

8-1. GENERAL.—The operations of welding, brazing, and soldering have been developed to such a state that they are widely used throughout industry. The methods available and the applications possible have increased until it is impossible for this section to cover the subject to great depth. It is intended only to summarize the operations and give information in a few special areas such as joints in waveguides, bus bars, and wiring. In addition, a small section on safe practices has been included, since hazards are always present in this type of work.

a. **SAFETY.**—Due to the personal dangers inherent in welding and brazing, and to a lesser extent, soldering, it is important that safety be stressed. Personnel must be aware of the dangers from fire, fumes, electrical hazards, and defective equipment.

(1) **DANGERS.**—Welding and brazing should not be done where flammable dust, vapors, liquids, or lint are exposed to a flame or an arc. Sparks should be shielded by the use of shields or curtains where possible. Suitable fire extinguishing equipment should be readily available. Dangerous fumes, both from metals and from the chemicals used for welding, should be properly exhausted from work areas. Where these fumes are allowed to collect there is always a danger of suffocation, asphyxiation, or respiratory contamination. Filter masks should always be used where needed and the proper ventilation should be supplied. The direct current and alternating current found where arc and resistance welding are done are constant dangers to the user. The first safety requirement for electrical welding is a good ground for the equipment. This is in addition to the work lead or welding ground. Water, either as puddles or in containers, should never be left in an area where electric welding is done. Welding leads should be secured and out of the way of traffic.

(2) **PERSONAL PROTECTION.**—It is essential that head or face shields be used to protect an operators face and eyes from spatter, sparks, and from the direct rays of arcs. The shield should be comfortable. Lenses should be of the correct shade. Although permanent damage will not result from looking at an arc, a temporary eyeburn and extreme pain can result. An apron of some fire resisting material will furnish excellent body protection. Gauntlet type gloves are sufficient for hand protection. Trouser cuffs should be turned down and should be well below the tops of the shoes, as a drop of molten metal inside the shoe can be an extremely uncomfortable thing.

(3) **EQUIPMENT HANDLING.**—The careful and regular inspection of welding equipment is a worthwhile effort. Leakage in lines, regulators, and other fittings should be repaired before using the equipment. Never grease valves and fittings. Don't attempt to tape leaking lines. Don't attempt to test for leaks with a flame; effective testing can be done with a grease-free soap and water. Handle oxygen and acetylene tanks carefully. Always have a place to secure your torch or electrode holder when it is not being used. Use a friction lighter to ignite the torch; don't use matches. Maintenance work on electric welding equipment, both arc and resistance, should be done only by qualified personnel.

b. **WELDER QUALIFICATIONS.**—Welding shall be performed only by welders or welder operators who have met the requirements of standard MIL-STD-248 for the particular group of materials and types of welding involved.

c. **PREPARATION OF PARTS.**—Any grooves, vees, or scarves should be cut or ground before cleaning. The mating surfaces and adjacent areas of all parts to be joined should then be thoroughly cleaned. It is important to remove all oil, grease, paint, dirt, scale or foreign substances that might prevent a good joint. Parts to be joined should then be securely held in position by jigs, clamps, or other supports.

d. **POST HEAT TREATMENT.**—Post heat treatment of welds may be desirable for relieving stress, maintaining dimensional stability, or improving the physical characteristics of the base or weld metal. It may be done in the following ways:

(1) Heating the complete welded structure as a unit.

(2) Heating a section containing the parts to be treated before attachment to other parts of the structure.

(3) Locally heating the weld and adjacent areas of the base metal uniformly in a local stress-relieving furnace. Control of the temperature should be by thermocouples attached to the anticipated hottest and coolest points on the weldment. Heavy sections of weldments may be subject to formation of high stresses if they are heated or cooled too rapidly. MIL-STD-278 (SHIPS) lists maximum rates of heating and cooling (see table 1-1). Good judgement must be exercised in heat treatment due to the difference in the way the various metals will react under heat. All heat treatment must be in accordance with MIL-STD-278.

e. **INSPECTION OF FINISHED JOINTS.**—Once a weld or braze joint is made, the soundness, quality and efficiency of it can only be controlled through inspection. Visual inspection is the most common method employed. Where the work requires more critical inspection, there are mechanical, electrical, and chemical methods available to the inspectors. Usually the methods used will depend upon the service requirements of the work. In production work destructive testing may be used. On the other hand, inspection of such items as pipelines, pressure hulls, or bridge construction will only permit non-destructive testing. Destructive testing may involve selection of samples and subjecting them to mechanical stress chemical tests, or temperature extremes. Non-destructive tests may include visual inspection, chemical analysis, magnetic particle testing, chemical penetrant inspection, radiography, and ultrasonic testing.

(1) **DESTRUCTIVE TESTING.**—In destructive testing a sample may be cut to standard dimensions and subjected to bend, tension, shear, and other mechanical stresses. It may be polished and etched to study the grain structure and weld penetration, or it may be chemically analyzed to determine the composition of the material.

(2) **NON-DESTRUCTIVE TESTING.**—Visual inspection may reveal flaws, such as cracks, porosity, undercutting, and unfilled craters. It can also confirm dimensional accuracy, conformance to specification requirements, and suitable weld appearance. Chemical analysis may reveal corrosive tendencies of the weld or base metal. Radiography is an inspection used to reveal internal discontinuities by passing rays through the material, where they are registered on a film. Study of the film will give a good idea of the soundness of the weld, particularly when exposure is made from several different angles. Ultrasonic testing employs an electrically timed sound wave which is propagated through the metal and reflected to indicate any void or discontinuity. With this method, the ability to interpret the results as read on a cathode ray tube is of greatest importance. Dye penetrant inspection and magnetic particle inspection are described in section 8-5, Submarine Pressure Hull Welding.

f. **CLEANING FINISHED JOINTS.**—Upon completion of welding or brazing, the joint should be thoroughly cleaned of any remaining flux. The major portion of the flux should be removed by mechanical means, such as a rotary wire brush. When a brush is used, if possible, the wire composition should be similar to the composition of the metal being welded. The remainder of the flux can be removed by brushing with hot water, then flushing with cold water. Failure to clean thoroughly may result in corrosion and extensive damage to the work.

TABLE 1-1. MAXIMUM RATE OF TEMPERATURE CHANGE

MAXIMUM THICKNESS OF SECTION (Inches)	MAXIMUM RATE OF RAISING AND LOWERING TEMPERATURE (°F/Hr.)
1	200
2	150
3	100
4	80
5	60
6 and up	50

8-2. SOFT SOLDERING.—Soft soldering is a process used for joining parts, in which a low-temperature-melting alloy is brought to the fusion temperature, usually below 700°F, and allowed to cool, forming a bond between the parts being joined. The reliability of equipment in which soft soldering is used can depend to an appreciable degree on the quality of the soldered joints, particularly where moisture or vibration is present.

a. **GENERAL.**—The selection of soldering equipment, such as a source of heat, the type of solder and flux, and the technique used in actually soldering the joint, in the end determine whether the joint will give satisfactory service or will fail.

b. **SOLDERING EQUIPMENT.**

(1) **SOLDERING IRONS.**—The three most common types of approved soldering irons (Interim Federal Specification W-S-00570-1) are as follows:

(a) **TYPE I.**—Type I is the standard plug tip type, and shall have a maximum tip temperature of 850°F. The type I iron shall conform to table 2-1 and shall be similar to figure 2-1.

TABLE 2-1. STANDARD PLUG TIP SOLDERING IRON

DIAMETER (Inch) A +2 Percent	LENGTH EXTENDING FROM SHELL (Inch) B (Min)	HEATING TIME (Minutes) (Max)
1/4	1-1/4	2-1/2
3/8	2	4
1/2	2	4-1/2
5/8	2-1/4	5
7/8	2-1/4	6

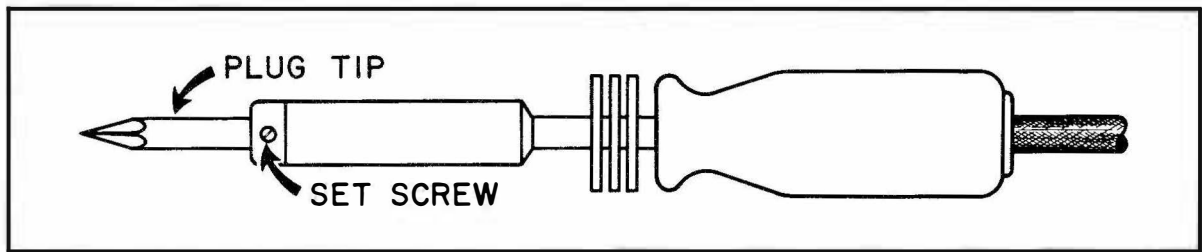


Figure 2-1. Type I Soldering Iron Assembly.

(b) **TYPE II.**—This type has a temperature controlled screw tip with a thermostatic characteristic which shall maintain a tip temperature between 700°F and 850°F. The overall length of the iron is 13 inches and the heating time is two minutes. The interchangeable screw tips and the iron are shown in figure 2-2.

(c) **TYPE III.**—The type III irons are of 2 styles and are both "pencil" irons.

1. **STYLE "A".**—This style conforms to the dimensions shown in table 2-2 and is similar to the one shown in figure 2-3a.

2. **STYLE "B".**—This style "B" iron is designed so that the handle is provided with a screw socket for use with interchangeable tips and heating units. The soldering iron has a maximum weight of six ounces and is similar to figure 2-3b. The tips are available in 1/8, 1/4, 5/16, and 3/8 inch diameters. The tip length extending from the heating unit is 7/8 inch. This style is shown in figure 2-3b.

(d) **SELF-HEATING SOLDERING IRON.**—This soldering iron (GGG-S-600) is a self heating iron which incorporates a single-shot cartridge unit loaded with a chemical thermal charge (see figure 2-4). It has no external connections and is useful where electric power is not available or convenient, or where use of a blowtorch or other flame would be hazardous. Included as a part of the unit is one wire brush and one each of the 3/8 inch pyramid and chisel-type tips. Figure 2-4 lists the sizes available for each size tip. The thermal charge is inserted into the body and the tip is screwed on. A firing pin or actuating rod sets off the charge (non-explosive) to begin the heat cycle. The iron has the capability of obtaining a temperature of at least 350°F in 30 seconds, and holding that temperature for 6 minutes when the surrounding temperature is 75°F.

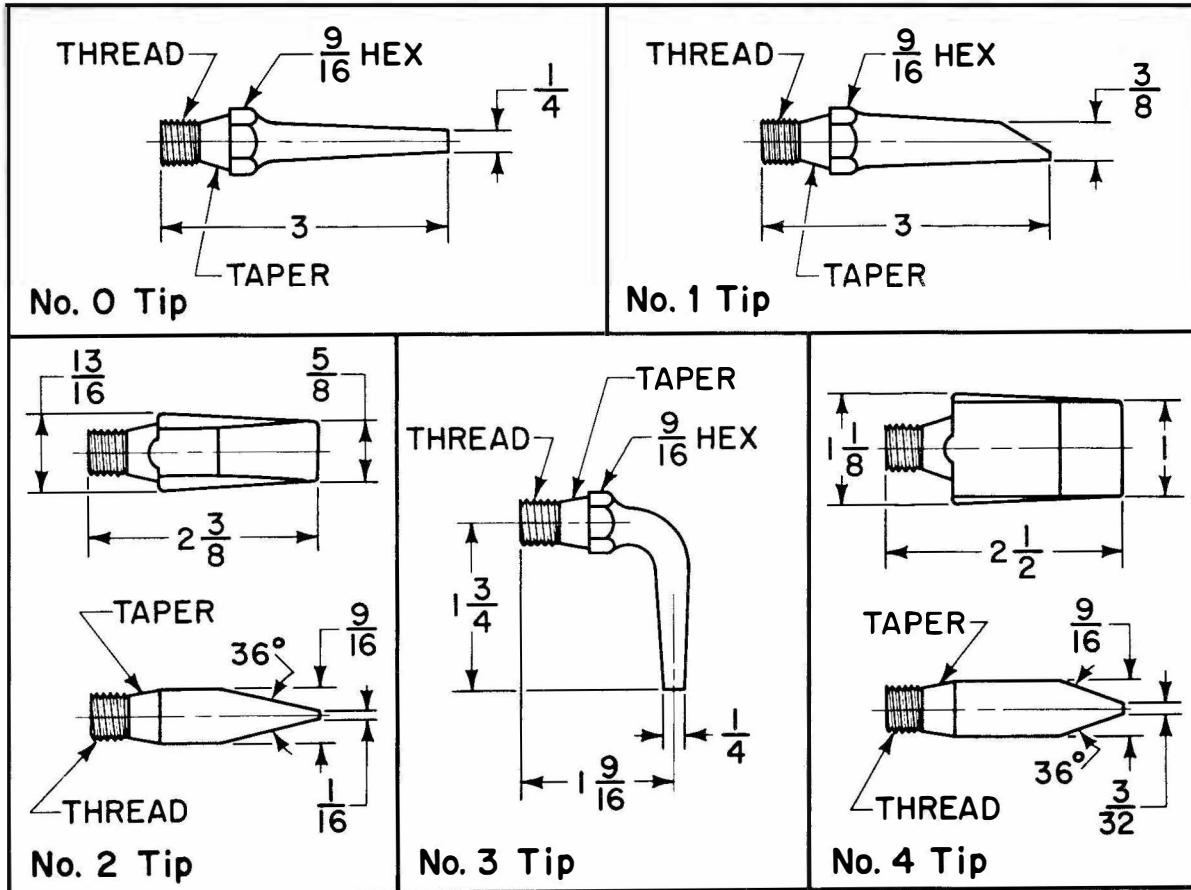
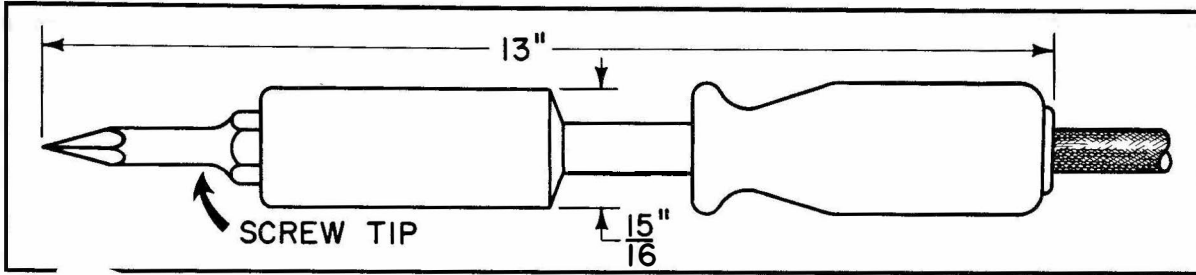


Figure 2-2. Type II Iron With Available Tips.

TABLE 2-2. TYPE III, STYLE "A", PENCIL PLUG TIP IRON

DIAMETER	TIP		SHELL ASSEMBLY DIAMETER (Inch)	HEATING TIME (Minutes)
	LENGTH EXTENDING FROM SHELL (Inch)			
A +2 Percent	B (Min)	C (Max)		(Max)
1/8	7/8	3/8		1-1/2
1/4	1-1/4	1/2		2

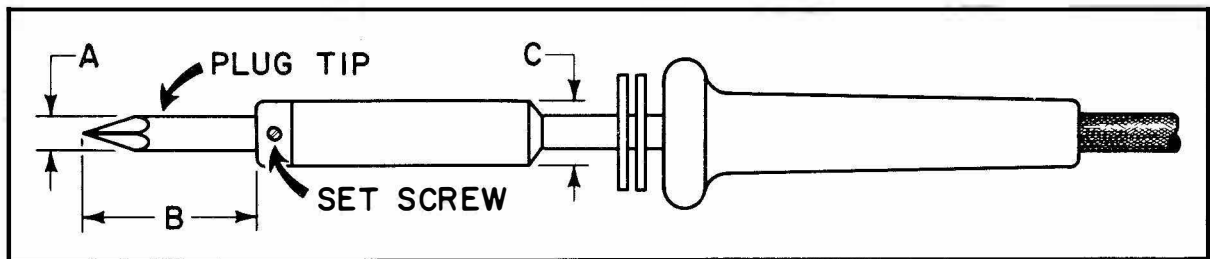


Figure 2-3a. Type III Soldering Iron, Style "A".

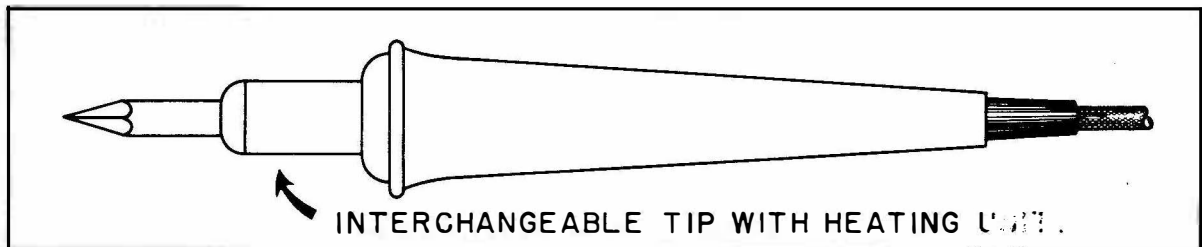


Figure 2-3b. Type III Soldering Iron, Style "B".

(2) **SOLDERING GUNS.**—There are two approved types of soldering guns (Interim Federal Specification W-S-00564). Each type has three classes: Heavy, medium, and light duty.

(a) **TYPE I.**—Type I soldering guns are designed to utilize a transformer which operates on 115 volts, AC, 60 cycles, single phase. The type I guns are provided in the three above named classes and conform to table 2-3. The type I soldering gun is shown in figure 2-5. The tip is a part of the secondary of the transformer and is made of pure copper.

(b) **TYPE II.**—Type II soldering guns are without a transformer and are designed to operate on 115 volts AC, 60 cycles, single phase, or 115 volts DC. The type II guns are provided in the three above named classes and conform to table 2-4. The type II soldering gun is shown in figure 2-6. The tip assembly is provided with a male plug contact provided in the case. The working tip is made of pure copper.

(3) **SOLDERING AID.**—The soldering aid is a very useful item when properly used (see figure 2-7). It is best used in close quarters where one is unable to use his hands. The soldering aid can be used to place the wire to be soldered around or through the terminal to which the wire is to be soldered. When using the soldering aid with shielded wire, care must be taken not to damage the shielding. The soldering aid shall conform to Military Standard MS17007 (Ships).

c. **TYPES OF SOLDERING.**

(1) **DIP SOLDERING.**—Joints may be prepared in advance by fluxing, tinning, or by merely making tight mechanical connections. The joints are then dipped into a bath of molten solder to such a depth that all connections are soldered simultaneously. This method is adaptable to mass production methods and the parts to be soldered must be designed and assembled for this purpose. The types of fluxes that float on the molten solder are not suitable for military purposes because of their corrosive nature. Rosin-based fluxes would quickly vaporize if floated on molten solder. Rosin flux applied to the joints just prior to dipping is a preferred technique.

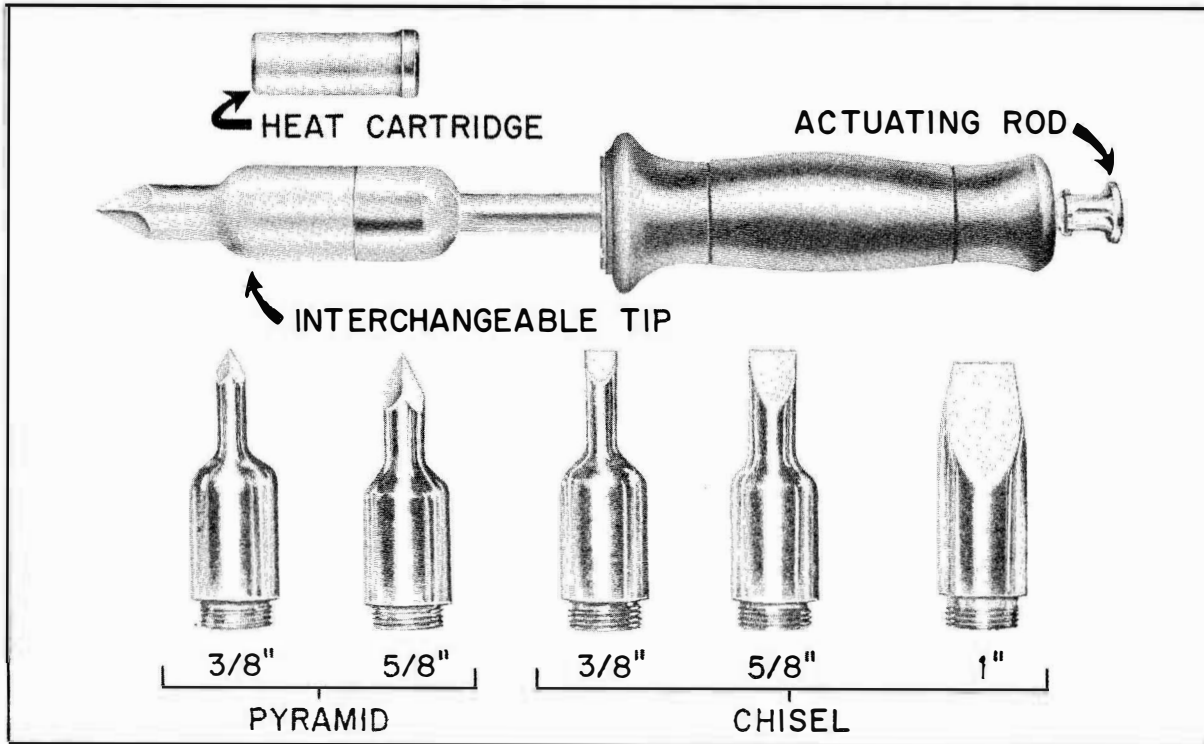


Figure 2-4. Self-heating Soldering Iron and Available Tips.

