
- To improve the moistureproof nature of the product.

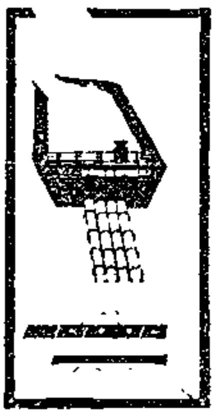
CHEMICAL RESISTANCE

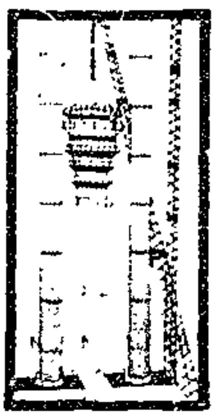
FRP's inherent chemical stability is influenced by design characteristics of each of the product components: the polyester resins, the fibreglass reinforcing material and the coupling agent.

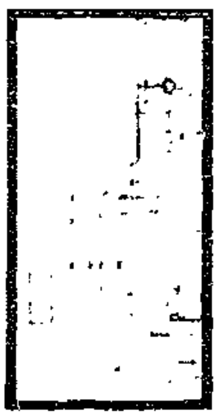
Principal Applications of FRP in Chemical Environments

1. Acid environments within specified temperature ranges
2. Chlorine/bleach service
3. Gases (except fluorine and bromine), within specified temperatures in some instances
4. Inorganic salts and salt solutions (most salts)
5. Petroleum products (except alcohol).

Chapter 13
HYDRO-ELECTRIC POWER DEVELOPMENT







INTRODUCTION

Hydro-electric power is produced when the force of moving water is harnessed by man. The energy is derived indirectly from the sun, since the sun constantly raises water, evaporated from oceans, lakes, rivers and marshes, into the atmosphere where condensation produces clouds. Rain and snow from these clouds return the water to the earth.

Rivers with fast descending waterways, falls or rapids are chosen as damsites for power production on the basis of three factors:

1. Volume of water moving through the area
2. Rate of descent
3. Capability of the reservoir.

STAGES OF DEVELOPMENT

Site preparation

The following areas are cleared for construction:

1. Area selected for the powerhouse
2. Upstream area selected for the reservoir
3. Area of the actual damfill.

Temporary water diversion

The flow of the river must be diverted for the period of construction on the project. A diversion dam and/or tunnel is built before excavation of the damsite begins.

Dam Construction

Two types of dam may be used, earth fill (Figure 13-1) or concrete (Figure 13-2). The dam is built to a height determined by engineering studies to create a reservoir or lake from which water will be drawn to run the turbines.

Powerhouse Construction

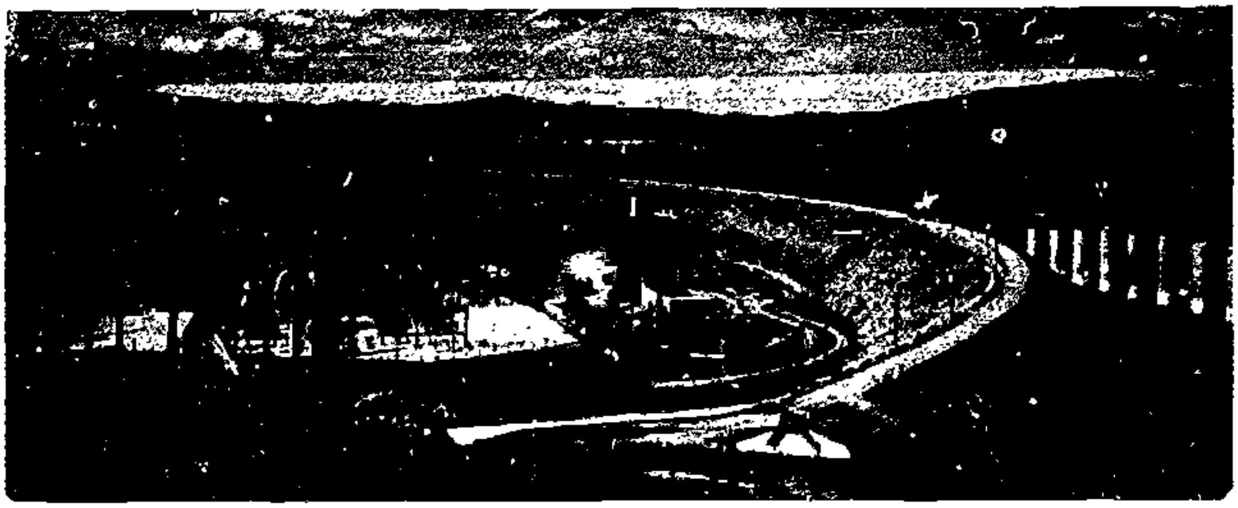
The powerhouse may be located underground or above ground, and consists of a cavern or structure that will house the turbines (Figure 13-3). Usually two bridge cranes are installed (one is visible in Figure 13-3) to expedite construction and for subsequent maintenance operations.

CONSTRUCTION OF WATER INTAKE CONTROLS

The inflow of water from the reservoir to the tailrace must pass through a series of controls (See Figure 13-4).

Trash Racks

Trash racks are steel screens that provide a barrier to logs and other potentially damaging items from entering the penstock.



W.A.C. BENNETT DAM — Length: $1\frac{3}{4}$ miles; Thickness (at base): $\frac{1}{2}$ mile; Height: 600 feet; Volume: 57.2 million cubic yards of fill (100 millimeters); Crest elevation: 2,230 feet above sea level; Reservoir: 640 square miles.

Figure 13-1. Earth and Rock Fill Dam

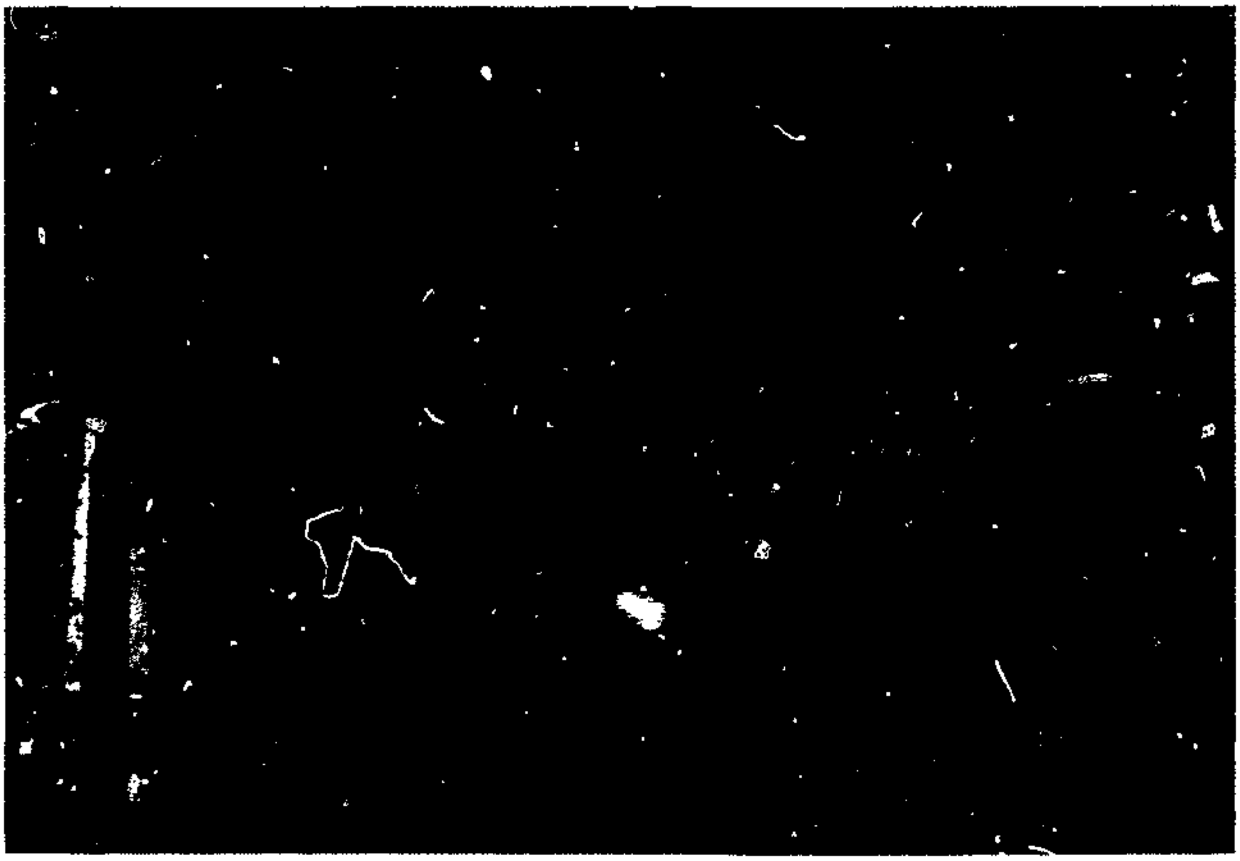


Figure 13-2. Concrete Dam

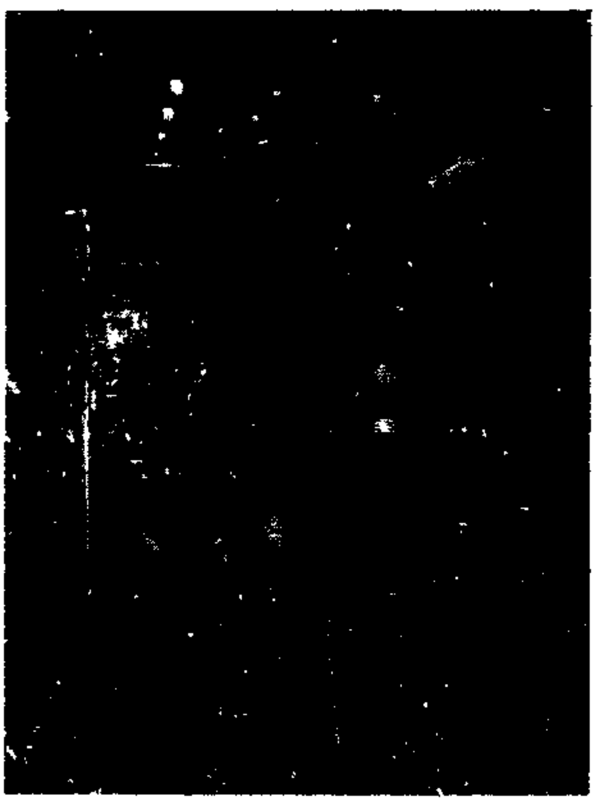


Figure 13-3. View of Underground Powerhouse During Early Construction

Stop Logs

The stop log assembly is a number of solid steel frames with timber and rubber seals that can be lowered between the trash racks and control gates to reduce pressure on the control gates.

