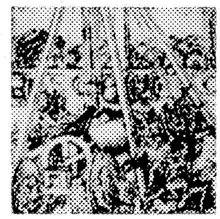
WELDING DRAWINGS

Chapter 22



LEARNING OBJECTIVES

Upon completion of this chapter you will be able to:

1. Understand welding methods and processes.
2. Determine the weldability of a material.
3. Identify various types of welds, symbols, and joint preparations.
4. Produce complete welding symbols.
5. Recognize supplementary welding symbols.
6. Apply and position appropriate weld type, size, length, and location for complete welding symbols.

22.1 INTRODUCTION

Knowledge of welding processes (Fig. 22.1) is essential for engineers because it is one of the basic manufacturing processes in industry. As an engineer, you will need to know how to communicate to the welder the type, dimensions, and position of the weld to be used. It is important to keep welds simple and to eliminate possible misunderstandings on engineering communications. Intricate welds take time and are expensive; moreover, time is often lost when interpreting the complex symbols. Through education and experience, you will learn the welding theory necessary for determining adequate weld sizes, placement, and welding procedures.

Welds are used to fasten an assembly together permanently. The parts to be fastened can be of the same type of metal or of dissimilar metals. Welding is for assemblies (Fig. 22.2) that require no disassembly for service or maintenance and where only one or a small number of assemblies is required. Because the heat that accompanies the welding process will distort the workpiece, any machining needed on a welded assembly is completed *after* the welding.

22.2 WELDING METHODS

Welding is the procedure by which two pieces of metal are fused together along a line or a surface between them or at a certain point. Welding can be classified by process or by source of energy. With **nonpressure welding** (fusion and brazing), no mechanical pressure is applied. The pieces of metal are welded at the point of contact by heat, which is created by an electric arc or a gas flame. **Pressure welding,** or **resistance welding,** forms a joint by passing an electrical current through the area of the joint as mechanical pressure is applied. Welding may also be classified by the source of energy for developing the temperatures required to produce the molten pool (chemical, electrical, mechanical, etc.). It is

FIGURE 22.1 Welding

usually convenient, however, to classify welds into three separate categories: resistance welding, gas welding, and arc welding.

Resistance welding involves applying heat and pressure at the same time, usually by a machine. Two or more parts can be welded by passing an electric current through the work as pressure is applied. Electronic beam, laser, and ultrasonic methods are also used. The main types of resistance welds are spot, seam, projection, flash, and upset.

In **fusion welding**, also known as **gas** or **oxyfuel welding**, heat is created by the combustion of a gas and air or pure oxygen. In oxyacetylene welding, a flame is produced by the combustion of oxygen and acetylene gases. Today, this type of welding is less common (except when flame cutting). Besides guiding the torch, the welder may also introduce the filler rod as the welding material (Fig. 22.1).

22.2.1 Arc Welding

The most common method of welding is **arc welding,** which includes submerged arc welding, shielded arc welding, gas-metal arc welding, and gas-tungsten arc welding.

In **submerged arc welding,** coalescence is produced by the heating from an electric arc generated between the electrode and the workpiece. The workpiece is shielded by a blanket of granular, fusible material called **flux.** The flux protects the weld pool (floats on it). Leftover flux creates slag, which must be removed at the end of the process. The filler material is obtained from a supplementary welding rod or from the electrode itself. In this process, loose flux (also called *melt* or *welding composition*) is placed over the joint to be welded. After the arc is established, the flux melts to form a shield that coats the molten metal (Fig. 22.3). A bare wire electrode is used in this process instead of a coated electrode, and the flux is supplied separately.

In **shielded arc welding,** the electric arc is produced by passing a current from a coated metal electrode to the material to be welded. A gap exists between the electrode and the workpiece. Fusion takes place during the intermingling of the molten metals. Figure 22.4 illustrates manual shielded arc welding. Notice how slag is formed on top of the base metal or on top of the solidified weld metal. Slag must be removed *after* the welding. Figure 22.3, by way of contrast, shows how the electrode in submerged arc welding extends into the work itself and how the base materials are fused together in molten weld metal. The flux may have

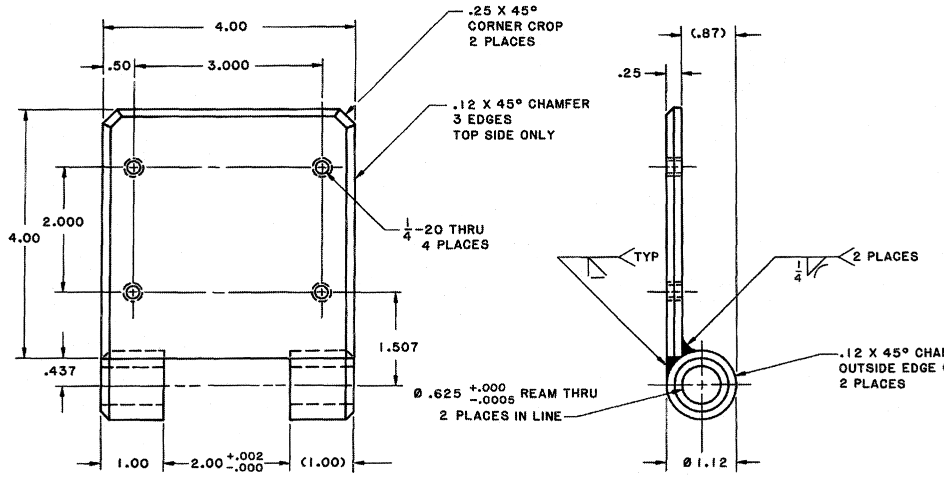


FIGURE 22.2 Weldment Detail

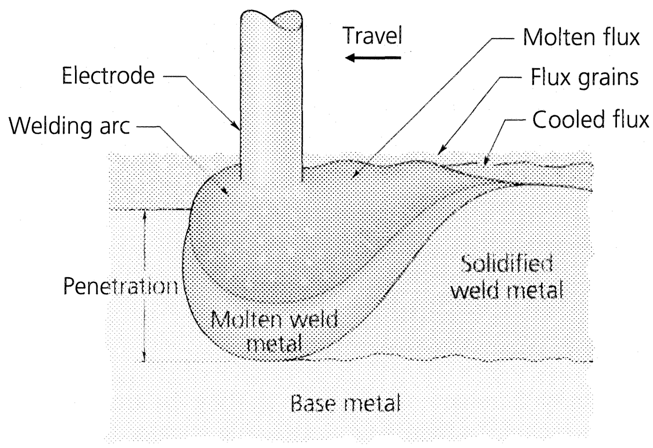


FIGURE 22.3 Submerged Arc Welding

some additives that become part of the weld. The penetration is much deeper than in shielded arc welding.

Shielded arc welding is usually done manually by a trained welder. It is found quite often in structural systems (see Fig. 22.10) because it is easy to use in the field. It is also good for **tack welding** (holding parts in position prior to final welding).

In **gas-metal arc welding (GMAW),** heat is created electrically, as in the process just described, but the shielding is accomplished by a blanket of gas (Fig. 22.5). The term **MIG** is normally used when referring to this process, not GMAW. Pressure may or may not be involved, but welding is generally pressureless. The electrode is the filler metal and becomes an integral part of the weld. The filler metal may also be added to the welding zone *prior* to welding, in which case inert gases are fed into the welding area to form a blanket. This welding procedure is for magnesium, aluminum, and carbon steel.

Gas-tungsten arc welding (GTAW) is different from GMAW because the electrode is tungsten. The term **TIG** is commonly used when referring to this process, not GTAW. The electrode transmits electric current but is not a filler metal. The TIG process produces root beads of high quality

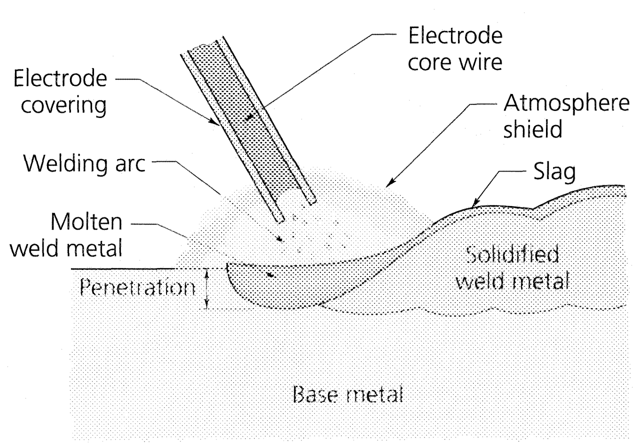


FIGURE 22.4 Manual Shielded Metal Arc Welding

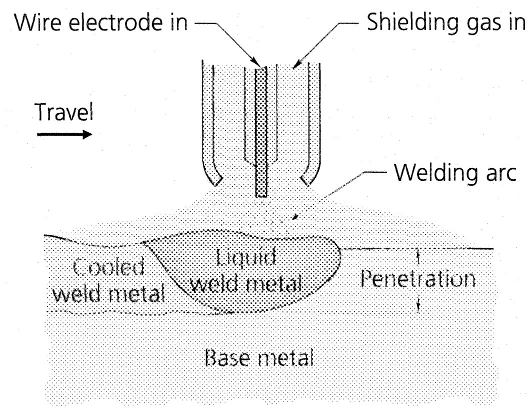


FIGURE 22.5 Gas-Metal Arc Welding

and is seldom used for the entire weld unless there are special circumstances. TIG is typically for aluminum, stainless steel, and exotic materials.

22.3 WELDING MATERIALS

Weldability is the capacity of a metal to be welded in relation to its suitability to the design and service requirements. Metals that become fused during the welding process undergo changes similar to those that occur during manufacture. Chemical, thermal, physical, and metallurgical changes make it essential for the engineer to understand the nature of the materials to be fused. The metallurgy of welds is as complex as the metallurgy of the material. The weldability of different materials varies greatly, and so does the process by which the weld is completed. When welding cast iron to steel, for instance, cast-iron rods are the welding material and the steel must be preheated before an adequate weld can be made. When welding steel castings, there is no easy rule for the process because the carbon content can vary greatly between types of steel. Steel welding rods usually produce an adequate weld.

Brass is ordinarily brazed instead of welded because of the high temperature produced by the welding process and the low melting point of brass. **Brazing** is the process of soldering with a nonferrous alloy that melts at a lower temperature than that of the metals being joined. Copper must serve as a filler, and care must be taken not to produce oxidation when welding materials containing copper. The heat and the filler material create a metallurgical bond in which the melting point is above 840°F but still below the melting points of the materials being joined.

Soldering employs an alloy of tin and lead to join two metallic surfaces. Soldering requires nonferrous metals whose melting points are below 427°C (800°F).

Carbon steel welding is usually completed via shielded metal arc welding. Rod iron has characteristics similar to those of mild steel, and a similar process is involved in its welding.

Focus On . . .

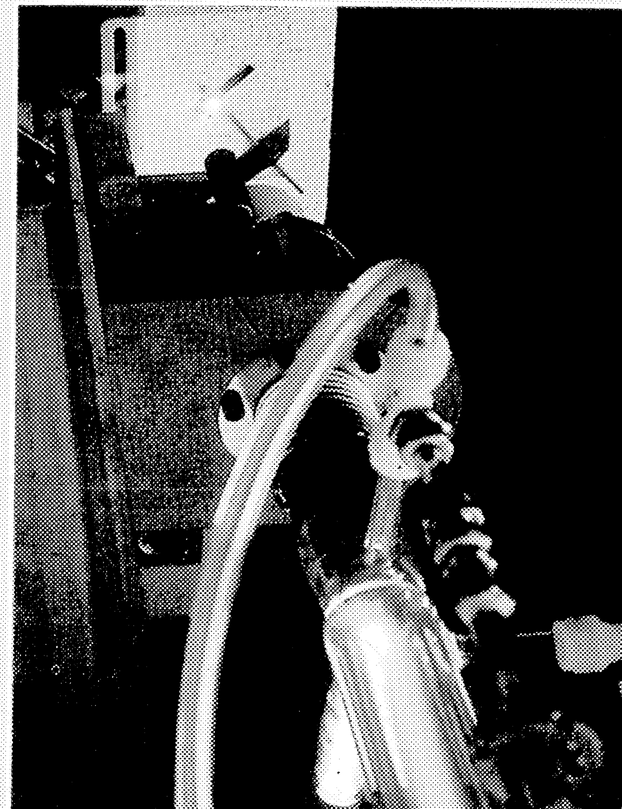
USING THE LASER TO WELD

One of the most important and most widely used applications of the laser is in fiber-optic communication systems. Laser-based communication systems are prevalent in the United States and Japan and are rapidly spreading throughout Europe. Laser beams that are transmitted by glass fibers carry thousands of times more information than copper cables. Even though lasers are a relatively new technology (1960), they have become one of our most useful tools.

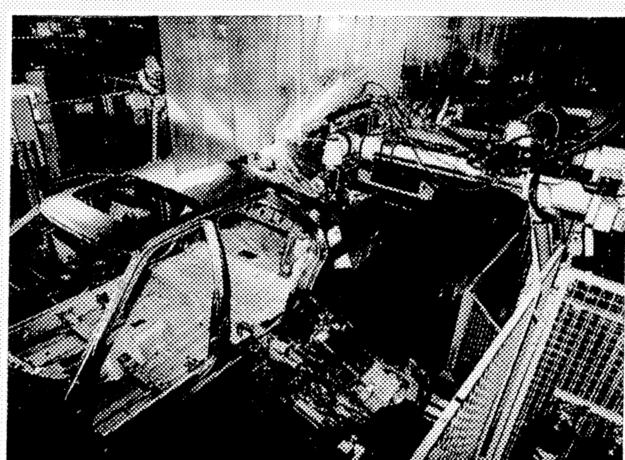
Laser applications in industry, ranging from manufacturing to the space program, have become quite popular. Laser-based tools serve for heat treating, cutting, drilling, and welding. Even though laser cutting and drilling are used, laser welding is by far the most common process.

There are two different laser welding processes. One is conduction, which occurs at the surface of the material; the other is deep penetration, in which heat is moved below the surface of the material. The conduction process is for joining thin sheets. The deep-penetration process creates a more efficient weld, with high tensile strength and hardness. Laser welding has achieved great success in shipbuilding, pipeline fabrication for the arctic, nickel steels, and low-alloy steels. The National Aeronautics and Space Agency developed a way to weld aluminum effectively with a laser. Aluminum is difficult to weld because it has a low melting temperature. Because of the developed process, aluminum vessels can now contain a high-pressure gas. Other precision aluminum pieces can be fabricated by the same process.

In laser welding, the welding rod is eliminated. The welding is accomplished without the excess heat that distorts and even destroys some materials in conventional welding. Even two dissimilar materials can be joined with laser welding. As larger and more powerful lasers are built, laser welding applications will grow in size and in number. Welding with lasers has made fabrications possible today that were impossible only forty years ago.