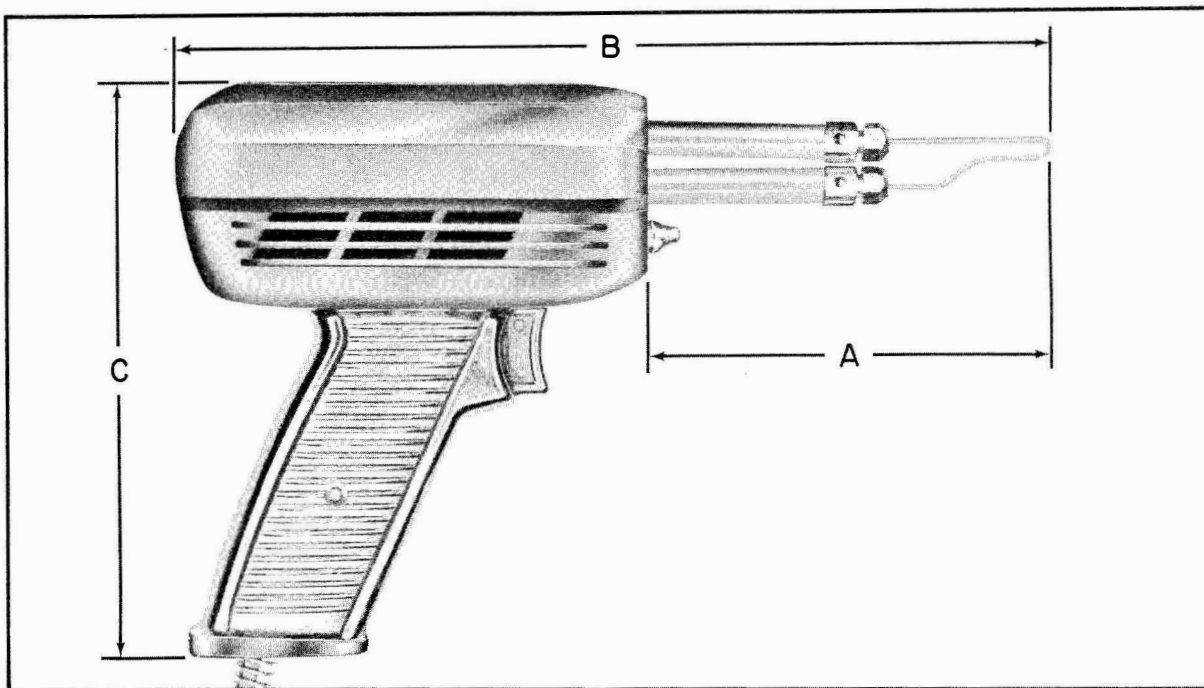


Figure 2-5. Type I Soldering Gun With Transformer

TABLE 2-3. TYPE I SOLDERING GUNS.

CLASS	DUTY	WEIGHT WITHOUT CORD (OUNCES)	A TIP LENGTH (Inches)	B OVERALL LENGTH (Inches)	C HEIGHT (Inches)	D WIDTH (Inches)
1	Heavy	50	5-7/8	12	7	3
2	Medium	48	5-3/8	12	7	3
3	Light	40	5-3/8	12	7	3

(b) TYPE II. - Type II soldering guns are without a transformer and are designed to operate on 115 volts AC, 60 cycles, single phase, or 115 volts DC. The type II guns are provided in the three above named classes and conform to table 2-4. The type II soldering gun is shown in figure 2-6. The tip assembly is provided with a male plug contact provided in the case. The working tip is made of pure copper.

TABLE 2-4. TYPE II SOLDERING GUNS.

CLASS	DUTY	WEIGHT WITHOUT CORD (OUNCES)	A TIP LENGTH (Inches)	B OVERALL LENGTH (Inches)	C HEIGHT (Inches)	D WIDTH (Inches)
1	Heavy	18	6-1/2	12	6	1-1/2
2	Medium	16	6	10	5-1/2	1-3/8
3	Light	10	5	9	5	1-1/4

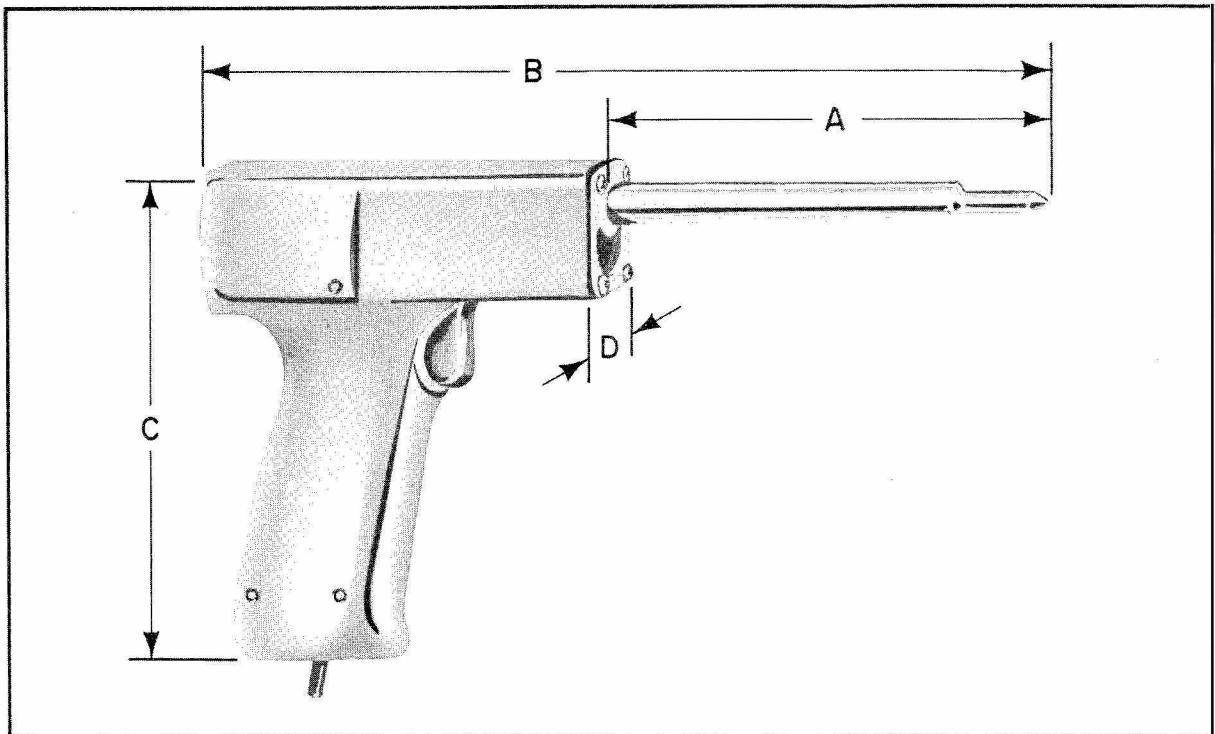


Figure 2-6. Type II Soldering Gun Without Transformer

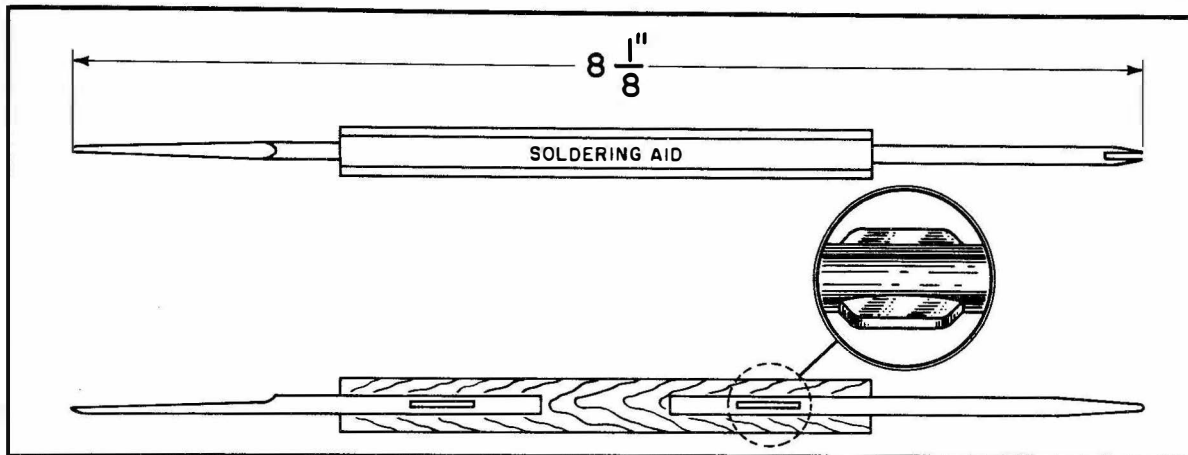


Figure 2-7. Soldering Aid, MS17007.

(2) **TORCH SOLDERING.**—Larger parts which cannot be heated with a soldering iron, and which are not suitable for dip or resistance soldering, may be soldered with an open flame, or torch soldered. The smaller portable alcohol, propane, or butane torches may be used for this. The correct technique is to heat the work and let the work heat the solder. Where extremely large pieces are involved, preheating may be done in a furnace. Apply the flux before heating is begun. Don't apply a flame directly to the flux. Bring the joint up to soldering temperature and apply the solder. Tinning should then occur. Apply more solder as needed.

(3) **RESISTANCE SOLDERING.**—This method employs an electrical current, supplied by a low-voltage transformer, to heat the metals to be joined. The parts are usually gripped between carbon blocks in a tong arrangement. Heat is generated directly in the metal joint, due to the resistance to current flow. Resistance soldering can be done more rapidly than iron soldering, by as much as 20 or 30 percent.

(4) **IRON AND GUN SOLDERING.**—Proper use of a soldering iron, with adequate attention to simple details and required conditions, will produce good solder joints consistently. The following requirements are to be observed.

(a) The soldering iron should be used at its rated voltage, allowing for proper warm-up time. The warm-up time depends upon the iron and tip size.

(b) The tip should be tinned and carry a bright smooth layer on the surface for most effective heat transfer to the joint. If the tip does not tin with solder and flux, cool the iron and file the tip to remove surface corrosion. Immediately after cleaning, the iron should be fluxed, heated, and tinned with solder. Increased tip life with excellent heat transfer is possible by cleaning the tip and tinning with a good grade of silver solder. Where possible, pre-tinning of individual parts is recommended to more quickly obtain reliable solder joints.

(c) All elements of the joint to be soldered must be clean. Clean metal-to-metal contact is necessary without an intervening layer of dirt, oxide film, or foreign matter.

(d) Heat the joint with the hot tip of the iron and apply solder to the junction of the tip and joint. As soon as the soldering temperature is reached (solder wets the joint surfaces and flows smoothly), remove the iron from the joint. Avoid excessive use of solder.

(e) The soldering iron must be properly maintained during use. A clean cloth or wiping pad used at intervals will remove excess solder and slag which speed erosion of the tip. When not in actual soldering use, a soldering iron should be rested on a stand which has adequate heat dissipating area. This stand provides a controlling factor over the idle temperature of the iron, and helps to avoid damaging effects to the iron caused by overheating.

d. **SOLDERS.**—The most common solders are alloys of lead and tin in various proportions with certain other metals present for controlling the character of the alloy. The alloy does not liquify immediately as the temperature is raised. It first becomes plastic, then semi-liquid, then finally completely liquid. Table 2-5 gives the approximate composition and melting range of some common alloys.

Solder is available in numerous physical forms. It is supplied commercially as bar, stick, toil, wire, strip, or powder. Selection of a specific size and mass depends on the metal areas to be joined. Large conductors may require the bar or stick solder.

e. **FLUXES.**—Nearly all metals require a good flux of the proper type if a sound joint is to be obtained. Most fluxes will be in paste form. When heating the work with a torch, the flame should never be applied directly to the flux; the work should heat the flux. Some fluxes will fume or smoke as an indication that the correct soldering temperature has

TABLE 2-5. MELTING RANGE vs COMPOSITION

NOMINAL TIN %	COMPOSITION LEAD %	MELTING RANGE (deg F)
4	96	560-600
10	90	515-575
15	85	435-555
30	70	361-495
33	67	361-485
38	62	361-465
40	60	361-460
45	55	361-440
50	50	361-415
60	40	361-370
62	38	361-361
75	25	361-380

been reached. Excessive temperatures will cause a chemical breakdown in the flux, and a hard crust will form. If this happens, the crust must be removed, the work re-cleaned and the operation started again.

f. MECHANICAL CONNECTIONS.—Where possible, the parts to be soldered must be securely joined mechanically before any soldering is done.

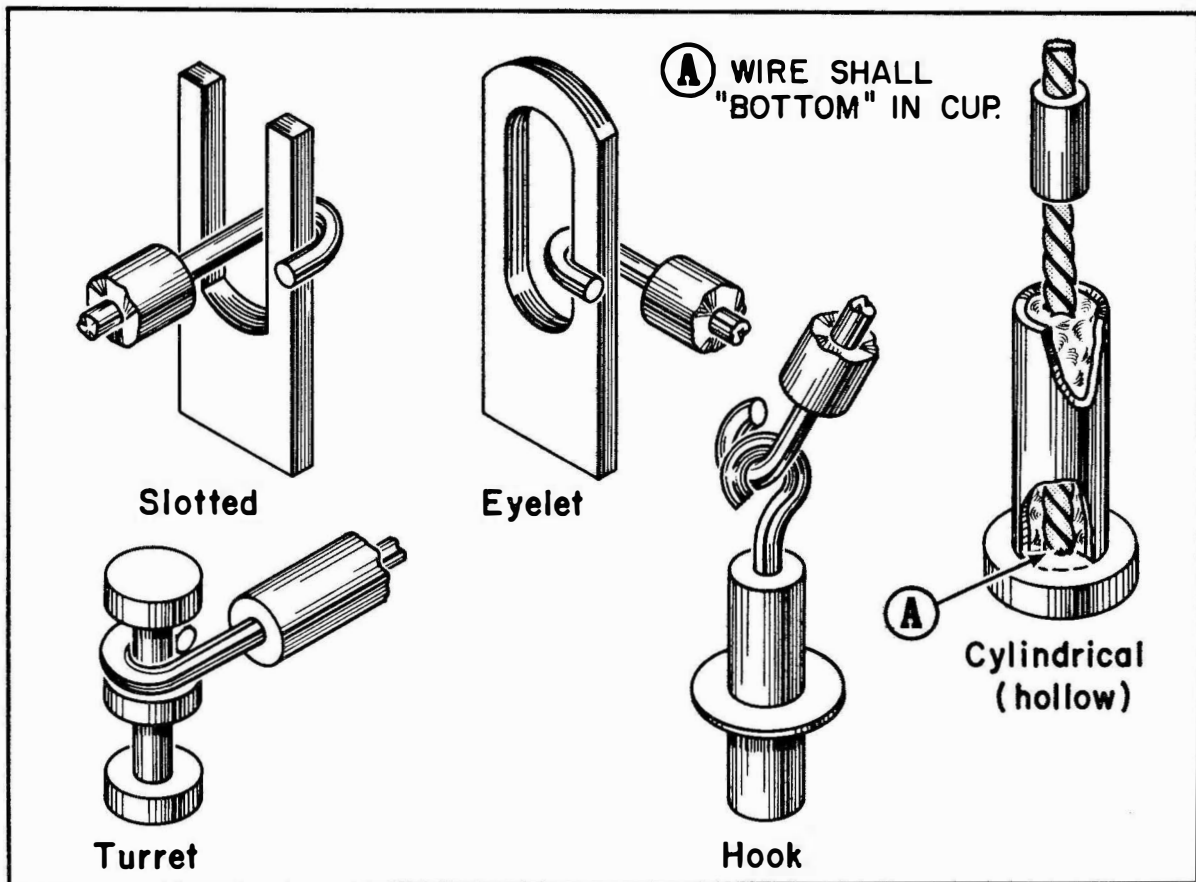


Figure 2-8. Wire Terminals.

(1) **HOOKE UP WIRE.**—All wiring should be neat, sturdy, and as short as possible. Service loops providing sufficient wire slack to make at least two re-connections shall be provided at each electrical connection. The approved wire, insulation, and color code should always be used. When the wire is stripped, prior to soldering, there should be no nicks nor broken strands. When a piece of hookup wire is broken after installation, it should not be spliced, but replaced with a new wire.

(2) **TERMINALS.**—Wires and leads should be wrapped tightly around terminals at least one-half and never more than three-fourths turn. The insulation on the wire should be no more than 1/8 inch from the solder joint.

Whenever possible large wires being terminated in thin eyelet terminals should be pre-formed to avoid damage. Movement of the parts being soldered during the cooling of the solder creates cold solder joints. The appearance of the surface is dull. A cold joint is weak mechanically and has high electrical resistance. A cold joint can develop into a hard-to-find fault, giving intermittent operation of the equipment with more noise than is desired. A good solder joint is bright and gleaming. Figure 2-9 illustrates proper and improper connections.

The accepted standards of workmanship require that: (1) the apparatus and parts be free from solder splashes; (2) while the parts to be soldered should be entirely covered with solder, any excess should be withdrawn from the connection; (3) the space allowed between soldered joints is sufficient clearance for the voltage to be used.

g. SOLDERING TO SPECIAL SURFACES.

(1) **SILVER COATED SURFACES.**—A silver-bearing solder is recommended for soldering to silvered surfaces. If a conventional tin-lead solder is used on a silver-fired ceramic or other silver surface, the solder dissolves the silver from the surface and no bond is formed, or at best, the bond is weak.

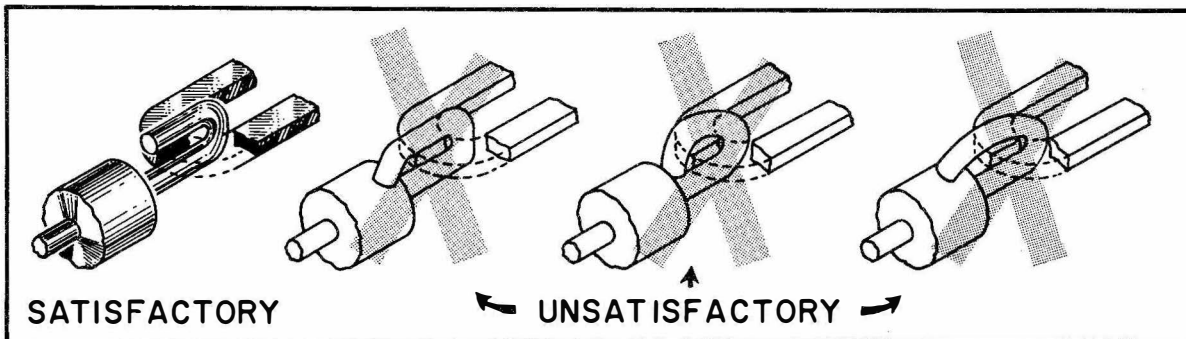


Figure 2-9a. Proper and Improper Connections (Mechanical).

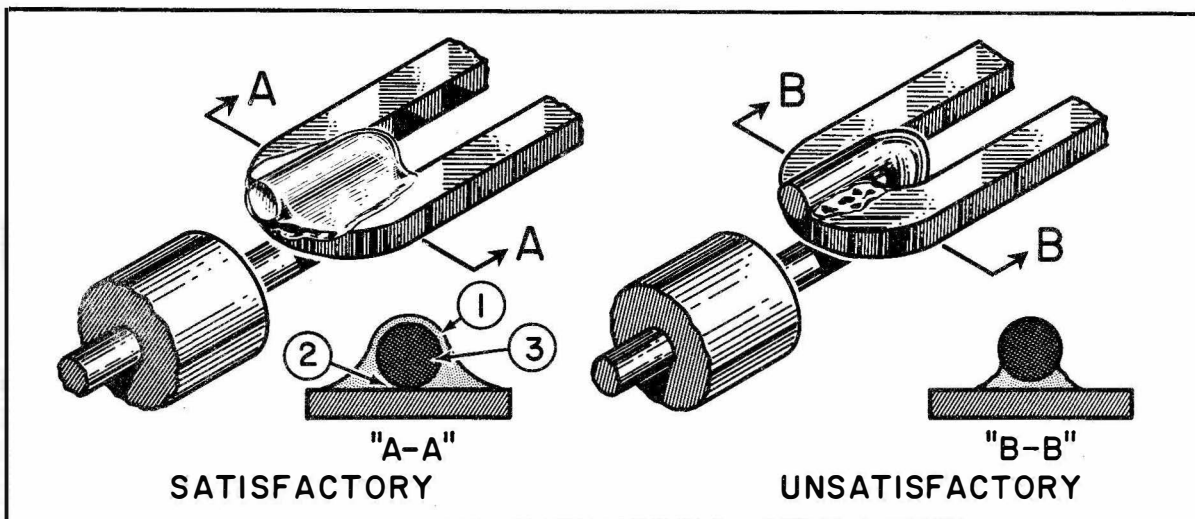


Figure 2-9b. Proper and Improper Connections (Soldering).