Control Gates

The control gates regulate the water flow into the inlet end of the penstock relative to the power demands of the area being serviced by the hydro installation. In addition to the power demand factor, the control gates are lowered to close off the water flow completely for maintenance operations on the penstock or spiral case assemblies.

Penstock

The penstock is a steel liner or pipeline for conveying water to the spiral case.

Spiral Case

The spiral case directs the water flow against the water wheel or "runner" portion of the turbine assembly.

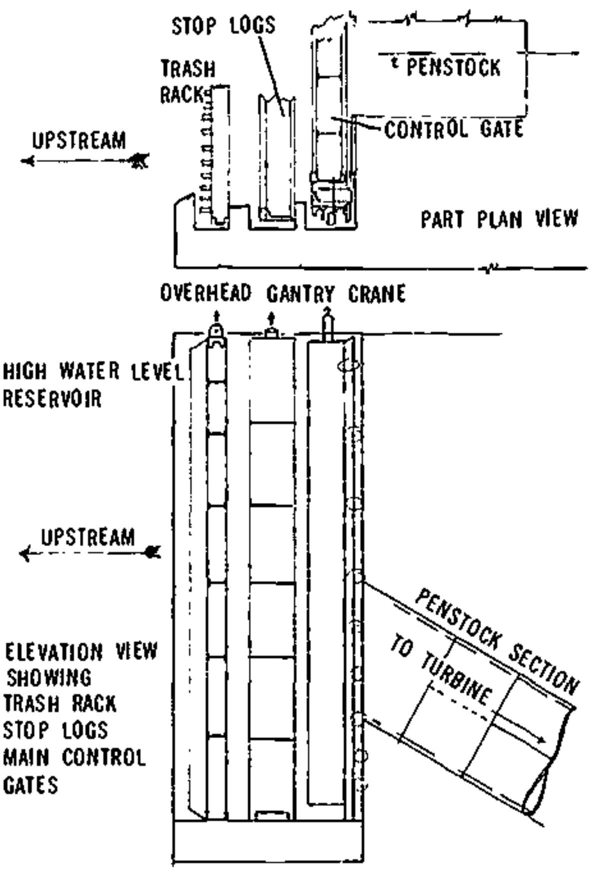


Figure 13-4. Hydro-Electric Power Dam Inlet

Turbine

The water rotates the waterwheel, shaft and rotor (moving parts of the turbine assembly) against the stationary stator to produce electricity.

Outflow Sequence

The spent water is drawn by gravity down the draft tube liner to the surge chamber and out the tailrace to the river below the dam.

In this chapter on hydro-electric power development the fabrication and erection of the penstock, spiral case and draft tube are described, as well as the installation of the turbine. These are the aspects of dam construction of concern to the Boilermaker.

PENSTOCKS

The purpose of a penstock in a hydro-electric power development is to convey water from the reservoir to the spiral case and then to the waterwheel. Ge: ally, penstocks are made of steel; however, depending upon function or cost, may be constructed of wood and concrete instead.

Penstocks may be located above ground (Figure 13-5) or underground, and may be laid in a horizontal or a sloping position. Supports (saddles) in which penstocks may rest can be constructed either of steel or concrete; the penstock may be held down in these saddles by steel hold-down straps (Figure 13-6). On major hydro-electric power developments, the steel penstocks are totally encased in concrete and located underground

PENSTOCK CONSTRUCTION

Plate thickness and penstock diameter are two variables dictated by:

1. Length of the penstock to be constructed
2. Vertical height of the water between the inlet and the spiral case.

As penstocks are built to suit different locations, a number of methods are used to construct and erect them in the field. Steel penstocks are usually fabricated in the contractor's shop. As

Figure 13-5. Penstock

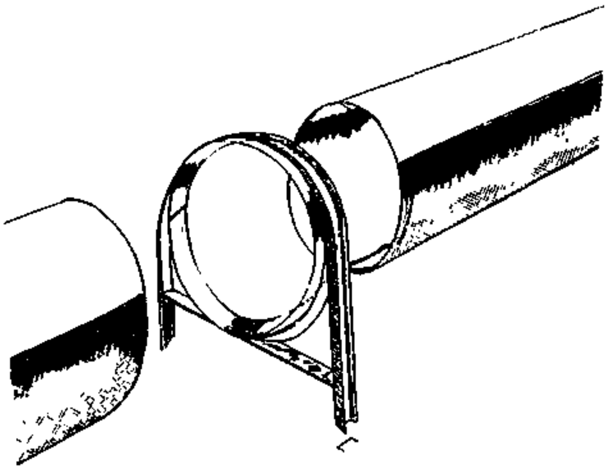


Figure 13-6. Penstock Hold Down

specifications and procedures may vary with the customer, the following sets out a specific method from fabrication in the shop to installation at the jobsite.

As steel is received at the contractor's yard from the steel mill, it is sorted into grades and thicknesses and batch numbers are recorded. Mill scale is removed from the plate by means of a wheelabrator (metal shot cleaning). The plate is then prepared for burning and painting. The plate is cut, "true and square," to the required size (based on mean dimensions) with the necessary edge preparations (bevels) for welding. The required number of plates are rolled to the specified radius and loaded for shipment to the field shop for pre-assembly of penstock cans.

In the field shop, the initial step is to place three rolled plates together in a circle and fit them together to the desired diameter of a penstock can. The fitting is accomplished by using key plates and bullpins (dogs and wedges) (Figure 13-7).

The welding on the prepared butt joints is done using the Submerged Arc Welding (S.A.W.) process. Individual cans are then joined together in pairs so as to form a section of penstock. The circumferential seams are also welded by the S.A.W. method. Stiffener rings are added to the sections to aid in maintaining roundness (Figure 13-8). After all welding on each section is completed, the welded joints are radiographed to ensure 100% competency.

As sections of the penstock are built in sequence, trunions (lifting lugs that permit the

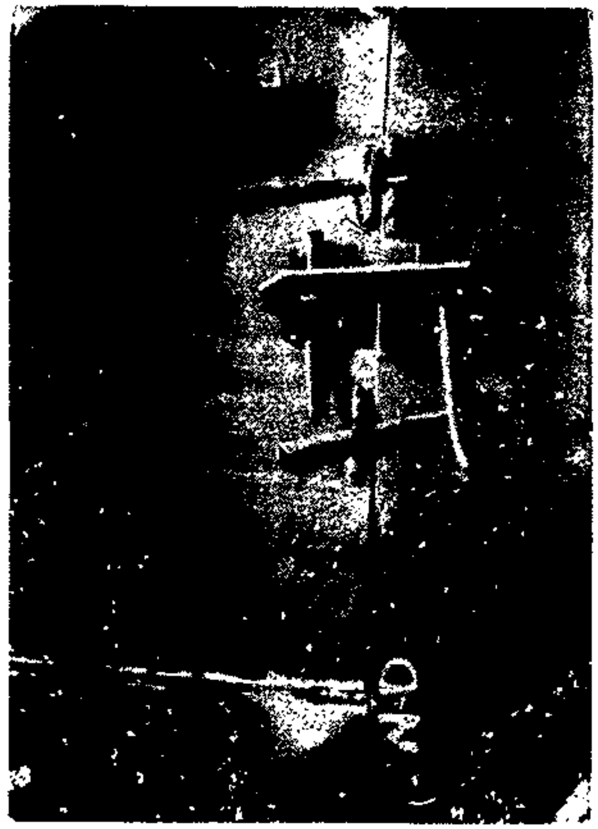


Figure 13-7. Fitting with Keyplates and Bullpins

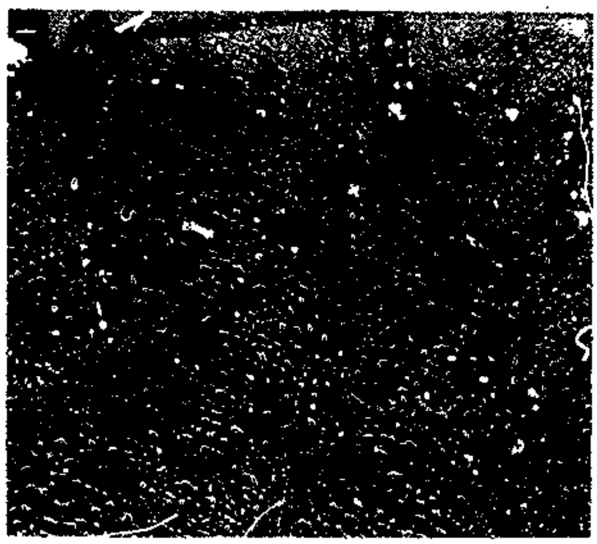


Figure 13-8. Penstock Section Ready for Transport Complete With Stiffener Rings and Trunions

can to rotate freely when suspended) are welded along the horizontal centre lines for lifting. (Note: In the illustrated rigging operation, the lifting or transporting device is a high line with a safe working load rated at 30 tons.)