Laser welding.



Arc welding using robots.

For aluminum and aluminum alloys, most of the commercial welding and brazing processes can be used, though the most common are GTAW and GMAW. Various problems are encountered when employing the acetylene process to weld aluminum because of an oxide film that prevents metal flow at welding temperatures. Aluminum is characterized by its low melting point and high thermal conductivity.

22.4 TYPES OF WELDS

As an engineer, you will be concerned with specifying symbols for the various welds and joint preparations. Weld symbols and types of welds are classified by process. Resistance weld symbols are grouped under flash or upset,

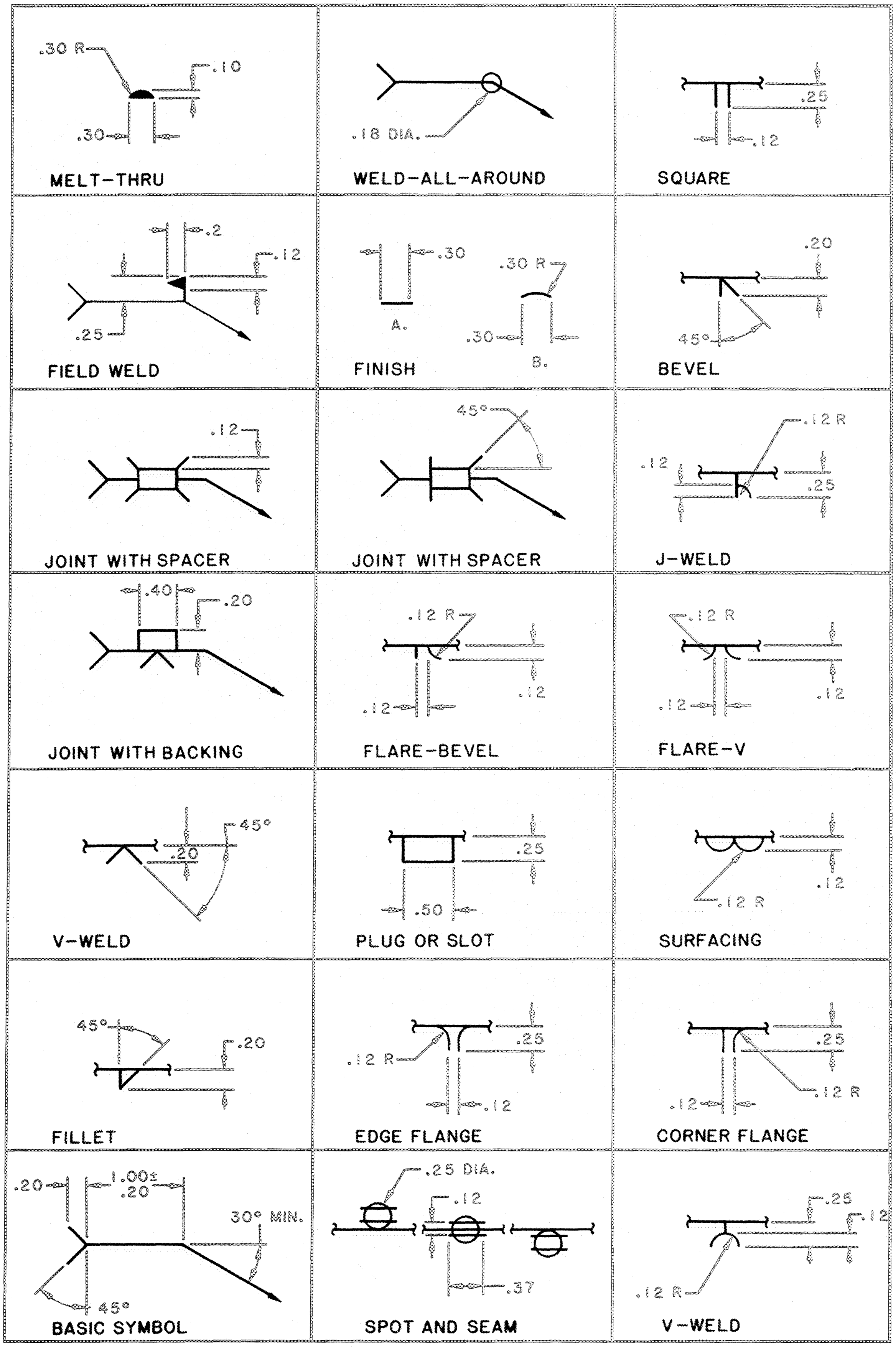


FIGURE 22.6 Weld Symbols

projection, seam, and spot, with supplementary descriptions such as contour weld and field weld.

Arc and gas weld symbols are divided into groove types (bevel, square, J, U, V), bead, fillet, plug, and slot welds. For bead and fillet welds, no special preparations are necessary for the metal. The essential difference between the various groove weld types is the edge preparation of the material to be welded—that is, whether it is to remain square, is to be beveled, or is to be machined into a V, U, or J shape. Although these welds can be combined, an effort should be made to keep welding symbols for similar joints both the same and simple.

22.4.1 Welding Symbols

Welding symbols communicate to the fabricator the weld type, size, and location. All welds can be identified by their profile or cross-sectional view. The welding drawing shows the parts or units that are to be made by welding (Fig. 22.2). Symbols define and locate the specific welds to be used. Each joint in the welding process must be fully described. The weld symbol (Fig. 22.6) denotes the desired type of weld: fillet, square, bevel, J, U, V, flare V, back, weld, arc seam, spot, plug, or slot. The complete welding symbol takes into account all welding information that might be needed: weld type, size, length, location, and place of construction (field or shop). Figure 22.7 shows the standard welding symbol and the location of its elements. This type of symbol, with the exception of the field weld flag, which is used by only a few companies, is standard throughout industry. The components of the complete welding symbol and their location are provided in this figure.

Welding symbols are composed of three basic parts:

- An **arrow** that points to the joint
- A **reference line** upon which all the dimensions and other data are placed
- The **weld symbol**, which indicates the type of weld required

The assembled welding symbol consists of the following eight elements or whatever number of these elements is necessary (Fig. 22.7):

Reference line
Arrow
Basic weld symbols
Dimensions and other data
Supplementary symbols
Finish symbols
Tail
Specifications, process, or other reference

Figure 22.8 shows five different joints that may be encountered in the construction of welded assemblies. Figure 22.9 offers a sample of various welds as applied to the particular joint. Besides the welding symbol, a cross-sectional view of the weld is drawn with the weld itself filled in. This provides a graphical description of the weld along with the symbolic description found in the welding symbol. The complete welding symbol is the most important information given to the welder. In many applications, the graphic representation of the weld is not shown on the drawing—only the symbol (see, for example, Fig. 22.13).

Usually the same welding process is referenced through-

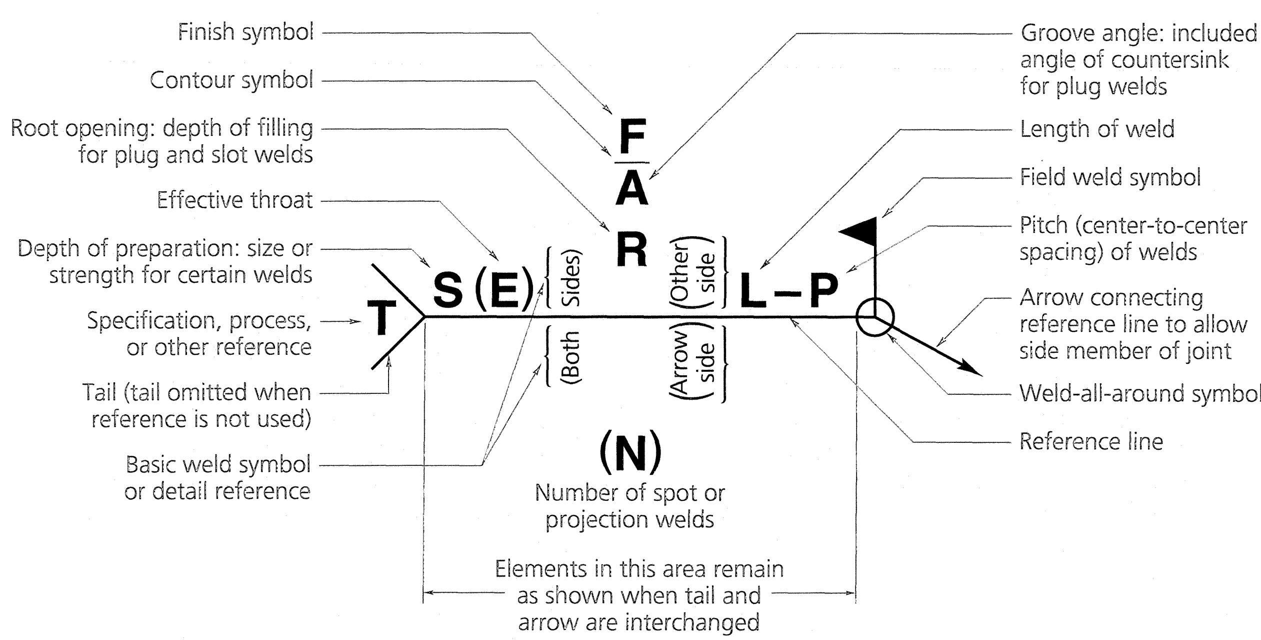
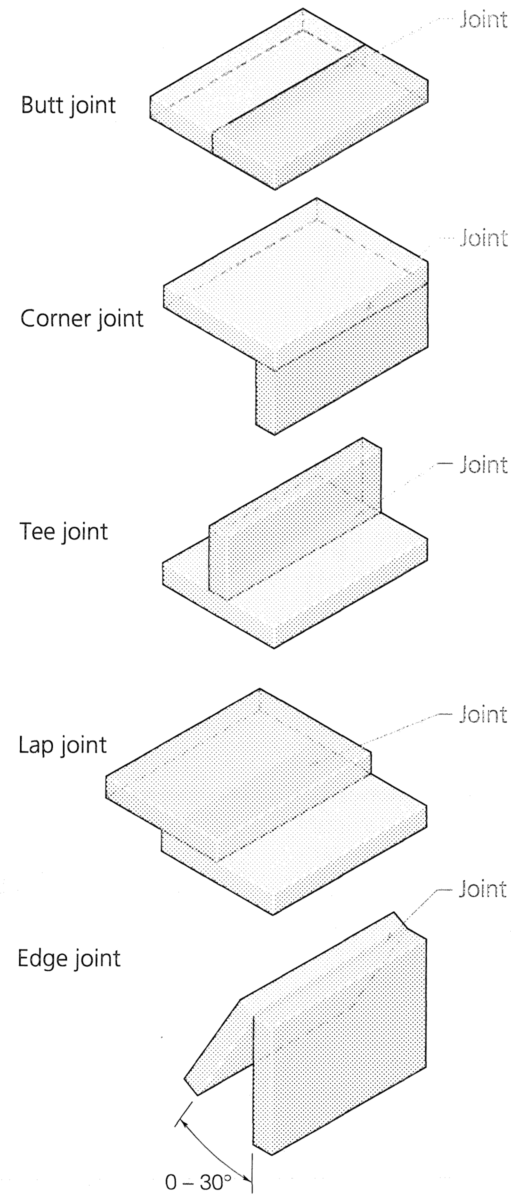


FIGURE 22.7 Standard Location of Elements of a Welding Symbol

FIGURE 22.8 Basic Types of Joints



APPLICABLE WELDS

Square-groove	Flare-v-groove
V-groove	Flare-bevel-groove
Bevel-groove	Edge-flange
U-groove	Braze
J-groove	
Fillet	Corner-flange
Square-groove	Edge-flange
V-groove	Spot
Bevel-groove	Projection
U-groove	Seam
J-groove	Flare-bevel-groove
Flare-v-groove	Braze
Fillet	Flare-bevel-groove
Plug	Spot
Slot	Projection
Bevel-groove	Seam
Square-groove	Braze
J-groove	
Fillet	Bevel-groove
Plug	J-groove
Slot	Flare-bevel-groove
Spot	Projection
Seam	Braze
Square-groove	J-groove
V-groove	Edge-flange
Bevel-groove	Corner-flange
U-groove	Seam
	Edge

out a drawing, as in Figure 22.10. If this is not the case—for instance, when the drawing contains submerged arc welding by machine and by manual welding—each process must be noted on the symbol when pointing to the joint to be completed. The particular welding process should be placed at the tail of the welding symbol. The tail is omitted when references are not needed to supplement the symbol.

Engineers usually employ templates (or a library of standard parts on a computer) for drawing welding symbols. But you should not become dependent on templates, because drawings require various sizes of symbols, depending on whether or not it will be reduced onto microfilm. With a CAD system, welding symbols can be programmed into the menu for instant selection and placement by digitizing or explicit coordinates. Symbols are created as blocks, subfigures, or subparts and saved in a library. Inserting the symbol can then be done quickly and accurately.

The welding symbol should be of a size adequate to be readily visible to the fabricator. At the junction of the arrow and the reference line within the welding symbol a flag or a solid field weld designation may be placed. Work that is to be performed on the job site, rather than shop fabricated, will have a **field weld designation.** The edge preparation for such welds is completed at the fabricating plant (seldom at the job site itself), so shop drawings contain all the edge preparation designations. Only field drawings contain field weld symbols. For more information, see ANSI standard Y32.3.