(2) **ALUMINUM.**—Aluminum soldering presents a substantial problem because the lead forms a galvanic couple with aluminum, in the presence of moisture, which is harmful to the stability and life of the joint. Also, aluminum oxide, which forms a film on the surface of aluminum, can only be removed with extreme difficulty. Vigorous wire brushing or some form of abrasive cleaning is required prior to soldering to get a satisfactory joint. If the area to be soldered is brushed while covered with a pool of molten solder the oxides will float to the surfaces and the molten pool of solder will prevent any subsequent oxidation. Aluminum soldering is generally not recommended for joints that will be exposed to the weather (MIL-S-12204). It is recommended that the soldered joint be protected by an organic protective coating. Solders of lead, tin, zinc, and aluminum composition are best for soldering aluminum. Table 2-6 lists solder per MIL-S-12204 which is recommended for soldering aluminum.

TABLE 2-6. COMPOSITION AND MELTING POINT OF ALUMINUM SOLDERS

COMPOSITION	TIN	ZINC	LEAD	ALUMINUM
A	33-35	2-4	Remainder	----
B	Remainder	15-50	-----	----
C	Remainder	5-15	-----	5-12

(3) **GLASS-TO-METAL.**—Indium with tin, lead, or silver, forms alloys of relatively low melting points which will wet glass and which are suitable alloys for soldering metal to glass. An alloy consisting of 50 percent tin and 50 percent indium, with a melting point of 241 F, is useful for this type of soldering.

(4) **STAINLESS STEEL.**—Success in soldering stainless steel requires thorough removal of all surface, dirt, rust, or organic material. Polished surfaces must be roughened with an abrasive wheel or cloth, and the residue wiped away with a clean cloth. Tin-lead solders can be used successfully for soldering stainless steel by using any of the customary methods.

(5) **NICKEL.**—There are no special solders for nickel surfaces. Satisfactory results require good fluxing and soldering craftsmanship.

(6) **GALVANIZED IRON.**—In soldering galvanized iron, an alloy is used which contains less than 0.5 percent antimony. Antimony free lead-tin solders are preferred. The flux used is a mixture of ammonium chloride and zinc chloride.

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8-3. BRAZING.—Brazing is defined by the American Welding Society as follows: "A group of welding processes wherein coalescence is produced by heating to suitable temperatures above 800°F and by using a nonferrous filler metal, having a melting point below that of the base metals." The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction. Brazing requires less heat than welding and therefore may be used to join metals that may be injured by high heats. As the definition of brazing implies, the base metal is not melted. The filler metal adheres to the base metal by molecular attraction; it does not fuse and amalgamate with them.

a. TYPES OF BRAZING.—Brazing shall be of the following types:

- (1) TORCH BRAZING.
- (2) FURNACE BRAZING.
- (3) INDUCTION BRAZING.
- (4) RESISTANCE BRAZING.
- (5) DIP BRAZING.

b. FILLER METALS.—With the exception of torch brazing, the filler metal is usually pre-placed for brazing and will usually be in the form of clips, rings, washers, filings, or powder. Normally, wire filler is used for torch brazing. Unless otherwise specified, filler metal shall conform to specifications QQ-C-501, QQ-R-571, QQ-S-551, QQ-S-561, QQ-W-341, or 47C-3, except that copper-brazing filler shall be de-oxidized copper without residual deoxidizing agents. The requirement is in accordance with Mil-B-7883.

c. FLUXES.—Because each type of filler alloy requiring the use of a flux presents a special problem, no one flux is suitable for universal use. It is important that the correct flux be chosen for each individual brazing application. Fluxes are used to reduce oxidation, remove oxides formed during brazing, and to remove other impurities. They may be applied in the form of powder, paste, vapor gas, or coating on the filler rod.

d. BRAZE JOINTS.—The requirements for a good joint may be mechanical strength, electrical conductivity, pressure tightness, and good performance at elevated and subzero temperatures. The strength of the joint depends on the strength of the filler metal, the joint clearance, and the presence of defects, such as porosity, slag inclusions, and unbrazed areas or voids.

(1) BASIC JOINT DESIGN.—The three basic types of joint design used for brazing are the lap joint, butt joint, and scarf joint. Combinations and variations of these will meet most requirements. Figure 3-1 illustrates the basic joint designs. Generally, lap joints are stronger than butt or scarf joints.

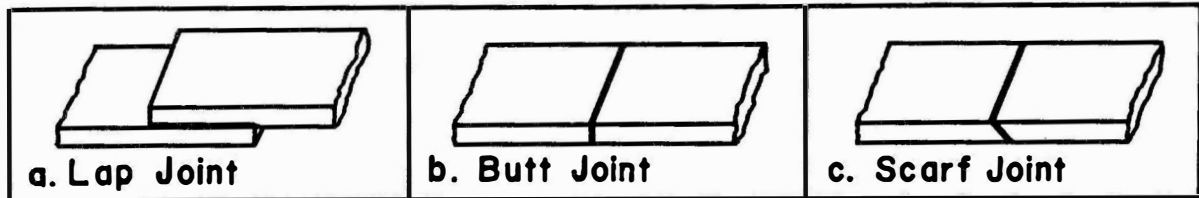


Figure 3-1. Basic Joints.

(2) JOINT DESIGNS FOR ELECTRICAL CONDUCTION.—The main factor in the design of electrical joints is good conductivity. Lap joints should be used where the design will permit. A rule of thumb method used to obtain maximum conductivity is to establish a lap length $1\frac{1}{2}$ times the thickness of the thinner member, (see figure 3-2).

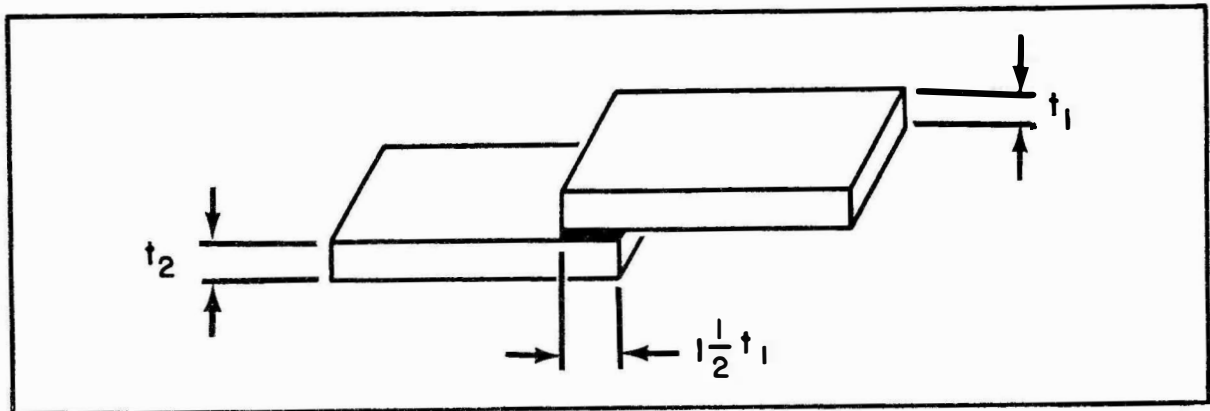


Figure 3-2. Joint Design for Good Conductivity.

(3) **JOINT CLEARANCES.**—Joint clearance should be considered for maximum strength. Room temperature clearance is a satisfactory guide with similar metals of about equal mass. Where dissimilar metals, or greatly differing masses of similar metals are concerned, unequal expansion may require that careful judgement be used to obtain the correct clearance, (see table 3-1).

TABLE 3-1. RECOMMENDED CLEARANCE AT BRAZING TEMPERATURES - SIMILAR METALS.

FILLER METAL	JOINT CLEARANCE, INCHES
Boron - Aluminum - Silicon Gp	0.006 - 0.010 for length of lap less than 1/4". 0.010 - 0.025 for length of lap greater than 1/4" .
Boron - Copper - Phosporous Gp	0.001 - 0.005
Boron - Silver Gp	0.002 - 0.005
Boron - Copper - Gold Gp	0.002 - 0.005
Boron - Copper Gp	0.002 - 0.002*
Boron - Copper - Zinc Gp	0.002 - 0.005
Boron - Magnesium Gp	0.004 - 0.010
Boron - Nickel - Chromium Gp	0.002 - 0.005
Boron - Silver - Manganese Gp	0.002 - 0.005

NOTE: In case of round or tubular members this means a clearance on the radius.

*For maximum strength use 0.000 clearance or a press fit.

(4) **SERVICE AT ELEVATED TEMPERATURES.**—Brazed assemblies subject to service at elevated temperatures lose strength as the temperature increases. Designs must take these losses into consideration. Table 3-2 gives continuous and maximum service temperatures for various filler metals.

TABLE 3-2. SERVICE TEMPERATURES FOR BRAZING FILLER METALS.

FILLER METAL	SUGGESTED LIMITING CONTINUOUS SERVICE TEMP., °F	SUGGESTED MAXIMUM SERVICE TEMP., °F
Boron - Copper - Phosporous Gp	300	300
Boron - Silver Gp	400	500
Boron - Copper - Fire Gp	400	500
Boron - Copper Gp	400	900
Boron - Silver - Manganese Gp	500	900
Boron - Nickel - Chromium Gp	1000	2000

e. **BRAZING TECHNIQUE.**—The correct positioning of the parts to be brazed, application of the flux and filler material, and the distribution of the applied heat are as important to a good weld joint as using the correct materials. For this reason, each type of brazing will be described in detail.

(1) **TORCH BRAZING.**—Although silver soldering is a type of brazing, because it requires a slightly different technique it will be discussed separately from general alloy brazing.

(a) **GENERAL ALLOY BRAZING.**—After the parts to be brazed are properly clamped or otherwise supported and fluxed, start the preheating step. Each joint requires a slightly different treatment to obtain best results. Less heat is required for open chamfer joints, fillets, and overlays. More heat is needed when the filler metal has to flow by capillary attraction through square butt or lap joints. An excess acetylene flame has the lowest heat and an oxidizing or excess oxygen flame the highest heat (see figure 3-3a). The amount of heat transferred to the base metal with a given flame depends on the distance the torch is held from the metal (see figure 3-3b). Figure 3-3c illustrates what can occur when the flame is held for too long a period at one point on the filler metal. The first two views shown the filler metal before and after melting down and spreading evenly. The last view illustrates the melting of the base metal when it was overheated. The flame should be kept moving in a constant circular motion to spread the heat evenly (see figure 3-3d and 3-3e), or in the case of thinner metals, back and forth as in figure 3-3f. Remember that although some metals will give an indication of their temperature by their color, others, such as aluminum will become plastic without any color indication. Also, some metals containing lead, zinc, or copper, may give off toxic fumes without any warning. The filler metal is introduced at the edge of the joint in a crevice provided for the purpose. The metal is added until the joint is completely filled. Do not allow the flame to concentrate on one spot so as to burn the flux or melt the base metal. Once the filler metal has started to flow into the joint the heat should not be increased. After the joint has cooled all traces of the flux should be removed to prevent corrosion of the parts.

(b) **SILVER BRAZING.**--Silver brazing, or hard soldering, as it is sometimes called, is excellent for tubing, small parts, and electrical connections, especially where vibration is present. It has good mechanical strength as well as good electrical conductivity. Table 3-3 gives information on the 8 classes of silver solder. This soldering requires a slightly different technique to other brazing. A soft brush-type flame should be used. The flame should be as large as possible with an air-acetylene torch; however, if oxyacetylene is used there should be a sharply defined inner cone. The parts should be cleaned, evenly fluxed, and clamped tightly together.

TABLE 3-3. SILVER SOLDER CLASSES AND APPLICATION

CLASS	MELTING POINT OF	COLOR	APPLICATION
0	1430	Yellow	Ordinary brazing where high physical properties are required and appearance is not a factor.
1	1250	Nearly White	For general range of soldering, including turbine blades.
2	1280	White	Where high silver content is required and where application requires high strength, resistance to corrosion, and good appearance.
3	1200	Gray-White	Only on copper and copper-based alloys. Not to be used on ferrous alloys.
4	1160	Yellow-White	General purpose for copper, brass, ferrous metals, and particularly nickel-copper alloys and alloy steels.
5	1195	Yellow-White	For copper, brass, ferrous metals, particularly nickel-copper alloys and alloy steels, and where design necessitates a fillet. Also used for cemented carbides.
6	1166	Yellow-White	Approximately the same as class 4.
6A	116A	Yellow-White	To be used when class 4 is not available.

The assembly should now be evenly heated by moving the torch in circles. If oxyacetylene is used, keep the inner cone a few inches from the work. Move the flame away when the metal is dull red. Now touch the fluxed brazing wire to the joint and capillary action will make it flow into the joint. Don't overheat the work. Apply just enough heat to melt the silver wire. Don't apply the torch to the joint or to the silver wire. Remove all traces of flux after the joint has cooled. The silver brazed joints of piping and tubing in equipment cooling systems employing liquid coolants shall be air tested upon completion of the system installation. The cooling system shall be pressurized to 1-1/4 times the normal system working pressure and isolated, with a suitable gage, for approximately one hour. If no significant pressure drop is noted during this period, the pressure may be released and the system filled with coolant. If the cooling system does not meet the requirements of this pressure test, all joints shall be tested with a brush and soap solution. After the repair of the leaky joints, the system shall again be tested in the same manner as before.

(2) **FURNACE BRAZING.**--Any gas or electric furnace that will maintain the required uniform and constant temperature is suitable for furnace brazing. The parts should be cleaned and clamped into position. The flux and filler alloy are preplaced. The filler alloy may be in the form of washers, wire, sheet, or filings and should be used in the correct quantity and placed in such relation so as to obtain the best joint possible. The parts are then charged into the furnace (MIL-B-7883) and remain there until the bond is formed. After the assembly is removed and cooled it should be thoroughly cleaned.

(3) **INDUCTION BRAZING.**--In induction brazing heating is brought about from hysteresis and eddy current losses. Where non-ferrous metals are involved heating must be by eddy current losses only. This may limit the application in some cases. The area and depth of heating can be more closely controlled by this type of brazing than some others. This type of brazing is particularly suited to making sleeve joints in tubing, and other types of joints lying near the surface of the work. In case of joints at an appreciable distance below the surface, there is danger of overheating at the surface before the joint reaches the flow temperature of the filler alloy. The best method of heat control for this type of brazing is by controlling the amount of time that the workpiece is within the induction coil. The part is positioned, fluxed, and the filler metal replaced. The joint area is then heated by placing it near or in a suitable induction coil. After the bond is formed the part must be thoroughly cleaned to remove the flux.

(4) **RESISTANCE BRAZING.**--This type of brazing employs the heat generated by resistance to an electric current through the parts to be joined. The parts are positioned with relation to each other, fluxed, and the filler alloy is

prepositioned. The electrodes are attached and a current is passed through the joint. Heat generated due to resistance at the joint melts and bonds the filler material to the base metals. As with induction brazing, this method requires precise control to add just the correct amount of heat to the joint. This is usually done by timing the flow of current. Careful cleaning is required to remove all flux after the work is joined.

(5) **DIP BRAZING.**—Dip brazing, or salt bath brazing as it is sometimes called, may be done by either of two methods. The first is prepositioning the filler alloy in the joint and dipping the work into a bath which transfers the heat to joint and melts the filler alloy. The second method is to dip the work into a bath which consists of a molten brazing alloy and which contains its own flux. The work is then passed through a bath which washes it free of flux. This type of brazing is particularly suitable for small parts. The main requirements with this method of brazing are correct temperature and a bath which is not actively corrosive to the combination of metals present.

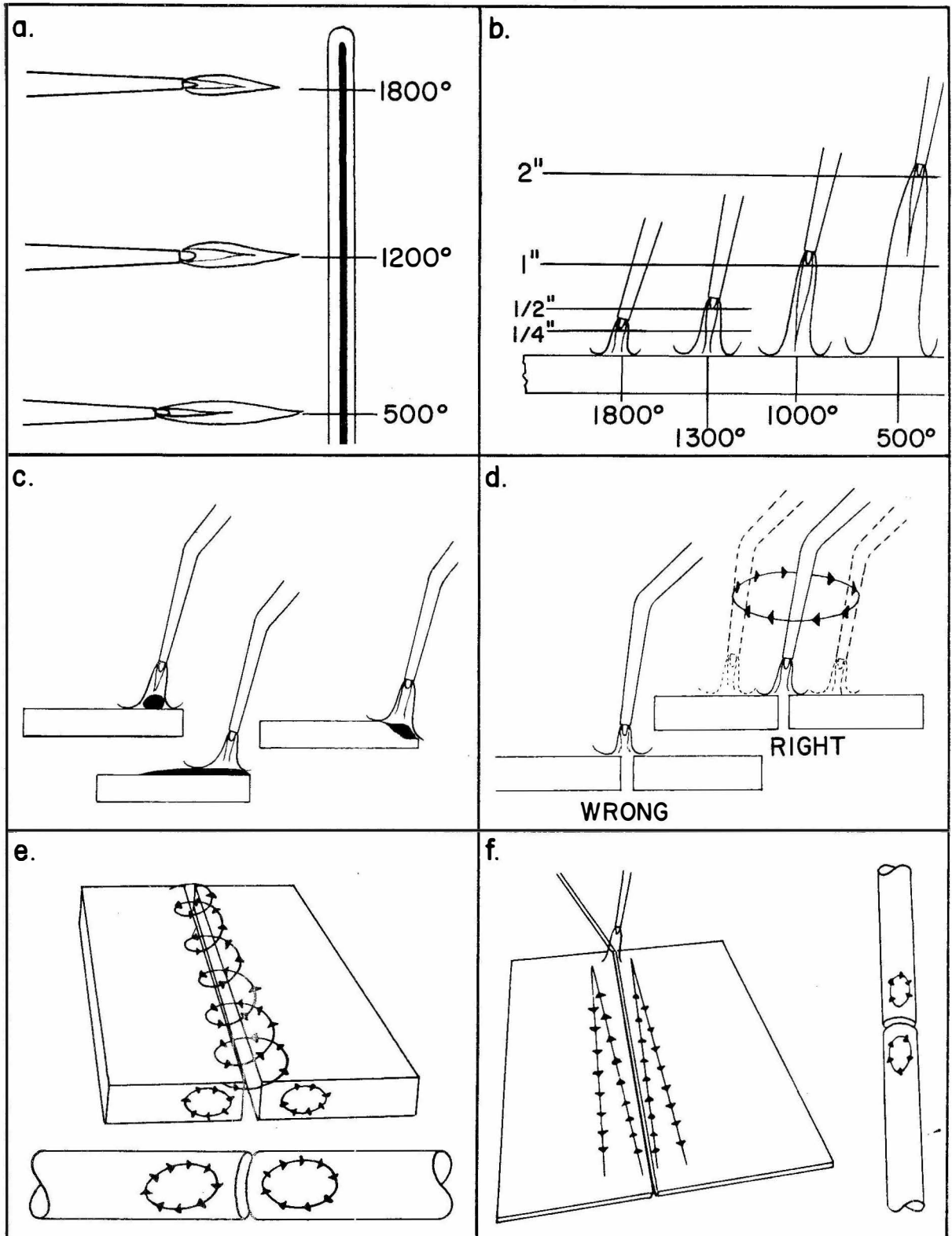


Figure 3-3. Flame Temperature and Application.



8-4. WELDING.—The welding process is defined by the American Welding Society as: "A metal joining process wherein coalescence is produced by heating to suitable temperature, with or without the application of pressure, and with or without the use of filler metal." The molten pool arising out of this process is usually supplemented with filler metal (rod or wire) that has the same approximate chemical composition as the base metal. This filler is added to the weld joint by feeding into the high temperature fusion area. The quality of a weld joint depends upon the type of joint, procedure used, materials used, and joint treatment before and after the welding operation.

a. TYPES OF WELDING.