The predetermined sequence of penstock sections are loaded onto a low-bed truck and transported to a location under the high line (Figure 13-9). The sections are picked off the truck by the high line and lowered to the preconstructed supports (Figure 13-10 and Figure 13-11). As succeeding sections are lowered into place, the adjoining circumferential seams are fitted and manually welded (Figure 13-12). Again the seams are X-rayed. As the penstock is built upward, it is systematically enveloped in concrete (Figure 13-13). A portion of the penstock at the outlet end is left free of concrete to facilitate connection to the coupling, connecting it to the spiral case.

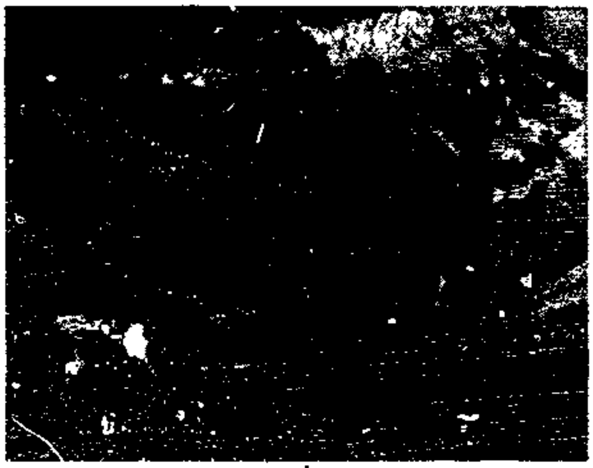


Figure 13-9. Penstock Section Being Transported

Figure 13-10. Penstock Section Being Lowered

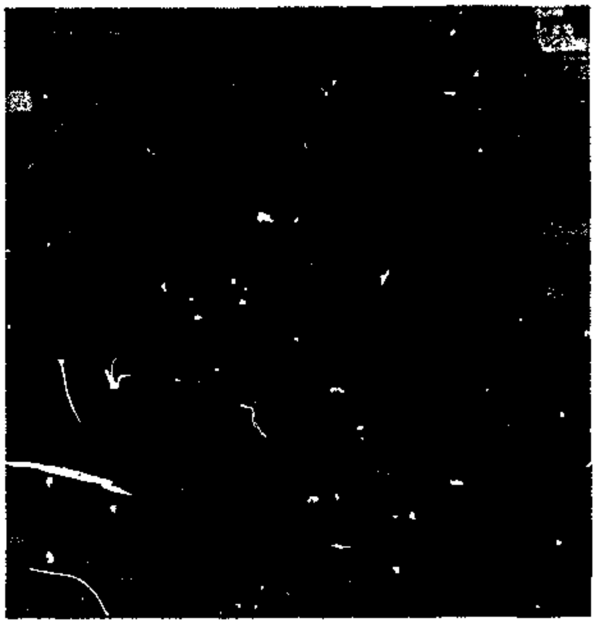


Figure 13-11. Lowered Penstock Section Being Manoeuvered Into Position

Figure 13-12. Welding on Fitted Butt Joint of Penstock Section

Figure 13-13. Penstock Encased in Concrete

Spiders

Spiders are used to hold a penstock "round" until it is completely welded in its final position. Penstock to be buried in concrete has the spiders left in place until the concrete has been poured and allowed to set (Figure 13-14). When permanent stiffener rings are installed on the outside of the penstock, spiders are unnecessary on the inside. Spiders may be constructed from a number of different structural shapes, such as pipe, angle or square tubing.

Tolerances

For installing penstock as described here, the out-of-round tolerance must be within 1/4" at the downstream end where the penstock joins the spiral case. Other areas of the penstock must be within 1" of the theoretical centre line with no "out-of-round" or "flat spots" exceeding 3/8". Misalignment of plates for welding cannot exceed 1/16". Figure 13-15 illustrates an elevation view of the penstock installation described above.

SPIRAL CASE

After completion of the penstock, the spiral case is ready to be installed at the outlet end of the penstock. The first step is installation of a draft tube liner directly below the centre line of the designated turbine location. Once in place, the draft tube is set to elevation and location and held in place by turnbuckles and anchors (Figure 13-16). The outside of the secured draft tube is completely encased in concrete

Placed directly on top of the draft tube liner is the discharge ring which acts as a connection between the draft tube liner and the stay ring. The stay ring usually consists of four pieces that form the inner core from which the spiral case is hung (Figure 13-17). Each quadrant of the stay ring can weigh as much as 80 tons. The stay ring is bolted and welded together. Between the top and bottom sections of the stay rings are stationary gates or vanes whose function is described in the turbine section.

Figure 13-14. Spiders Installed in Penstock Section

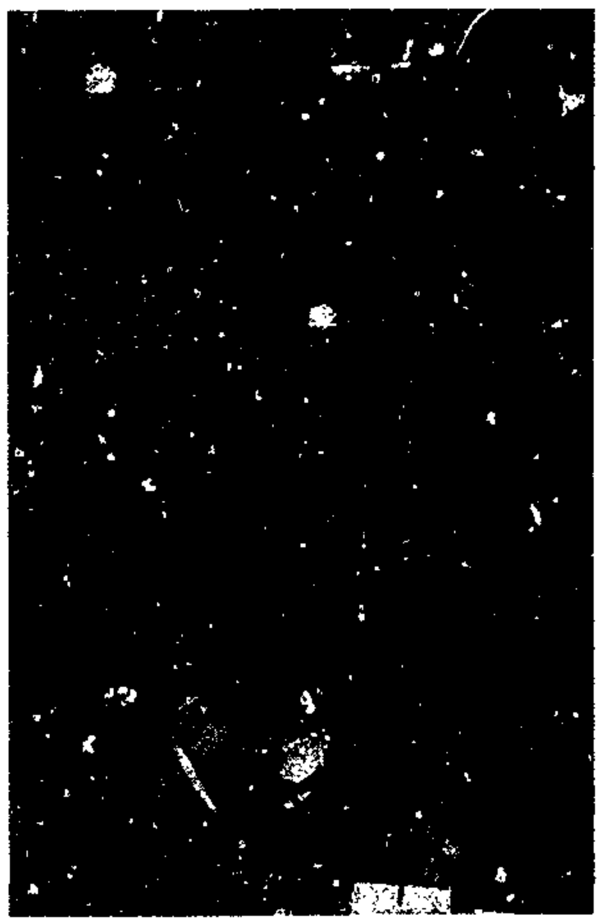


Figure 13-16. Fully Erected Draft Tube Ready for Concrete Pour

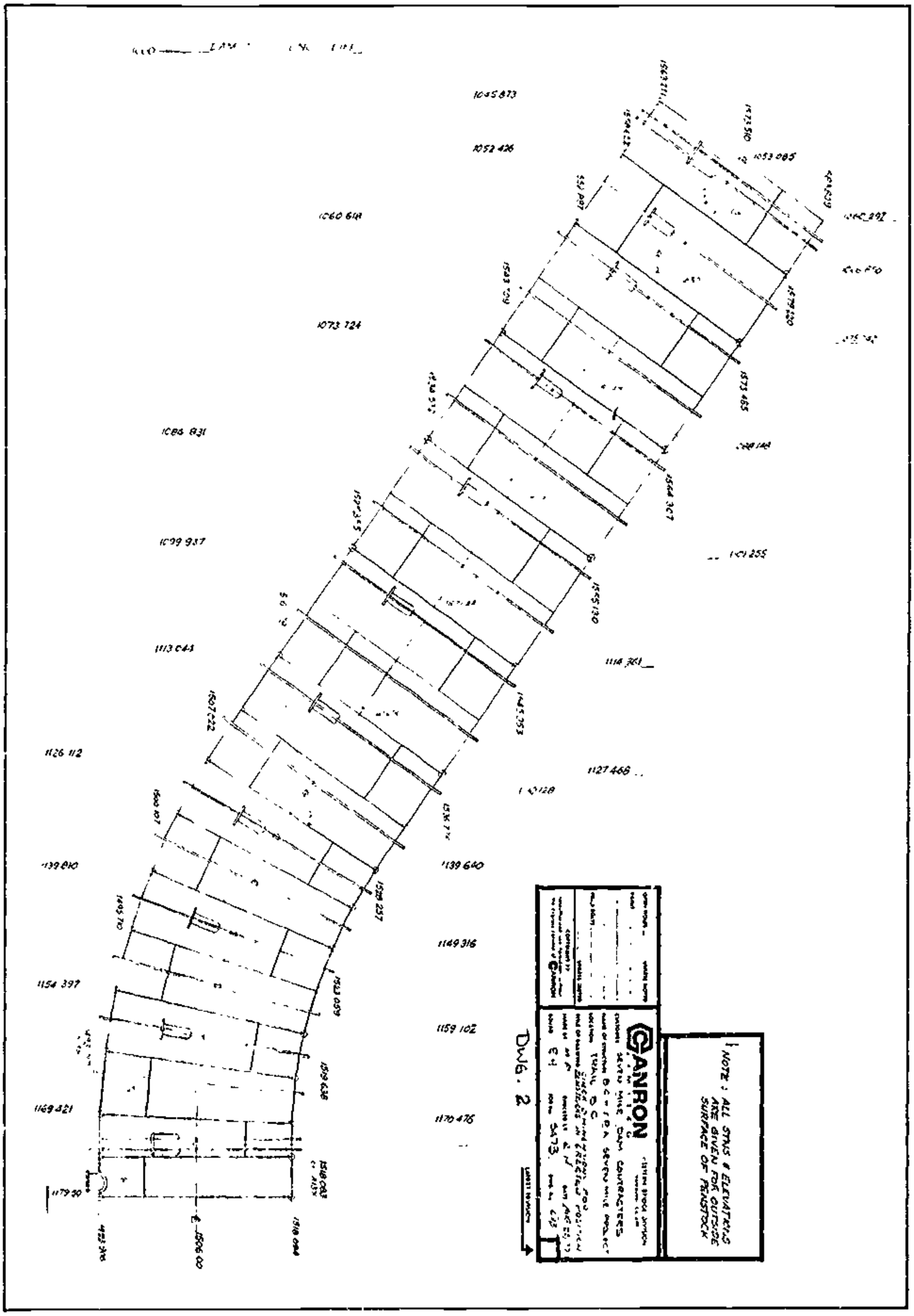


Figure 13-15. Elevation View of a Penstock

Figure 13-17. Stay Ring Fully Erected

The elevation and location of the draft tube liner, discharge ring and stay ring are critical because this assembly must be positioned directly underneath the turbine centre line. In addition, the positioning of this assembly determines the position of the spiral case whose inlet end must align with the completed outlet end of the penstock.

