Welding Principles

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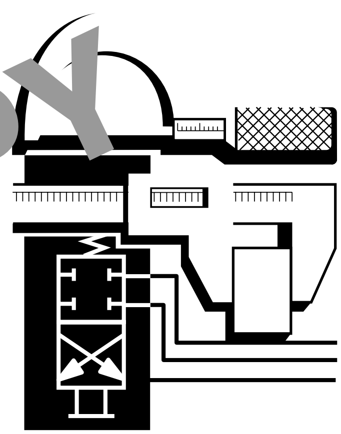
WELDING PRINCIPLES

Lesson One

Fundamentals of Welding



TPC Training Systems

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Lesson 1 Fundamentals of Welding

TOPICS

The Working of Metals
Common Welding Processes
Production Welding Processes
Kinds of Welded Joints
Kinds of Welds
Identifying Weld Parts
Fusion and Penetration
Joint Design and Fitup

OBJECTIVES

After studying this Lesson, you should be able to…

- Describe fusion welding, resistance welding, filler rods, and electrodes.
- Compare the oxyfuel and arc welding processes and compare the SMAW, GMAW, and GTAW processes.
- Describe and sketch the following kinds of joints—butt, lap, tee, corner, and edge.
- Describe the following kinds of welds—groove, fillet, plug, slot, spot, and seam.
- Name and locate the parts of a weld.
- Discuss basic considerations in joint design and fitup.

KEY TECHNICAL TERMS

Electrode 1.04 metal wire or rod that forms a part of the electric circuit in arc welding and may or may not become part of the weld
Alloy 1.06 combination of two or more metals
SMAW 1.12, 1.13 shielded metal arc welding, sometimes referred to as stick welding
GMAW 1.12, 1.14 gas metal arc welding, sometimes referred to as metal inert gas (MIG) welding
GTAW 1.12, 1.17 gas tungsten arc welding, sometimes referred to as tungsten inert gas (TIG) welding
Laying a bead 1.26 making a weld
Stringer pass 1.26 straight bead made without any side-to-side weaving motion
Fillet *(fill-it)* weld 1.29 weld that joins two surfaces at right angles to each other
Strap joint 1.46 combination lap and butt joint

Welding has become an important industrial process for joining metals. In production areas, welding processes are often used to fabricate and construct mass-produced products, large and small machines, plant equipment—for example, tanks and pipelines—and the structural framework for buildings. Most maintenance departments are equipped with welding equipment to make repairs, fabricate welded assemblies, and install plant equipment. Therefore, maintenance workers should understand the various welding processes and their applications.

This Lesson describes the most common welding processes, defines terms, and explains and illustrates the kinds of joints and weld characteristics. This information will lay the groundwork for a good working knowledge of welding.

The Working of Metals

1.01 The American Welding Society (AWS) defines *welding* as "a joining process that produces coalescence of materials by heating them to the welding temperature, with or without the application of pressure or by the application of pressure alone, and with or without the use of filler metal." Generally, welding involves heating the edges or parts of two pieces of metal until they become molten (melted) and flow together. This process, referred to as *fusion welding*, requires that metals be heated above their melting points. Welds can be aided by applying pressure and/or adding filler metal, which is frequently, but not always, desirable. When two or more metal parts are joined by a weld, the assembly is referred to as a *weldment.*

1.02 The most widely used welding processes for maintenance welding are *oxyfuel welding* and *arc welding*. The high temperatures needed for fusion are obtained with a gas flame in oxyfuel welding and with an electric arc in arc welding. *Resistance welding* requires electricity and the application of pressure to make welded joints. Resistance welding is primarily a production welding operation. Common welding processes are listed in Table 1-1.

1.03 The metals added during a welding process are referred to as *filler metals*. They include welding rods, more commonly called filler rods, and electrodes. In some welding processes, a space is left between the edges of the parts to be joined. Filler metal is put in the space to help distribute heat and to build up and strengthen the joint. This method—filling the space—helps promote better penetration in joints in metals more than 1/4-in. (6mm) thick.

1.04 The terms "filler rod" and "electrode" should not be used interchangeably because there is an important difference between them.

- A *filler rod* is the metal wire or rod used in oxyfuel welding and in certain arc welding processes in which the filler metal is not a part of the electric circuit. The only purpose of filler rods is to supply filler metal to the joint.
- A welding *electrode* is a metal wire or rod that, in arc welding, forms a part of the electric circuit. Some electrodes are a source of filler metal and are consumed (used up) in making a weld. Others are used only as an electric element for forming the arc.

1.05 Metalworking began in prehistoric times when stones were pounded and chipped to make sharp implements and weapons. This pounding and shaping led to methods of forging and blacksmithing. It was found that stones having a high content of copper, tin, or iron made better tools and weapons

Table 1-1. Common welding processes

Maintenance and production processes		Production processes
Oxyfuel welding	Arc welding	Resistance welding
Fusion welding	SMAW	Spot
Torch brazing	GMAW	Seam
	GTAW	Projection
	Submerged arc	Flash
		Upset

Fig. 1-1. Oxyfuel welding

Fig. 1-2. The SMAW process

because they held an edge better than other stones. Silver and gold were easier to work, but they were too soft for uses other than ornamental.

1.06 Soon people found that certain stones were easier to work when heated. Archaeologists believe copper was one of the first metals worked, followed closely by tin and iron. About 7000 BC, the hardness of copper was improved when it was combined with tin. The result was bronze, the first *alloy* (a combination of two or more metals).

1.07 The first alloys were made by heating two dissimilar metals and hammering them together, an early form of forge welding. Later, when people learned to make hotter fires, they found that by melting and mixing two dissimilar metals, they could produce an alloy that changed or improved the properties of the metals. The process of casting metals (pouring molten metal into a mold or form to obtain desired shapes) began at about this time.