- (1) ELECTRIC ARC WELDING.
- (2) OXYGEN WELDING.
- (3) ELECTRIC RESISTANCE WELDING.
- (4) ATOMIC HYDROGEN WELDING.
- (5) INERT GAS METAL ARC WELDING.
- (6) THERMIT WELDING.
- (7) STUD WELDING.
- (8) FORGE WELDING.

b. WELDING RODS.—The selection of the correct welding rod or electrode for a particular purpose must take into consideration the physical properties required, the type of joint employed, position in which the weld is made, i.e., flat, vertical or overhead, and type of joint, such as fillet or groove. The filler metal used in welding dissimilar metals must be compatible with the base metal in maintaining the mechanical properties and corrosion resistance of the base metals.

c. WELDING FLUXES.—The flux used for welding must have the ability to remove the oxides and other impurities. It can be manually applied to the welding rod or may be present in the coating applied to the rod during manufacturing. In some types of joints it may be applied directly to the joint.

d. JOINT SELECTION.—The selection of a joint for a particular application usually depends upon the following:

- (1) The type of load applied; whether it is to be in tension or compression and whether bending, fatigue or impact stresses in any combination are present.
- (2) The manner in which the load is applied; whether load application is steady, variable, or sudden. Figure 4-1 illustrates some basic joints in accordance with MIL-STD-22A.

e. WELDING TECHNIQUE.—Exact procedures are impossible to outline due to the many variables present in each type of welding; however, the general procedures which follow will apply to most welding work.

(1) METAL ARC WELDING.—When an arc is drawn between the work or base metal and an electrode, the base metal in the path of the arc stream is melted, forming a pool of molten metal. Subsequent solidification of the molten metal results in fusion of the workpieces. Depth of penetration will generally depend on the current and voltage of the arc. Correct arc length will vary with size and type of electrode used and the amount of heat required. Where a consumable type electrode is used, it becomes the filler metal. In striking the arc, except in welding aluminum, the electrode is brought against the work and then moved away quickly. In welding aluminum this procedure will cause sticking. Instead, the electrode should be brushed against the base metal, like striking a match. The shorter the arc, the easier it is to maintain and control. To restart an arc, it should be struck just ahead of the end of the bead. After a short interval the arc should be moved backwards to completely remelt the end of the bead and fill up any crater which might have occurred. In proceeding with the bead, a near vertical position should be assumed for the electrode. In most cases the angle should not be less than 60° with the work. The rate of advance can be determined by watching the solidifying metal. The arc should not be advanced too rapidly. Any undercutting which appears should be filled before the arc is advanced. Best results are obtained if the weld is allowed to cool between succeeding beads. Where multiple layer welds are deposited, each layer should be thoroughly cleaned and all slag and impurities removed before deposition of the next bead. When welding shapes of unequal thickness, the arc should be directed in such a manner so that both pieces being welded are heated equally. If possible the molten pool of weld metal should be kept horizontal. Where vertical or overhead welding is necessary smaller electrodes are usually used. In vertical welding the direction of weld, up or down, will depend on the type of joint, the type of electrode, and what is required in the completed joint. Generally, a sound weld can be more easily obtained by welding down than welding up. Horizontal welding on a vertical surface is the least preferable, although good quality welds can be obtained as with the other positions.

(a) ATOMIC HYDROGEN WELDING.—This is a process in which the heat for welding is obtained from the recombination of dissociated hydrogen. The hydrogen is broken down by passing through an electric arc and, as it recombines, heat is given off. The arc is sustained between two permanent tungsten electrodes. Since the arc can be moved closer to, or further away from the parent metal, more control can be had over the amount of heat added than with the metallic arc-welding process. In this process, two advantages are derived from the hydrogen. First, it furnishes the heat for fusion; secondly, it serves as a blanket to exclude the atmosphere from the weld area. Usually the equipment includes a movable primary coil to control the arc. The hydrogen regulator is similar to the acetylene regulator. Flux is not normally required except for aluminum, copper, and their alloys.

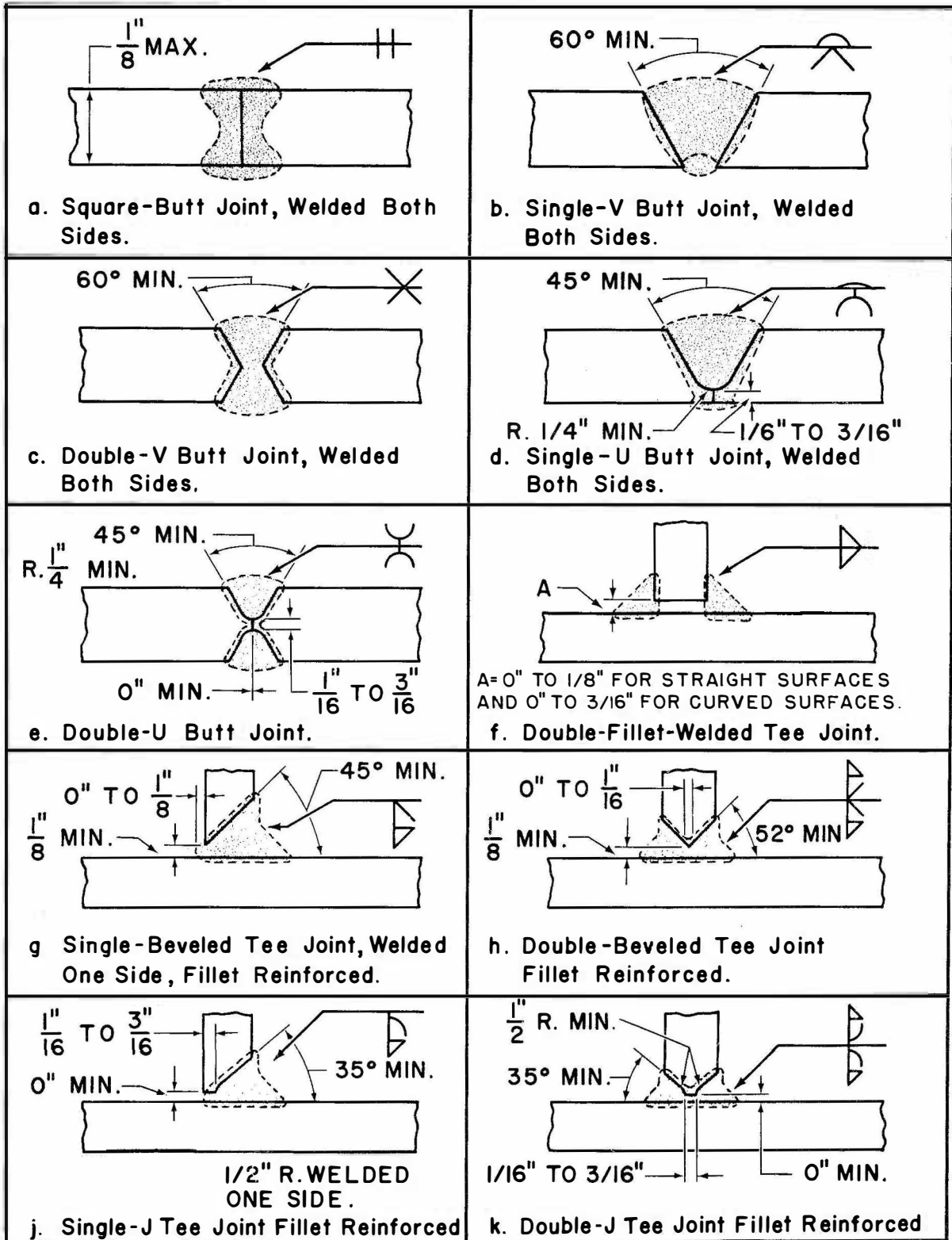


Figure 4-1a. Recommended Weld Joints With Symbols.

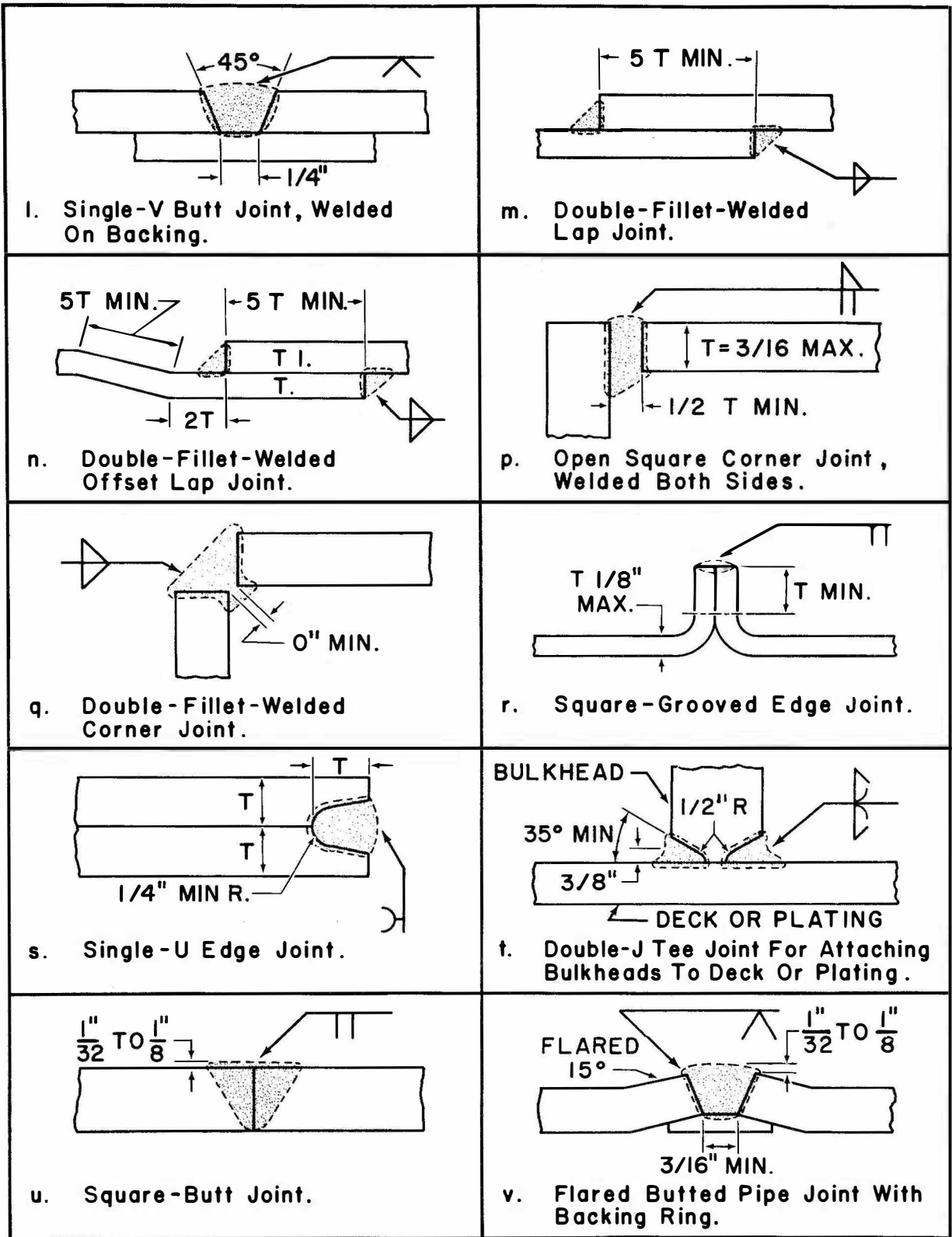


Figure 4-1b. Recommended Weld Joints With Symbols.

(b) **INERT GAS METAL ARC WELDING.**—(See figure 4-2.) By use of this method, almost any non-volatile metal can be welded. In the first process of this type welding the electrodes consist of the work piece and a tungsten wire (non-consumable) which are protected from the atmosphere by a continuous stream of inert gas (usually argon or helium). Using DC current, if the workpiece is positive, the electrode remains cool. With the electrode positive, the electrode heats up and is consumed rapidly. Excessive penetration may be avoided by using positive polarity with DC power. AC current is generally used for welding metals that have a tough oxide surface. The second process of this type employs a filler type of consumable electrode. It is similar to shielded metal arc welding except in the method of protecting the weld pool, arc stream and electrode tip from the effects of the atmosphere.

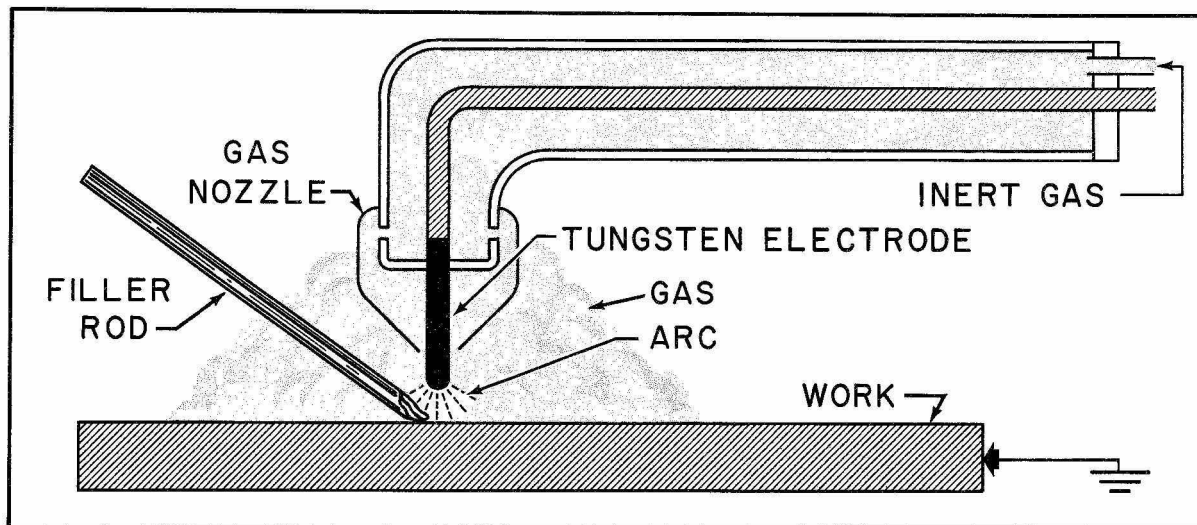


Figure 4-2. Inert Gas Metal Arc Welding.

(c) **SHIELDED METAL ARC WELDING.**—This method is similar to inert gas metal arc welding except that the protective gas is released from a coating on the rods, in contrast to the gas being delivered from an external source for the inert gas metal arc process.

(2) **CARBON ARC WELDING.**—This type of welding uses a non-consumable carbon electrode. Since no metal is transferred through the arc stream, the carbon arc serves only as a source of heat. When filler metal is required, it must be fed into the welding zone in rod form. Diameter of the carbon point should be approximately half the diameter of the carbon used. The taper should be gradual back to the point where it is gripped in the holder. The carbon should be gripped as closely to the arc as possible to reduce vaporization of the rod. This method may be with or without an inert gas blanket.

(3) **THERMIT WELDING.**—(See figure 4-4.) When finely divided iron oxide and aluminum react, they produce pure iron, aluminum oxide, and great amounts of heat. It is this reaction that makes thermit welding possible. The parts to be welded are positioned and a wax pattern that approximates the finished weld is formed around the joint. Next a sand mold is compacted around the wax, the sand is heated, and the wax is driven out. When the joint is cherry red, the thermit mixture is allowed to flow into the mold where fusion takes place and a strong, homogeneous weld is formed. Subsequent steps consist of cooling, tearing down the mold, removing gates and risers, and chipping.

(4) **STUD WELDING.**—Stud welding is a variation of the arc welding process. Studs, insulation pins, buttons, lashing hooks, etc., constitute the electrode. Striking the arc, holding the stud, and controlling the duration of current flow are done by the equipment. The stud gun resembles a pistol, usually made of bakelite. When the pushbutton switch is operated to start the cycle, an armature establishes the arc gap after current flow is started. The current is interrupted after a predetermined lapse of time and a spring in the gun barrel moves the stud toward the parent metal, forcing the molten electrode end into the weld pool to complete the weld. Special ring and hook fasteners, as well as threaded studs, are available for this process. The gun is portable and this process is commonly used for installation of conduit, pipe hangers, plank decking, and insulation. The flux is contained in the stud if the shape permits.

(5) **FORGE WELDING.**—The forge weld consists primarily of heating pieces to be joined in a forge fire to a highly plastic temperature and completing the weld by applying pressure. The pressure application is usually in the form of hammer impact over an anvil.

(6) **ELECTRIC RESISTANCE WELDING.**—Placing two pieces of metallic materials between two low resistance conductors and impressing a low voltage, high amperage current will heat the materials by virtue of their resistance to current flow. By forcing the pieces together at their contact surfaces after they have reached the plastic temperature, a

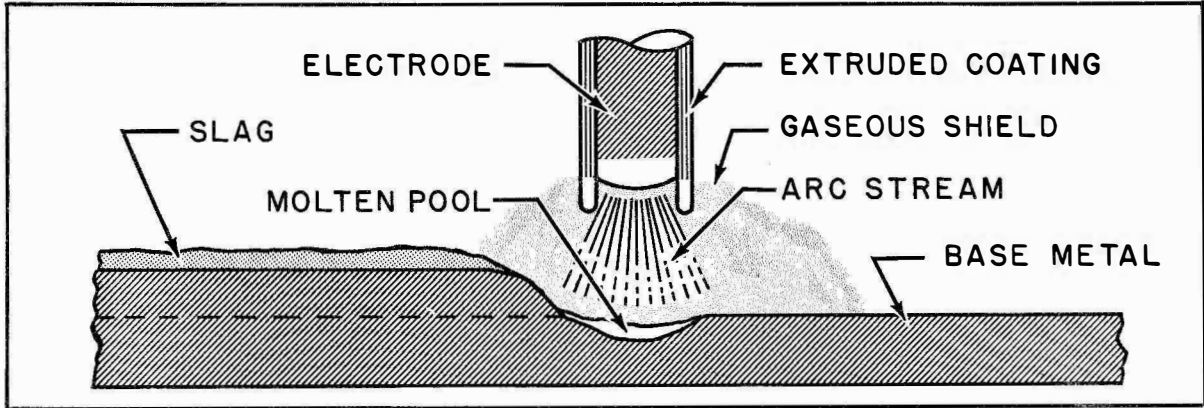


Figure 4-3. Shielded Metal Arc Welding.

bond is effected. To complete the weld, the current is then interrupted and the electrode pressure retained until the weld metal strengthens or cools. Combinations of thick and thin sections, dissimilar metals and several thicknesses of metal can all be welded by this process. Electric resistance welding can take such forms as spot welding, seam welding, upset welding, and flash welding.

(a) SPOT WELDING.—(See figure 4-5.) Spot welders are of the portable or stationary type. Both embody a set of low resistance copper alloy electrodes, usually water cooled. In addition, there is a generator for the welding

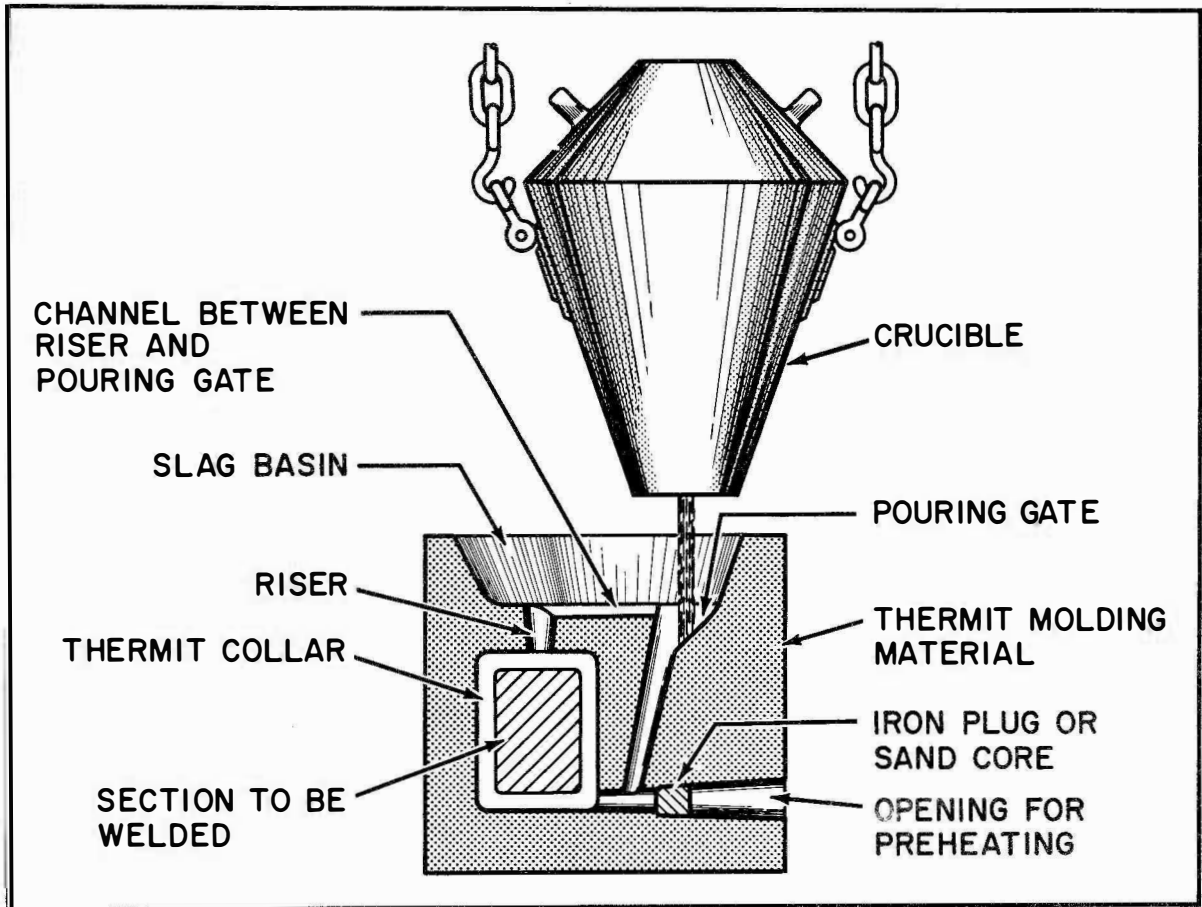


Figure 4-4. Thermit Welding.

current and a suitable frame for mounting the electrodes and control devices. Accurate timing of the current flow is the key to satisfactory joints. Short periods of current flow afford less opportunity for heat dissipation into the parent metal and minimize distortion. Pressure is applied by mechanical, hydraulic, or pneumatic devices.