The spiral case is now ready to be hung off the stay ring. The spiral case is customarily shipped to the powerhouse site from the fabrication shop where it was test-fitted to confirm that the component parts will assemble (Figure 13-18 and Figure 13-19). The spiral case sections are hung off the stay ring and secured by tack welding and bolting (Figure 13-20 and 13-21). Spiral case support brackets are positioned and welded, the spiral case is also supported from underneath by screw jacks to maintain the required elevation; once attained, the spiral case is held in position by turnbuckles welded to the spiral case at one end and hooked through eyebolts in the deck (Figure 13-22). As the sections of the spiral case are being lowered into place, fitting is begun on

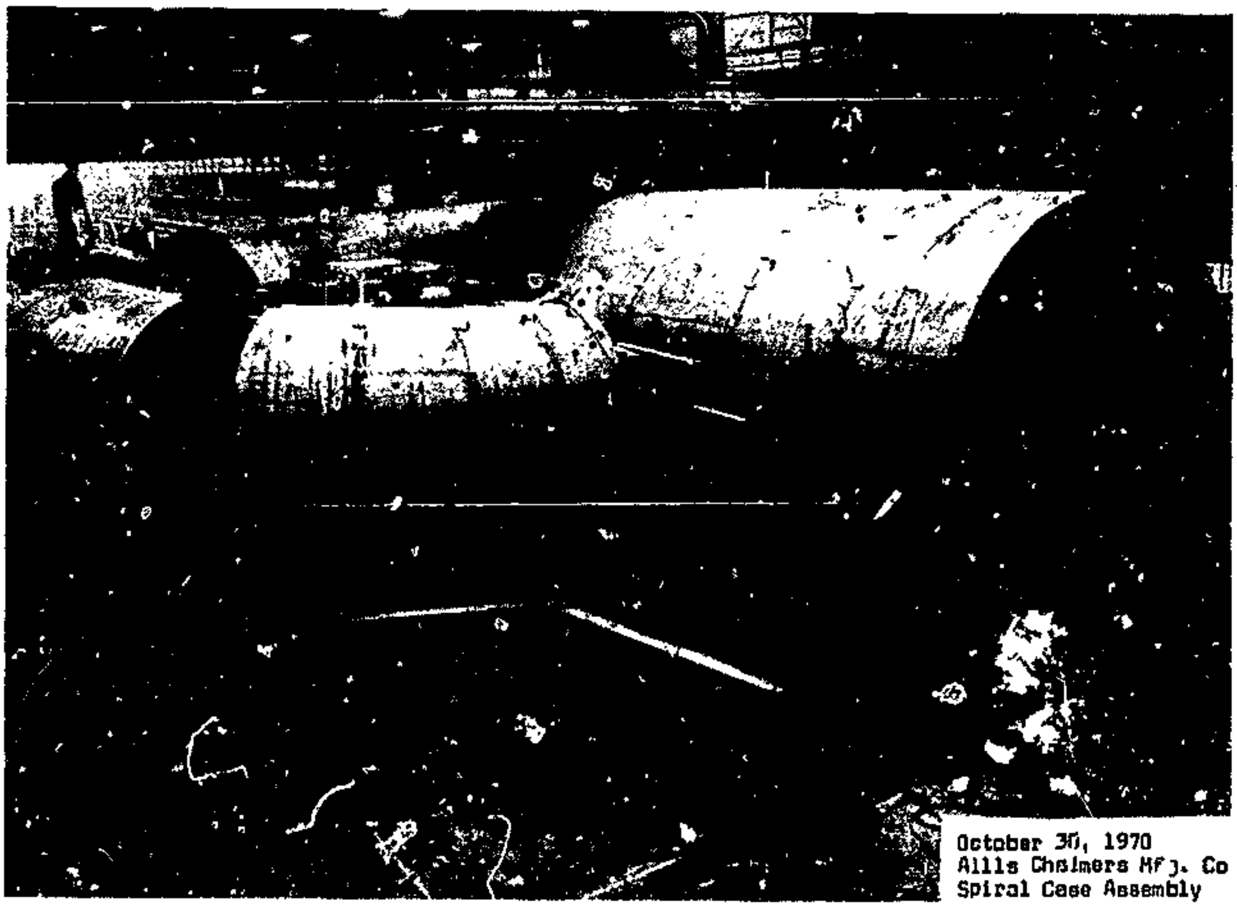


Figure 13-18. Spiral Case Fabrication

Figure 13-19. Spiral Case Test-Fitted to Stay Ring

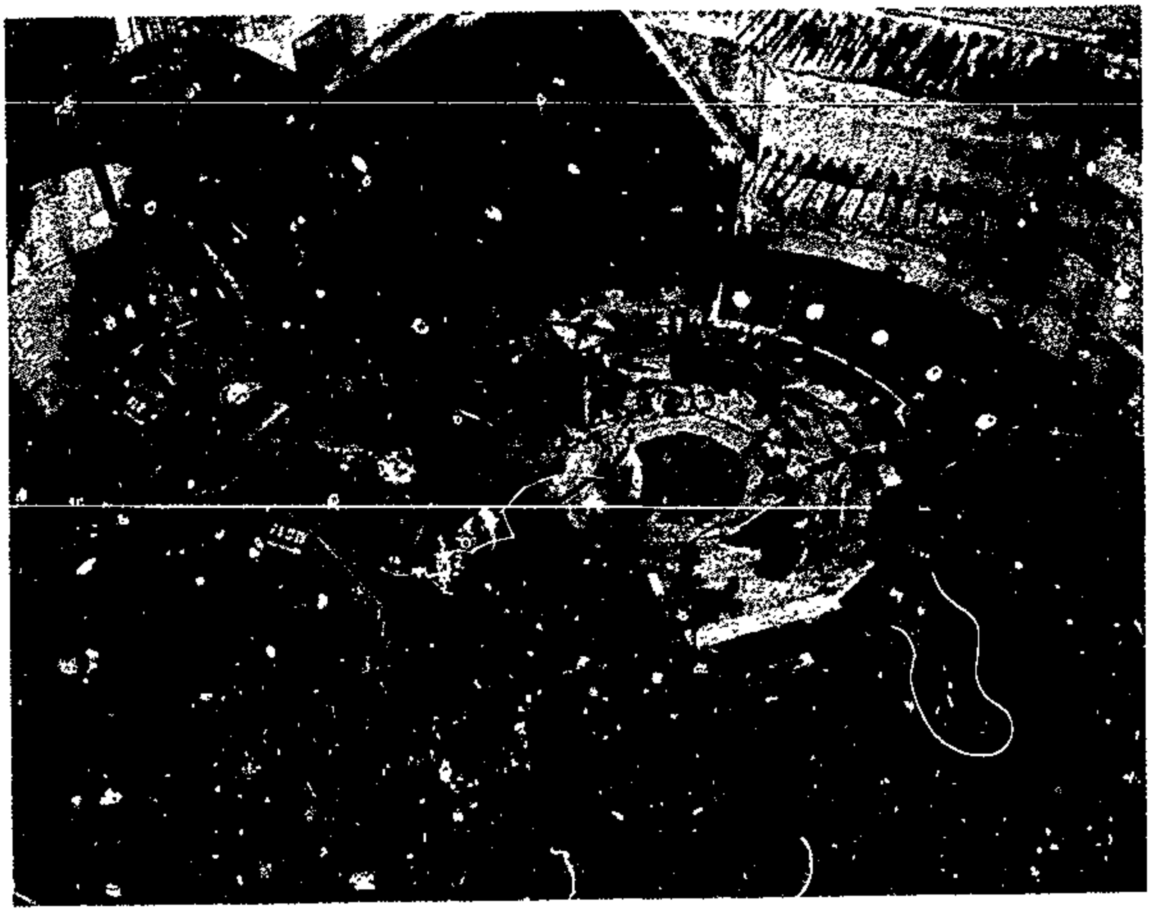


Figure 13-20. Erection of Spiral Case

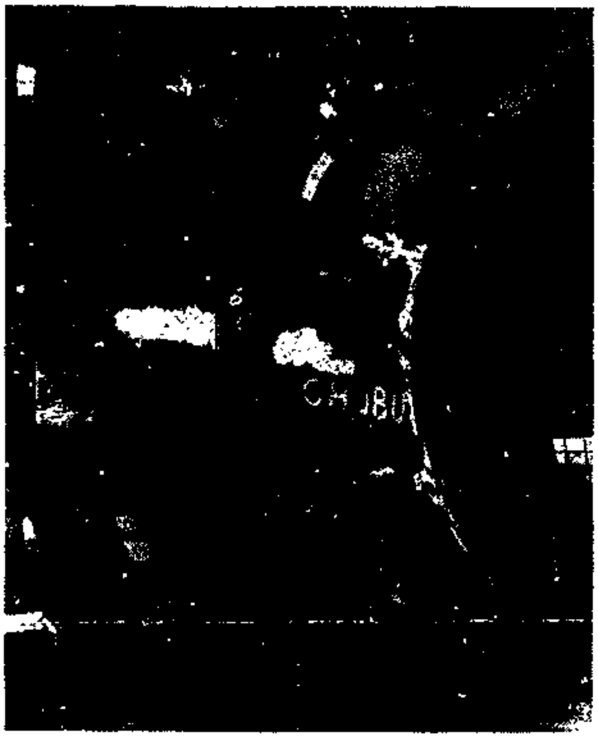


Figura 13-21. Fitting of Weirsection of Spiral Case

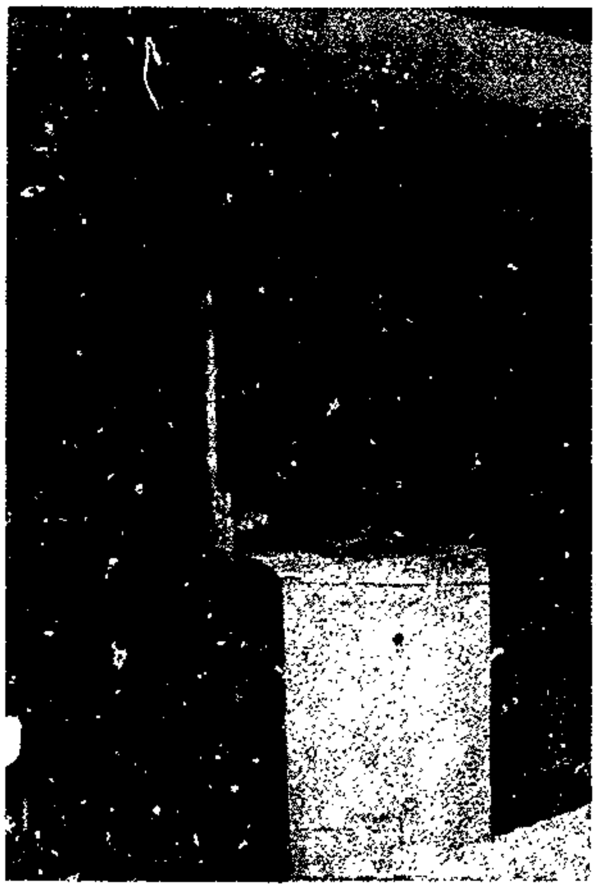


Figure 13-22. Spiral Case Supports: Screw Jacks and Turnbuckles

the longitudinal seams first followed by circumferential fitting. The fitting is accomplished by using dogs, wedges and hydraulic jacks (Figure 13-23).

Circumferential welding is done only after the longitudinal seams have been welded. Joint preparations on spiral casing are done specifically to ensure that the majority of the welding can be accomplished in the vertical, flat and horizontal positions. The only overhead welding required is for filling the back-gouged root weld. All welds except the first and last pass must be back-stepped and peened to provide a mechanical stress relief.

When all the spiral case welds are completed, the spiral case assembly is permanently affixed to the stay ring by welding. All welded seams on the spiral case are X-rayed. In addition to the X-ray testing of the welds, a hydrostatic test of the unit is done. A test head is welded to the inlet end of the spiral case, and a test ring is installed to "blank off" the stay ring from the spiral case. The spiral case unit is subjected to a controlled hydrostatic test.

Following a successful test, the test head and test ring are removed, and the spiral case and stay ring are checked for final alignment. All

Figure 13-23. Fitting the Spiral Case