1.08 For thousands of years, metalworking was limited to the forging, alloying, and casting processes. Then, in the 1880s, electricity was introduced into metalworking. The first arc welding outfit was used mainly to fill holes and cracks in castings. It operated with a DC power source that consisted of a bank of batteries with cables and a stick of carbon.

1.09 An electric spark or arc was produced between the base metal and the carbon stick. The arc melted a small area on the base metal, and metal was added to fill casting defects. Soon, bare metal rods were substituted for the carbon stick, and about 1912, coated metal electrodes were introduced. Ac power sources for welding were not accepted by industry until after 1930. Since then, many technological advances have made welding a basic industrial process.

Common Welding Processes

1.10 **Oxyfuel welding.** Oxyfuel welding is popular for maintenance and repair work because the oxyfuel welding outfit is easy to move, set up, and operate, and it does not require external power. When oxygen and fuel gases are mixed in the proper proportions and burned, they produce an extremely hot flame that melts practically all metals. Normally, a filler rod is applied to help build up and strengthen the weld. The process by which the flame melts the base metal and filler metal, causing them to flow together and form a permanent welded joint, is one form of fusion welding.

1.11 Most oxyfuel welding is a two-handed operation. The torch is moved with one hand while the other hand feeds in the filler rod, as in Fig. 1-1. Practice is needed to coordinate these movements.

1.12 **Arc welding.** Electric arc welding processes are frequently used for industrial maintenance and production work because neat and strong welds can be made quickly. The most common processes are shielded metal arc welding (SMAW), gas metal arc welding (GMAW), and gas tungsten arc welding (GTAW). In each of these arc processes, electrical power is fed through and regulated by a welding machine, and then it is fed through cables to the point of operation. When relatively low voltage and high amperage (current) are applied, an electric arc is formed between an electrode and the metal to be welded. Heat from the arc melts both the base metal and the electrode, which flow together and form a permanent joint. This process is another kind of fusion welding.

1.13 In the *SMAW* process, sometimes referred to as stick welding, the weld is made with special consumable metal rods or electrodes, as shown in Fig. 1-2. The arc melts the electrode, and the filler metal from the electrode core is added to the weld. Special materials in the electrode coating create a gaseous cloud that shields the arc area from atmospheric contamination. As the weld cools and solidifies, it is further protected by a deposit of slag formed as the electrode coating is burned away. In most cases this slag must be cleaned off after the weld is completed.

1.14 Another form of arc welding is *GMAW*, sometimes referred to as metal inert gas (MIG) welding. MIG welding is no longer an accurate term because gases used today are not necessarily inert. (Inert gases do not react chemically with the electrode and base metal.) In the GMAW process a continuous consumable wire electrode is mechanically fed through a special gun. A wire feed control unit pushes the electrode wire through a flexible cable to the gun. During the welding operation a shielding gas—for example, carbon dioxide (CO_2), argon, helium, or a mixture of these gases—is fed into the arc area to protect the molten weld from atmospheric contamination. Shielding gas is drawn from a pressurized cylinder through a tube to the arc area.

1.15 The GMAW process is faster than SMAW and requires less operator training and practice. Because of its high speed and narrow heat zone, the GMAW process causes less distortion of the base metal around the weld area. GMAW also requires less weld cleaning because there is no slag deposit as there is with SMAW.

1.16 However, the GMAW equipment requires more complex setup and adjustment procedures. A typical GMAW outfit, shown in Fig. 1-3, consists of a DC welding machine, a wire feed control unit, and a cylinder of shielding gas with a regulator. Although the GMAW equipment is generally large and bulky, some GMAW outfits are mounted on carts or trailers so they are portable. Portable GMAW outfits can be used wherever there is a source of electric power.

1.17 The third common form of arc welding, *GTAW*, is sometimes referred to as tungsten inert gas (TIG) welding. Heliarc® is one manufacturer's name for its GTAW equipment. In the GTAW process, a nonconsumable tungsten electrode creates an arc while an inert shielding gas is fed into the arc area as in the GMAW process. If filler metal is required, it is fed in separately, either mechanically or by hand in the weld puddle. GTAW requires more careful joint fitup and preweld cleaning than other processes, but it is particularly well suited to welding thin base metal and metals that are difficult to weld.

1.18 The GTAW outfit consists of a standard AC/DC or DC welding machine, a cylinder of shielding gas, a gas regulator, and a special holder for the tungsten electrode. These holders, referred to as torches, are either air cooled or water cooled because the tungsten electrode produces very high temperatures.

Production Welding Processes

1.19 Besides oxyfuel welding, SMAW, GMAW, and GTAW, some maintenance shops are also equipped with

Fig. 1-3. GMAW outfit

®Heliarc is a trademark of ESAB Welding and Cutting Products.

Fig. 1-4. Typical portable spot welding machine

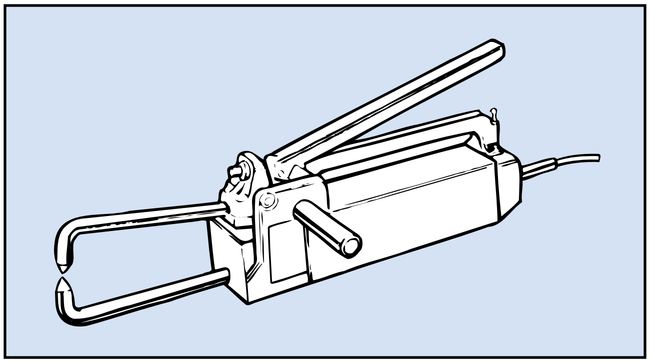
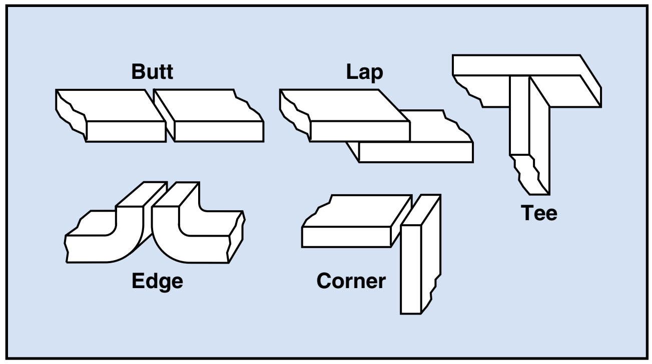