(b) **SEAM WELDING.**—Seam welding is done much the same as spot welding except that wheel type electrodes are used, the work being fed between the wheels. The weld current is regularly interrupted to produce a chain spot effect. The spots are overlapped to produce a continuous fluid-tight joint. This process is usually limited to sheet metal applications.

(c) **OTHER RESISTANCE WELDING.**—(See figure 4-6.) Upset, flash, and percussion welding are less common methods of resistance welding. The first is simply placing the parts together and passing a current through the junction to produce the heat of fusion. Pressure is then applied to force the plastic surfaces together and produce the weld. Flash welding is accomplished by placing the workpieces near enough to form an arc. The arc produces fusion temperatures and a force is applied to bring the pieces together and produce a weld. Percussion welding is similar to flash welding; the exception being that the force is applied more suddenly in percussion welding.

(7) **OXYGEN WELDING.**—Satisfactory oxygen welding requires that a fuel gas be employed which will produce a high temperature concentrated flame when burned in the presence of oxygen. Acetylene gas is the most common gas used as a source of heat. It is described as colorless and with an obnoxious odor. The components required for oxygen welding are a torch (see figure 4-7) oxygen and gas (acetylene or hydrogen) hoses, oxygen and gas regulators, and a supply of oxygen and gas. The regulators deliver the acetylene and oxygen at the correct pressure to the hoses. In addition, the welder should have the protective equipment listed in section 9-8-1. The torch has two functions: (1) to receive and mix the two gases properly, and (2) to shape the flame and direct it at the correct angle. It is made up of

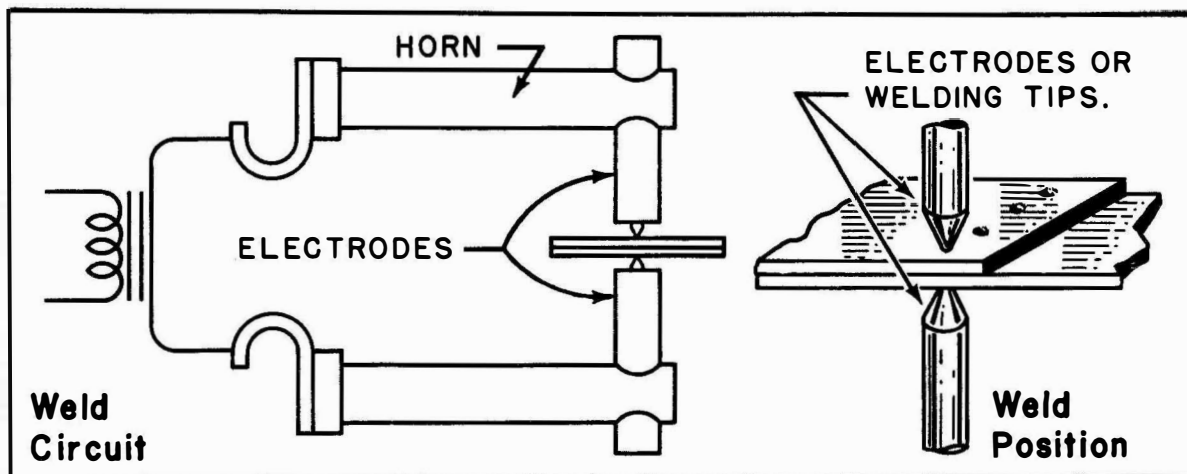


Figure 4-5. Basic Spot Welding Circuit.

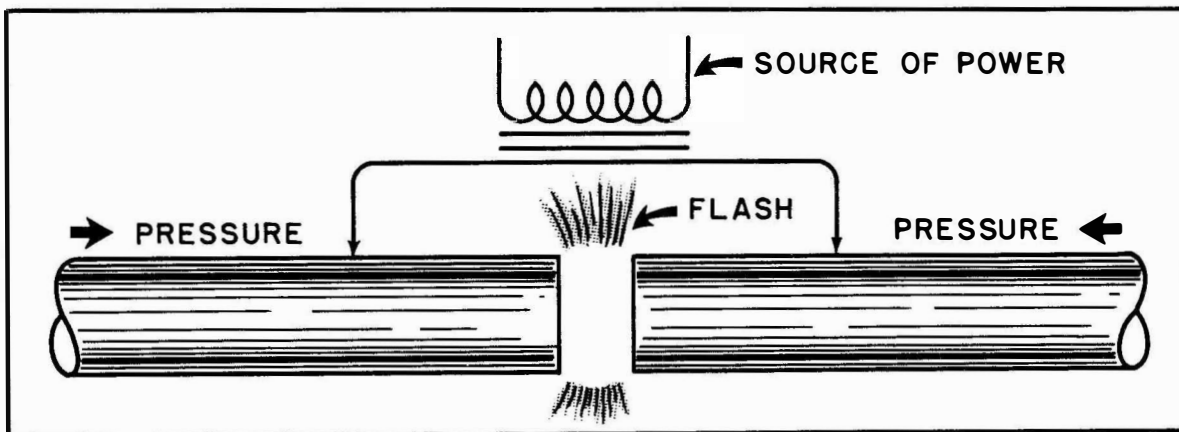


Figure 4-6. Basic Flash Welder.

regulating valves, a body, a mixing head and various size tips. The body is shaped to grip with the hand. The flame produced depends on the relative amounts of gas and oxygen used in the mixture. There are three distinct types of flames:

(a) **NEUTRAL FLAME.**—This is a chemically balanced flame which has no tendency to react with any material with which it comes into contact. Its temperature is about 6500°F, and it will melt most metals and refractories. It is identified by a well defined inner cone and outer envelope.

(b) **CARBURIZING FLAME.**—This flame has an excess of acetylene and is identifiable by the reddish feathers which appear at the tip of the inner cone. This flame is capable of rapid reduction of oxides and some molten metals will absorb a portion of the excess carbon produced by excessive acetylene.

(c) **OXIDIZING FLAME.**—As the name indicates, this flame has an excess of oxygen and can rapidly form oxides of the metals being welded. It may result in difficulties and weld deposits of inferior quality.

Most metals can be oxygas welded. A neutral flame is usually satisfactory. The joint is ground to the correct shape, cleaned, and supported. The flame is applied until the metal is just under the melting temperature. The flame is then concentrated on a local area. When a small puddle appears, the end of the welding rod is placed into the puddle and the correct amount of metal is added. The rod should be moved around to get the metal just where it is wanted. The molten metal from the rod should not be allowed to flow on metal that is not in a molten state. The flame should be kept moving ahead of the puddle to melt the metal. The welding speed is important in that welding too rapidly produces poor penetration, while welding too slowly will result in burning, piling up of slag, or other defects. Aluminum, stainless steel, magnesium, copper and brass should, where possible, be welded with a blanket arc such as inert-gas shielded electric arc welding.

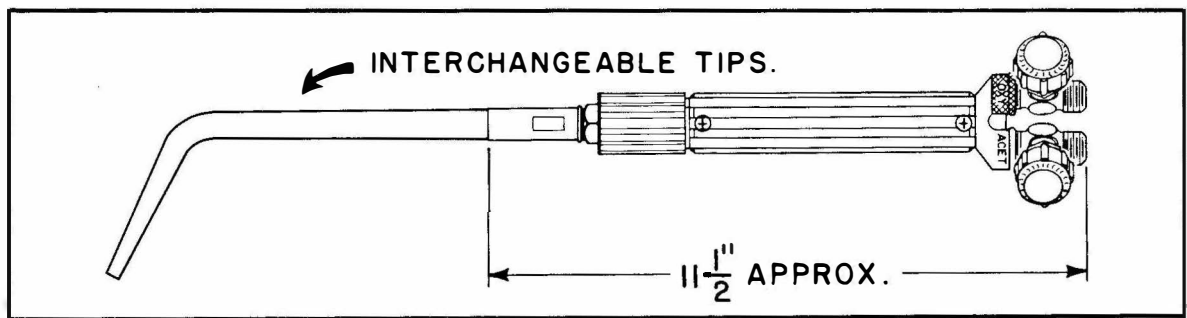


Figure 4-7. Hand Welding Torch, MS15834.

f. **REPAIR OF CASTINGS.**—Castings can, in some instances, be welded. It is important to identify the metal because some types, such as malleable cast iron, should be bronze welded. Also, aluminum castings require great skill and a lower heat than cast iron. If the piece is not completely broken, holes should be drilled at the end of the cracks to prevent spreading. The parts should first be clamped or supported. The whole casting should be preheated if it is not too large. Tack welds may aid in starting the welding. After welding is completed the casting must be allowed to cool very slowly to prevent cracking. It can be wrapped in asbestos paper or covered with dry sand to slow down the cooling. Very large castings may be preheated and cooled slowly in a furnace. Another method of repairing castings is by thermit welding, as described in section 4(e)(3).

g. **METAL CUTTING WITH HEAT.**—All metals will burn when heated to their respective kindling temperature and exposed to oxygen. The cutting equipment is required to heat the metal to its kindling point and direct a stream of pure oxygen against the region heated. Once cutting is started its continuation is achieved by moving the heat source and oxygen jet along the desired path. Other types of cutting use an electric arc with or without oxygen.

(1) **TORCH CUTTING.**—Flame cutting is one of the fastest methods of cutting metal. With the proper equipment material up to 4 foot thick can be cut. Also, accuracy to 1/32 inch can be maintained in metals up to 6" thick. The torch nozzle is constructed so that the preheating flame plays on an area to heat it bright red, then the oxygen jet is directed on the area. Fast combustion takes place to remove the metal. The path of cutting should be premarked with soapstone. A center punch can be used to make marks along the soapstone line. The start of the cut will usually be at an edge of the workpiece where preheating is rapid. With the tip of the flame inner cone in contact with the metal, a small area is brought to a bright red temperature. The oxygen trigger valve is then opened to direct oxygen against the heated area. Opening the valve slowly will prevent spatter. As the torch is moved along the soapstone line, cutting will be sustained as long as the torch is not moved too fast. A narrow portion of the metal is removed along the path of the torch. If the torch is moved too fast cutting will cease. In this case the operator should go back to where the cutting stopped and begin again. With the various nozzles available, groove cutting, removal of imperfections, and other

operations can be done. For the operation just described, a cutting attachment similar to MS-16007 to fit welding torch MS-15834 is suitable (see figure 4-8). For production cutting, a torch such as MS-15008 is recommended.

(2) **ELECTRIC ARC CUTTING.**--There are 3 types of arc cutting in general uses. One, arc-oxygen cutting, uses an action similar to flame oxygen cutting. The oxygen is introduced through a tubular electrode to cause oxidation and erosion of the metal. The other two types, carbon arc and solid core metal arc, do not use oxygen. The heat derived from the arc simply melts a path through the metal. In solid core metal arc cutting, another benefit is available in that the coating shields the electrode against side arcing, thereby allowing the electrode to penetrate deeper into a cut. Special electrodes are usually used, although regular welding electrodes may be used in an emergency. Electric arc cutting requires somewhat higher currents than welding. Higher heats are possible than with oxygen-flame cutting, thereby permitting metals such as cast iron to be cut with more ease.

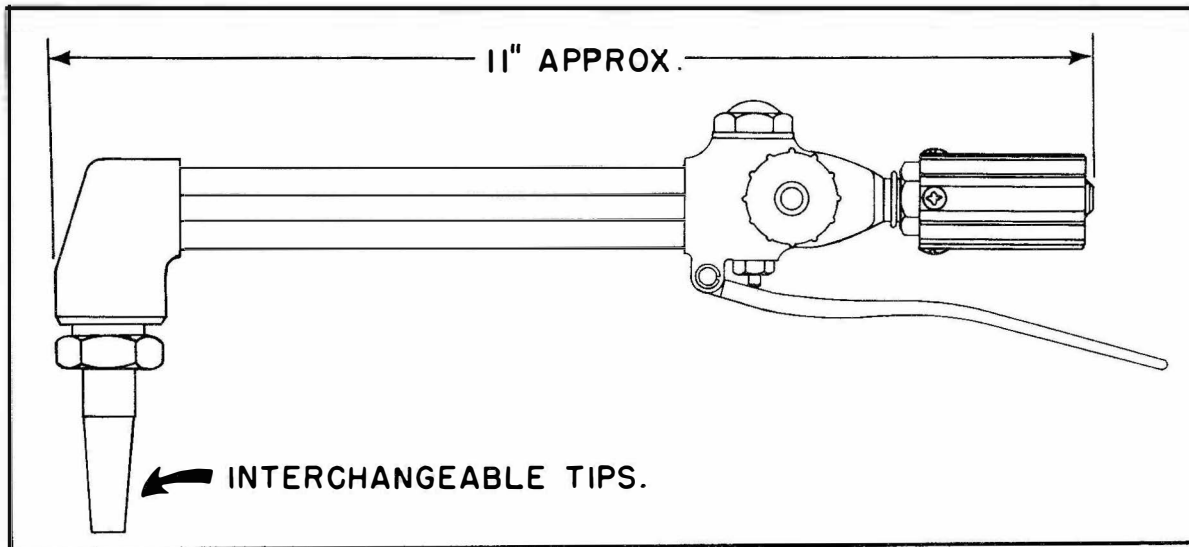


Figure 4-8. Cutting Attachment MS-16007.

8-5. SUBMARINE PRESSURE HULL WELDING.—Shipyards and other repair or overhaul activities equipped and prepared to carry out the full requirements outlined herein need no longer request Bureau of Ships approval for the cutting and welding of pressure hulls in the following instances: (1) Openings which were originally designed as closure plates regardless of size, (2) Plating renewals five feet in circumferential girth or less and extending not more than two frames, and (3) Installation of fittings.

a. **HOLE LOCATION.**—The location of holes cut in the pressure hull and watertight bulkheads for fitting and patch plates, should where possible, be made through existing welds in order to reduce the total number of welds. Where possible, location of the cuts should be such that the least disturbance of the structure as a whole results.

(1) **EXISTING STUFFING TUBES.**—If existing unused stuffing tube installations are available, these locations should be used for hull entry wherever practicable.

(a) **SMALLER STUFFING TUBES.**—If the existing stuffing tube is smaller than the new one, remove the old tube by chipping or grinding, then drill the hole to the proper size for the new one.

(b) **LARGER STUFFING TUBES.**—In cases where the old stuffing tube is larger in diameter, up to 3/4 inch greater than the new one, remove the old tube by chipping or grinding. Then, reduce the diameter of the old hole by building up the wall with weld. Grind the metal flush with the pressure hull and drill to correct size (see figure 5-1).

NOTE

The maximum permissible thickness of weld metal build up is 3/8 inch.

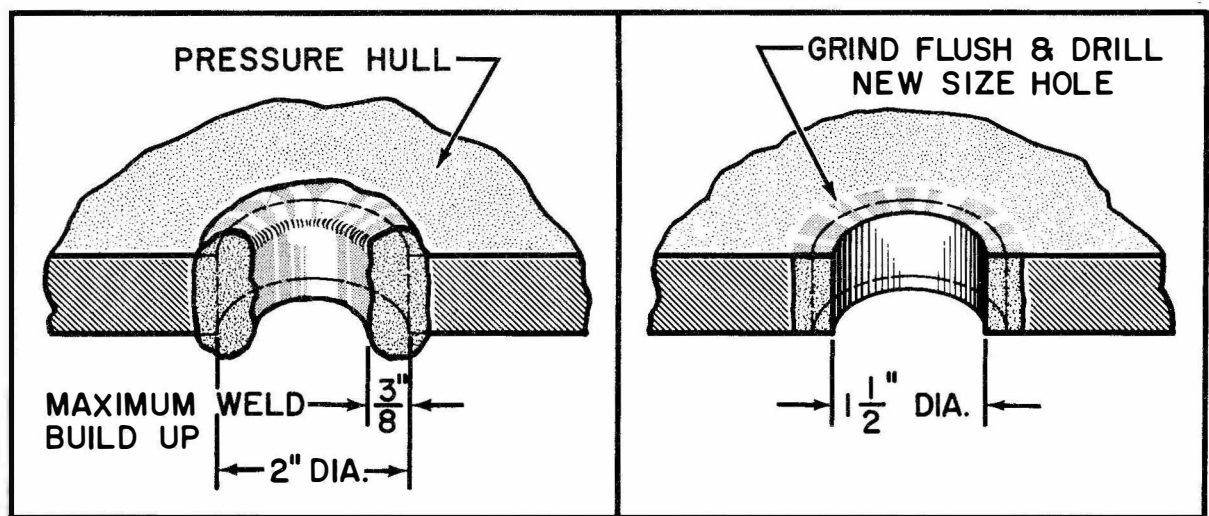


Figure 5-1. Reducing Hole Diameter.

b. **FITTING INSPECTION.**—Before the fitting body is welded in place, inspect and remove any foreign matter that may be present in the fitting. If rust or corrosion has penetrated groove sealing surfaces to a depth greater than 32 microinches, discard that piece and obtain a new one. Remove rust, if any, from the exterior body.

c. **FITTING INSTALLATION.**—When the proper size hole has been drilled in the pressure hull to accommodate the fitting, clean the metal around the hole, inboard and outboard, for welding. Insert a wet asbestos cloth in the tube body to protect the sealing surfaces during the welding operation. Install the pressure fitting body in the hull entry hole from the outboard side with the shoulder resting on the pressure hull. Weld to the pressure hull outboard and inboard with a fillet weld of the proper dimension as given in table 5-1. Figure 5-2 shows the completed fitting body installation.

d. **WELDING ELECTRODES.**—The electrodes used will depend upon the type steel and the type of joint to be welded.

(1) **MEDIUM AND HIGH TENSILE STEELS.**—For welding medium and high tensile steels use electrodes conforming to MIL-E-18038, type MIL-8015-16.

(2) **HIGH YIELD STEEL (HY-80).**—For welding butt and corner joints in high yield steel (HY-80) use electrodes conforming to MIL-E-986, type MIL-260.

(a) **TEE AND LAP JOINTS (HY-80).**—For welding tee and lap joints in high yield steel (HY-80), use electrodes conforming to MIL-E-18038, types MIL-100-15-16.

(3) **STS STEEL.**—For welding butt and corner joints in STS steel use electrodes conforming to MIL-E-986, type MIL-260.

(a) **TEE AND LAP JOINTS (STS).**—For welding tee and lap joints in STS steel use electrodes conforming to MIL-E-16715, type MIL-310.

NOTE

Medium and high tensile steel was used to fabricate the pressure hull proper and STS steel was used to fabricate the conning towers of submarines with hull numbers 285 and up, except that hull numbers 361, 362, 363 and 364 had conning towers of high tensile steel. High yield steel (HY-80) is used in fabricating the pressure hull of submarines with hull numbers 585, 588 and up through 615.

e. **PATCHING.**—When it is required that several stuffing tubes or other openings be closed in the pressure hull, it may be done by cutting out a section of the pressure hull that contains the openings and then welding in a patch plate.

(1) **PATCH PLATE JOINT DESIGN.**—Design of joints, in general, shall be as shown in MIL-STD-22.

Figure 5-3(a) and (b) indicate the preferred joint designs for making the butt joint in pressure hull patch plates for permanent closure. Although some modifications to the scarf design, as indicated in figure 5-3, are permitted, under no circumstances shall the principle of a complete joint penetration weld, welded from both sides, be violated. Similar requirements apply to butt joints where sections of framing are being replaced over permanent closure plates.

TABLE 5-1. HOLE AND FILLET WELD SIZES.