The arrow in a welding symbol connects the reference line to the joint (Fig. 22.11). The side that the arrow is on is

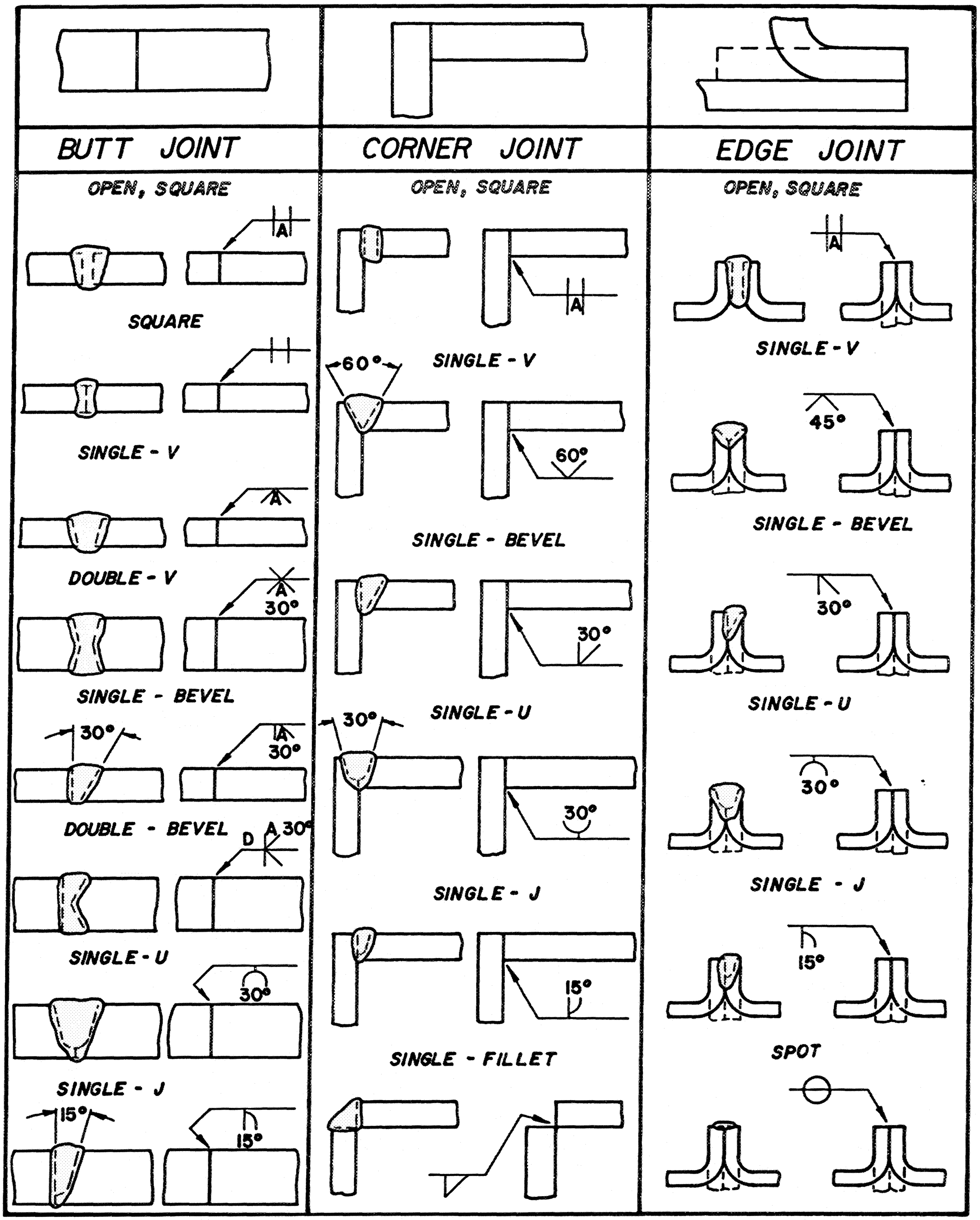


FIGURE 22.9 Joints and Appropriate Welds—*Continues*

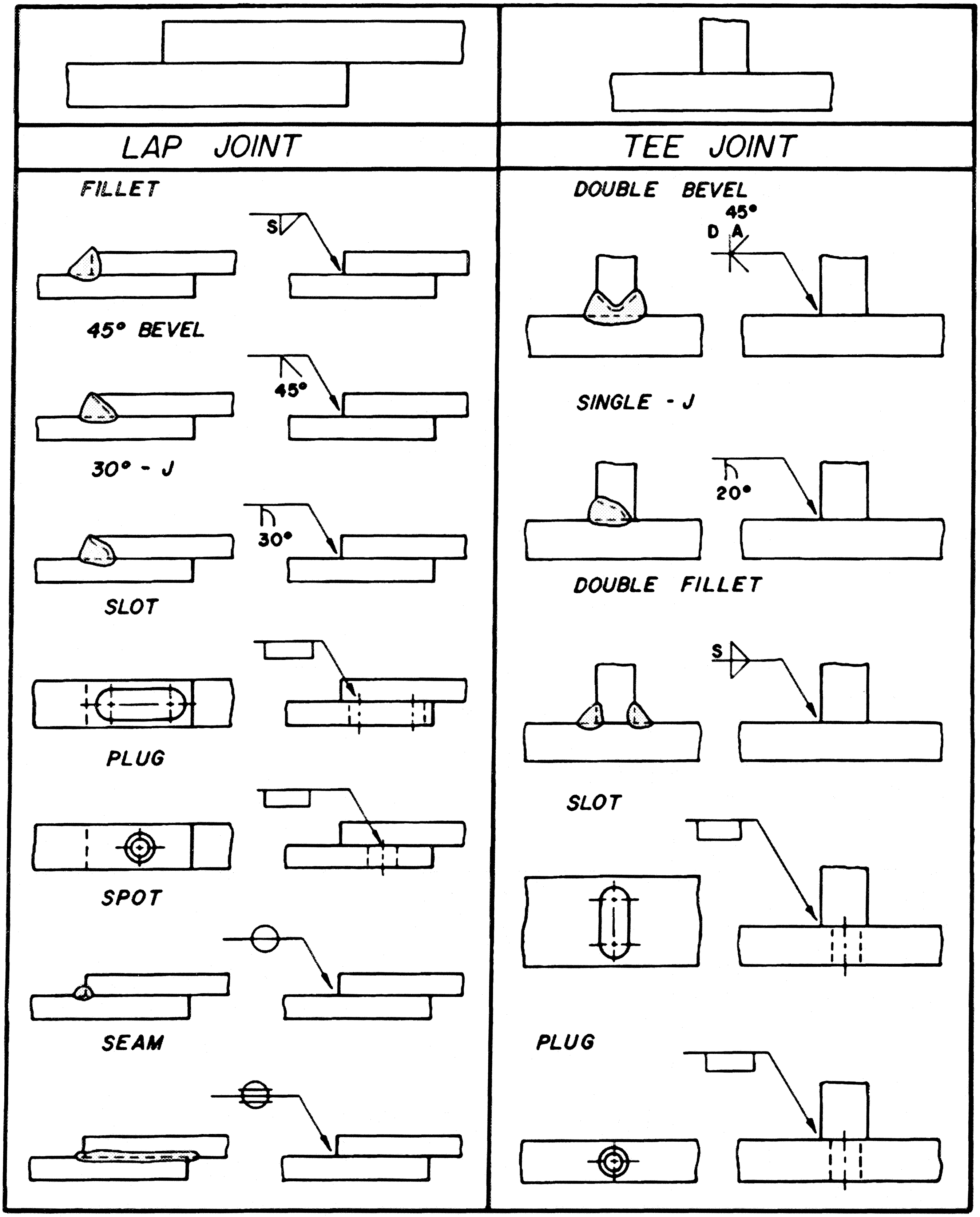


FIGURE 22.9 Joints and Appropriate Welds—*Continued*

DET.#	DESCRIPTION	QUAN
1	54 X 7.7, 2'-11" LG.	1
2	54 X 7.7, 13-1/4" LG.	2
3	54 X 7.7, 6-13/16" LG.	1
4	54 X 7.7, 8-3/4" LG.	1
	1/2" X 2-9/16", C.S. PLATE, 4" LG.	3
	8-P PART 298 FOR 3" PIPE	2

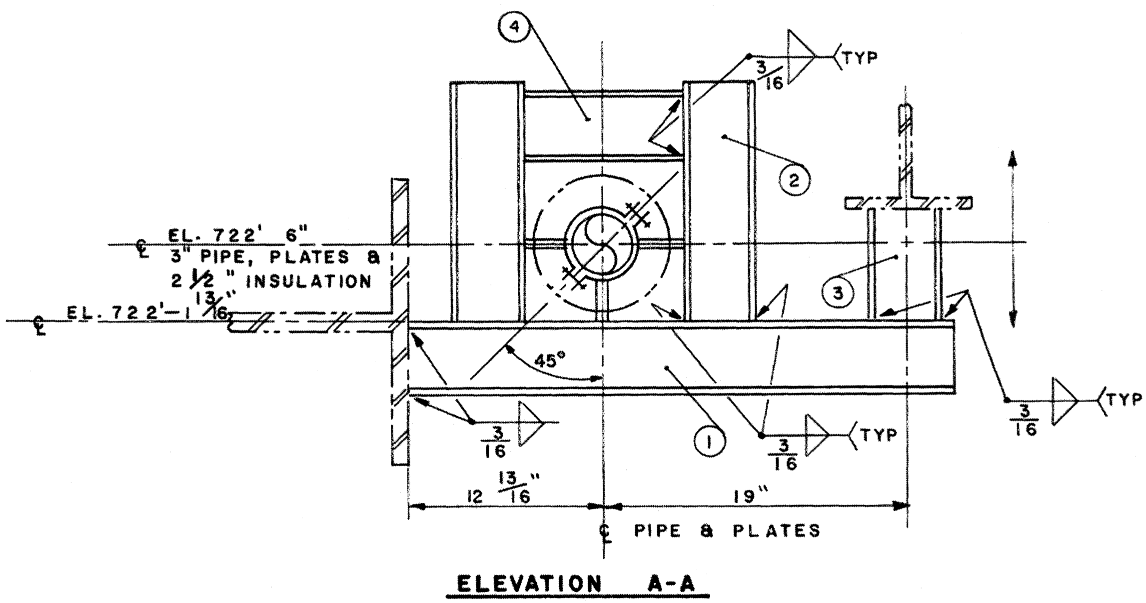


FIGURE 22.10 Welded Pipe Support Using Structural Steel

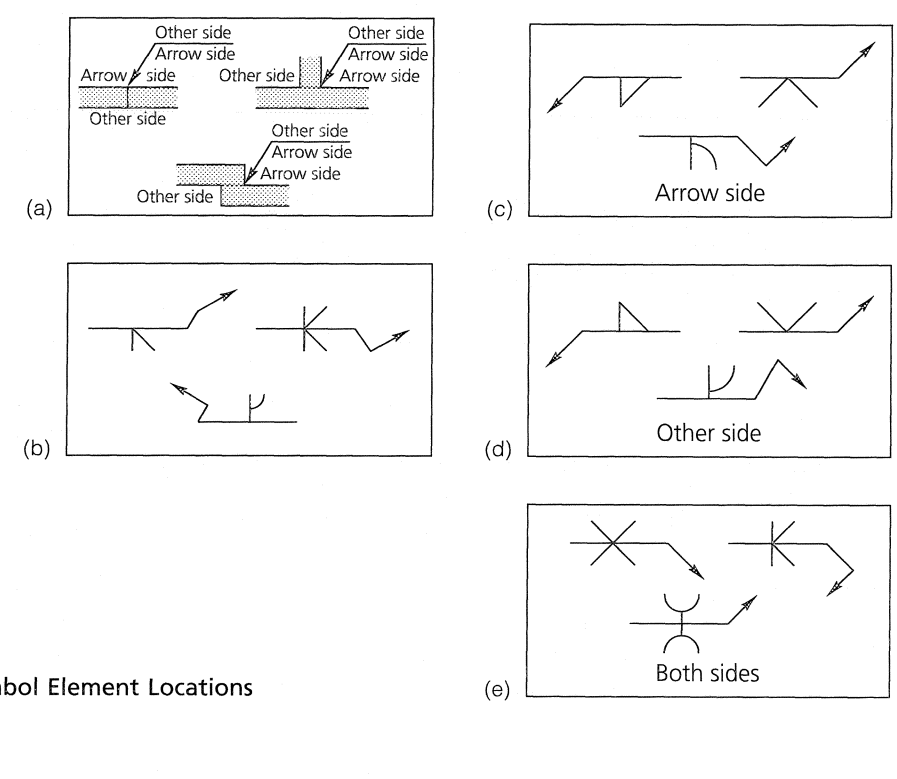
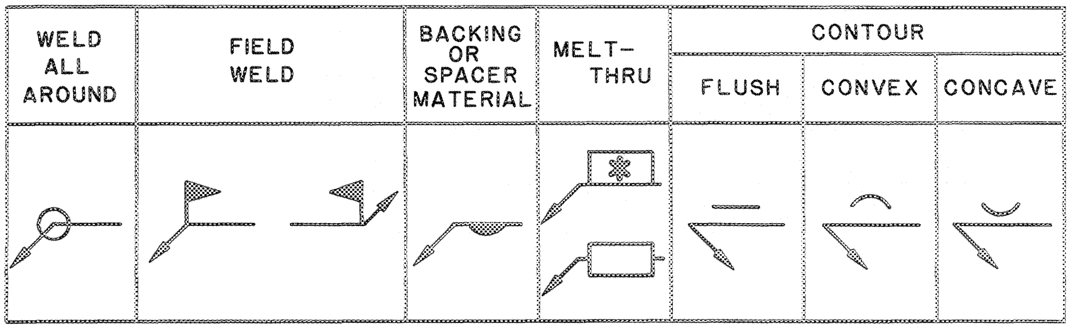


FIGURE 22.11 Examples of Welded Symbol Element Locations

FIGURE 22.12 Supplementary Symbols



called the **arrow side** of the joint [Fig. 22.11(a)]. The side opposite the arrow is the **opposite side** [other side, Fig. 22.11(d)] of the joint, except for plug, slot, seam, and other projection welds, where the arrow connects the symbol to the surface to be acted on. The arrow side of the joint is always considered the near side. Welds on the arrow side of the joint are shown by placing the weld symbol on the side nearest to the reader. To show welds on both sides, the weld symbol is placed on both sides of the reference line [Fig. 22.11(e)].

In many situations one welding symbol is shown on the drawing and a note is included that specifies the type of weld to be used on the entire drawing—such as ALL WELDS TO BE 4 IN. UNLESS OTHERWISE NOTED. On welds that are to be on all sides of a particular joint, the **weld-all-around symbol** is placed at the junction of the arrow line and the reference line, which may also contain a field weld symbol at the same joint (Fig. 22.12). When welds are to be finished or contoured, this requirement must be shown on the symbol (Fig. 22.12). It is also possible to combine different weld symbols in one welding symbol. Remember, the weld symbol is always placed according to the side of the joint on which the weld is to be made.

22.5 WELDING SYMBOL SPECIFICATIONS

Weld symbols are to be drawn as in Figure 22.6. The sizes shown in that figure are a guide for symbol construction, with their minimum values given. The actual size of the weld symbol and the welding symbol will vary according to the drawing size. Basic weld symbols on drawings are proportioned as shown in Figure 22.6 and are of a size compatible with microfilm reduction requirements.

When drawing welding symbols, no distinction is made between arc and gas welding. Weld symbols are shown only as part of the welding symbol. Symbols are drawn "on" the reference line. Fillet, bevel-groove, J-groove, flare-bevel groove, and corner-flange weld symbols are shown with the *perpendicular leg always to the left.* Symbols are drawn a uniform size throughout the drawing. If the arrow is directed to the outer surface of one of the members of the joint (plug, slot, seam, and projection welds) at the centerline of the desired weld, the member to which the arrow points is considered the arrow-side member.

22.5.1 Supplementary Welding Symbols

Supplementary welding symbols, shown in Figure 22.12, are used as applicable to define specific welding requirements. The *weld-all-around* symbol indicates welds that extend completely around a joint (Figs. 22.13 and 22.14). Welds completely around a joint in which the metal intersections at the points of welding are in more than one plane are also indicated by the weld-all-around symbol. The **melt-thru** symbol (Fig. 22.15) is used only where 100% joint or member penetration plus reinforcement is required in welds made from one side only. Reinforcement (melt-thru) height may be shown on the welding symbol [Fig. 22.15(a)]. Melt-thru that is to be made flush by mechanical means is shown by adding both the flush contour symbol and the finish symbol [Fig. 22.15(b)]. Melt-thru that is to be mechanically finished to a convex contour is shown by adding both the convex contour symbol and the finish symbol.