Fig. 1-5. The five basic weld joints



resistance welding equipment. In spot welding, one form of resistance welding, two pieces of metal are placed together and clamped between two electrodes. Then a short burst of high electric current heats and fuses the metals at the spot under pressure. A disadvantage of resistance welding is that it is generally limited to joining metals less than 1/4 in (6 mm). thick. One kind of portable spot welding machine is shown in Fig. 1-4.

1.20 Resistance welding is primarily a production welding process. It includes spot, seam, flash, upset, and projection welding. Other production welding processes including stud, forge, thermite, electron beam, laser, and plasma welding are not normally available in a maintenance shop, but they are used on some production lines and in welding fabrication shops.

Kinds of Welded Joints

1.21 A welded joint is the union of two or more pieces of metal by means of a welding process. The five basic kinds of welded joints are the butt, edge, tee, corner, and lap joints, which are shown in Fig. 1-5. Each of these joints has several variations.

1.22 *Butt joints* join the edges of two metals that are placed against each other end to end in the same plane. These joints are frequently used for plate, sheet metal, and pipe work.

1.23 *Lap joints* connect overlapping pieces of metal, which are often part of a structure or assembly. The lap joint is popular because it is strong and easy to weld. In addition, special beveling or edge preparations are seldom necessary. Lap joints are common in torch brazing processes, for which filler metal is drawn into the joint area by capillary action, and in sheet metal structures fabricated with the spot welding process.

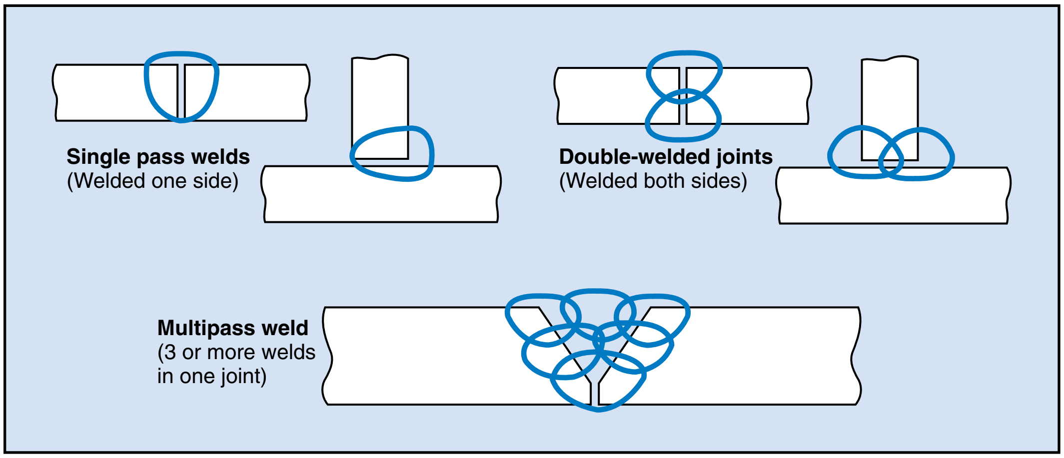
1.24 *Tee joints* and *corner joints* connect two metals that are positioned at right angles to each other. The corner joint is L-shaped and the tee joint is T-shaped. Low-pressure tanks, boxes, trays, and other objects are made with corner joints.

1.25 *Edge joints* are made when one or more of the pieces to be connected is flared or flanged. The metals can be joined positioned next to each other or with one on top of the other, as long as their flared or flanged surfaces are connected. Edge joints are sometimes used in plate work, but more frequently with sheet metal. They also fasten reinforcing plates to the flanges of I-beams and to the edges of angles.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of the book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. In fusion welding, parts of two metals are heated until they become ________ and flow together.	1-1. MOLTEN Ref: 1.01
1-2. The main difference between filler rods and electrodes is that ________ are part of an electric circuit.	1-2. ELECTRODES Ref: 1.04
1-3. The heat for oxyfuel welding is produced by a(n) ________ when two gases are burned.	1-3. FLAME Ref: 1.10
1-4. Arc welding processes use relatively ________ voltage and ________ amperage.	1-4. LOW; HIGH Ref: 1.12
1-5. Both the ________ and the ________ arc processes use consumable electrodes, but only ________ forms a slag deposit.	1-5. SMAW, GMAW; SMAW Ref: 1.13
1-6. Because of its high speed and narrow heat zone, the GMAW process causes less ________ of the base metal than SMAW does.	1-6. DISTORTION Ref: 1.15
1-7. Resistance welding is generally limited to joining metals less than ________ in. (mm) thick.	1-7. $^{1}/_{4}$ in. (6 mm) Ref: 1.19
1-8. What kind of joint joins the edges of two metals without overlapping? What kind of joint joins flanged or flared surfaces?	1-8. BUTT; EDGE Ref: 1.22, 1.25

Fig. 1-6. Examples of single, double, and multipass welds



Kinds of Welds

1.26 The basic welds are the groove, fillet, plug, slot, spot, and seam. Welds are often called *beads*. The act of making a weld is often referred to as *laying a bead*. A straight bead made without any side-to-side weaving motion is called a *stringer pass*. A single-pass weld or a single-welded joint is made with a single bead. A double-welded joint is made with two single-pass beads, one on each side of the joint. A multipass weld is made with two or more beads that are added in layers. This weld is used for a wide joint in thick metals. Examples of single and multiple welds are shown in Fig. 1-6.

