Joint Design

1. FACTORS AFFECTING PROCEDURES

For every welding job there is one procedure which will complete the joint at the lowest possible cost. The accomplishment of this task requires a knowledge of the factors affecting the type of weld to be performed.

The main factors to be considered are:

1. Type of joint to be made, included angle, root opening, and land (root face).
2. Type and size of electrode.
3. Type of current, polarity and amount (amperes).
4. Arc length (arc voltage).
5. Arc speed.
6. Position of welds (flat, horizontal, vertical, and overhead).

A large number of the above-mentioned factors can be determined by actually welding a sample joint. Such items as the type and size of electrode, polarity, current, arc characteristics, and shop techniques are best determined by the fabricator. The engineer must realize that these problems are present and should include them in his consideration of the joint designs.

Figure 1 indicates that the root opening (R) is the separation between the members to be joined.

A root opening is used for electrode accessibility to the base or root of the joint. The smaller the angle of the bevel, the larger the root opening must be to get good fusion at the root.

If the root opening is too small, root fusion is more difficult to obtain and smaller electrodes must be used, thus slowing down the welding process.

If the root opening is too large, weld quality does not suffer but more weld metal is required; this increases weld cost and will tend to increase distortion.

Figure 2 indicates how the root opening must be increased as the bevel's included angle is decreased. Backup strips are used on larger root openings. All three preparations are acceptable; all are conducive to good welding procedure and good weld quality. Selection, therefore, is usually based on cost.

Root opening and joint preparation will directly affect weld cost (pounds of metal required), and choice should be made with this in mind. Joint preparation includes the work required on plate edges prior to welding and includes beveling, providing a land, etc.

In Figure 3a if bevel and/or gap is too small, the weld will bridge the gap leaving slag at the root. Excessive back gouging is then required.

Figure 3b shows how proper joint preparation and

FIGURE 1

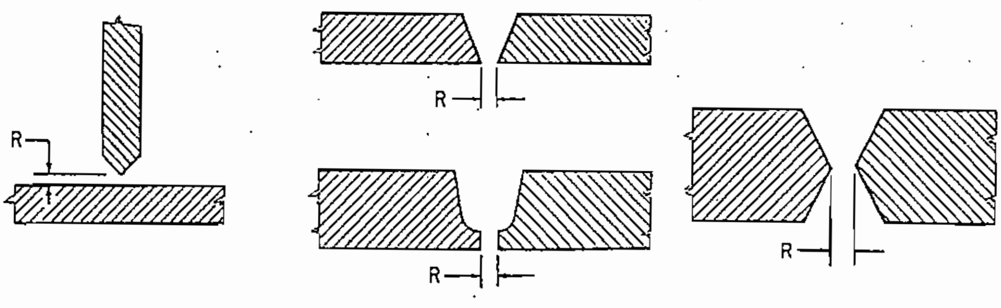
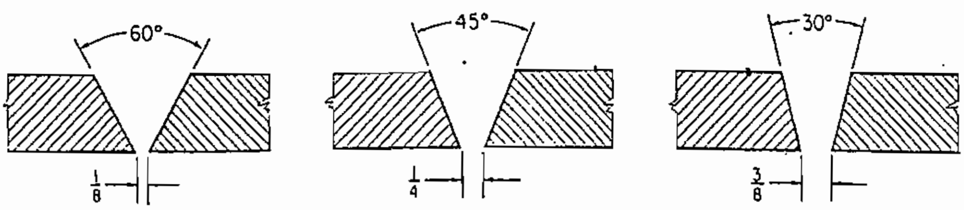