turnbuckles anchors and jacks are secured: the entire spiral case is then encased in concrete except for approximately 3 at the inlet end This is left exposed to permit connection to the outlet end of the penstock by a coupling assembly The coupling is used as a transition or connecting channel between the outlet of the penstock and the inlet of the spiral case The coupling unit has a variable length to accommodate the actual distance between the two openings

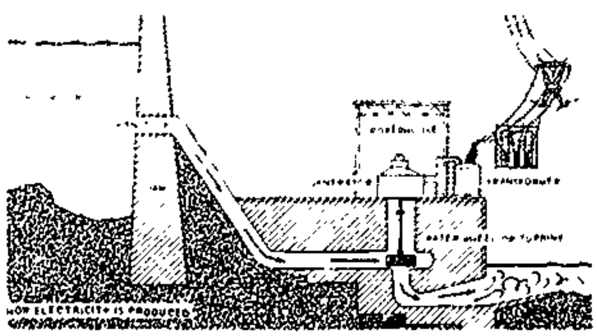
TURBINE ASSEMBLY

The turbine assembly represents the electricity-producing component of a hydro-electric power installation. it is the mechanism that actually converts moving water into electrical current

The principle of electricity generation is based on this sequence.

1 Water moving under pressure (gravity) turns a wheel
2 The wheel turns a shaft.
3 A powerful electromagnet (rotor) housed near the top of the shaft is activated by the spinning shaft.
4 Conductors housed within the stator cut the magnetic field of the rotor and pick up the electrical current so formed.

The electricity flows through the conductors to the transformers. along transmission lines to substations. then to the consumer via local distribution lines (Figure 13-24).



The cut away drawing shows in elementary form how electricity is produced In this case hydro power is supplying the energy to turn the turbines

Figure 13-24. Schematic Drawing of Hydro-Electric Power Generating Project

ERECTING THE TURBINE

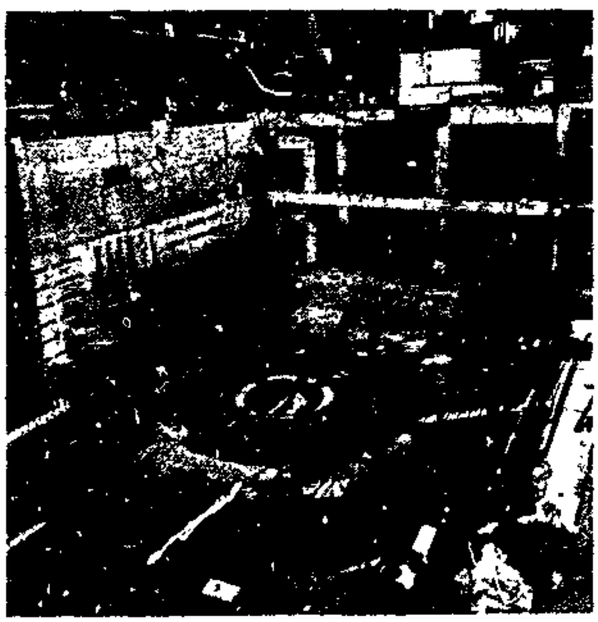
When the spiral case has been erected to the final stages and tested, erection of the turbine can begin Various other tradesmen such as electricians. pipefitters. ironworkers. carpenters and labourers have specific roles in installing components and connecting various electrical and mechanical systems required to render the unit operational.

The turbine installation generally follows a sequence similar to that described below For each component. the procedure involves test-fitting and aligning before final installation. Two overhead cranes are provided in the powerhouse for handling the turbine and generator components. Figure 13-25 illustrates a section of a typical generator and turbine unit. depicting the spatial relationships between the components.

1. **Installation of Turbine Pit Liner**

   Figure 13-26 shows the spiral case before the turbine pit liner is installed

   Figure 13-27 shows the turbine pit liner in place. The spiral case and lower portion of the turbine pit liner may now be encased in concrete. Although the spiral case is totally encased in concrete. access to it and the draft tube liner for maintenance is provided by corridors in the concrete leading to man-way doors.