Contour symbols serve, as applicable, to indicate the appropriate weld contour desired (flat, convex, or concave), either with mechanical finishing (in conjunction with a finish symbol) or without. Finishing of welds, other than cleaning, is indicated by suitable contour and finish symbols [Fig. 22.15(b) and (c)]. Welds indicated by symbols are continuous between abrupt changes in the direction of the joint except when the weld-all-around symbol appears, or as specified by length dimension on the welding symbol or dimension lines on the view. Welds extending beyond abrupt changes in direction are indicated by means of additional arrows pointing to each section of the joint to be welded. A symbol is shown for each weld on joints having more than one weld. When the basic weld symbols are inadequate to indicate the desired weld, the weld is shown by a cross section, detail, or other data, with a reference on the welding symbol.

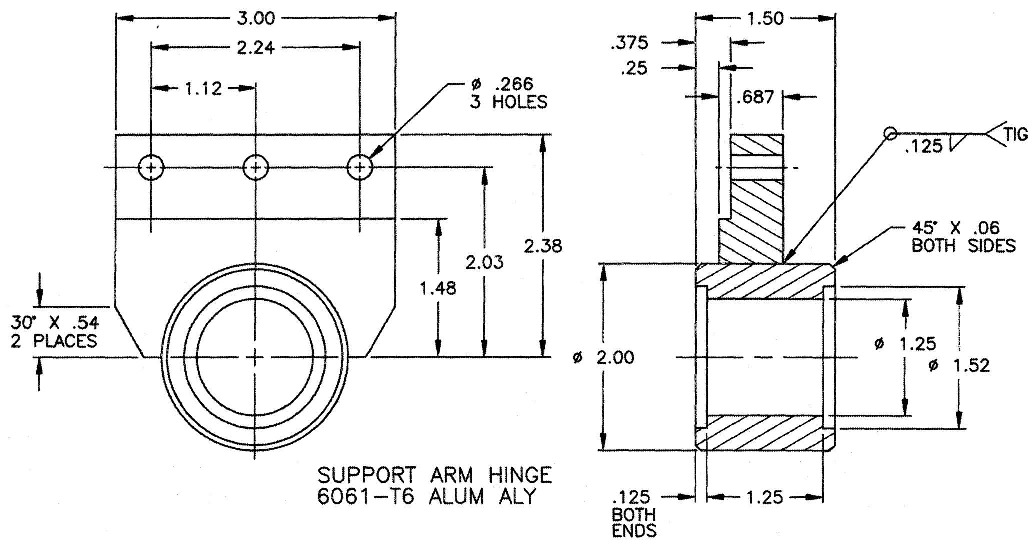


FIGURE 22.13 Detail Drawing of a Weldment

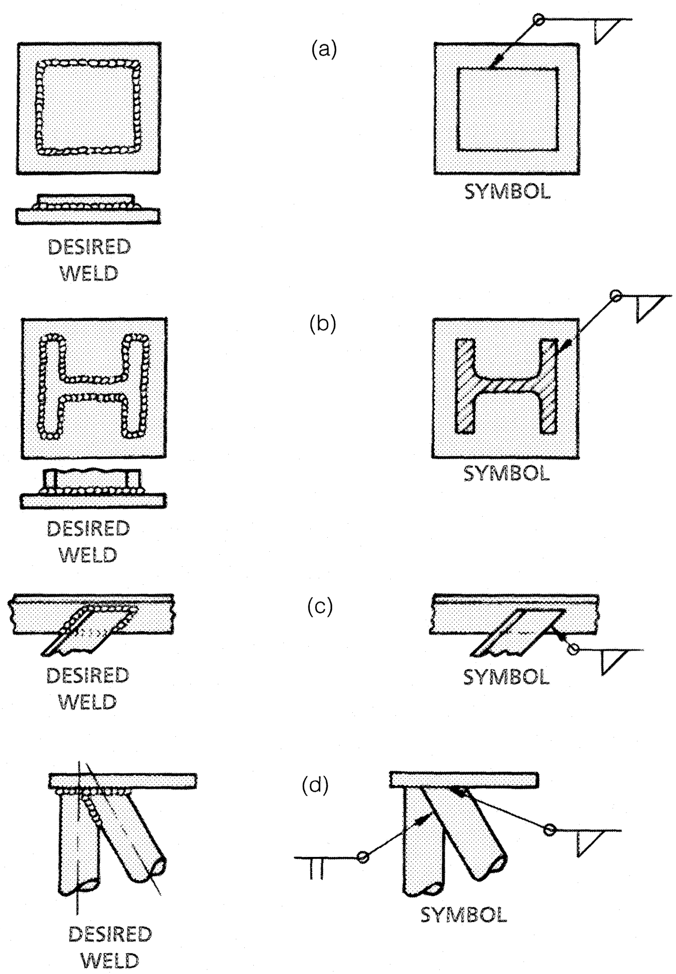
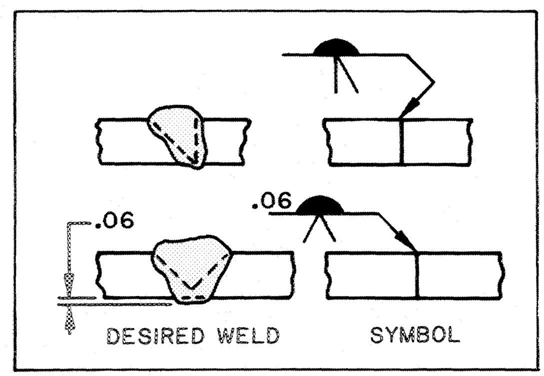
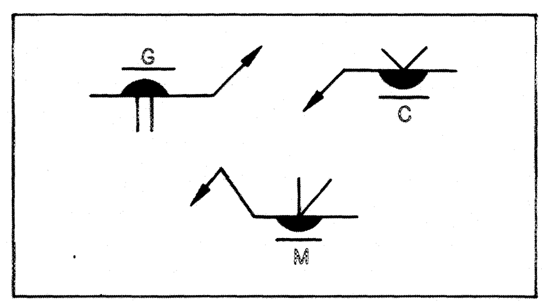


FIGURE 22.14 Weld-All-Around Symbols

The **pitch** (center-to-center spacing) of intermittent welds is shown to the right of the length dimension and separated from it by a hyphen [Fig. 22.16(a)]. The pitch indicates the distance between centers of the welds on one



(a) Use of a melt-thru symbol

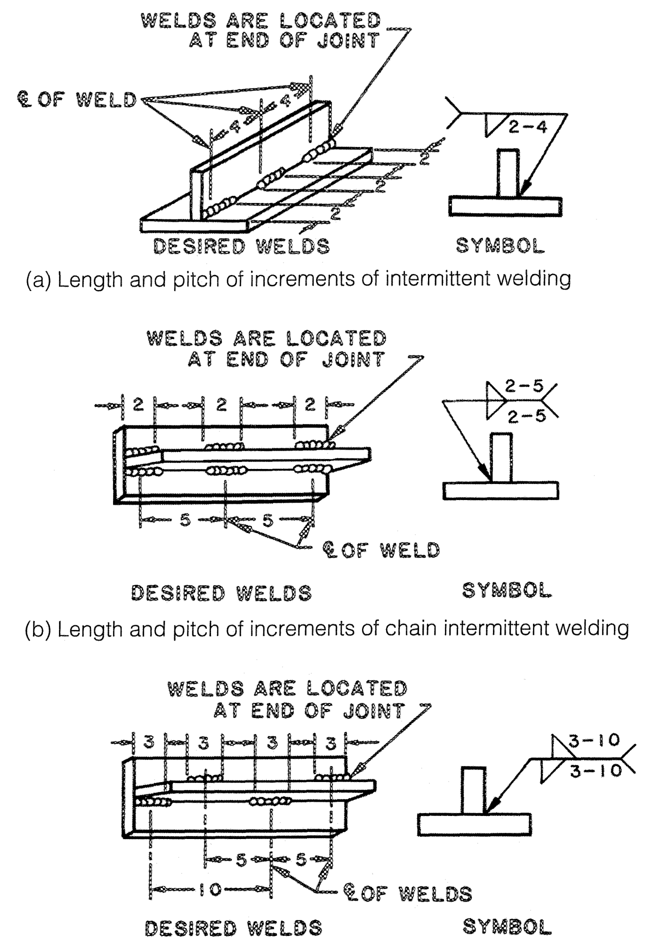


(b) Melt-thru finished flush

METHOD OF FINISH				
CHIP	GRIND	MACHINE	ROLL	HAMMER
C	G	M	R	H

(c) Weld finish symbols

FIGURE 22.15 Melt-Thru and Finish Symbols



(a) Length and pitch of increments of intermittent welding

(b) Length and pitch of increments of chain intermittent welding

(c) Length and pitch of increments of staggered intermittent welding

FIGURE 22.16 Application of Dimensions to Intermittent Fillet Welding Symbols

side of the joint. Chain and staggered intermittent weld dimensions are shown on both sides of the reference line [Fig. 22.16(b) and (c)]. When intermittent welding is called out by itself, the symbol indicates that welds are located at the ends of the joint. When intermittent welding is called out between continuous welding, the symbol indicates that spaces equal to the pitch minus the length of one increment are left between the end of the continuous weld and the intermittent weld [Fig. 22.16(c)]. Unless otherwise specified, staggered intermittent welds on both sides are spaced symmetrically, as shown in Figure 22.16(c). Separate welding symbols are given for intermittent welding and for continuous welding when the two are used in combination along one side of the joint.

Two or more reference lines can indicate a sequence of operations. The first operation is shown on the reference line nearest the arrow. Subsequent operations are shown sequentially on other reference lines. Additional reference lines can show data supplementary to welding symbol information included on the reference line nearest the arrow. Test information may be shown on a second or third reference line away from the arrow. When required, the weld-all-around symbol is placed at the junction of the arrow line and the reference line for each operation to which it is applicable. The field weld symbol may also be applied in the same manner. The letters **CP** in the tail of the arrow indicate a *complete penetration* weld, regardless of the type of weld or joint preparation.

22.5.2 Fillet Welds

Fillet welds (Fig. 22.17) usually have a triangular cross section and join two or more surfaces at right angles—such as lap, tee, and corner joints (see Fig. 22.9). They are often found in combination with groove welds for corner joints. The dimensions of fillet welds are placed on the welding symbol. The weld size goes to the left of the fillet weld symbol; the length of the weld is placed to the right of the basic weld symbol when required.

Weld size is determined by the thicker of the two parts to be joined. Rule-of-thumb weld size is the thickness of the thinner part, unless the larger size is required by calculated stress.

Fillet welds are also good in larger holes and slots where plug and slot welds are inappropriate. Generally, fillet welds are not finished unless a specific finishing process is specified on the symbol. The two basic types of fillet welds are those with *equal legs* and those with *unequal legs.*

The size of fillet welds is shown on the same side of the reference line as the weld symbol and to the left of the weld symbol (Fig. 22.17). When welds on both sides of the joint have the same dimensions, both are dimensioned (Fig. 22.18). The size of a weld with unequal legs is shown in parentheses to the left of the weld symbol. Weld orientation is not indicated by the symbol and is shown graphically on the drawing when required (Fig. 22.18). Fillet weld size can also be specified in a general note such as:

NOTE: UNLESS OTHERWISE SPECIFIED
ALL FILLET WELDS SHALL BE 20 MM SIZE

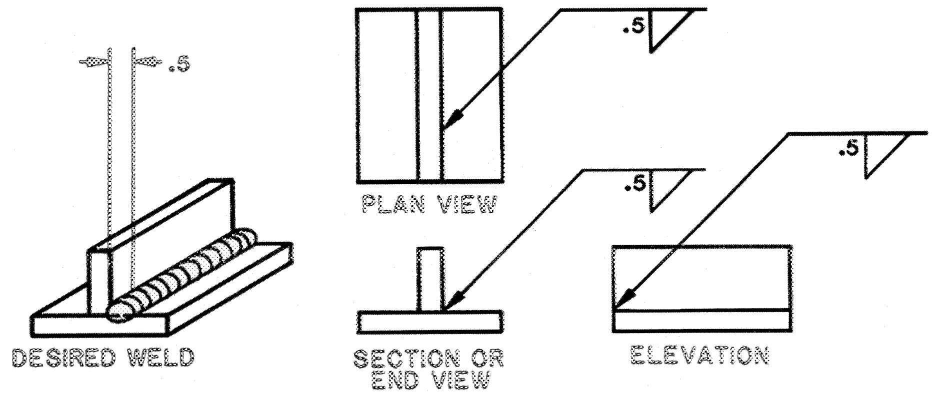
Specified lengths of fillet welding may be indicated by symbols in conjunction with dimension lines [Fig. 22.19(a) and (b)]. When necessary for clarity, the length of fillet welding may be graphically shown by *hatching* and dimensioned directly on the drawing (Fig. 22.20). No length dimension need be shown when the weld extends for the full distance between abrupt direction changes.

When a design requires fillet welds to be welded approximately flat-faced, convex-faced, or concave-faced, the contour symbol is added to the weld symbol [Fig. 22.21(a)]. If the weld is to be contoured mechanically, the weld finish symbol is added to the contour symbol [Fig. 22.21(b)].