FITTING	HOLE SIZE	FILLET WELD SIZE	FITTING	HOLE SIZE	FILLET WELD SIZE
MX-2326/U	1-1/2"	7/16"	UG-640/U	1-1/2"	7/16"
MX-2327/U	1"	5/16"	UG-988/U	1-1/2"	7/16"
MX-2646/U	1"	5/16"	UG-983A/U	15/16"	3/16"

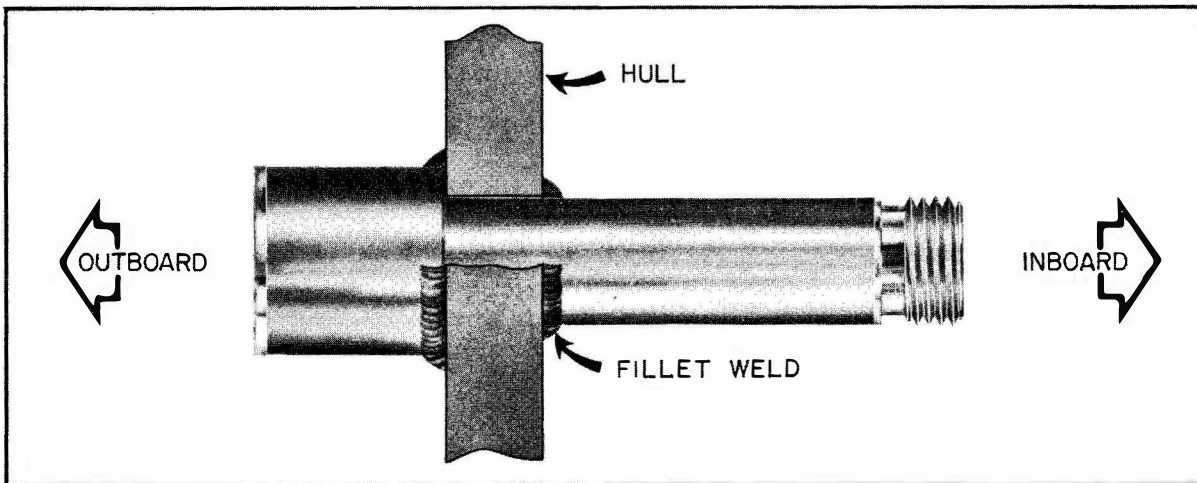


Figure 5-2. Pressure Fitting Weld.

CAUTION

All welding shall be done in compliance with current Bureau of Ships instructions and section S9-1 of General Specifications for Ships of the United States Navy. The Welder shall be qualified in accordance with MIL-STD-248.

(a) **ONE SIDE WELDING.**—In the event that it is impossible or absolutely impracticable to weld a particular joint or portion of a joint from both sides, then the weld must be made against a permanent bar on the inaccessible side of the plating as shown in figure 5-4. Fillet welds joining framing to the pressure hull or insert plates shall conform to the best new construction practices and design.

(b) **OTHER REQUIREMENTS.**—The retention of the original geometry of the structure as delineated in the current Bureau of Ships Instruction is required. The provisions of General Specifications for Ships, Section S9-1, govern in the usage of welding sequences and mechanical peening for reducing residual stresses or to minimize distortion. Root passes shall be back chipped or ground to sound metal. In addition, root welds, faces, and adjacent base metal surfaces in pressure hull plating butt joints shall be proven crackfree by the magnetic particle or liquid penetrant method of testing.

(c) **MINIMUM DIAMETER OF PATCH PLATES.**—Patch plates are used for permanent closure of holes greater than one inch in diameter. In pressure hull plating 1-1/4 inches or less in thickness, the minimum diameter of

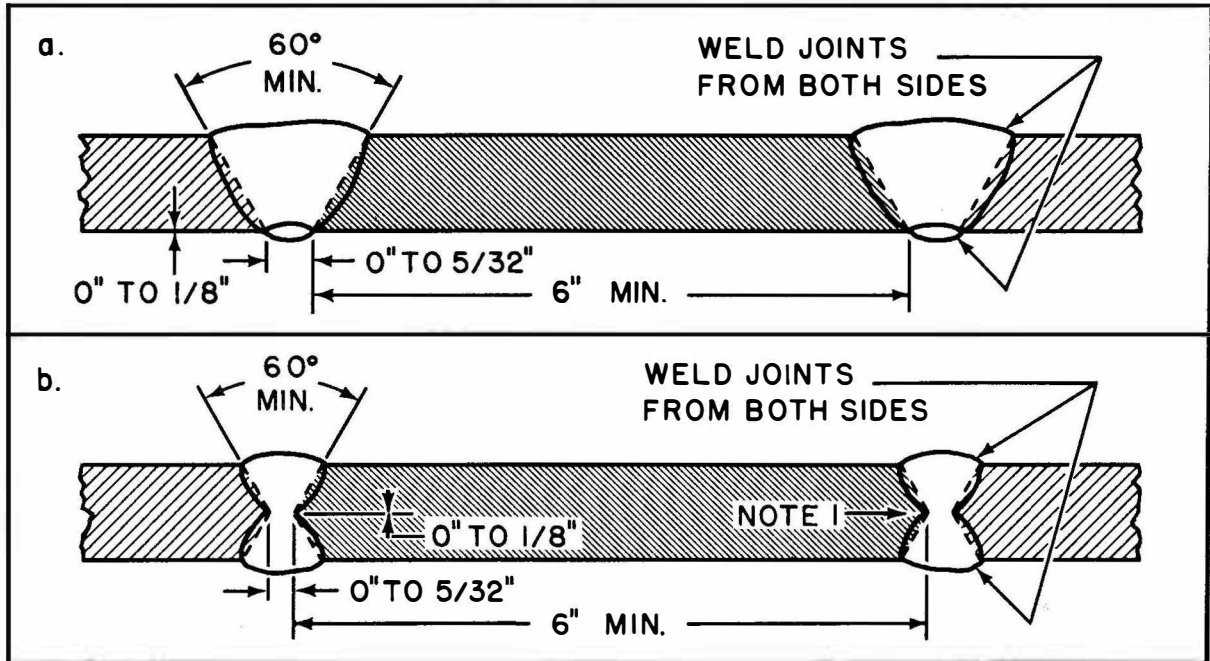


Figure 5-3. Patch Plate Joint Design.

patch plates permitted is six inches. The minimum diameter for patch plates for thicker hull plating shall be increased sufficiently to produce welds which meet the radiographic requirements specified under weld inspections.

(2) **PLUG WELDS.**—Plug welds are used to close holes one inch or less in diameter. When the hole diameter is less than one inch, it shall be enlarged to one inch before welding it closed. Plug welds shall be in accordance with

f. **TEMPORARY FITTING CLOSURES.**—Temporary closure methods may be used in those instances where removal of the fitting and installation of a weld patch would require extensive removal and reinstallation of other existing fitting and/or equipment. No attempt is made here to cover all the details of the many designs of stuffing boxes, etc., which will be encountered, but rather to give a general guide. Each application must be considered on its own merit and the best suited method used.

(1) **DESIRABLE.**—The most desirable temporary closure methods for blanking-off obsolete or unused pressure hull fittings are shown in figures 5-6 and 5-7.

(2) **LEAST DESIRABLE.**—The temporary closure methods illustrated in figures 5-8 and 5-9, are considered the least desirable; however, these methods may be used in emergencies.

(3) **TEMPORARY CLOSURE ELECTRODES.**—In the event welding difficulties are encountered in welding in plugs on free machining steel stuffing boxes, for example, it is recommended that austenitic (25 Cr-20-Ni) electrodes MIL-310 of MIL-E-16715 be used in such instances.

g. **WELD INSPECTIONS.**—All welds made in the pressure hull shall be inspected in accordance with the General Specification for Ships of the United States Navy.

(1) **RADIOGRAPHIC INSPECTION.**—Butt joint welds involving permanent closure patch plates in the pressure hull shall be radiographed. Defective welds shall be repaired as necessary to insure conformance with Group 2 of Bureau of Ships X-ray Standards for Production and Repair Welds (NAVSHIPS 250-692-Z).

(2) **OTHER METHODS OF TESTING.**—Where radiographic inspection of welds is not practical, as in the installation of RF cable stuffing tubes, inspection will be made with magnetic particle testing or by testing with a dye penetrant.

(a) **MAGNETIC PARTICLE INSPECTION.**—If the weld being tested is made part of a strong magnetic path, sprinkling or spraying it with magnetic particles will disclose the presence, location, and extent of defects. The diffusion of the magnetic flux increases with its distance from the defect; therefore, the depth of the defect can be judged to some extent by observing the pattern assumed by the powder particles. Magnetic powder of high permeability and suitable particle shape is applied to the surface to be inspected. Once the defect is located it is necessary to grind it out and reweld it.

(b) FLOURESCENT PENETRANT INSPECTION.--This method works equally well on either ferrous or non-ferrous materials. The penetrating agent has a low surface tension and will be drawn into small surface openings readily by capillary attraction. When exposed under ultraviolet light, voids or cracks will become visible. The surface is brushed or sprayed with penetrant and time is allowed for the agent to penetrate any openings present. After penetration, all traces of the agent must be washed off with water. When the surface is dry the developer is sprayed on and allowed to act for approximately one-half the penetrating time. Inspection is then done under an ultra-violet light and any flaws in the surface of the weld will become visible. The defects can then be corrected.

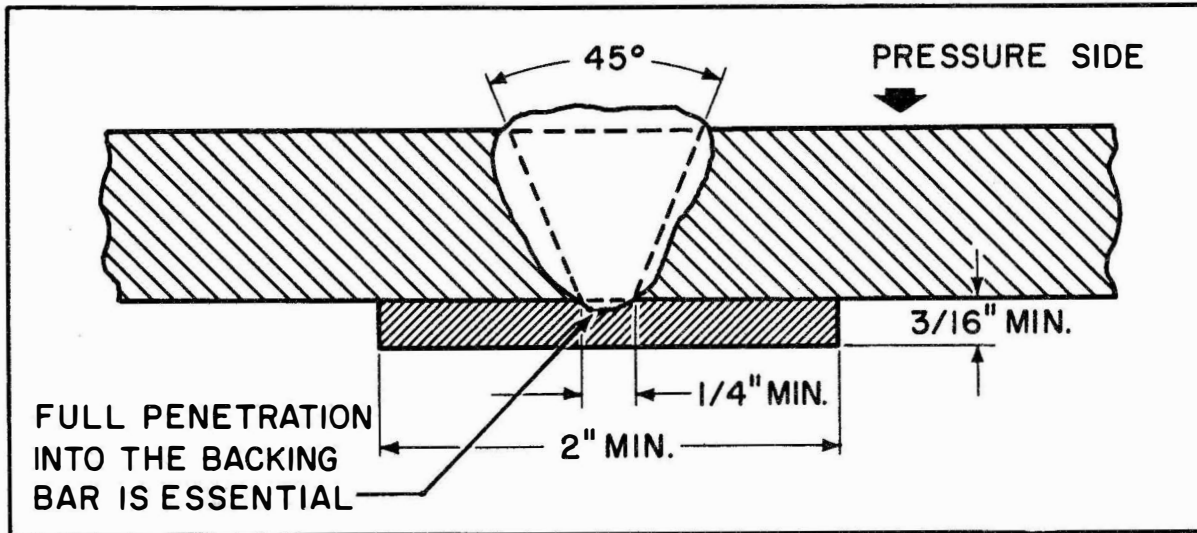


Figure 5-4. One Side Welding.

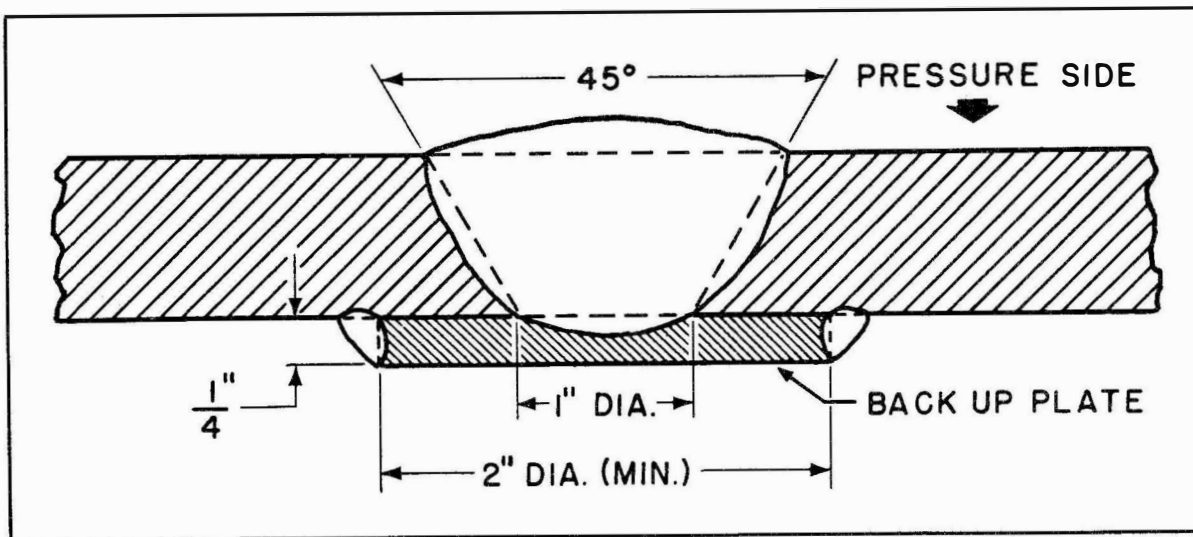


Figure 5-5. Plug Welds.

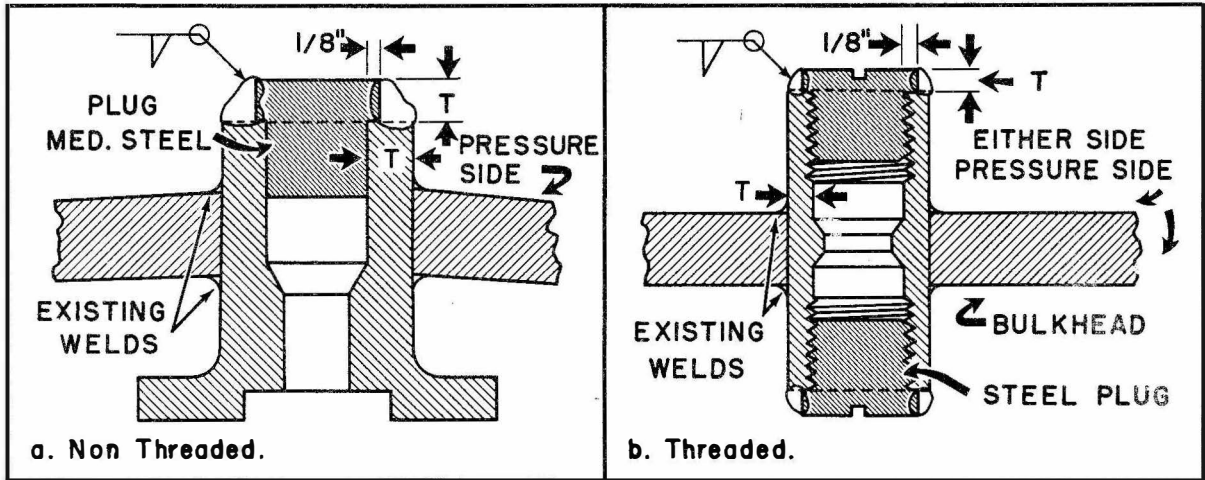


Figure 5-6. Temporary Closure.

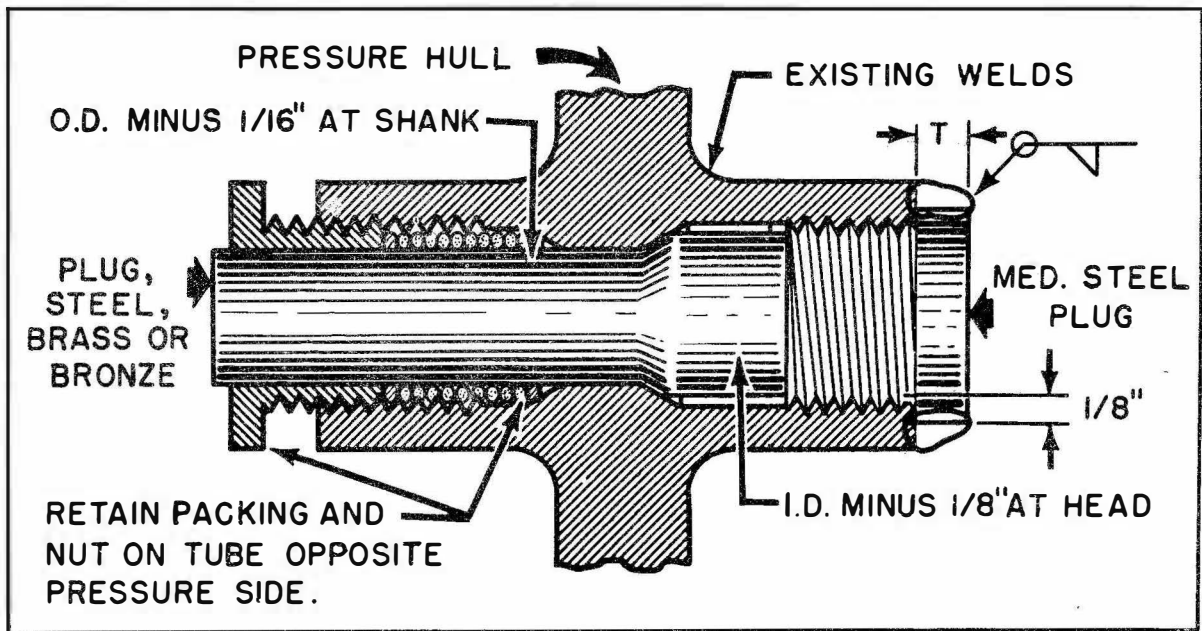


Figure 5-7. Temporary Closure.

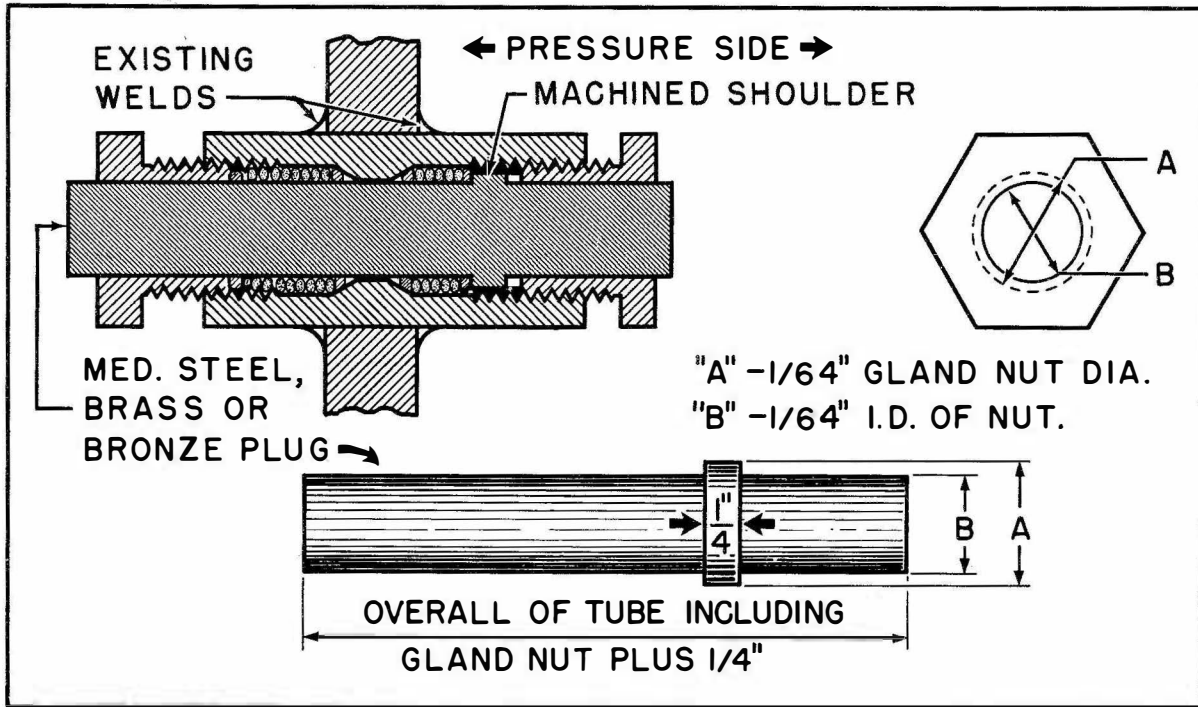


Figure 5-8. Temporary Closure (least desirable).