Note Turbine Headcover Temporarily Located in Centre of Unit

Figure 13-26. Spiral Case Nearing Completion

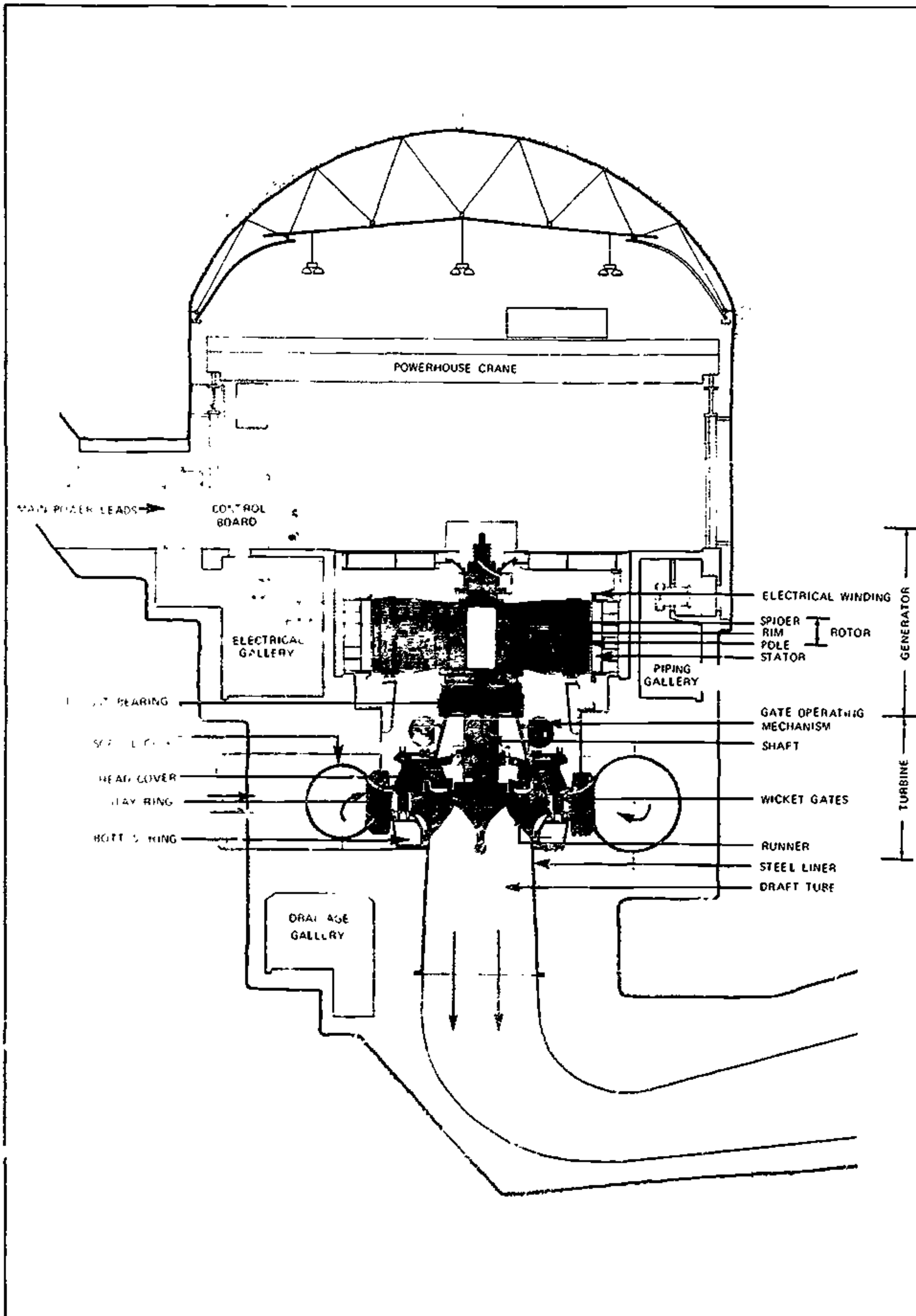


Figure 13-25. Section of a Typical Generator and Turbine Unit

Figure 13-27. Turbine Pit Liner Installed

2. **Installation and Alignment of Discharge Ring and Gate Ring**

   The discharge ring is positioned on top of the draft tube liner and welded into place. The gate ring is then set on top of the discharge ring and bolted in position. The gate ring is the structure into which the bottom ends of the wicket gates are fitted.

3. **Fitting of Wicket Gates**

   The wicket gates are test-fitted into the gate ring. Once fitted and aligned, they may be left in position ready to receive the headcover (Figure 13-28), or they may be fitted into the headcover and installed as a composite unit.

4. **Installation of Runner and Shaft Assembly**

   The runner, runner cone and shaft are fitted, aligned and installed as a unit. Figure 13-29 shows the assembly ready to be lowered into the turbine pit. Figure 13-30 shows the assembly in the final stages of installation.

5. **Installation of Headcover**

   The headcover is lowered over the shaft, eased onto the gates, set on and bolted to the inside circumference of the spiral case stay ring. Figure 13-31 shows an instance in which the wicket gates were pre-fitted to the headcover and the assembly installed as a unit.

6. **Installation of Wicket Gate Servo-Motors**

   The function of the servo-motors is to open or close the wicket gates against the flow of water to the turbine. Figure 13-32 shows the servo-motors located in recesses in the turbine pit.

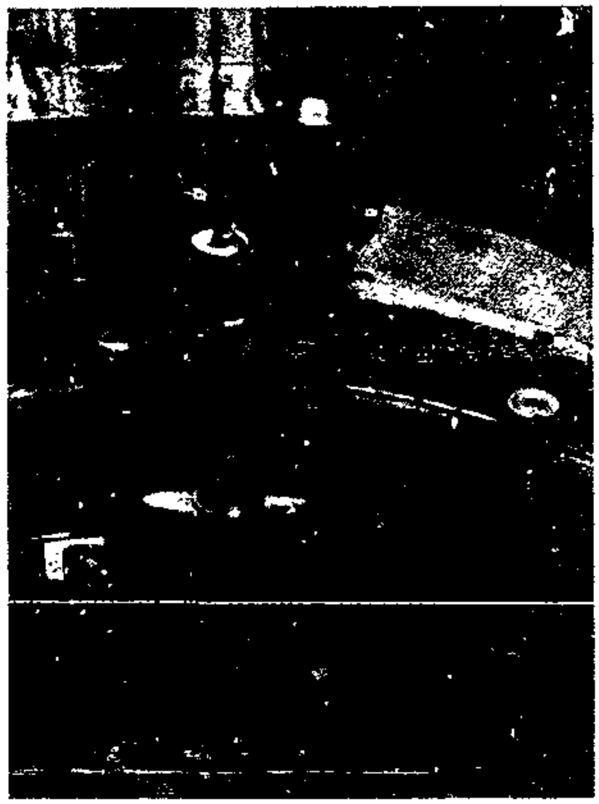


Figure 13-28. Installation of Wicket Gates Into Gate Ring

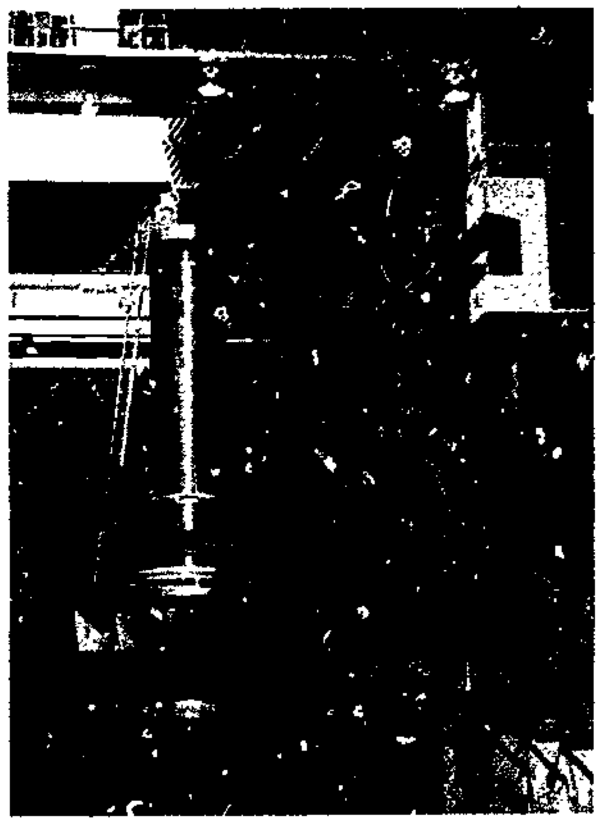


Figure 13-29. Shaft and [illegible] Assembl[illegible] About to be Low[illegible] Into Po[illegible]tion

Figure 13-30. Shaft and Runner Assembly Being Positioned

7. **Installation of Stator**

The stator is positioned on top of the turbine pit. Figure 13-33 shows the stator being moved toward its final position.

8. **Installation of Rotor**

Figure 13-34 shows the rotor being assembled Figure 13-35 depicts the final positioning of the rotor, bolted on top of the shaft, within the stator. Mechanical testing for balance, performance, running temperatures and speeds are monitored closely, and any necessary adjustments are made. Electrical testing of the generator is the last step before power can be transported.

9. **Final Enclosure of Turbine Unit**

After all components have been installed and the turbine tested successfully as a unit, enclosure operations begin. Figure 13-36 shows structural support members in place before installation of final decking as illustrated in Figure 13-37.