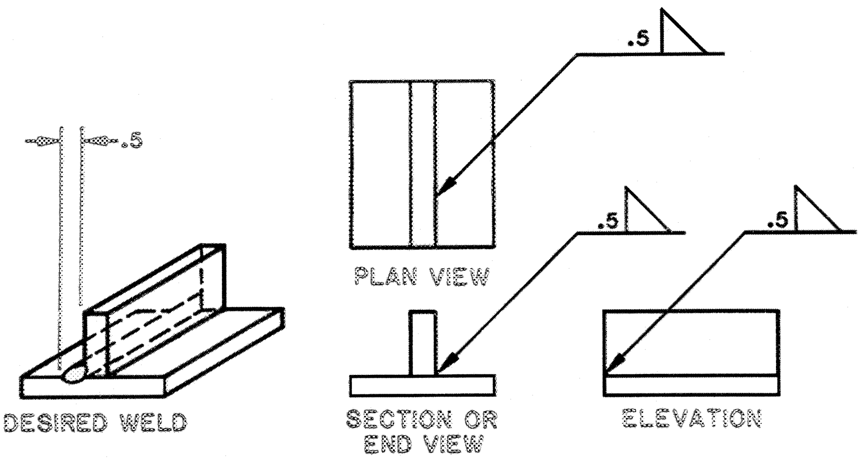
22.5.3 Plug and Slot Welds

The rectangular basic weld symbol (Fig. 22.22) designates **plug welds** and **slot welds.** All the rules for drawing symbols and their locations apply to these types of weld as well. Plug and slot welds are often found in butt joints and

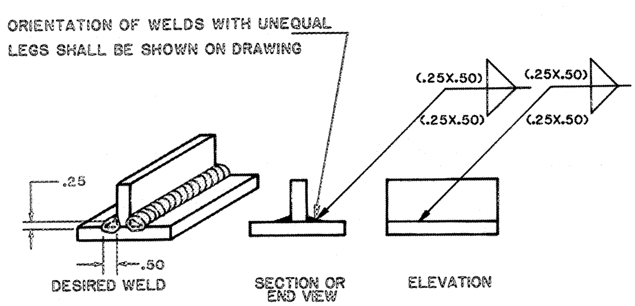
FIGURE 22.17 Application of Fillet Welding Symbols



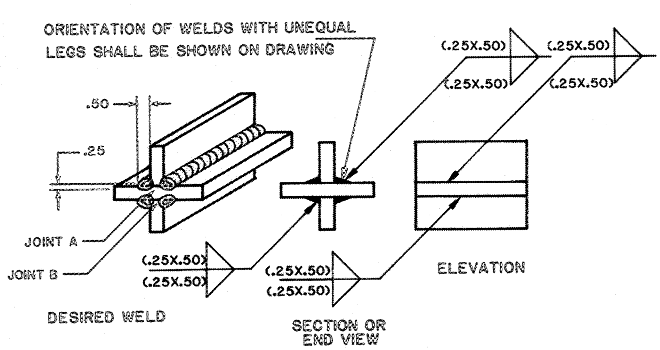
(a) Arrow-side fillet welding symbol



(b) Other-side fillet welding symbol

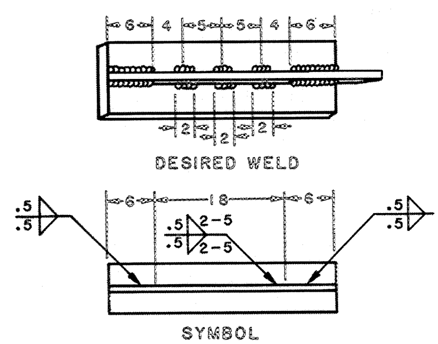


(a) Both-sides fillet welding symbol for one joint

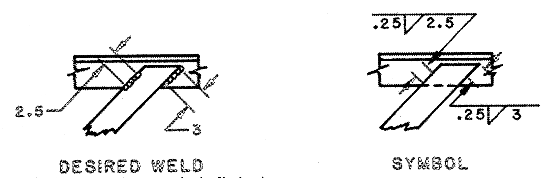


(b) Both-sides fillet welding symbol for two joints

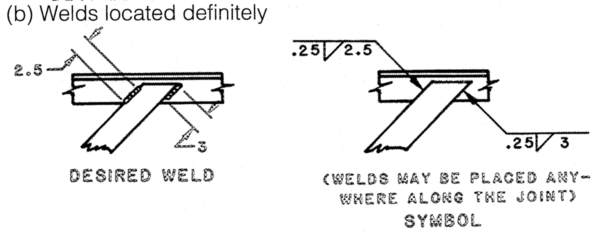
FIGURE 22.18 Fillet Welding Symbol Application



(a) Combined intermittent and continuous welding



(b) Welds located definitely



(c) Welds located approximately

FIGURE 22.19 Location and Extent of Fillet Welds

Applying Parametric Design . . .

WELDING SYMBOLS ON DRAWINGS

A **symbol** is a collection of drafting geometry and text (see Fig. A). In a drawing, a symbol becomes a single entity or instance. You can add as many instances of a symbol as you like. Symbols, stored in a specified directory, create a standard symbol library specific to a discipline, project, orientation, or company.

Pro/ENGINEER supports two kinds of symbols:

- **Simple symbol** Creates symbol instances identical to the symbol.
- **Generic symbol** Creates a variety of instances using entities included in the generic definition. Geometry and notes in a generic can be arranged in a tree definition structure (Fig. B); therefore, when creating an instance, you can specify groups to be included in a particular instance.

The symbol functionality is accessed through **Create** from the DETAIL menu and through **Symbol** from the DETAIL ITEM menu. This brings up the SYMBOL TYPE menu, with the following options:

- **Definition** Define/redefine a symbol
- **Instance** Create an instance

The general procedure for defining symbols includes the following steps:

1. Specify the name of the symbol.
2. Specify geometry to be included in the symbol.
3. For generic symbols, create a tree definition structure (Fig. C).
4. Define symbol attributes.
5. Specify the attachment point for the origin orientation leader.
6. If variable text is present, enter the default text.
7. Store the symbol to disk.

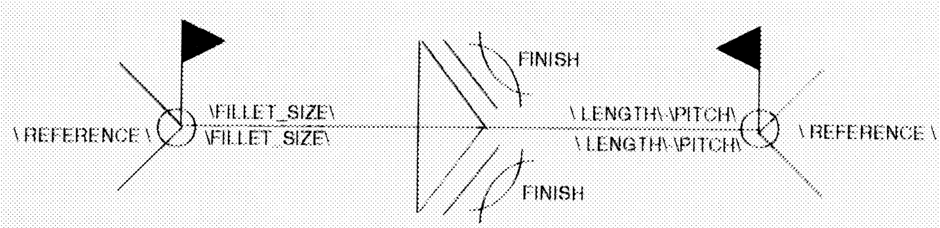


FIGURE A Generic Welding Symbol (Fillet Welding Symbol Shown)

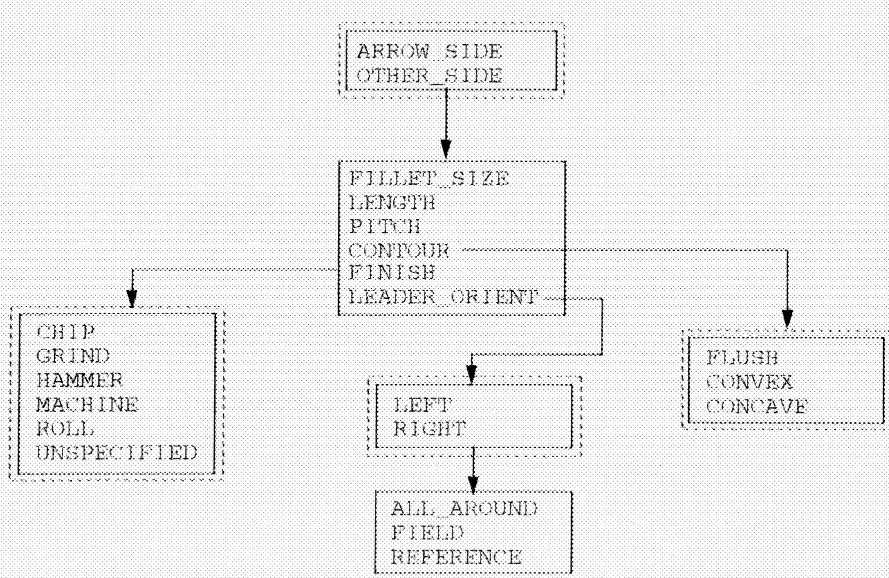
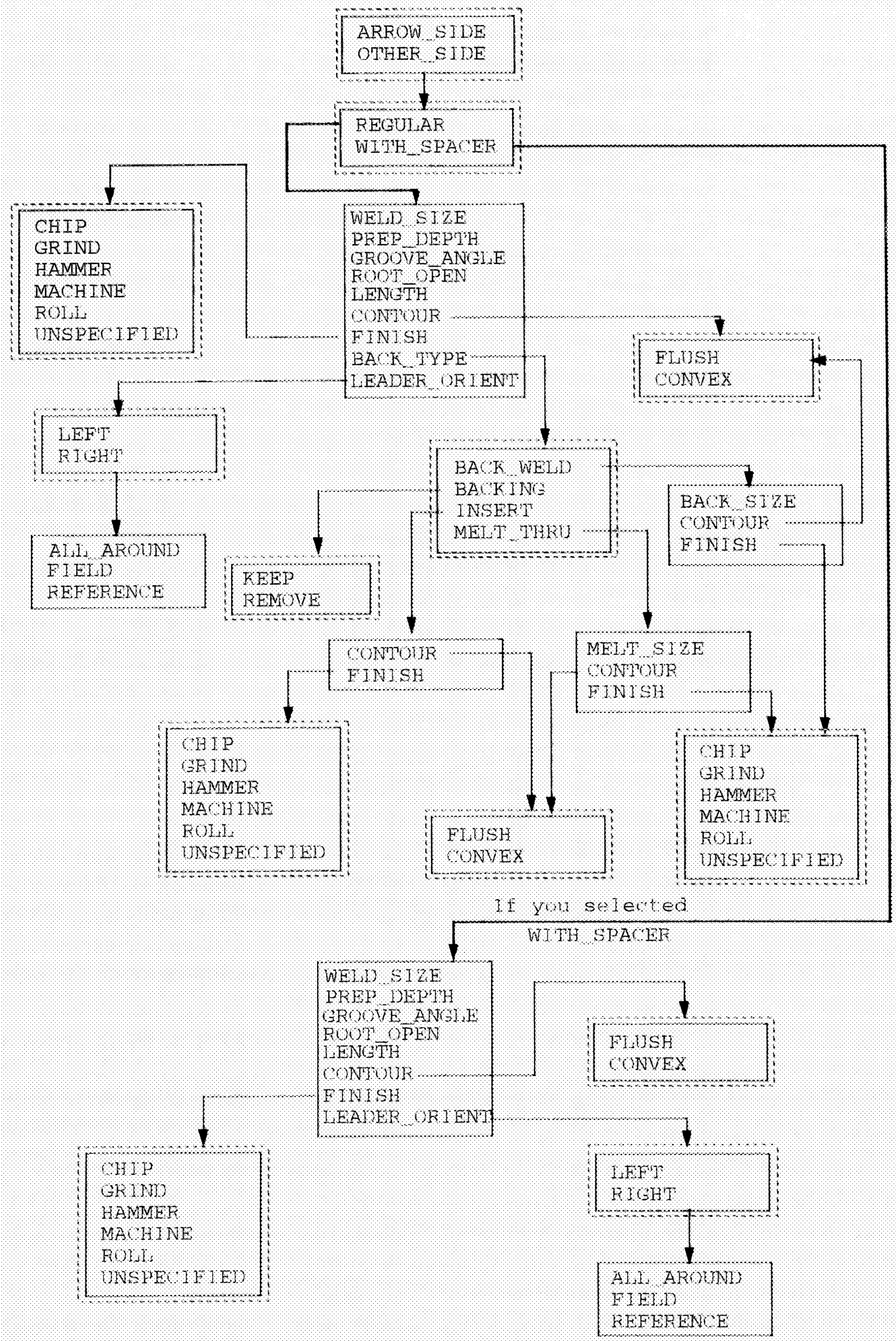


FIGURE C Symbol Definition Structure

FIGURE B Symbol Tree



The **Generic Welding Symbol** command creates a welding symbol with welds on both sides or on either side of a reference line. The command provides forty-eight different welding symbols (excluding the choice of independent weld characteristics or variable leader orientation). Here are a few notes (see Fig. A):

1. When creating combined groove welds, the root opening of the weld must be specified only on one of the welding symbols.
2. When you create chained intermittent fillet welds, LENGTH and PITCH values for the arrow side and for the other side must be identical.
3. When you select FINISH, you must also consider CONTOUR.
4. ALL_AROUND should not be selected if LENGTH and PITCH are selected.
5. Arrow-side and other-side significance for text entry is indicated by the following suffixes:

_AS for arrow side
_OS for other side

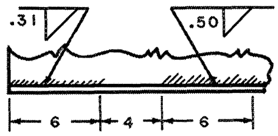


FIGURE 22.20 Length of Fillet Welds

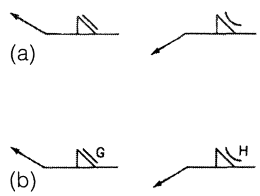


FIGURE 22.21 Surface Contours for Fillet Welds

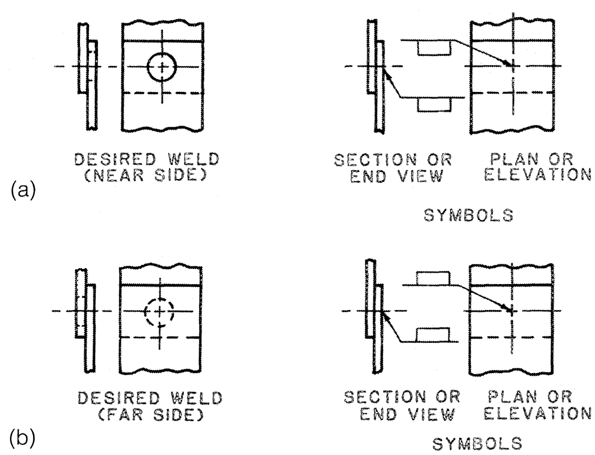
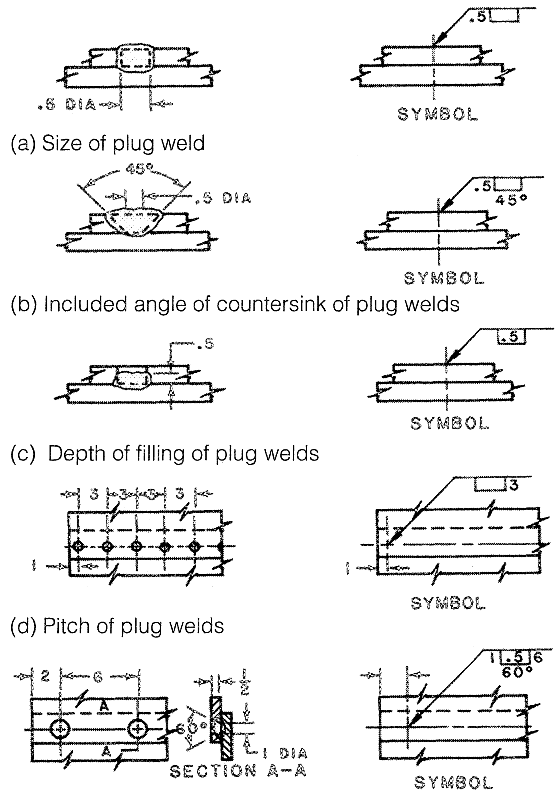


FIGURE 22.22 Plug Welds



(a) Size of plug weld

(b) Included angle of countersink of plug welds

(c) Depth of filling of plug welds

(d) Pitch of plug welds

(e) Plug welding symbol showing use of combined dimensions

FIGURE 22.23 Dimensions on Plug Welding Symbols

lap joints for reinforcement. When the slot or hole is too large to make plug or slot welds effective or economical, fillet welds are used.