1.27 **Groove welds.** Groove welds are made in a specially prepared furrow or groove that has been cut, ground, or filed in the joint edges. Often joint edges are prepared for groove welding by flame cutting, shearing, machining, or chipping. Various groove welds are shown in Fig. 1-7. Groove welds are chosen according to plate thickness, welding process, and operator skill. Of those shown, the square, bevel, and vee grooves are most commonly used for maintenance welding.

1.28 Although the term "groove weld" generally describes butt joints, groove variations are sometimes applied to the perpendicular part of a tee joint or the exposed ends of an edge joint. Lap joint edges are rarely grooved. The kind of groove weld to be made depends on the design of the part, how easy it is to reach the part, and the depth of penetration necessary. Whenever possible, the square groove is used because no special beveling or edge preparation is necessary.

1.29 **Fillet welds.** A *fillet weld* is triangular in cross section and is used in joints that have two surfaces approximately at right angles to each other. Fillet welds are applied to lap, tee, and corner joints. Common variations of the fillet weld are shown in Fig. 1-8.

1.30 Another fillet weld (not shown) is the *boxing fillet* or a *weld-all-around,* which is a box-shaped weld bead run around the perimeter of a small piece of metal lying on top of a larger piece. The boxing fillet is a continuous fillet weld made to attach the smaller piece of metal firmly to the larger one. It is often used to attach stiffeners, wear plates, brackets, handles, or guides to the face of a large metal surface.

1.31 **Plug and slot welds.** Plug welds and slot welds, shown in Fig. 1-9, are sometimes used to join overlapping plates whose edges cannot be easily reached for welding. These welds are used primarily to fill holes rather than to join metals. They can be used to join face hardened plate from the back (soft side), to line tanks with metals, or to fill a hole in a plate. Occasionally, a plug weld is made through a hole in one member of a lap or tee joint to help bond that member to another.

1.32 Slot welds are similar to plug welds except that the slot, or hole, is longer and more of the bottom member is exposed. Slot welds fill the slot. When a weld is made inside a slot at the intersection of the

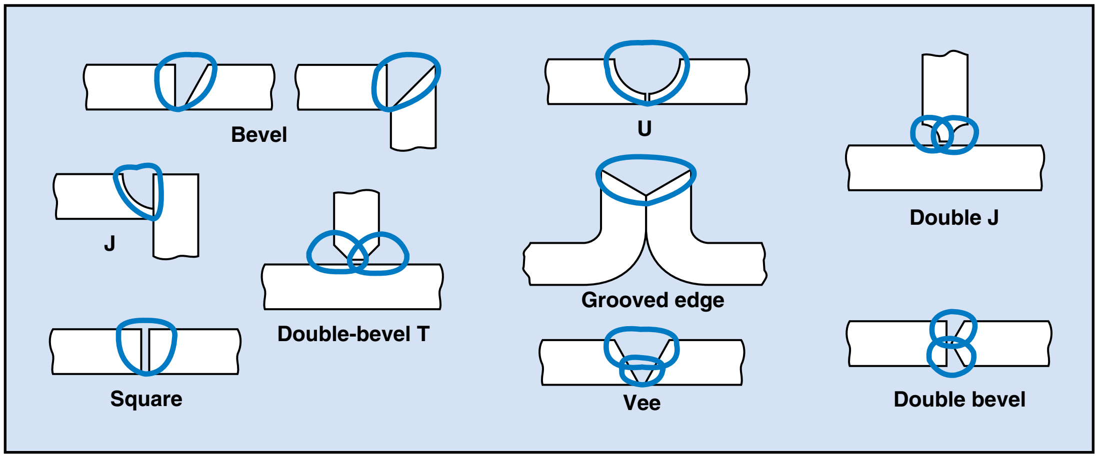


Fig. 1-7. Common groove weld variations

slot edge and the surface of the bottom member but does not fill the slot, it is a fillet weld, not a slot weld. Fillet welds inside slots can strengthen an assembly in which standard fillet or groove welds are not suitable.

1.33 **Spot and seam welds.** Spot welds and seam welds are common welded joints made by resistance welding. The welds are made by a combination of applied pressure and the heat obtained from the resistance of the base metal to the electric current. A spot weld is made when the parts of the joint overlap. A seam weld is similar to a spot weld and can be made as a series of overlapping spot welds. More commonly, however, a seam weld is a continuous weld made with a circular (wheel) electrode.

1.34 In addition, welds are referred to as tack welds, skip welds, or continuous welds. *Tack welds* are temporary welds that align the metals to be joined before final welding. They are usually less than 1 in. (25 mm) long. *Skip welds* are made by spacing short weld beads intermittently along the length of the joint. These welds reduce the amount of welding in joints that do not have to withstand large stresses and reduce warping and distortion of the base metal caused by the heat. *Continuous welds* are made by laying an unbroken bead the entire length of the joint.

Identifying Weld Parts

1.35 Various weld parts are identified in Fig. 1-10 on the following page. *Reinforcement* is the thickness of weld metal piled above the surface of the base metal or above the plane from toe to toe of a fillet weld. Reinforcement thickness varies with base metal thickness, generally ranging from a maximum of 1/8 in. (3 mm) for