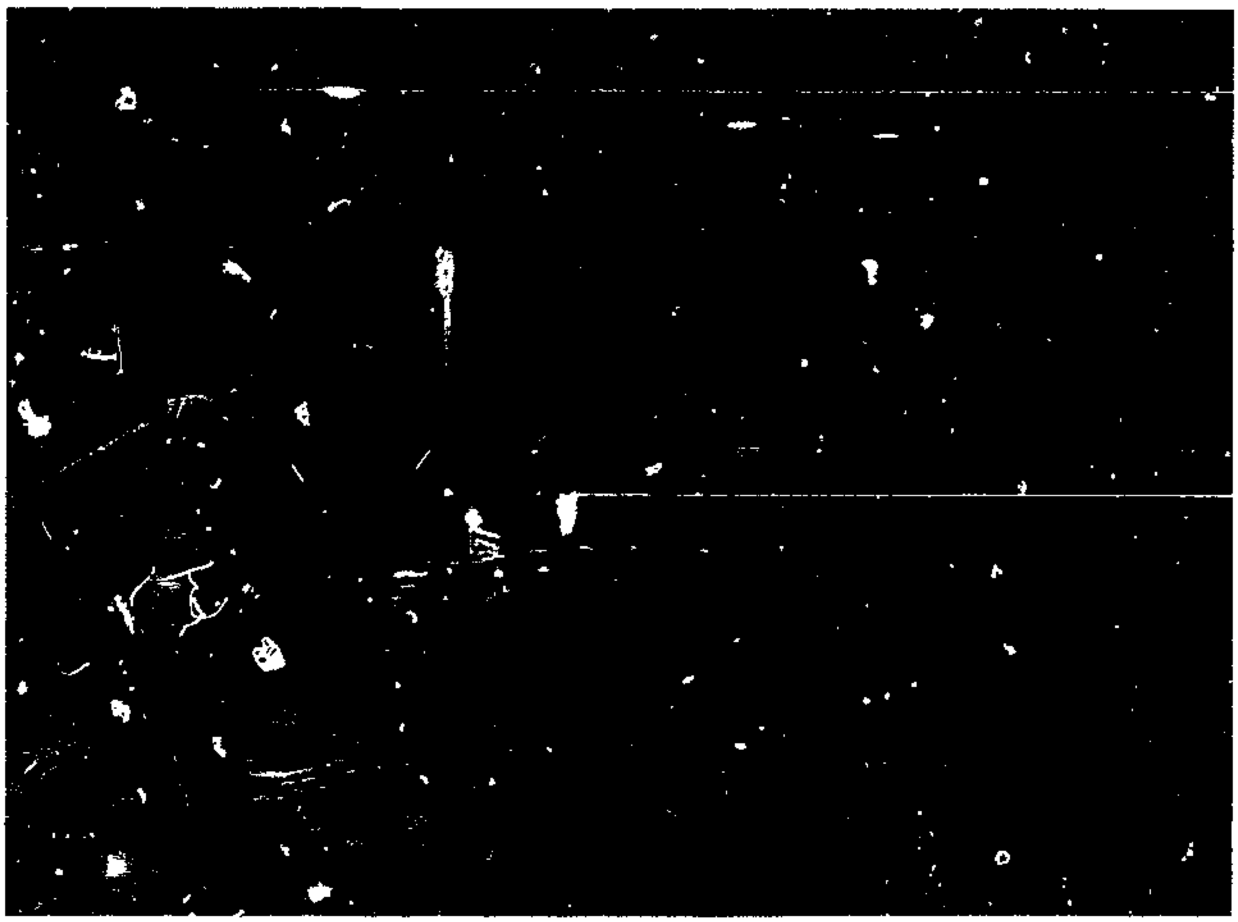


Figure 13-31. Headcover With Wicket Gates and Gate Levers Ready for Positioning

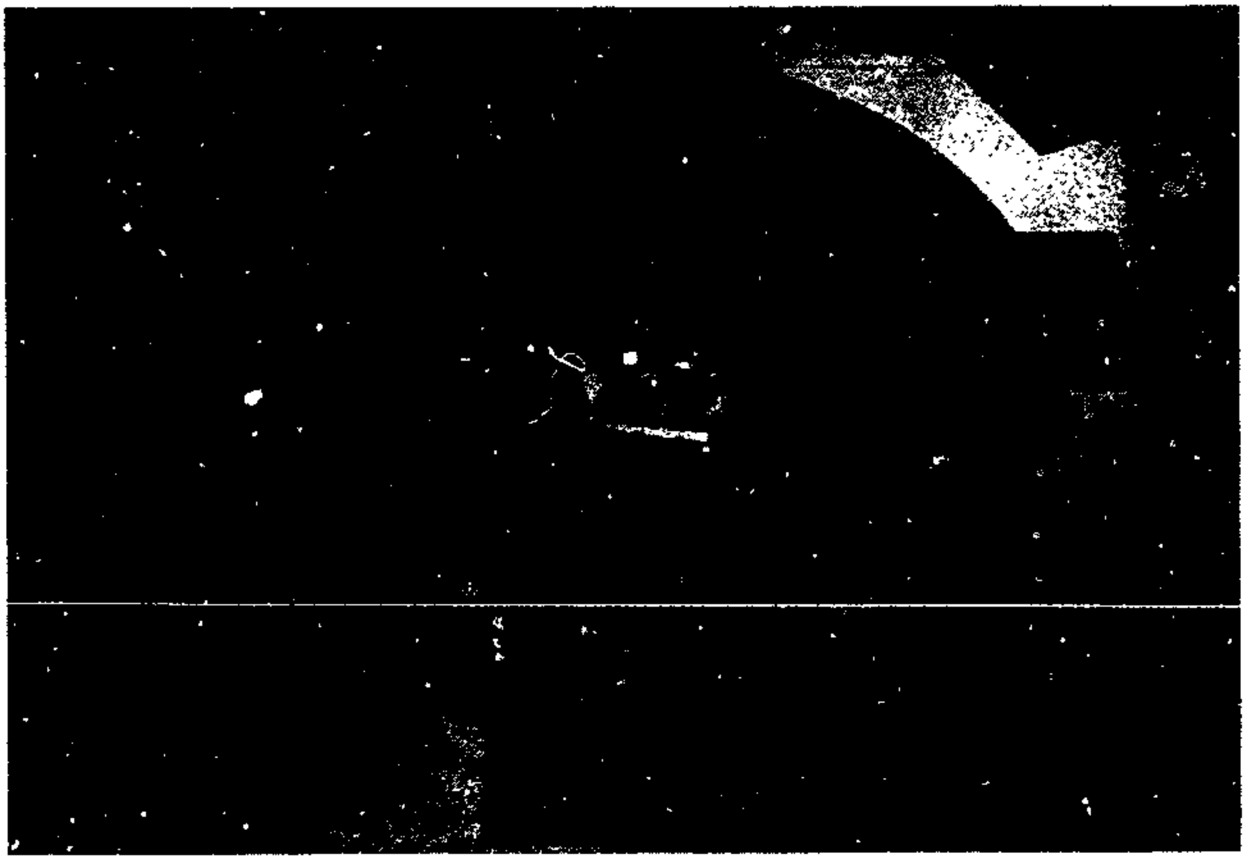


Figure 13-32. Servo-Motors Placed in Concrete Recesses Ready for Alignment

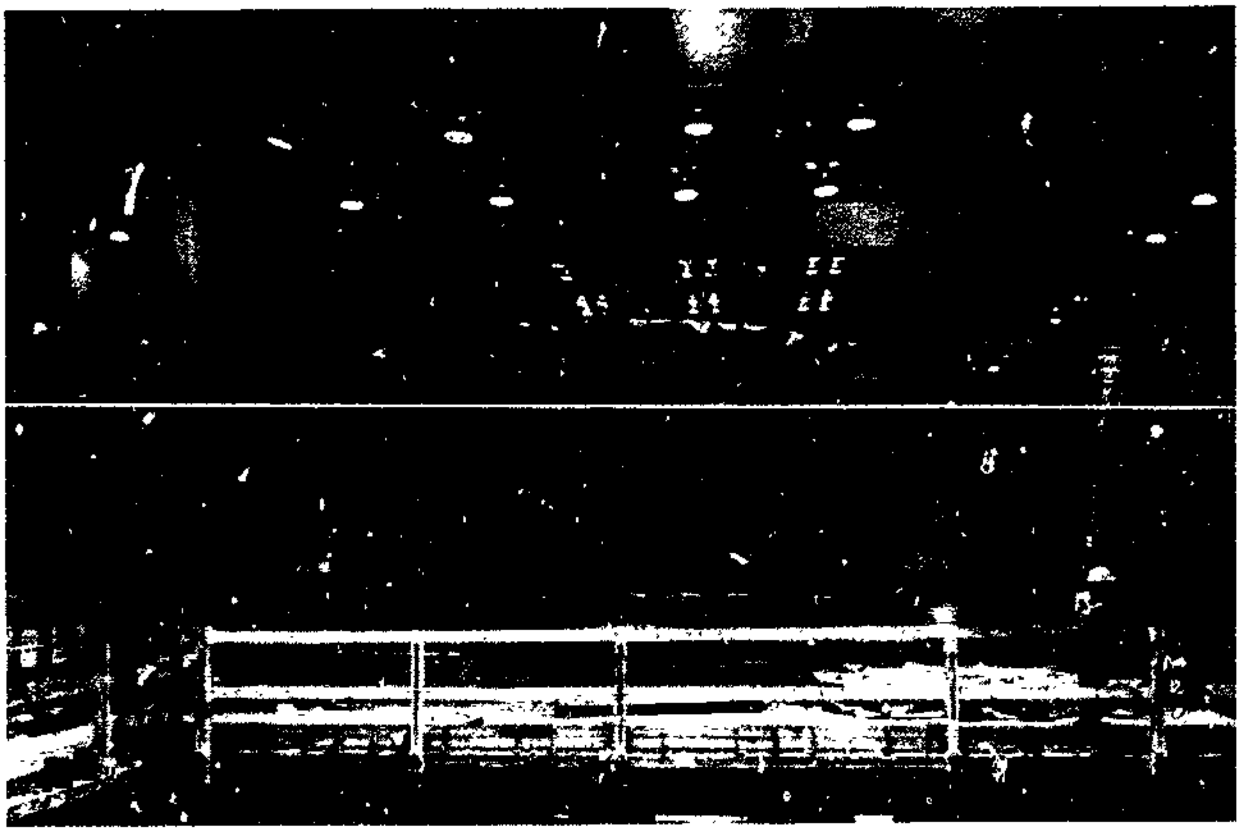


Figure 13-33. Stator Assembly in Transit to Generator Location