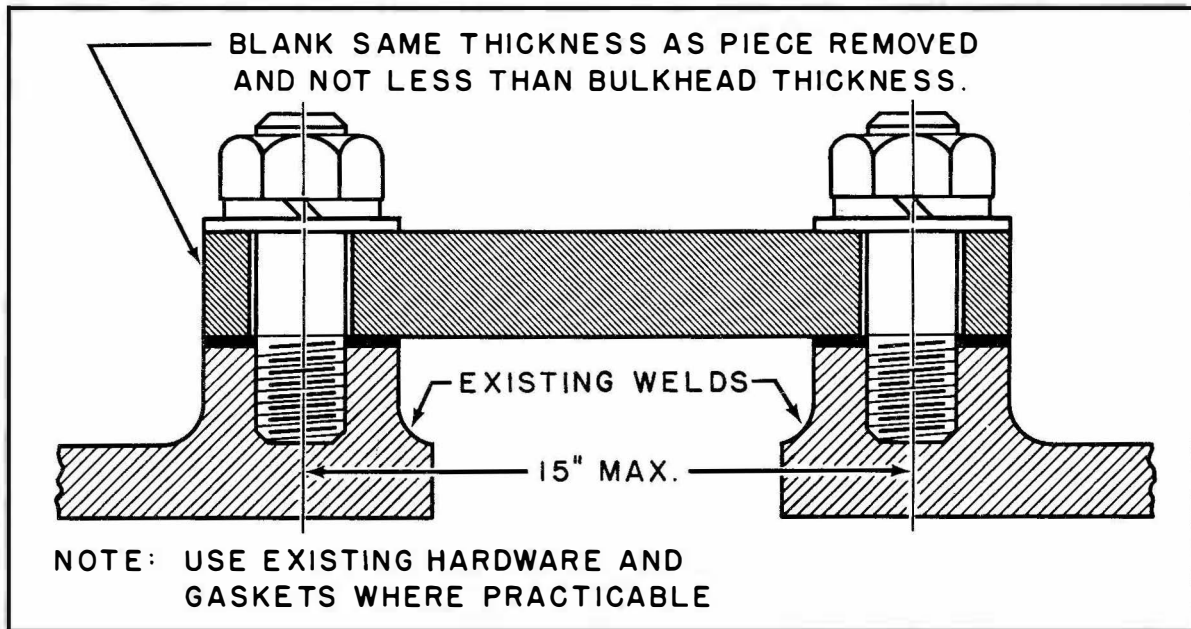


Figure 5-9. Temporary Closure (least desirable).

SECTION 9. SPECIAL TOOLS AND JIGS*

a. **OBJECTIVE** - Special tools and jigs devised by field activities have contributed to appreciable savings in man-hours and materials, with the resultant savings in hundreds of thousands of dollars. In most instances, special tools and jigs have improved the quality of the work in which they are utilized. The purpose of this sub-section is to disseminate information on special tools and jigs which will reduce the cost of installations, facilitate installation work, or provide greater safety for personnel; to the advantage and benefit of all personnel involved in the field of electronic installation.

b. **ADDITIONS** - Field activities and individuals (particularly military and civilian personnel performing the actual installation work) are encouraged to submit information on special tools and jigs. Submissions should be forwarded to the Electronics Division, Fleet Technical Branch (code 694), Bureau of Ships; and should include a written explanation of the device together with drawings or photographs when appropriate.

c. **SPECIAL TOOLS AND JIGS** - Special tools and jigs which have proven beneficial in installation of electronic and associated equipment.

(1) **KICKPIPE AND STUFFING-TUBE INSTALLATION GAGE** - A Philadelphia Naval Shipyard employee devised a positioning gage, shown in figure 9-1, for use in installing kickpipes and stuffing-tubes with more accurate alignment and satisfactory fit-up.

In the former method of installing kickpipes and stuffing tubes, a mechanic held the stuffing tube level, at a distance of 1/2 inch from one side of the bulkhead or deck, while a welder tacked the kickpipe to the other side. In this procedure improper fit-up frequently resulted from unsteadiness or poor eye-judgement.

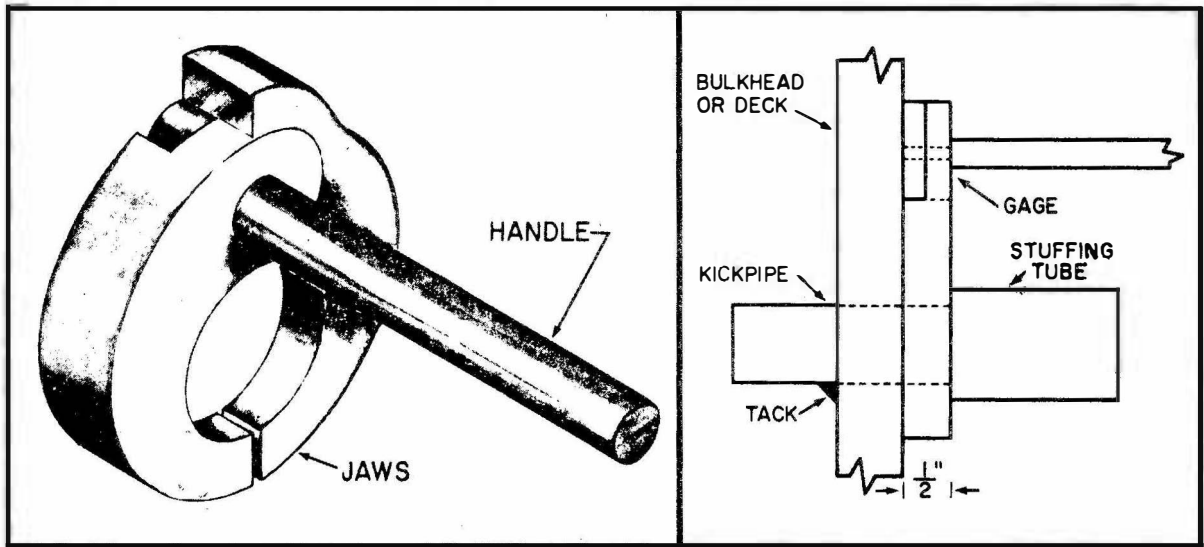


Figure 9-1. Kickpipe and Stuffing-Tube Installation Gage.

(2) **STABILIZER FOR BULKHEAD TUBE WRENCH** - An improved stabilizer for bulkhead tube wrenches has been devised by an employee of the Boston Naval Shipyard. The stabilizer fits over the bulkhead tube to keep the wrench from falling off the gland nut. See figure 9-2.

Previously, the stabilizer was a thin steel ring brazed to the wrench. The new stabilizer has expandable spring-steel fingers screw fastened to the wrench. It will fit both old and new type bulkhead tubes with ease. The fingers can be replaced if they are broken.

With the new stabilizer, the job can be done by one man instead of two. The shipyard estimates that the suggestion will save 500 man-hours a year.

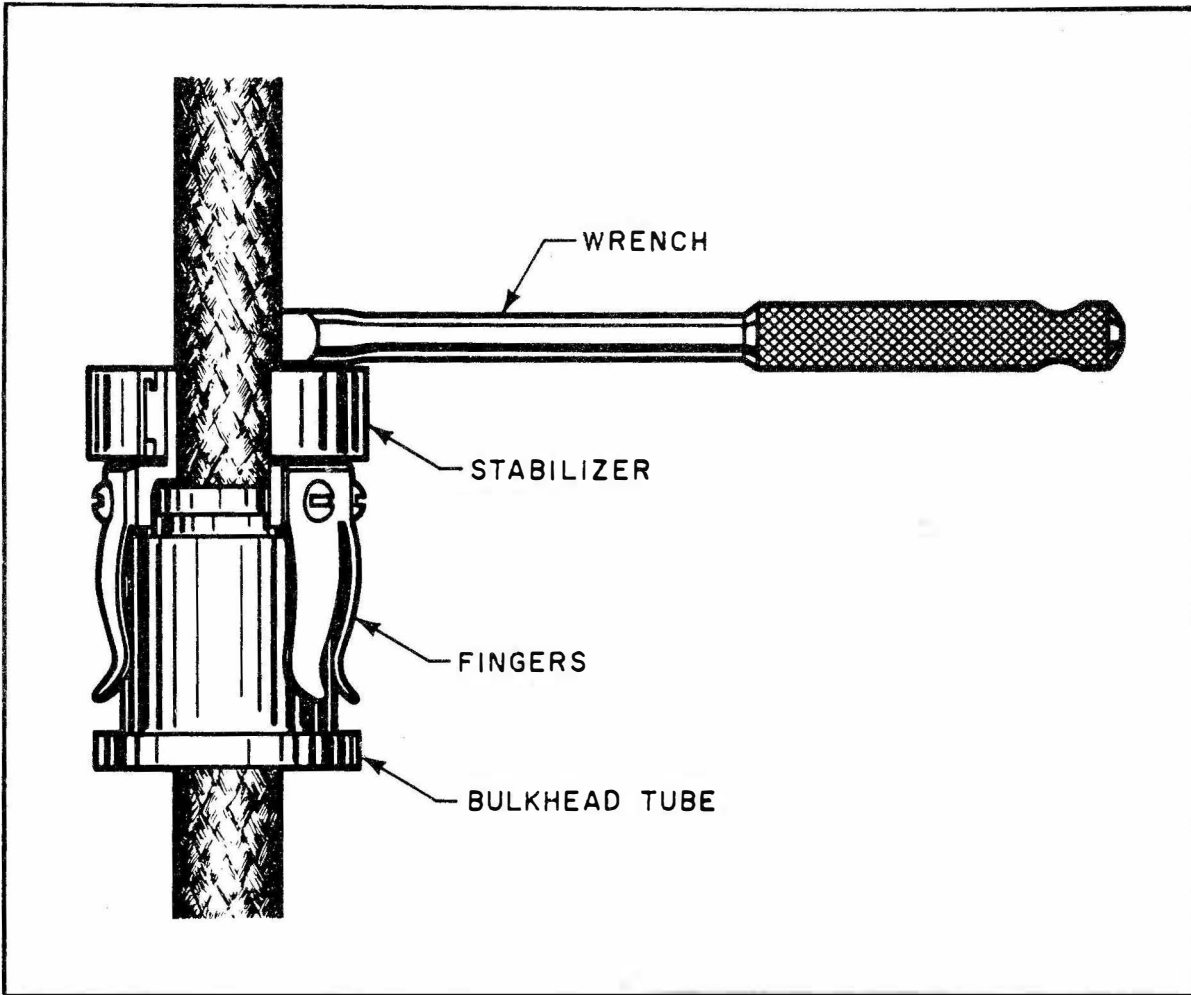


Figure 9-2. Stabilizer for Bulkhead Tube Wrench.

(3) **HOLE SAW FOR GLASS-WOOL INSULATION** - A tool that eliminates the need for patching glass-wool insulation after electrical studs are installed has been devised by an employee of U.S. Naval Repair Facility, San Diego. Formerly, large holes were cut in the insulation. The new tool cuts holes small enough to be covered by the gear being installed.

The hole saw consists of a center punch and two sizes of saw-edged holders. The center punch is driven through the insulation, marking the bulkhead where the stud is to be placed. The saw-edged holder, small for a straight stud or large for a collar stud, is placed over the punch and turned until the insulation is cut through to the bulkhead. See figures 9-3a and 9-3b.

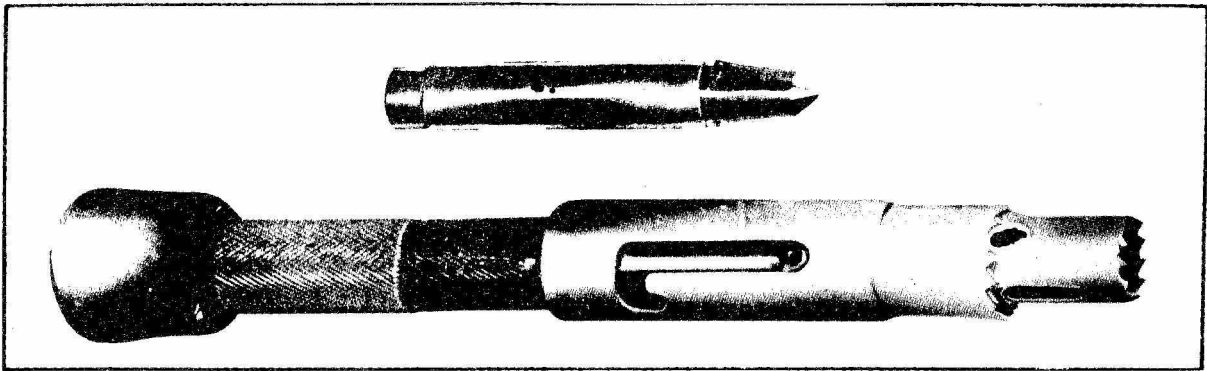


Figure 9-3a. Hole Saw for Glass-Wool Insulation.

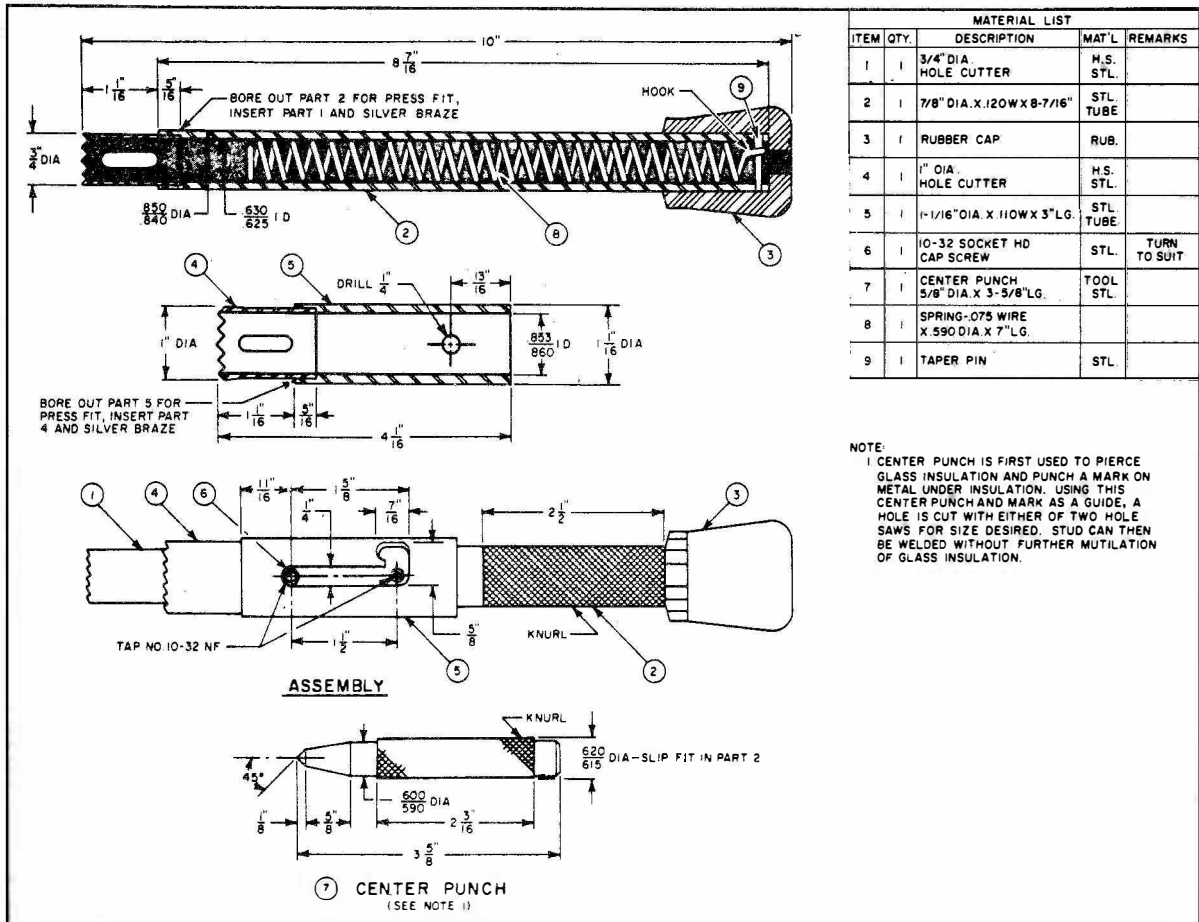


Figure 9-3b. Hole Saw for Glass-Wool Insulation - Fabrication Details.

(4) **CABLE MARKER PUNCH MACHINE** - An electrically operated punch for cable markers has been in use at the San Francisco Naval Shipyard for several years.

Previously, the markers were pierced with a hand-operated punch. With the solenoid-actuated piercing punch, marker production has increased from 700 to 1,200 markers an hour. In addition, the device completely eliminates the spoiling of markers, because it will not operate unless the marker is in the correct position. The slots are identically spaced on all markers.

The punch is soundproofed for impact noise by a form-fitting cover of plywood, lined with Cushiontone acoustical board. Although the punch is designed for aluminum tape, it can be used to pierce zinc tape if the punch end is modified to give the punch greater shearing action.

Manufacturing drawings and wiring diagrams may be obtained from the San Francisco Naval Shipyard.

(5) **CABLE BANDING STRAP REWINDING MACHINE** – At the Puget Sound Naval Shipyard, steel banding strap received on 100-pound spools is rewound on 10-pound coils so that it can be handled more easily. The steel banding strap is threaded through a hand guide. A safety cable is attached to the hand guide to prevent the operator's hand from being drawn into the revolving equipment if the strap should become jammed in the guide.

Manufacturing drawings of the rewind spools, the hand guide, and the assembly mandrel may be obtained from the Puget Sound Naval Shipyard.

(6) **GROUND LEAD STAPLER** – A shipboard use has been found for the familiar staple used in building fences and wiring dwellings. An employee of the Charleston Naval Shipyard believed that the method generally used to secure the grounding wires in wood hulls could be simplified. He suggested that a wire staple be used for supporting single cables instead of a single-hole, single-screw cable strap.

The staple is driven in place by a mechanical stapler to attach the branch ground leads to the hull. The stapler is modified slightly to shape the staple so that it fits snugly over the circular cross section of the ground wire.

(7) **PORTABLE OVERHEAD HOOK** – Frequently, material or equipment must be suspended from the overhead during installation or conversion work aboard ship. The usual procedure is to bend a line over a beam, pipe, or other convenient bracket. However, there is often no convenient bracket over which a line can be rigged.

A Philadelphia Naval Shipyard employee has devised a hook which makes it possible to suspend material or equipment from the I-beam in the overhead.

The simple device, resembling old-fashioned ice tongs, can be used to hang equipment from any overhead that provides an exposed I-beam. Illustrated in figure 9-4 is a portable overhead hook used at Philadelphia Naval Shipyard to suspend a doodlebug, a device used in welding operations.

A distinctive safety feature prevents the hooks from slipping off the I-beam; the weight hanging on the lower hooks of the tongs forces the upper hooks around the beam.

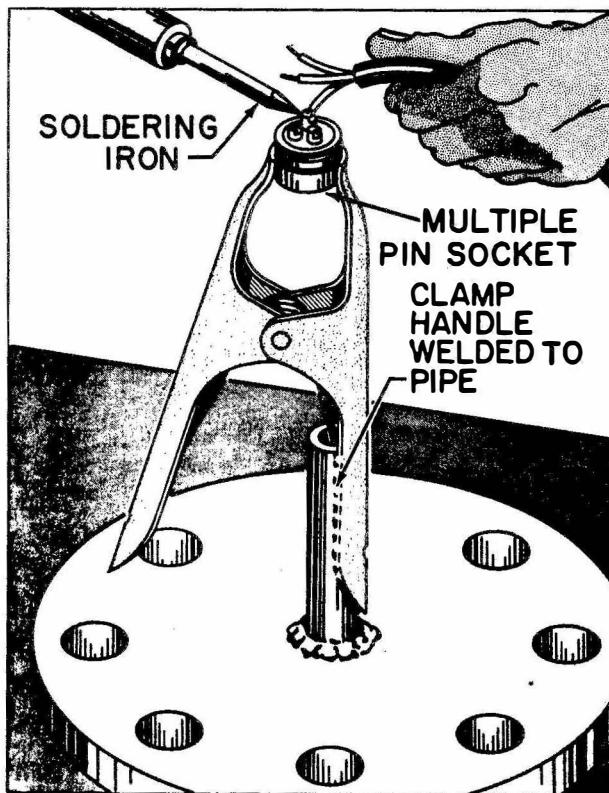
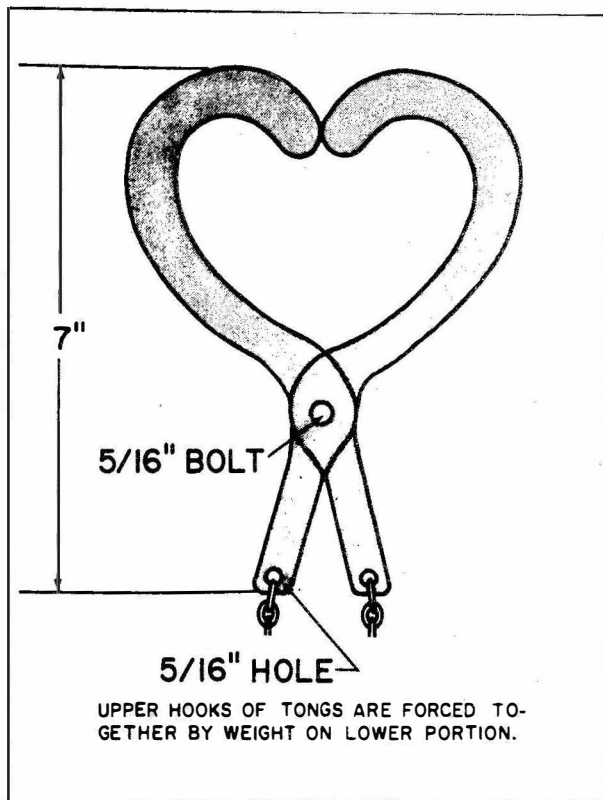


Figure 9-4. Portable Overhead-Hook. Figure 9-5. Portable Pressure-Grip Hand-Clamp Holder.