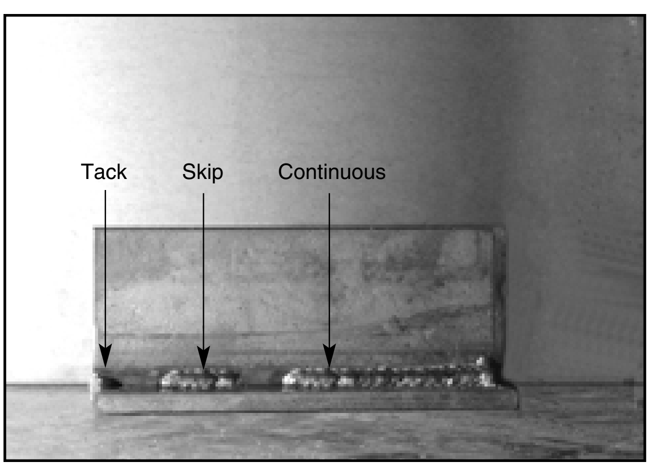


Fig. 1-8. Examples of fillet welds

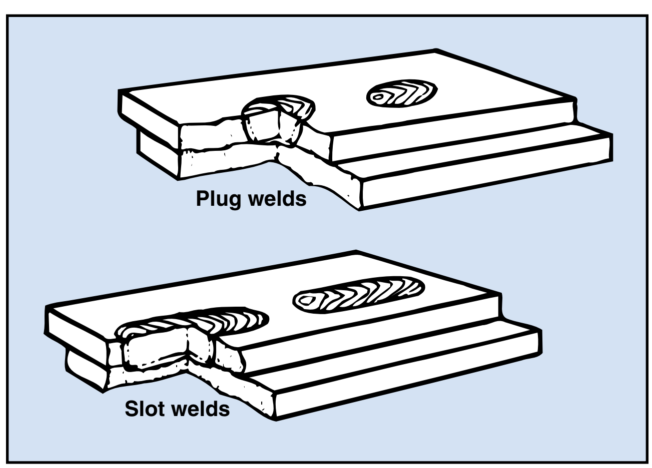
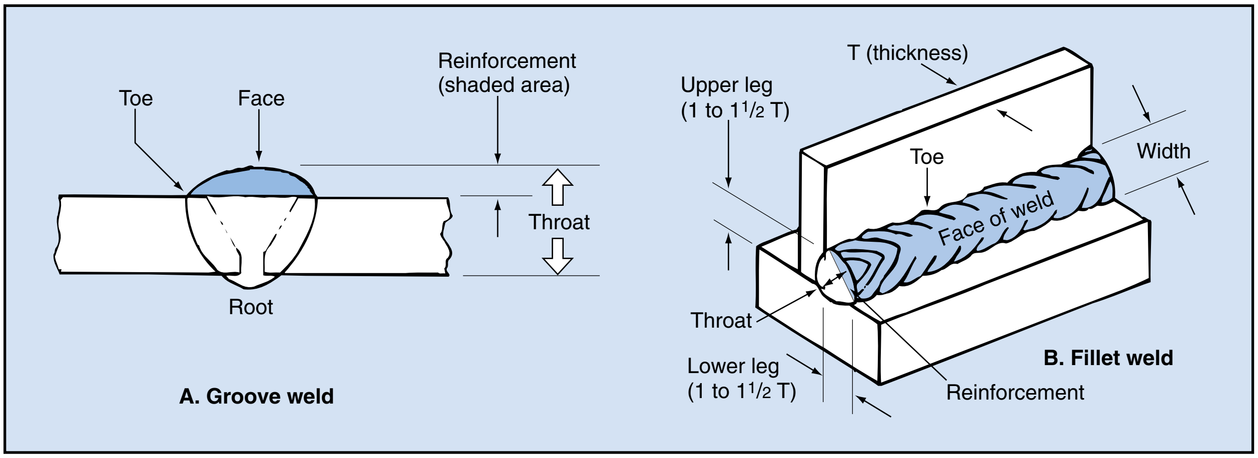


Fig. 1-9. Plug and slot welds

Fig. 1-10. Parts of a weld



base metals thicker than 1/4 in. (6 mm) to a minimum of 1/16 in. (2 mm) for base metals 1/16 in. (2 mm) or thinner.

1.36 The edges or sides of a weld where the weld metal meets the base metal are the *toes* of the weld. The exposed weld surface bounded by the toes is the *face* of the weld and can be convex (curved outward) as in Fig. 1-10A, or concave (curved inward). Most welds appear approximately triangular in cross section. The *root* of a weld is the point of the triangle opposite the face of the weld.

1.37 The distance across the face of a weld, measured from toe to toe, is its *width*. Width is related to base metal thickness and varies with the welding process used. For example, oxyfuel welds are generally wider than SMAW welds, which are generally wider than GMAW and GTAW welds. Weld width is determined mainly by the operator's skill and the techniques used. The average width of most single-pass welds is 1/4 in. to 1/2 in. (6 to 13 mm).

1.38 The distance through the center of a weld (from face to root) is the *throat* of the weld. Throat depth is about equal to the thinner of the two base metals. *Weld legs* describe the thickness of a fillet weld made in a lap or tee joint. Weld legs are the distances the weld metal rises and spreads on the base metal in the joint, as shown in Fig. 1-10B. Generally, the fillet weld legs should be about equal to, or slightly larger than, the thickness of the base metal.