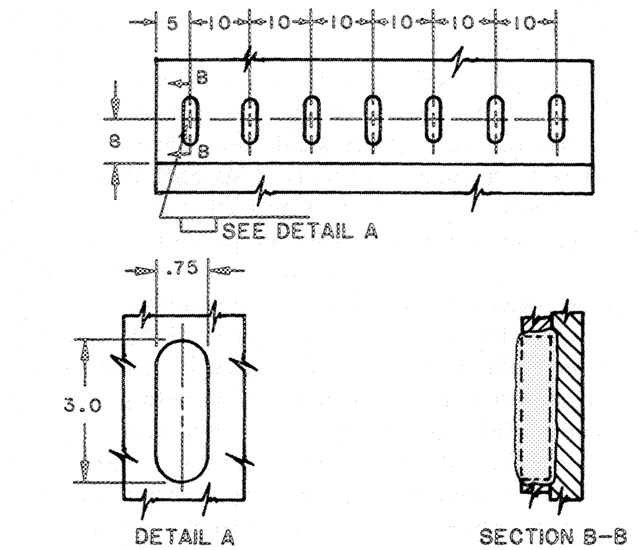
Plug welding holes in the arrow-side member of a joint are indicated by placing the weld symbol below the reference line. Holes in the other-side member are indicated by placing the weld symbol above the reference line (Fig. 22.22). Plug weld dimensions are shown on the same side of the reference line as the weld symbol (Fig. 22.23). The diameter of the base of the hole is shown to the left of the weld symbol. The hole is cylindrical, unless the included angle of countersink (taper) is shown above (other-side) or below (arrow-side) the weld symbol [Fig. 22.23(b)]. Plug welds completely fill the holes, unless depth of filling is shown inside the weld symbol [Fig. 22.23(c)]. The pitch of plug welds is shown to the right of the weld symbol [Fig. 22.23(d)].

Length, width, spacing, included angle of countersink (taper), orientation, and location of slot welds cannot be shown on the welding symbol. This information is given on the drawing, with a detail referenced on the welding symbol (Fig. 22.24). Unless otherwise indicated, the depth of filling of slot welds is understood to be complete. When the depth of filling is less than smooth or complete, the depth of filling is shown inside the weld symbol [Fig. 22.24(b)].

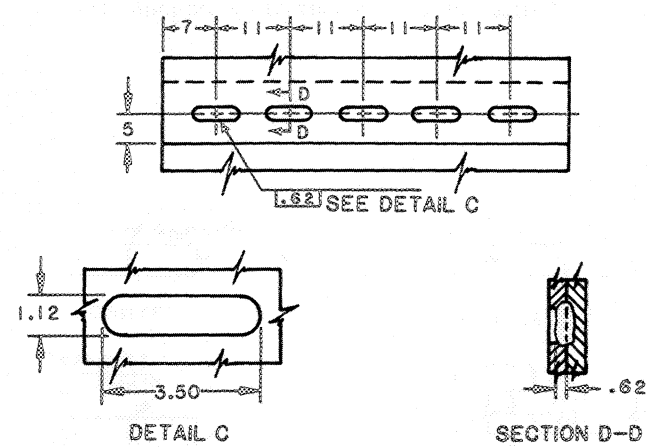
22.5.4 Projection Welds

When **projection welding** is required, the spot weld symbol is used, with the projection welding process reference in the tail of the welding symbol (Fig. 22.25). The spot weld symbol is placed above and below (never on) the reference line to indicate in which member the *embossment* is placed. Dimensions are shown on the same side of the reference line as the weld symbol, or on either side when the symbol is astride the reference line and has no arrow-side or other-side significance. The strength of spot welds is designated as the minimum shear strength per spot and, unless controlled by the applicable process, specification is shown to the left of the weld symbol (Fig. 22.26).

The pitch of spot and projection welds is shown to the right of the weld symbol [Fig. 22.26(b)]. When spot welding extends less than the distance between abrupt changes in direction or less than the full length of the joint, the extent is dimensioned on the drawing. When a definite number of spot welds is desired in a joint, the number is shown in parentheses either above or below the weld symbol [Fig. 22.26(c)].



(a) Completely filled slot welds



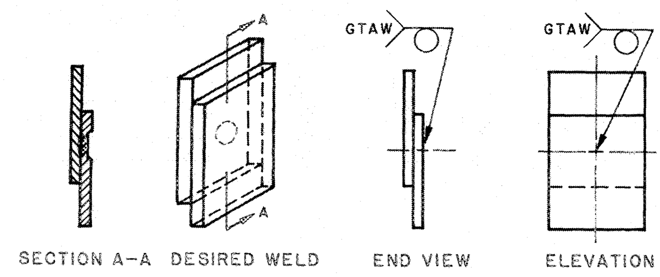
(b) Partially filled slot welds

FIGURE 22.24 Dimensions on Slot Welding Symbols

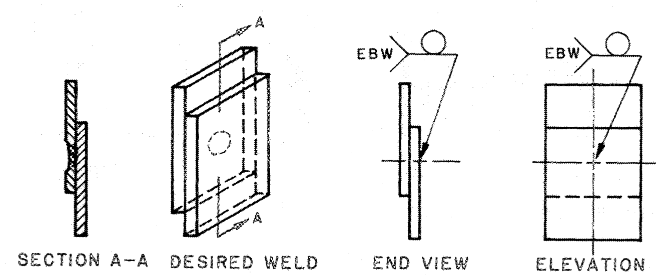
22.5.5 Seam Welds

One symbol designates all **seam welds**, regardless of the welding process. The process reference is shown in the tail of the welding symbol. The weld symbol may or may not have location significance, depending on the welding process. Dimensions are given on the same side of the reference line as the weld symbol, or on either side when the symbol is astride the reference line and has no arrow-side or other-side significance (Fig. 22.27).

Seam welds are dimensioned by either size or shear strength. Weld size is designated as the width of the weld. Shear strength is designated in pounds per linear inch minimum, and is shown to the left of the weld symbol [Fig. 22.27(b)]. The length of a seam weld that extends less than the full length of the joint or less than the distance between abrupt changes in direction is either shown to the right of the weld symbol or dimensioned on the drawing [Fig. 22.27(c)]. The flush contour symbol can indicate flushness

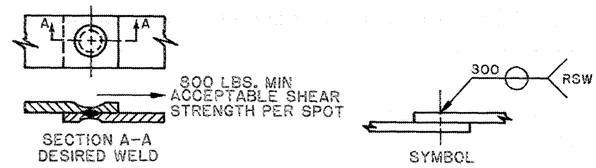


(a) Arrow-side spot weld symbol (gas tungsten-arc spot)

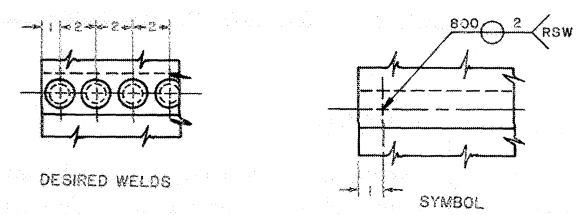


(b) Other-side spot weld symbol (electron beam spot)

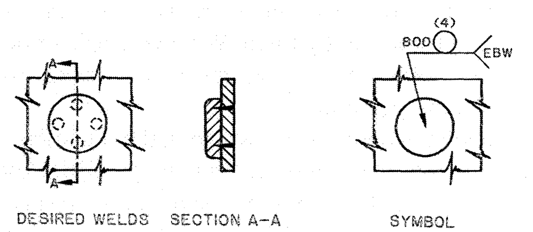
FIGURE 22.25 Spot Welding Symbol Applications



(a) Shear strength of spot welds (resistance spot)

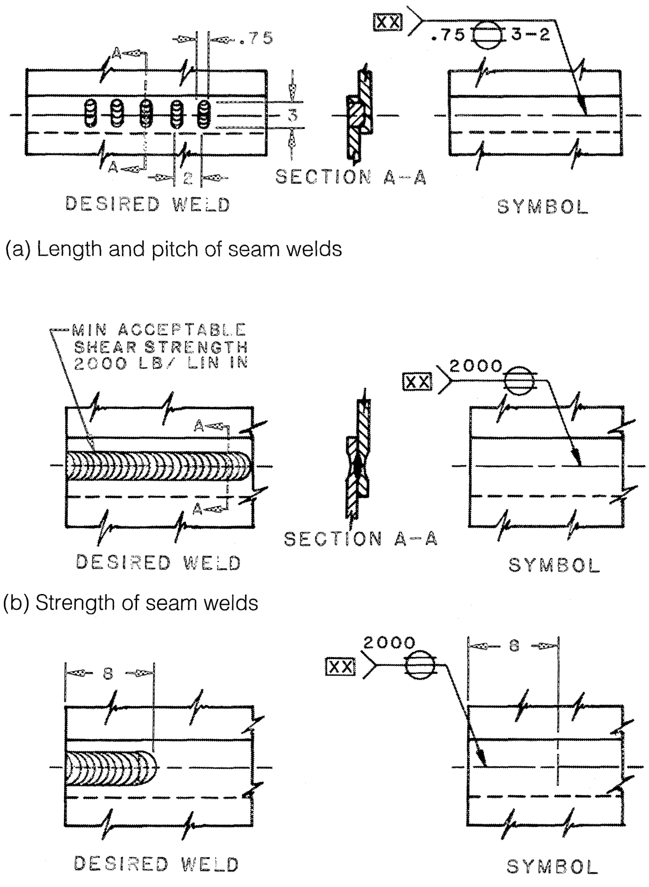


(b) Pitch of spot welds (resistance spot)



(c) Specified number of spot welds located at random (electron beam spot)

FIGURE 22.26 Application of Dimensions to Spot Welding Symbols



(a) Length and pitch of seam welds

(b) Strength of seam welds

(c) Extent of seam welds

FIGURE 22.27 Application of Dimensions to Seam Welding Symbols

of the exposed surface of either member of a seam-welded joint.

22.5.6 Groove Welds

The five basic **groove welds** are beveled, square, J, U, and V. However, various combinations are also used: single V, single bevel, single J, single U, double V, double bevel, double J, and double U. The edges in a groove weld are usually prepared by a flame cutting torch. Whether single or double, these are probably the easiest, most economical welded joints for joining two ends.

When a joint is prepared for welding, the thickness of the material must be taken into account. In small thicknesses, such as $\frac{1}{16}$ to $\frac{1}{8}$ in. (1.5 to 3 mm), welding can be successful when the edges are square. When the edges are thicker than this, bevels must be made to ensure full penetration and create an adequate joint; otherwise, the flame will not be hot enough to produce adequate fusion. A general rule to follow when material is thicker than $\frac{1}{8}$ in. (3 mm) is to prepare the edges for a groove channel and to add a filler material during the welding process.

In most cases, steel and iron are beveled at an angle of 45°. The included angle of the bevel is approximately 90° and V-shaped. Many groove welds use a *backing bar* or *backing weld.* The American Society of Mechanical Engineers (ASME) boiler code and other regulating codes require full-penetration welds, especially for pressure vessels and piping services that are considered critical. *Backup rings* are therefore employed in the construction of vessels and pipe joints where full penetration is required. ASME and the American Welding Society (AWS) provide standards for welding and should be consulted when necessary.

Complete (full) penetration is defined to have occurred when the weld and the base metal are fused through the entire depth of the joint. This way may or may not require backing bars or bead welds. Partial-penetration groove welds are appropriate when full penetration is not necessary because of stress levels to be carried by the joint. The only

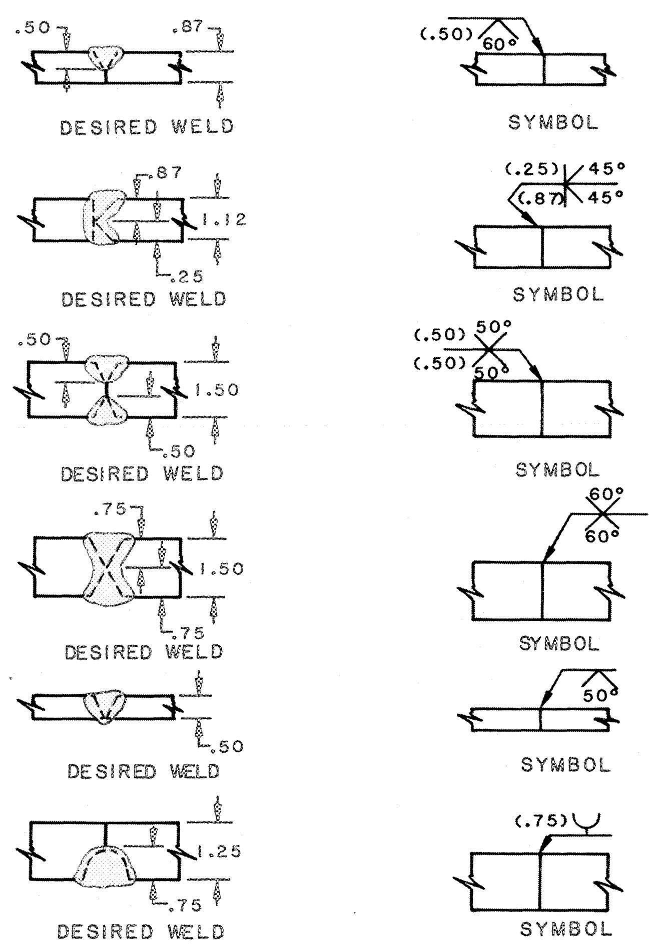
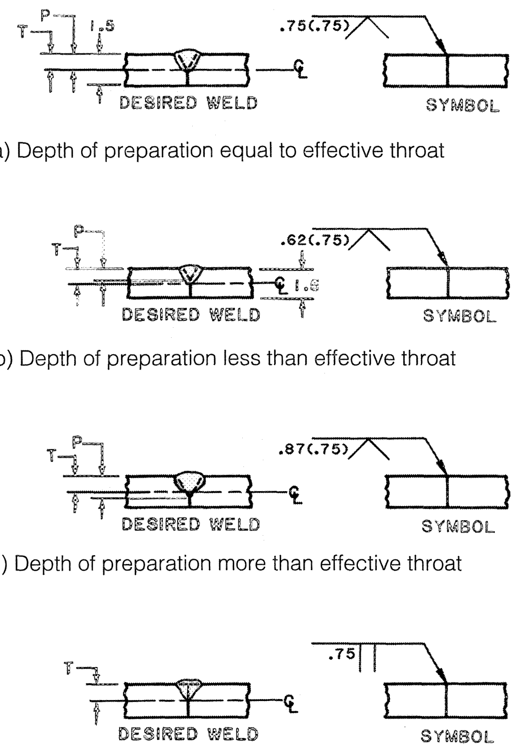


FIGURE 22.28 Designation of Size of Groove Welds with No Specified Root Penetration