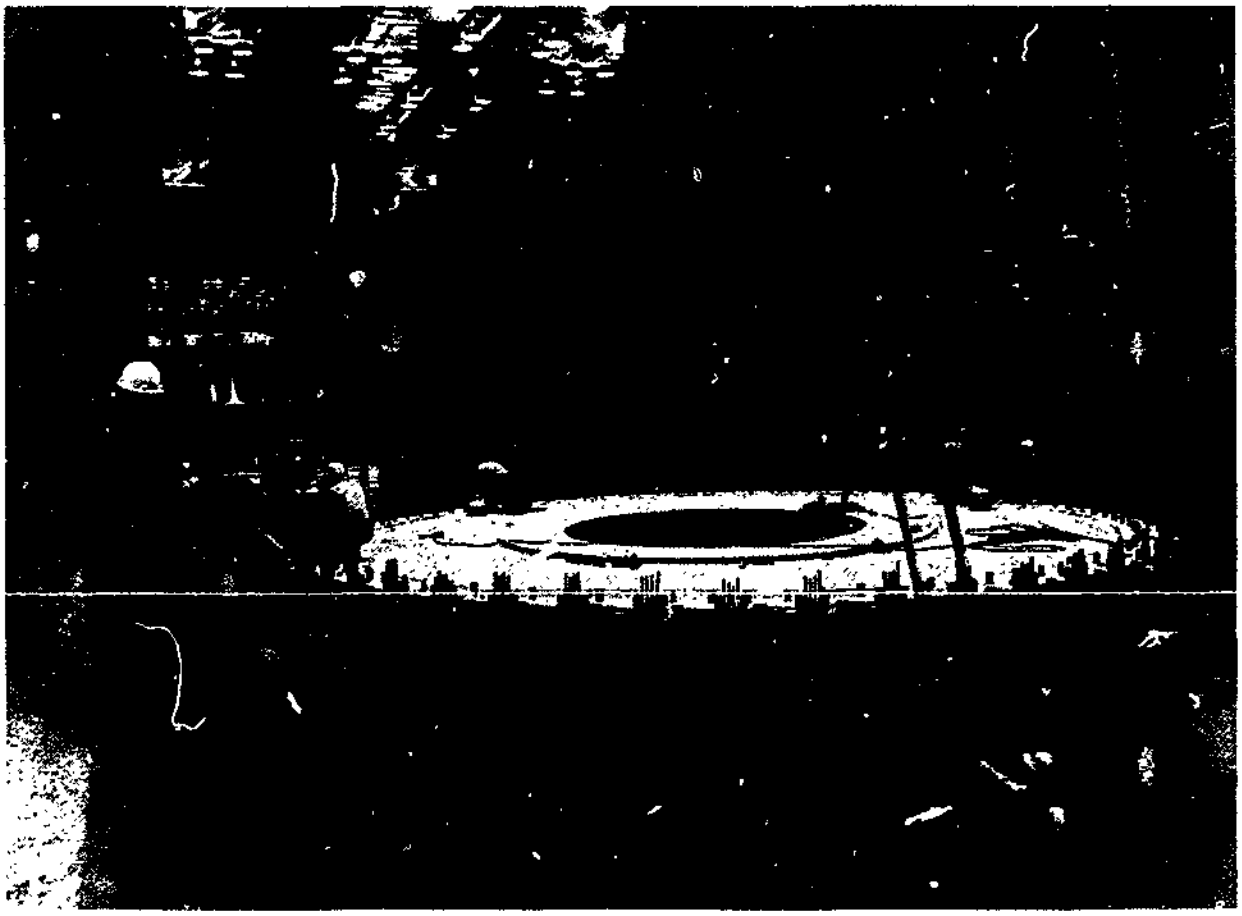


Figure 13-34. Rotor Assembly in Final Stages of Preparation

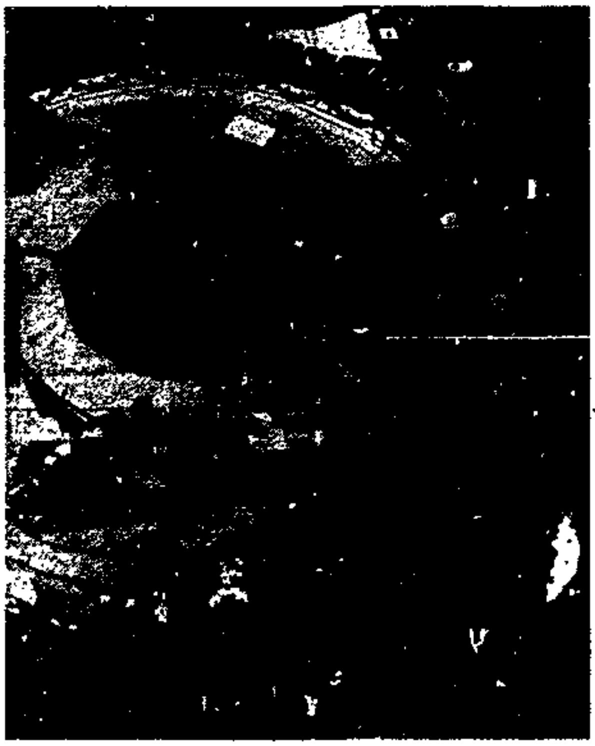


Figure 13-35. Rotor in Position Within Stator

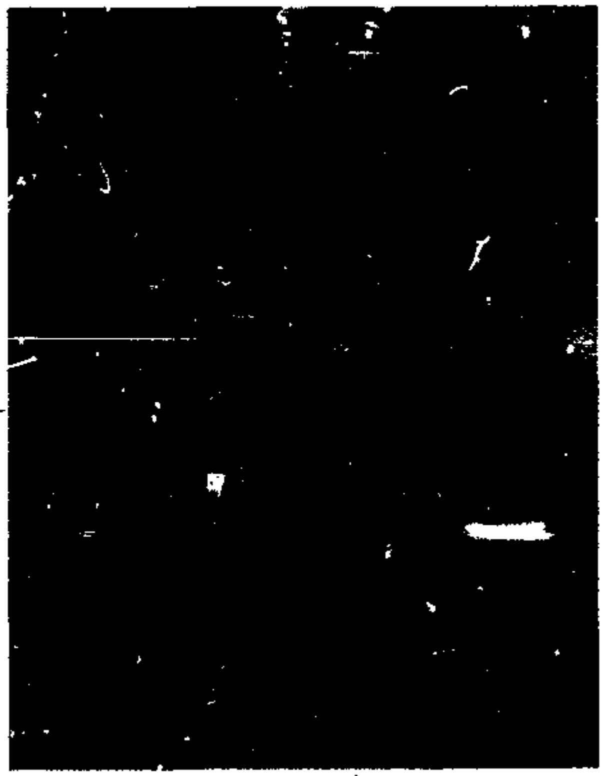


Figure 13-36. Structural Supports Erected

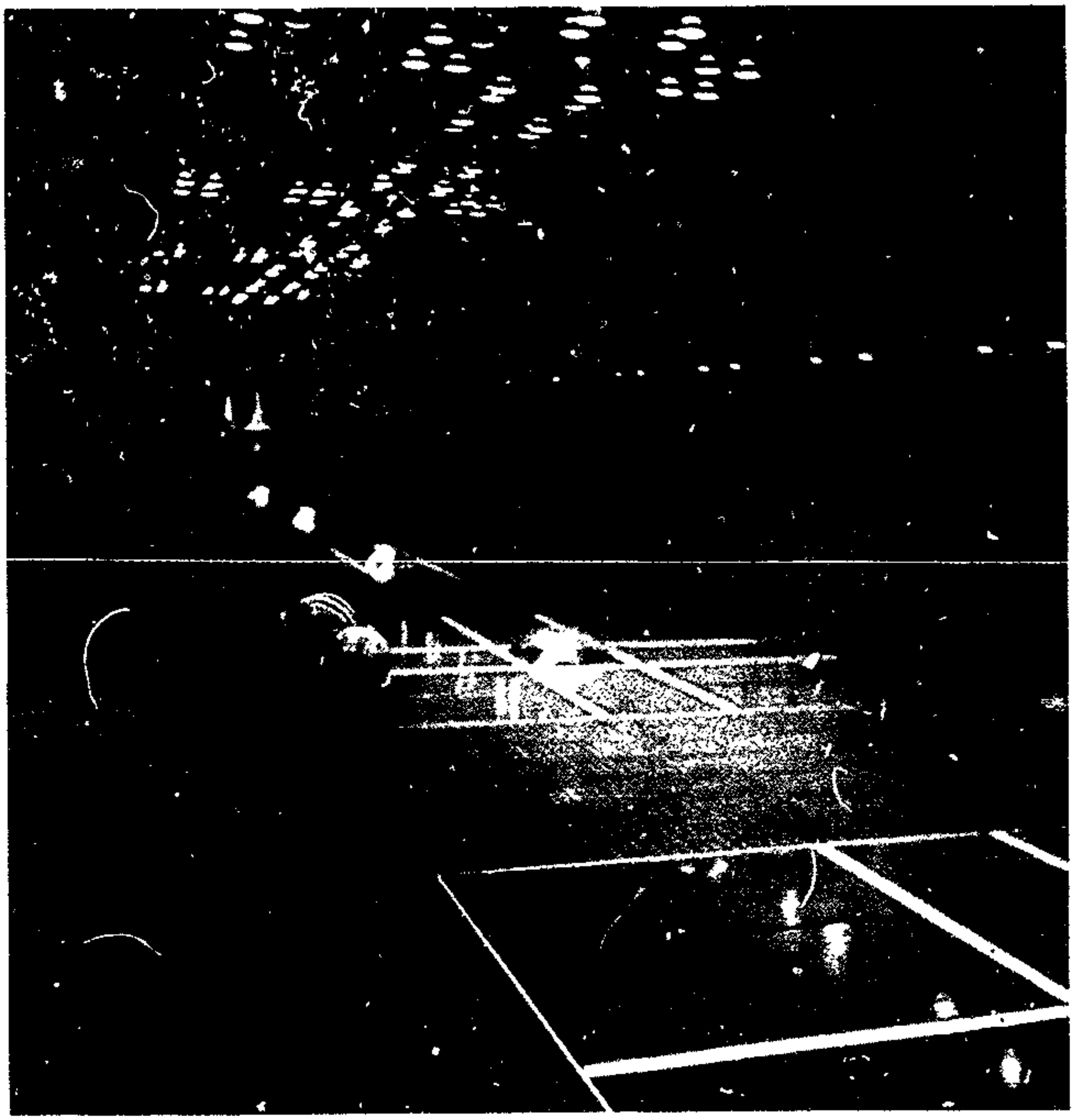


Figure 13-37. Turbine and Generator Assemblies Completed