Fusion and Penetration

1.39 Complete fusion and adequate joint penetration are necessary in any weld joint, especially if the fin-

Fig. 1-11. Weld fusion and joint penetration

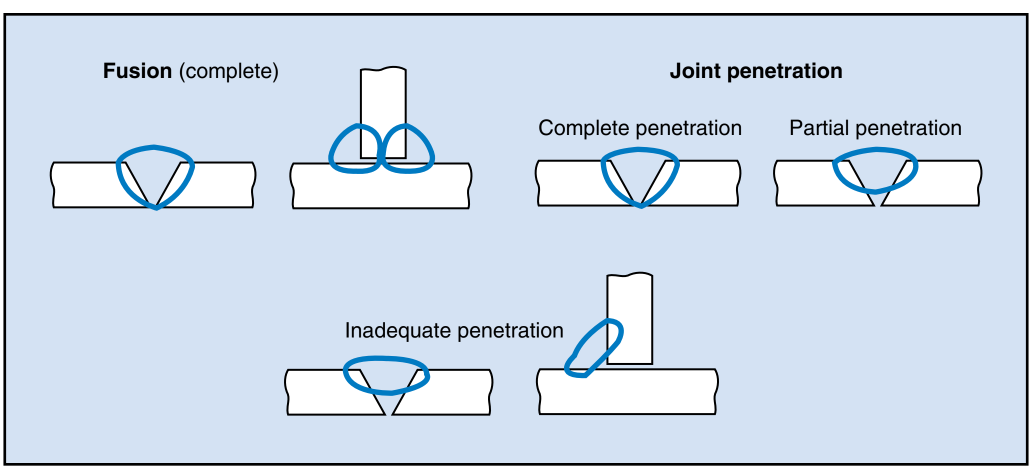
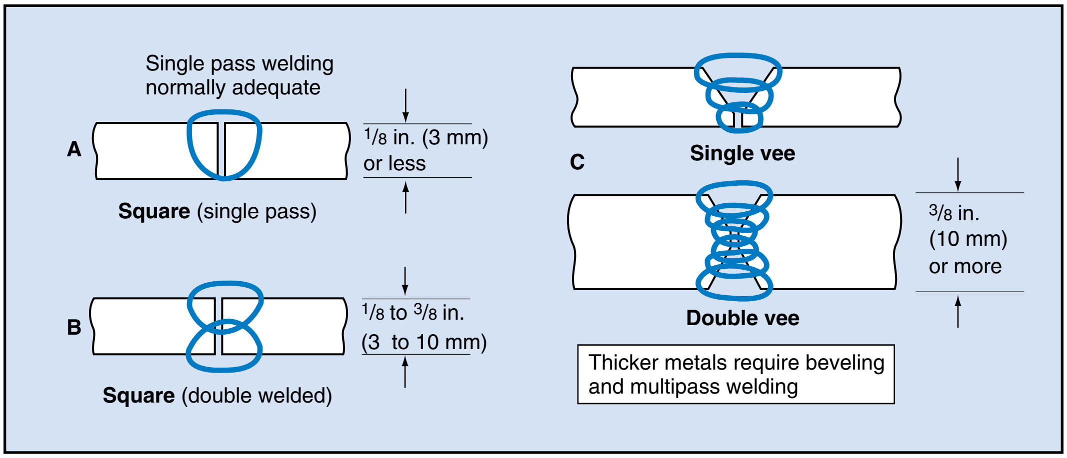


Fig. 1-12. Common butt welded joints



ished weld must withstand severe stress or high pressures. Fusion is complete if all of the original joint surfaces are melted and fused with filler metal as the weld is made, as shown in Fig. 1-11. Fusion to a depth of about 1/16 in. (2 mm) is considered adequate for most welds. Deeper fusion does not improve weld strength significantly, and the added heat can cause unnecessary distortion and weakening of the base metal.

1.40 Joint penetration refers to the depth to which the weld has entered the joint area. Examples of satisfactory and inadequate joint penetration are shown in Fig. 1-11.

Joint Design and Fitup

1.41 Adequate fusion and penetration depend mainly on joint fitup—that is, joint alignment, spacing, and edge preparation. For example, it is easier to achieve uniform fusion and sufficient penetration in thick metals with a bevel or vee-grooved butt joint because the groove exposes more of the joint surface for welding.

1.42 Joint design is the configuration (arrangement) and preparation of the edges or mating surfaces of a joint to be welded. Each of the basic joints (butt, lap, tee, corner, and edge) has numerous variations to fit the service requirements of finished welds. The kind of welded joint to be made depends on the loads or stresses (tension, compression, shear, torsion, and/or bending) it must withstand.

1.43 Butt joints, for example, can withstand tension better than they can the bending stresses concentrated at the root of the weld. The square butt joint is used primarily for metals less than 3/8 in. (10 mm) thick. Fitup for the square butt joint consists of aligning and spacing the squared edges. For metals up to 1/8 in. (3 mm) thick, single welding usually provides sufficient strength and penetration, as shown in Fig. 1-12A. Welding on both sides (double welding) is recommended for square butt joints in metals 1/8 to 3/8 in. (3 to 10 mm) thick, as shown in Fig. 1-12B.

1.44 When metal thickness exceeds 3/8 in. (10 mm), as shown in Fig. 1-12C, the joint edges should be beveled or grooved before the joint is welded. This edge preparation exposes more of the internal joint surfaces for better penetration in thicker metals. The vee-grooved butt joints generally require more weld filler metal than the U- or J-groove variations do. The double-vee butt joint is usually best for normal load and stress conditions. None of the butt joint variations are suitable for abnormal load conditions unless they are reinforced for greater strength. The decision to use single-pass or multipass welds depends on the metal thickness and joint width.

1.45 The double fillet lap joint, shown in Fig. 1-13 on the following page, is one of the most commonly used forms of lap joints. It can withstand more severe load and stress conditions than other lap joints, and little or no edge preparation is required. The single fillet lap joint is made when only one side of a lap joint is accessible. It is not as strong as the double fillet joint and therefore should not be used where severe loads or stresses