(a) Depth of preparation equal to effective throat

(b) Depth of preparation less than effective throat

(c) Depth of preparation more than effective throat

(d) No preparation

FIGURE 22.29 Depth of Groove Weld Preparation

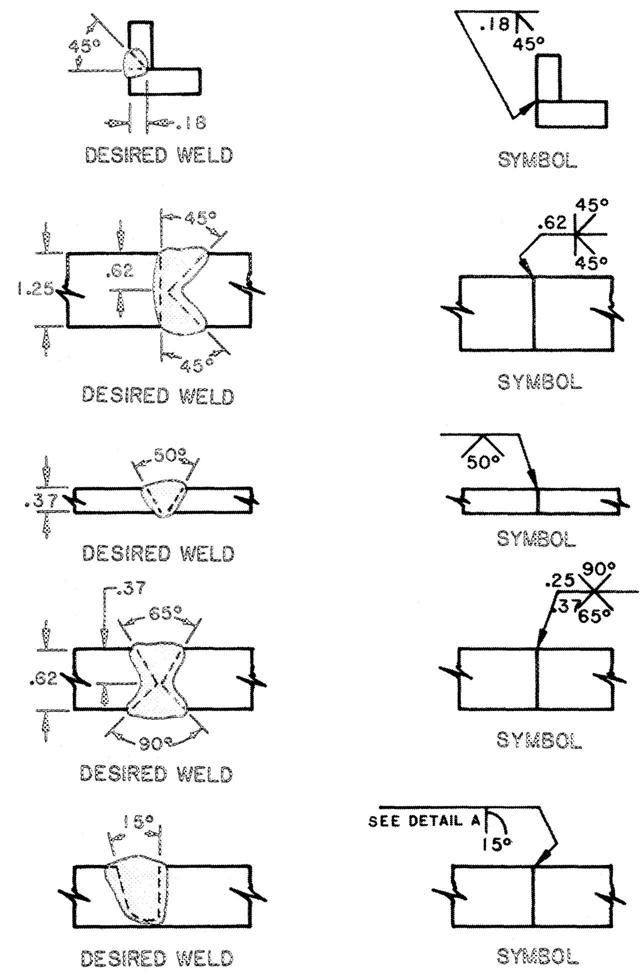


FIGURE 22.30 Groove Angle of Groove Welds

difference between the two penetrations is in the depth of the end preparation or edge preparation: Partial penetration does not cover the full thickness of the two materials to be joined. Root spacing will minimize lack-of-penetration notches caused by insufficient spacing or tight butting of joints. Root spacing is just one of the considerations that determine the quality of the joint. Alignment is also important, although slight imperfections are tolerable.

An engineer might be called on to detail different cross-sectional views of the joint geometry, including backing, space, or extension bars, and to show whether the weld is a full or partial penetration and its various angles and dimensions. **Joint geometry** is the basic cross-sectional shape of the joint prior to welding.

Dimensions of all types of groove welds (Fig. 22.28) are shown on the same side of the reference line as the weld symbol. If double-groove welds have the same dimensions, both are dimensioned. The depth of groove preparation and the effective throat of a groove weld are shown to the left of the weld symbol, with the effective throat in parentheses. The *effective throat* is the perpendicular depth of the groove cut. The total effective throat never exceeds the thickness of the thinner member of a joint. The effective throat is shown only for square groove welds in Figure 22.29, where P is the preparation thickness and T is the effective throat depth.

When no depth of groove preparation or effective throat is shown on the welding symbol for single-groove or symmetrical double-groove welds, complete penetration is required (Fig. 22.28). Unless specified in a general note, the groove angle or groove welds are shown *outside* the weld symbol (Fig. 22.30). And unless specified in a general note, the root opening of groove welds is shown *inside* the weld symbol (Fig. 22.31). Groove radii of U-groove and J-groove welds is specified in a general note, or by a detail view on the drawing, referenced on the welding symbol. The depth of preparation for flare-groove welds is considered as extending only to the tangent points (Figs. 22.32 and 22.33). Groove welds with contour requirements are indicated in the same manner as that prescribed for fillet welds.

The flush and convex supplementary weld symbols are also applied to groove welds—for instance, when the outer contour of the weld must be altered by grinding or machining.

You May Complete Exercises 22.1 Through 22.4 at This Time

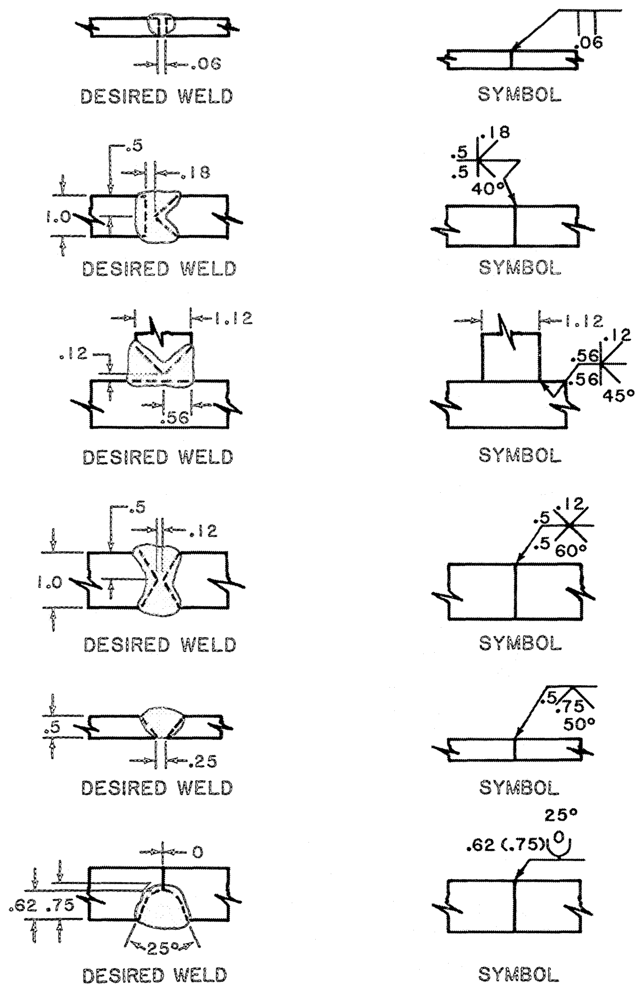


FIGURE 22.31 Root Opening of Groove Welds

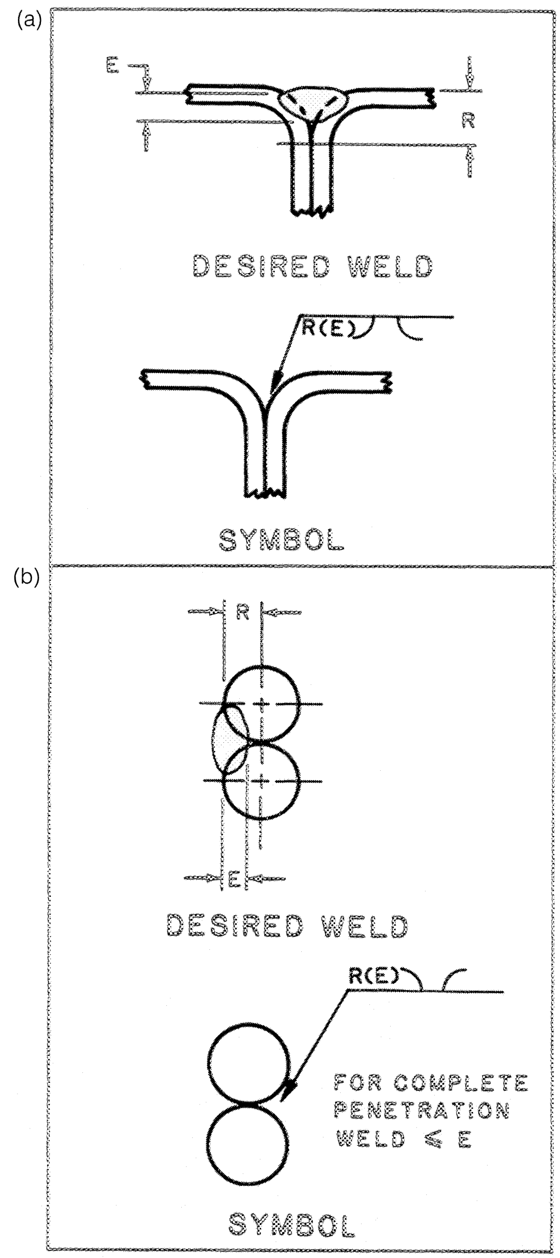


FIGURE 22.32 Bead Welds

22.5.7 Back or Backing Welds

The **back** or **backing welds** of single-groove welds are shown by placing a back or backing weld symbol on the side of the reference line opposite the groove weld symbol (Fig. 22.34). The welding symbol does not indicate the welding sequence (groove weld made before or after backing weld) or backing weld passes (single or multiple). The height of the weld bead is shown to the left of the backing weld symbol, when required. No other backing weld dimensions are shown on the welding symbol. Other dimensions may be shown pictorially on a drawing detail.

Back or backing welds that are to be welded flush without recourse to any method of finishing are shown by adding the flush contour symbol to the back or backing weld symbol. Those to be made flush by mechanical means are shown by adding the flush contour symbol and the finish symbol. A joint with spacer is indicated with the groove weld symbol modified to show a rectangle within it, with the rectangle including a notation as shown in Figure 22.35.

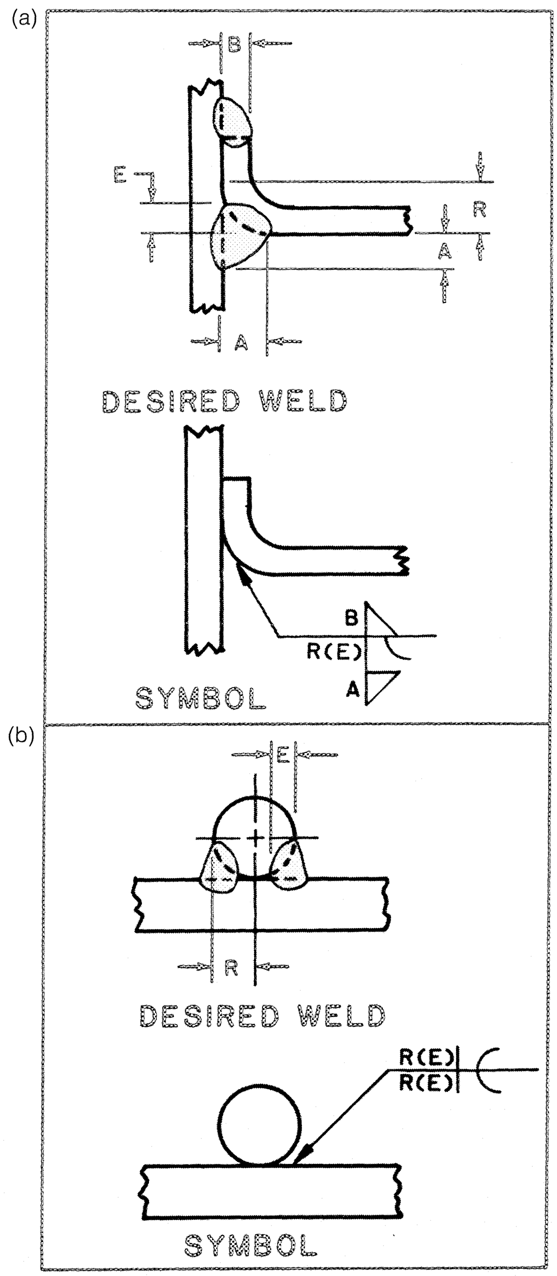


FIGURE 22.33 Bead Welds and Symbols

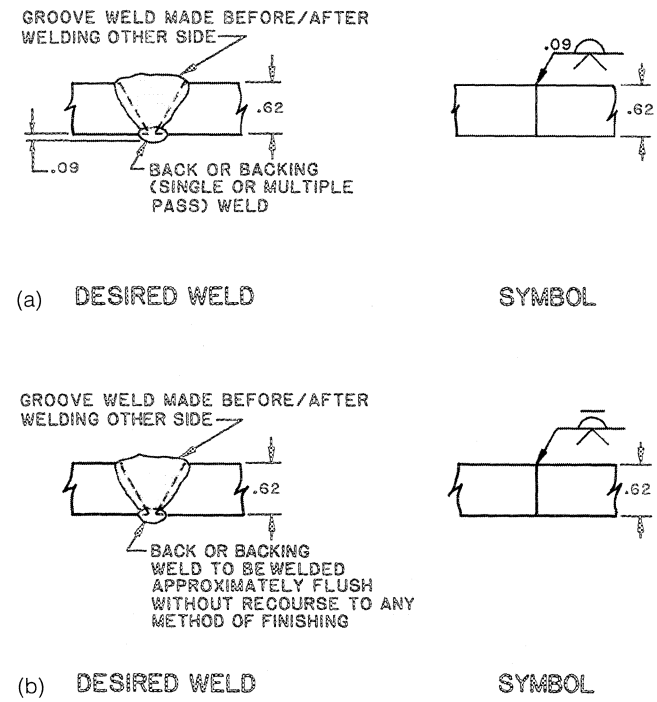
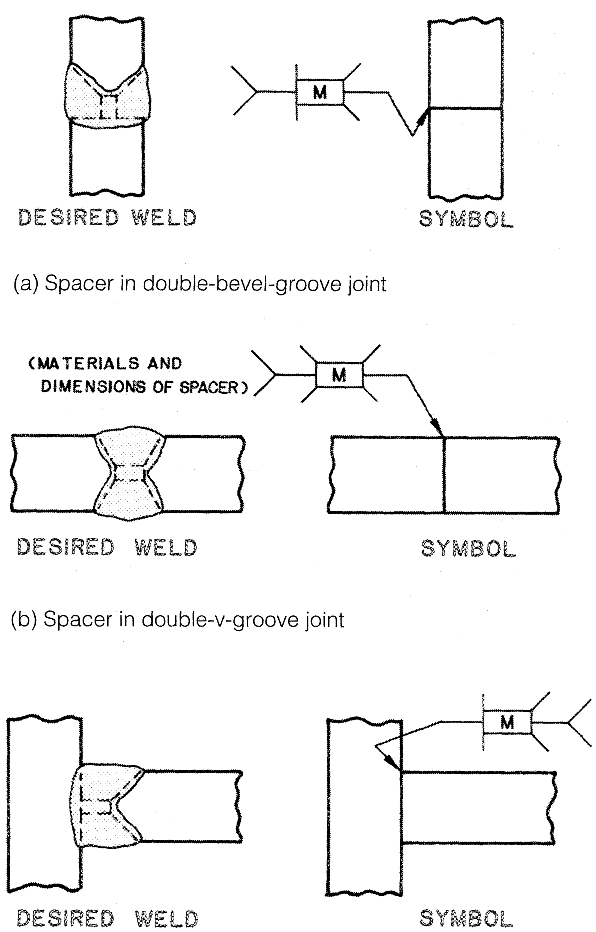


FIGURE 22.34 Bead Weld Symbols Used to Indicate Bead-Type Back and Backing Weld



(a) Spacer in double-bevel-groove joint

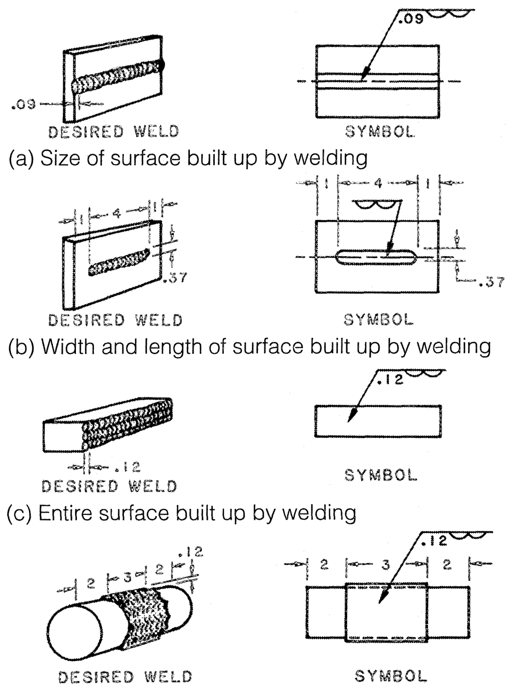
(b) Spacer in double-v-groove joint

(c) Spacer in double-bevel-groove joint

FIGURE 22.35 Spacers for Welds

22.5.8 Surfacing Welds

Basically, **surface welds** function to reclaim worn part surfaces or to add alloying elements to the base metal for added protection. Often, "surfaced" parts outlast plain parts. The surfacing weld symbol does not indicate the welding of a joint; therefore it does not have arrow-side or other-side significance. The symbol is placed below the reference line, and the arrow points clearly to the surface on which the weld is to be deposited.