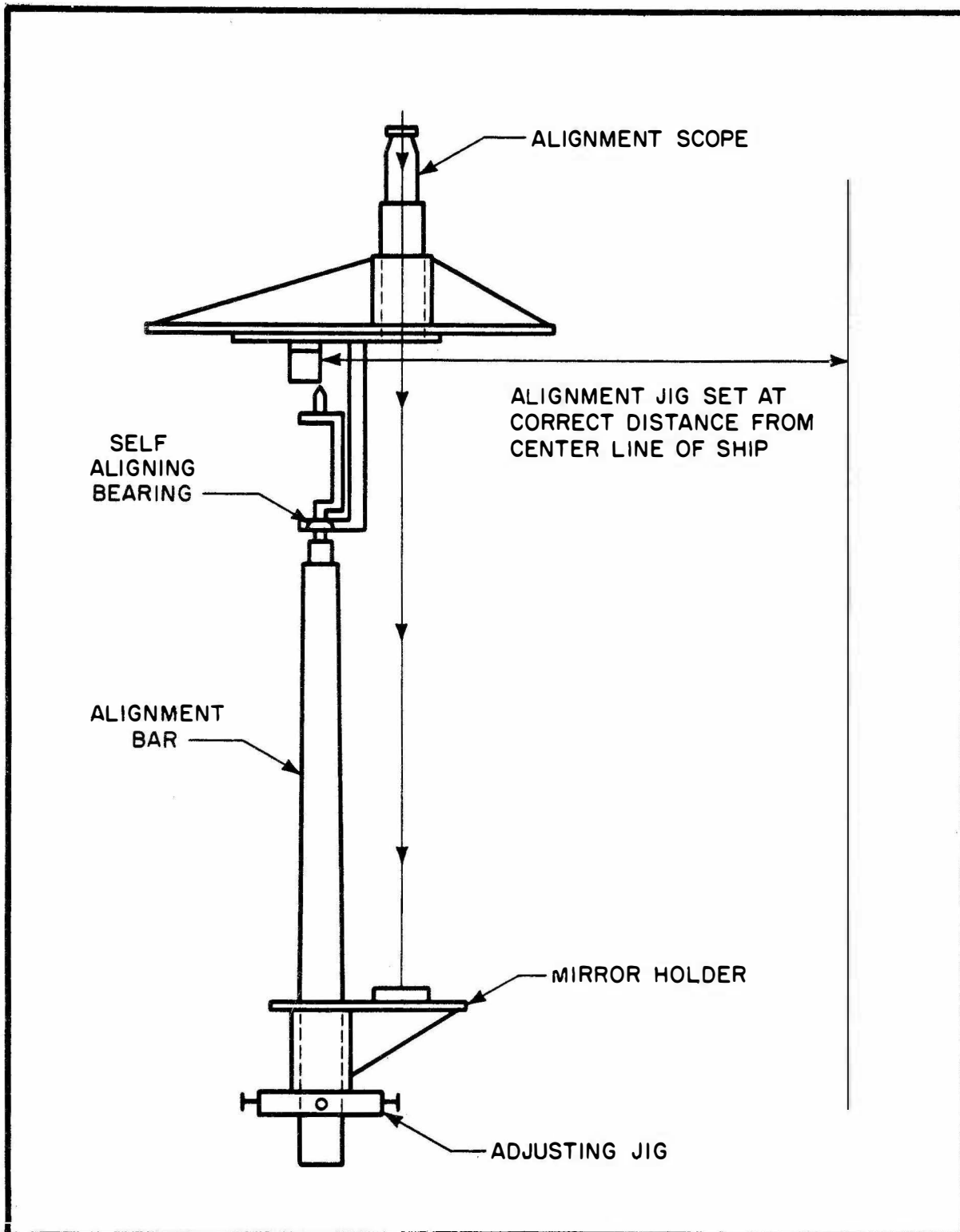


Figure 9-6. Hydrophone Alignment Jig.

(8) **PORTABLE PRESSURE-GRIP HAND-CLAMP HOLDER** – At Philadelphia Naval Shipyard, an employee has devised a holder for convenience in soldering leads to multiple pin sockets for electric and electronic equipment. It eliminates much of the difficulty formerly experienced in holding and turning the socket.

The holder involves the use of an all purpose, portable, pressure-grip, hand-clamp holder, as shown in figure 9-5. The socket can be easily inserted into the holder, and the holder can be conveniently turned around with the socket in it. Soldering of these multiple pin sockets can, therefore, be done much more expeditiously.

The device may be assembled from a clamp, a piece of pipe, and a flat circular base of 1/2 inch metal. The pipe is welded to the circular base and the clamp is welded to the pipe.

(9) **HYDROPHONE ALIGNMENT JIG** – An alignment jig for positioning hydrophones has been devised by an employee of the Pearl Harbor Naval Shipyard.

Formerly, the ship had to be held in drydock while each hydrophone position was aligned with a gunners quadrant.

With the new method, an alignment scope and a mirror are used to boresight each position by auto reflection. A special scope holder, mirror holder and adjusting jig were made for the job.

The scope holder is placed in the correct hydrophone position, obtained by a center line beam and a T-square marked for all 58 hydrophones. The alignment bar is inserted in the self-aligning bear. This end of the bar is then always in the correct position. The lower end of the bar is moved until the reflection of the mirror is picked up in the scope.

The line of sight establishes the reference points for the holes in the bottom mounting flange of the hydrophone. Then the mounting holes for the remaining mounting flanges can be located without difficulty.

The alignment set-up is then used to align the drilling jig. Once the drill jig is aligned, the holes can be accurately drilled with a portable pneumatic drill.

By use of this method, each position boresighted to within 0.008 inch in 11 feet. Actual time saved was approximately 267 man-hours. The hydrophone alignment jig is illustrated in figure 9-6.

(10) **TERMINAL-NUT REMOVAL TOOL** – The round nuts on standard Navy terminal boards can be removed without danger of shorting or loss of the nut by a simple modification of a common screwdriver.

A screwdriver with a 3/16-inch tip is preferable. The two-inch length of electrical insulation sleeving of proper diameter is placed over the tip such that it extends 3/16 inch beyond the tip end. The sleeving is secured to the screwdriver by electrical friction tape. See figure 9-7.

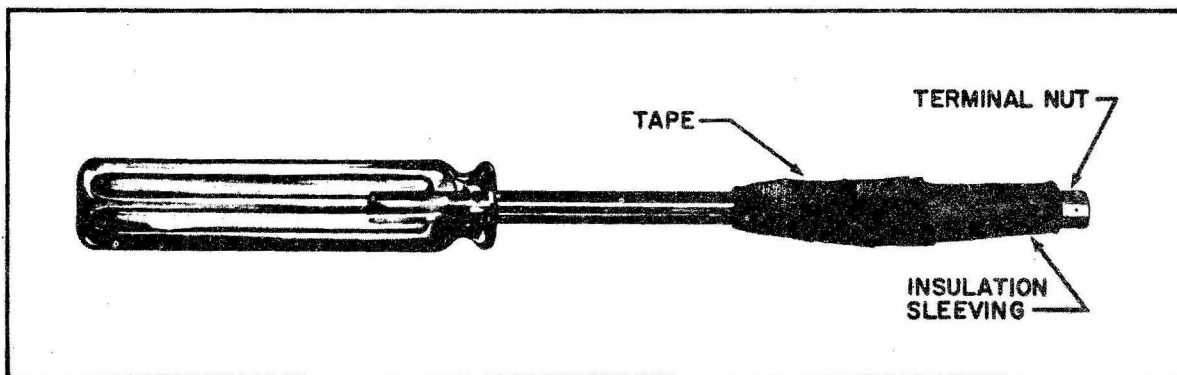


Figure 9-7. Terminal-Nut Removal Tool.

When the screwdriver is rotated slowly, the sleeving can be forced around the nut until the screwdriver tip engages the slot in the nut. When the nut is unscrewed it will be retained in the sleeving. To remove nuts from terminal board types 6TB, 7TB, 8TB, 9TB, 10TB, and 11RB use electrical insulation sleeving Stock Number G5970-221-5289; and Stock Number G5970-222-6644 for removing the nuts from terminal board types 25TB and 26TB.

(11) **CABLE-HANGER MACHINE** – A machine that rapidly makes shipboard cable hangers from square tubing has been developed by the Puget Sound Naval Shipyard.

The cable hangers are being used for new construction and conversion work, and several hundred thousand of the banding-type hangers are expected to be used for shipboard cableways in the future. All sizes of cable hangers are similar, and require a repetitious drilling and cut-off operation. A high production machine is therefore necessary and practical.

A cable hanger machine is now in the electric shop at the shipyard. The cable hangers it turns out are only half the cost of those produced under the previous method. The cable hangers are produced in a cycle time of 5 seconds for aluminum hangers, or 25 seconds for steel hangers.

Hangers from 3 to 17 inches in length are cut with a swinging cutoff wheel. A carbide-tipped saw is used for cutting aluminum tubing, and an abrasive wheel is used to cut the steel tubing. Two automatic air drills are mounted on the machine with tee-slots to permit various spacings for the drilled holes. Three styles of twist drills are used; one for aluminum, one ground for steel, and a stepped drill. When the mounting screw head is to be recessed within the hanger, the stepped-type drill makes a counterbored hole on one side of the tubing.

In operation the cycle is as follows:

1. The bar of tubing is slid along the guide by the operator. It extends beyond the cut-off wheel to such a point where the tubing strikes the length stop.
2. Three events occur simultaneously with the start of the cycle:
 - a. Two air clamps secure the tubing in its guide.
 - b. The air drills begin drilling through the tubing.
 - c. The cut-off wheel begins to feed through the tubing.
3. The cycle is timed so that the drills complete their operation first. As the cut-off is completed, the finished hanger drops into a box and the clamps, drills, and cut-off wheel retract to the starting positions.

A block insert for the stock guide is used to adapt the cable-hanger machine for drilling and cutting to length, the hanger supports used for the hangers. The cycle time for the angle is the same as that for the tubing.

(12) **CABLE BANDING TOOL** - Some time ago, Boston Naval Shipyard was experiencing difficulty in finding tools which could be used in banding cable. Four different types of tools were used, with no single tool being acceptable for all installations.

An employee of the Shipyard suggested manufacture of a low-cost tool from material available in the shipyard. This tool proved to be adaptable to 75 percent of the Shipyards banding requirements. The tool is made of tool steel and is used in conjunction with a 1/4 inch, squaredrive, reversible-ratchet handle. See figure 9-8.

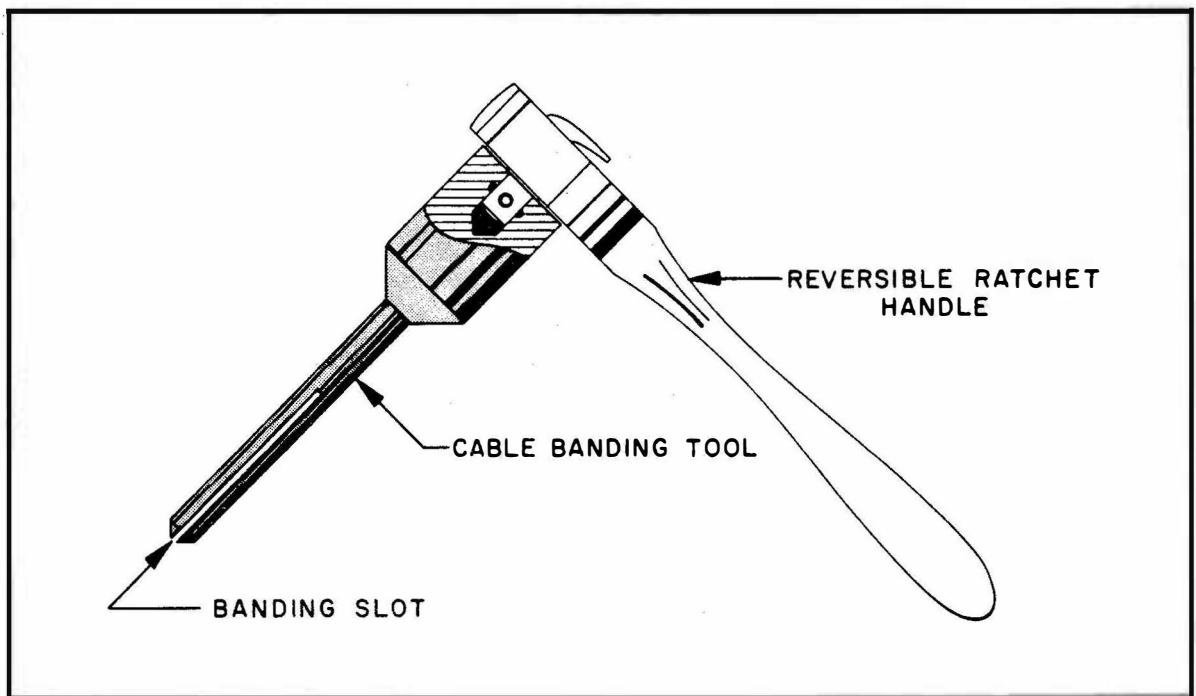


Figure 9-8. Cable Banding Tool.

The following steps are taken when the tool is used:

1. Cut sufficient banding to encompass cable and hanger.
2. Secure buckle on banding, and install around cable and hanger.
3. Take up slack by hand and cut off excess banding, leaving approximately 1 inch of banding beyond the buckle.
4. Insert banding in tool slot and tighten with ratchet.
5. When banding is tightened, bend roll against buckle and remove tool.

(13) **CABLE ASSEMBLY TEMPLATE** - A flat, 1/16 inch thick bakelite template can be made up as a guide in the assembly of coaxial cables to connectors.

Templates can be made up for the most commonly used assemblies and carried in a tool box. The small hole at the end of the template is used to fasten a sample of the cable and/or connector for quick means of identification. In addition, the template acts as a guide to proper lengths of cuts. See figure 9-9.

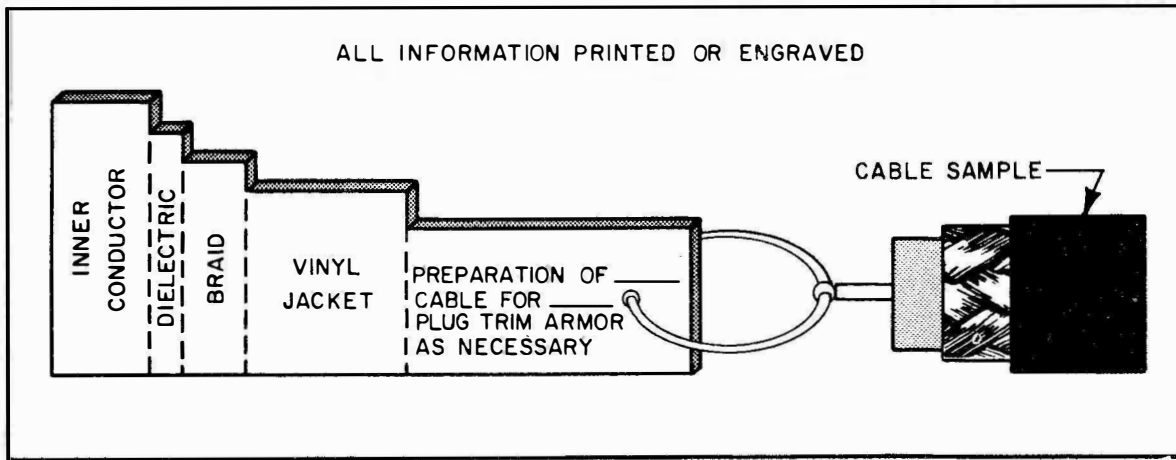


Figure 9-9. Cable Assembly Template.

(14) **ALUMINUM STUD WELDING ADAPTER** – An adapter for aluminum stud welding has been developed by an employee of the Boston Naval Shipyard. With the adapter, a regular steel stud gun can be used for aluminum. It is no longer necessary to change to a special controller and gun. See figure 9-10.

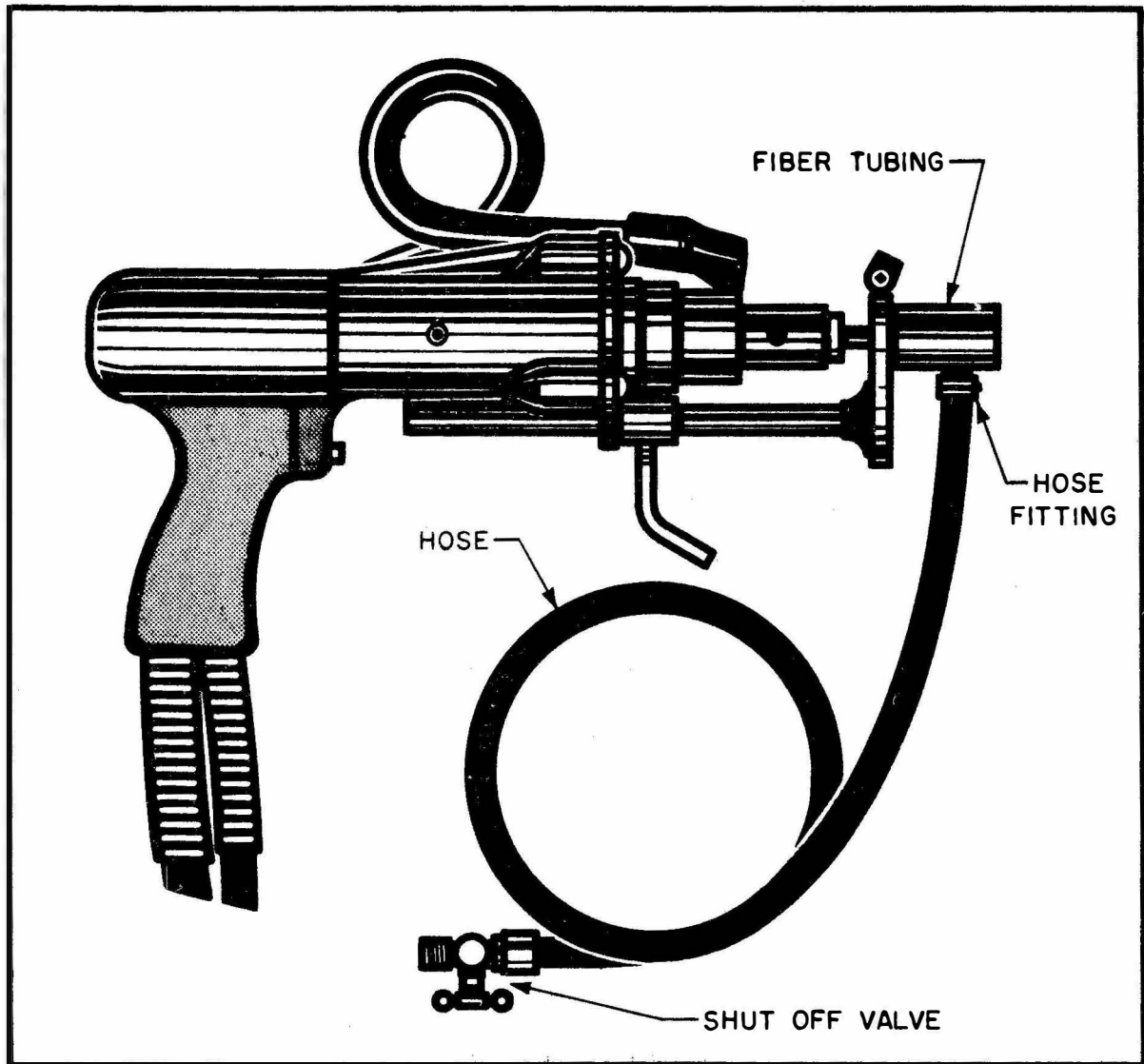


Figure 9-10. Aluminum Stud Welding Adapter.

The adapter consists of a piece of fiber tubing, 1/8 inch thick, 1 inch in diameter and 2 1/2 inches long. It is equipped with a hose fitting for gas, a hose, and a small shut-off valve. Approximately six evenly spaced triangular venting notches, about 1/32 inch deep, are cut around the bottom edge.