Fig. 1-13. Types of lap joint designs

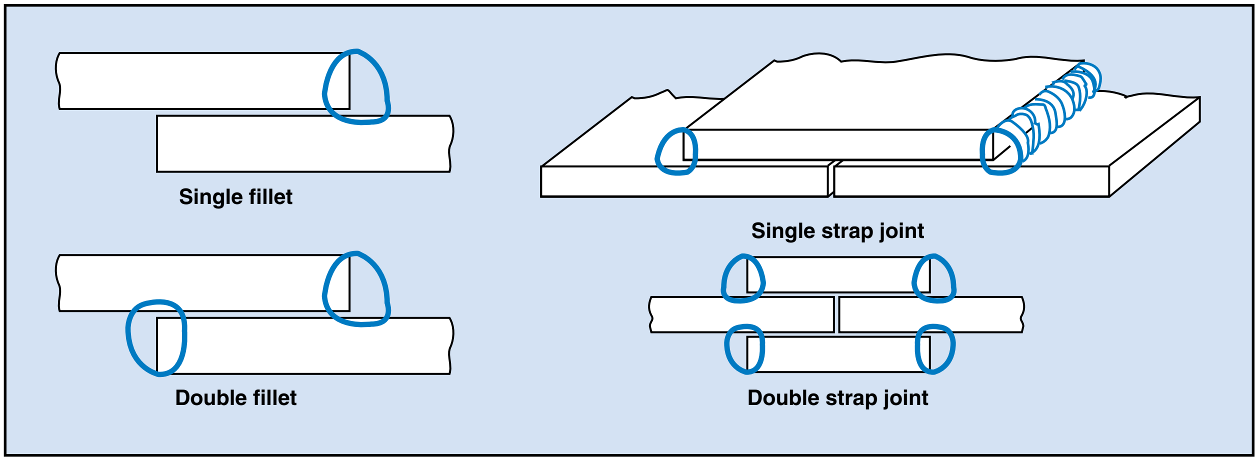
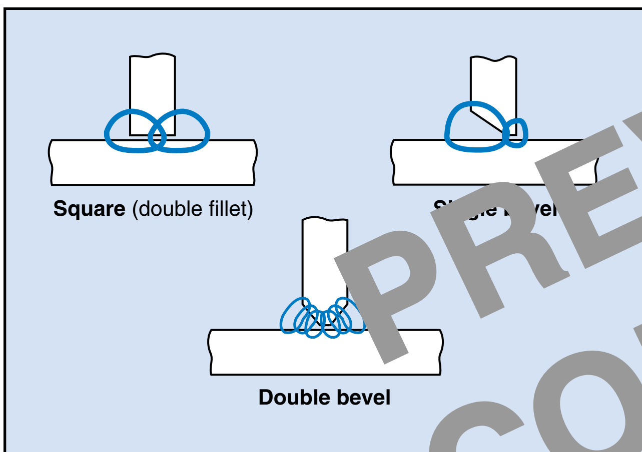


Fig. 1-14. Common tee joint variations

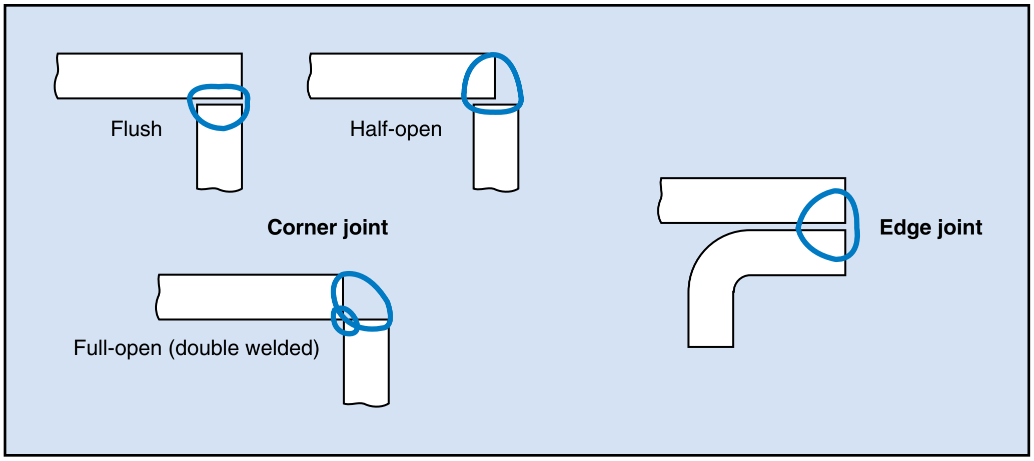


might be encountered. Also, lap joints should not be used if corrosion could occur between mating surfaces.

1.46 The *strap joint*, illustrated in Fig. 1-13, is a combination lap and butt joint. A strip of metal is fillet welded along both edges to join the butted pieces of metal. A double strap joint (strips on both sides of the butted pieces of metal) strengthens the strap joint.

1.47 The double fillet square tee design, shown in Fig. 1-14, is the most popular tee joint. Sometimes one or both sides of the tee must be beveled to provide better distribution of stresses. Single bevel tee joints are often made in metals up to about $^{1}/_{2}$ in. (13 mm) thick where welding can be done from only one

Fig. 1-15. Corner and edge joints



side. Double bevel tee joints are made in thicker metals where the weld must withstand heavy stresses and the joint can be welded from both sides. Other variations of the tee joint include single and double J-grooves.

1.48 Variations of the corner joint are shown in Fig. 1-15. The flush corner joint is generally limited to metals less than 1/8 in. (3 mm) thick. The half-open corner joint is often used on thicker metals because it allows better fusion and penetration. Full-open corner joints are made in assemblies where both the inside and outside of the corner can be reached for welding. Edge preparation (beveling) is rarely needed for corner joints except in applications for which the welded assembly design calls for flush corner joints in metals thicker than 1/8 in. (3 mm)

1.49 Because of its arrangement, the *edge joint*, shown in Fig. 1-15, is made only where it is not subjected to excessive loads or stresses. It is used primarily to seal joints in light-duty (less than 1/4 in. or 6 mm thick) sheet metal structures. Some typical examples include, air ducts, fume hoods, and smokestack liners. If an edge joint is necessary in metals thicker than 1/4 in. (6 mm) one or both edges must first be beveled to provide a groove for adequate penetration and weld strength.

1.50 Always determine the kind of service expected of a weld before making a joint. Then choose the most suitable joint design and fitup for the service conditions.