(d) Portion of surface built up by welding

FIGURE 22.36 Dual Bead Weld Symbol to Indicate Surfaces Built Up by Welding

The minimum thickness of the weld buildup is the only dimension shown on the welding symbol and is placed to its left. When no specific thickness of weld is required, no size dimension is given. When only a portion of the area of a plane or curved surface is to be built up by welding, the extent, location, and orientation of the area to be built up are dimensioned on the drawing (Fig. 22.36).

You May Complete Exercises 22.5 Through 22.8 at This Time

QUIZ

True or False

1. Welding knowledge is important for engineers to understand because they will be called on to draw and design mechanical parts that may need to be fastened permanently.
2. Welds are classified as resistance, gas, or nonpressure.
3. Arc welding is the most common type of welding today.
4. High-quality welds can be completed with gas-metal arc welding using nearly all metals.
5. When dissimilar metals are welded, the weld deposit is always that of one of the base metals.
6. Normally, different types of welding processes can be encountered on the same drawing.
7. Lack of penetration is the most common type of problem encountered with groove welds.
8. With fillet welds, weld size is determined by the thinner of the two parts to be joined.

Fill in the Blanks

9. Dimensions for all types of groove welds are shown on ________ ________ of the reference line as the weld symbol.
10. The assembled welding symbol consists of the following eight parts: a reference line, ________, ________, ________, ________, ________, ________, and specifications.
11. The five basic groove welds are beveled, ________, ________, ________, and ________.
12. Deeper weld penetration results from ________ arc welding.
13. The main difference between V, bevel, U, and J welds is in the ________ of the parts to be joined.
14. The size of the fillet weld is shown to the ________ of the ________ symbol.
15. Plug and slot welds are found primarily in ________ joints.
16. The tail of the weld symbol should be omitted when ________ or ________ are not used.

Answer the Following

17. Describe slot and plug welds and their differences.
18. Explain the difference between shielded arc and unshielded arc welding processes.
19. What is the name for the granulated welding cover used in submerged arc welding?
20. What factors can affect the weldability of metals?
21. Which process is most commonly used to weld dissimilar materials?
22. Why is it important to bevel plates before groove welding?
23. Name the elements of a complete weld symbol.
24. What is meant by *arrow side* and *opposite side?* For what is the tail of the symbol used on the drawing?

EXERCISES

Exercises may be assigned as sketching, instrument, or CAD projects. Transfer the given information to an "A"-size sheet of .25 in. grid paper. Complete all views, and solve for proper visibility, including centerlines, object lines, and hidden lines. Exercises that are not assigned by the instructor can be sketched in the text to provide practice and to enhance understanding of the preceding instructional material.

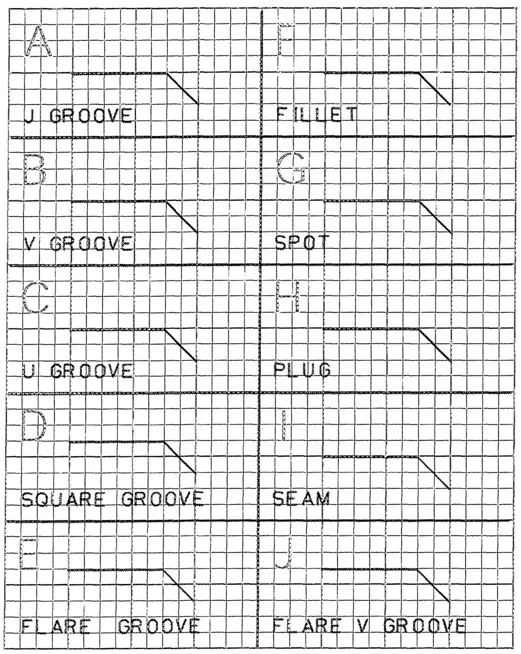
After Reading the Chapter Through Section 22.5.6 You May Complete the Following Four Exercises

Exercise 22.1 Draw the requested welding symbol, far side only. Complete the symbol, including the arrowhead.

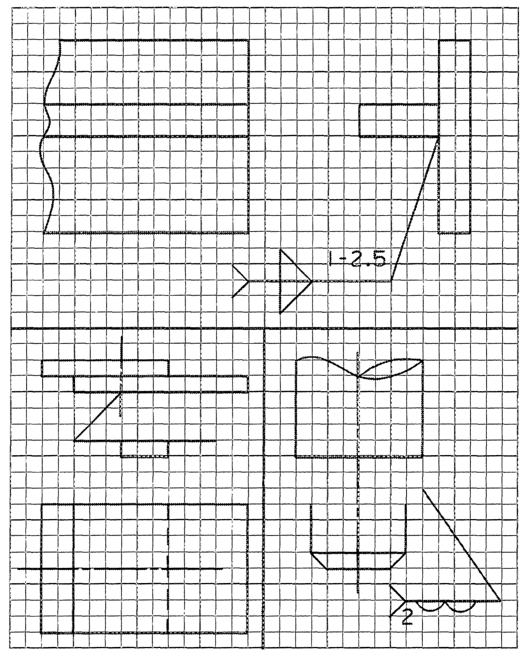
Exercise 22.2 Draw the requested weld and its associated symbol, for each joint.

Exercise 22.3 Complete the welding symbol and draw the weld on the given views. The shaft weld requires a surface weld.

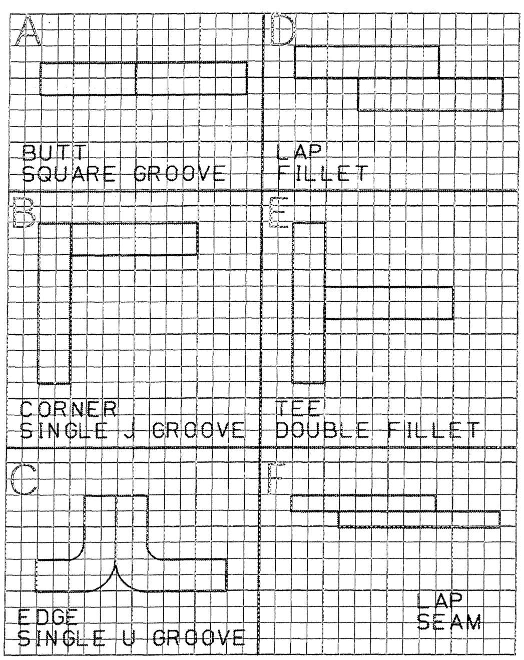
Exercise 22.4 Use .25 in. or 6 mm fillet welds and appropriate groove welds to construct the all-welded assembly. Show the welds and the welding symbols.



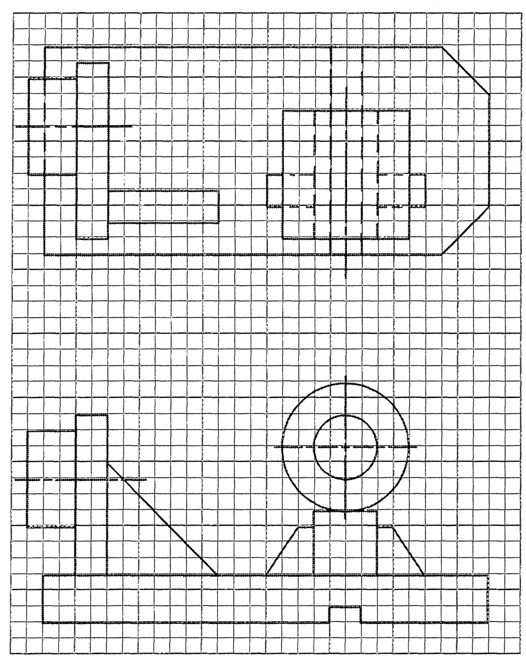
EXERCISE 22.1



EXERCISE 22.3



EXERCISE 22.2



EXERCISE 22.4

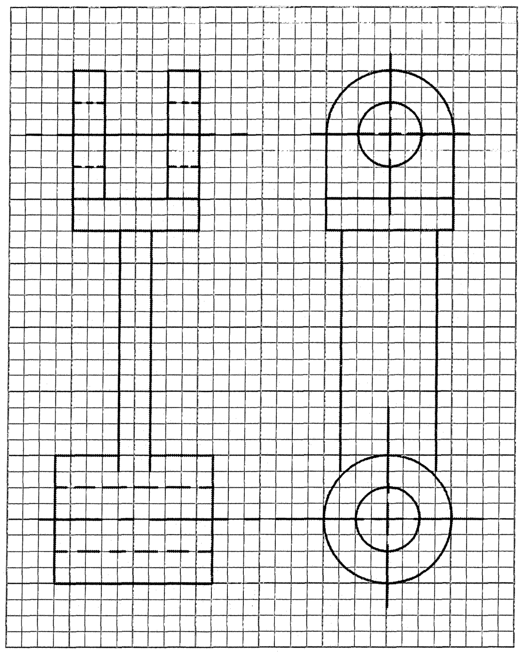
After Reading the Chapter Through Section 22.5.8 You May Complete the Following Exercises

Exercise 22.5 Using .25 in. or 6 mm fillet welds, show all symbols and welds for the part.

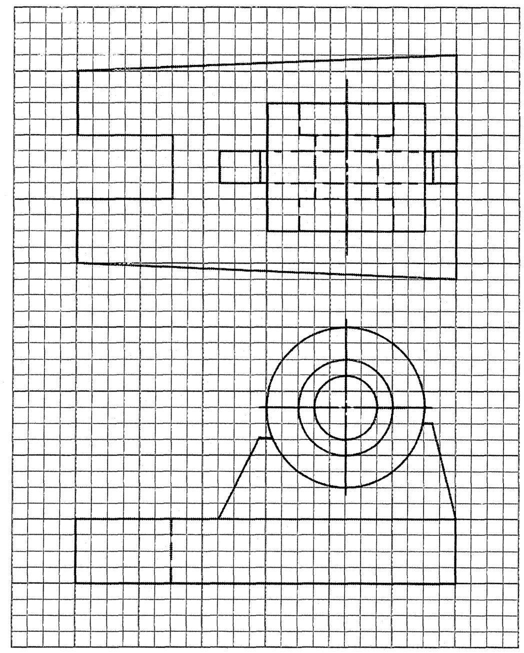
Exercise 22.6 Show appropriate welds and welding symbols for the all-welded assembly.

Exercise 22.7 Draw the welds and welding symbols for the all-welded assembly.

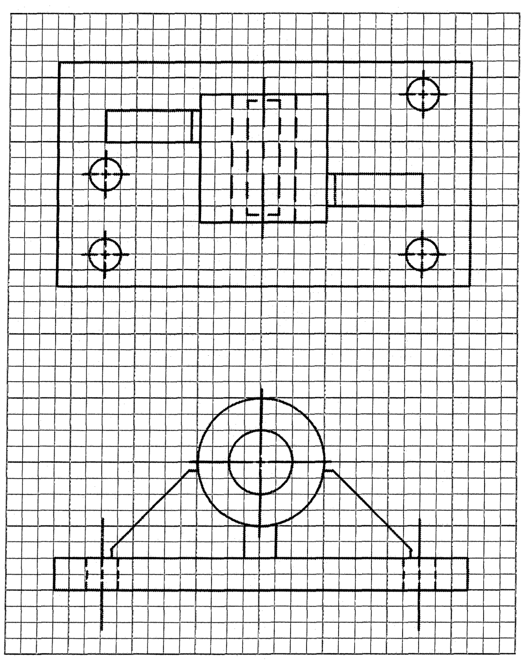
Exercise 22.8 Using spot welding for the angle and plate weldment, show the appropriate weld and welding symbol to attach the pieces with welds placed at 1 in. (25 mm) increments. For the two plates, use plug welds. Draw the welds and the welding symbols.



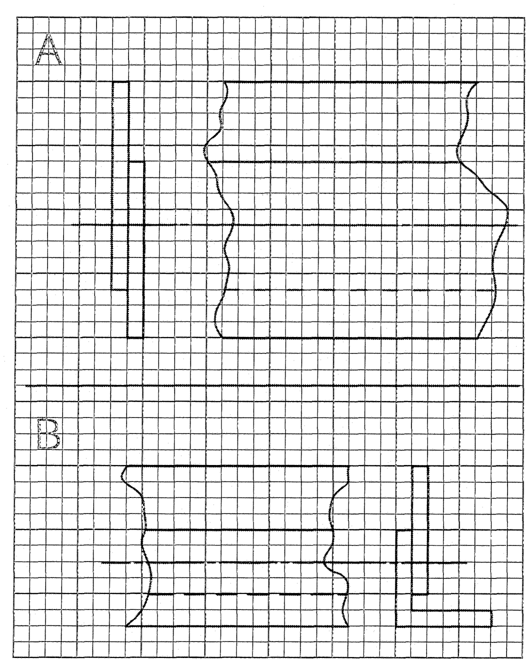
EXERCISE 22.5



EXERCISE 22.7



EXERCISE 22.6



EXERCISE 22.8