1-9. A straight bead made without any side-to-side motion is referred to as a(n) ________.	1-9. STRINGER PASS Ref: 1.26
1-10. The ________ weld joins two surfaces at right angles to each other.	1-10. FILLET Ref: 1.29
1-11. The welds used mainly for filling rather than joining are the ________ and ________ welds.	1-11. PLUG, SLOT Ref: 1.31
1-12. Spot and seam welds are made by the ________ welding process.	1-12. RESISTANCE Ref: 1.33
1-13. The root of a weld is the point of the triangle opposite its ________.	1-13. FACE Ref: 1.36
1-14. The throat depth of a weld should be about equal to the thinner of the ________.	1-14. BASE METAL Ref: 1.38
1-15. Butt joints should be grooved or beveled before welding if base metal thickness exceeds ________ in. (mm).	1-15. $^{3}/_{8}$ in. (10 mm) Ref: 1.44
1-16. The strap joint is a combination ________ and ________ joint.	1-16. BUTT, LAP Ref: 1.46

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. The main difference between filler rods and electrodes is that electrodes

- ☐ a. are made of nonferrous materials
- ☐ b. form part of an electric circuit
- ☐ c. require more skill to use
- ☐ d. supply filler metal

1-2. The oxyfuel welding process is popular for maintenance and repair work because

- ☐ a. applied pressure decreases the required temperatures
- ☐ b. equipment is portable and self-contained
- ☐ c. filler metals are seldom required
- ☐ d. it is a one-handed operation requiring little coordination

1-3. An advantage of the GTAW process is that it

- ☐ a. distorts the base metal less than other processes
- ☐ b. forms a protective slag
- ☐ c. is particularly suitable for thin base metal
- ☐ d. requires less preweld cleaning than other processes

1-4. The ________ joint is used to fasten reinforcing plates to the flanges of I-beams.

- ☐ a. butt
- ☐ b. corner
- ☐ c. edge
- ☐ d. tee

1-5. The ________ groove weld is preferred over other variations because it requires no edge preparation.

- ☐ a. bevel
- ☐ b. double J
- ☐ c. square
- ☐ d. vee

1-6. Which maintenance weld is the best selection for attaching handles to metal plate surfaces?

- ☐ a. Boxing fillet
- ☐ b. J-groove
- ☐ c. Seam
- ☐ d. Slot

1-7. Maintenance welders use a ________ weld as a temporary attachment to align parts before final welding.

- ☐ a. face
- ☐ b. skip
- ☐ c. spot
- ☐ d. tack

1-8. What welding process generally produces the widest welds?

- ☐ a. GMAW
- ☐ b. GTAW
- ☐ c. Oxyfuel
- ☐ d. SMAW

1-9. Fusion to a depth of about _______ in. (mm) is considered adequate for most welds.

- ☐ a. 1/32 in. (1 mm)
- ☐ b. 1/16 in. (2 mm)
- ☐ c. 1/8 in. (3 mm)
- ☐ d. 1/4 in. (6 mm)

1-10. The main consideration(s) in selection of joint design is (are) the

- ☐ a. composition of the base and filler metals
- ☐ b. size and thickness of the workpiece
- ☐ c. stresses the joint must withstand
- ☐ d. welding process to be used

SUMMARY

Fusion welding is the process of heating parts of two pieces of metal until they become molten and flow together. The joined parts are a weldment. Most maintenance welding is done by welding with an oxyfuel flame or welding with an electric arc (arc welding). Resistance welding, primarily a production operation, requires electricity and applied pressure. Filler metals include filler rods and electrodes. An electrode is part of an electric circuit, but a filler rod is not.

Alloys date back to about 7000 BC. Metalworking was limited to forging, alloying, and casting processes for thousands of years. The first arc welding outfit was used in the 1880s and coated metal electrodes were introduced about 30 years later. Welding is now a basic industrial process.

The oxyfuel welding outfit is nonelectric and easy to move, set up, and operate. The proper combination of oxygen and fuel gas burns at high enough temperatures to melt most metals. Usually but not always, a filler rod is applied.

Arc welding makes neat, strong welds quickly. The most common processes are shielded metal arc welding (SMAW), gas metal arc welding (GMAW), and gas tungsten arc welding (GTAW). Each requires electrical power. SMAW uses consumable electrodes that produce a gaseous cloud and form a slag deposit. GMAW uses a consumable continuous wire electrode fed through a special gun and a cylinder of shielding gas. GTAW uses a nonconsumable tungsten electrode in an air- or water-cooled torch, a cylinder of inert shielding gas, and sometimes filler metal.

The five basic kinds of welded joints are butt, lap, tee, corner, and edge. The basic welds are the groove, fillet, plug, slot, spot, and seam. Multipass welds are used for wide joints in thick metals. Parts of the weld include reinforcement, the toes, face, root, throat, and legs. Complete fusion and adequate joint penetration are necessary in any weld joint. The joint design and fitup depend on the joint application, especially the stresses it must withstand. The kind of weld is determined mainly by the thickness of the metal.

Answers to Self-Check Quiz

1-1. b. Form part of an electric circuit. Ref: 1.04

1-2. b. Equipment is portable and self-contained. Ref: 1.10

1-3. c. Is particularly suitable for thin base metal. Ref: 1.17

1-4. c. Edge. Ref: 1.25

1-5. c. Square. Ref: 1.28

1-6. a. Boxing fillet. Ref: 1.30

1-7. d. Tack. Ref: 1.34

1-8. c. Oxyfuel. Ref: 1.37

1-9. b. $^{1}/_{16}$ in. (2 mm). Ref: 1.39

1-10. c. Stresses the joint must withstand. Ref: 1.42

Contributions from the following sources are appreciated:

Figure 1-1. McHenry Welding Service; photo by Robin Sheffield
Figure 1-2. Century Mfg. Co.
Figure 1-3. Alexander Binzel Corp.
Figure 1-8. McHenry Welding Service; photo by Robin Sheffield