FIGURE 2



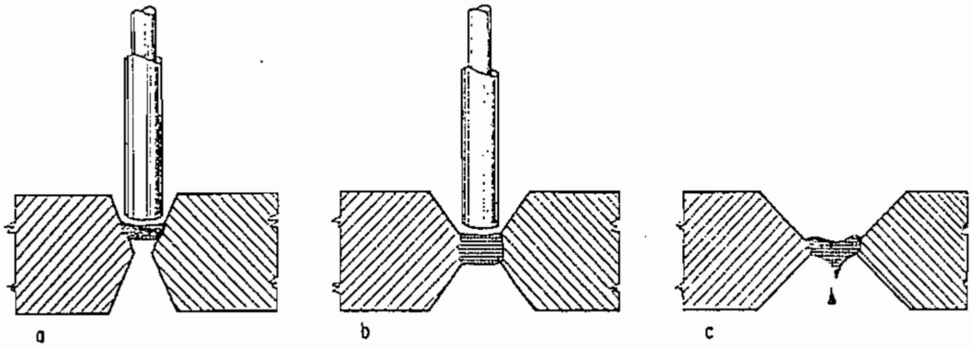


FIGURE 3

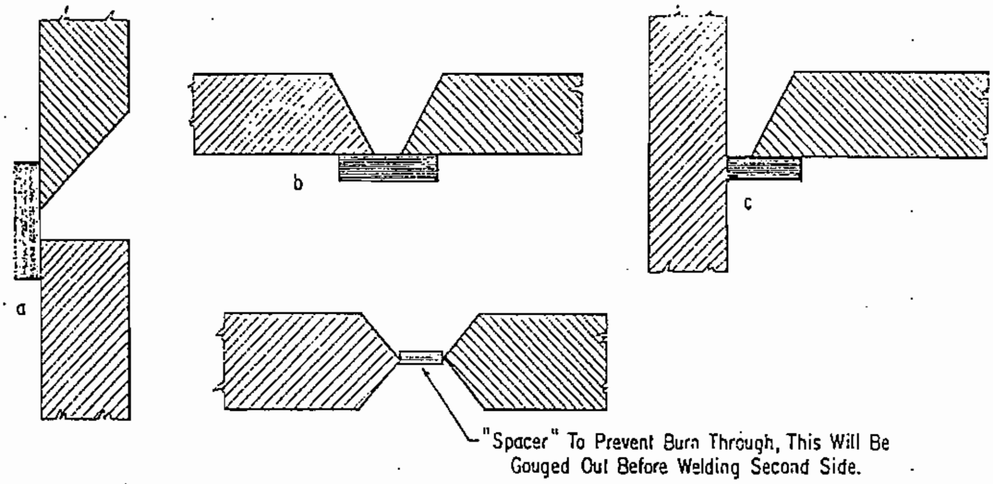


FIGURE 4

procedure will produce good root fusion and will minimize back gouging.

In Figure 3c a large root opening will result in burn-through. Spacer strip may be used, in which case the joint must be back gouged.

Backup strips are commonly used when all welding must be done from one side, or when the root opening is excessive. Backup strips, shown in Figure 4a, b and c, are generally left in place and become an integral part of the joint.

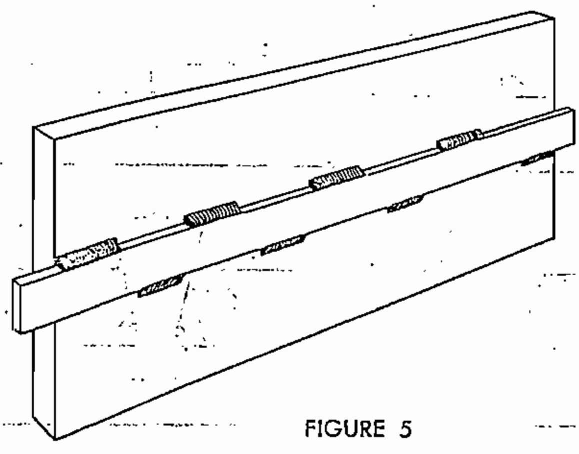


FIGURE 5

Spacer strips may be used especially in the case of double-vee joints to prevent burn-through. The spacer, Figure 4d, to prevent burn-through, will be gouged out before welding the second side.

Backup Strips

Backup strip material should conform to the base me— Feather edges of the plate are recommended when using a backup strip.

Short intermittent tack welds should be used to hold the backup strip in place, and these should preferably be staggered to reduce any initial restraint of the joint. They should not be directly opposite one another, Figure 5.

The backup strip should be in intimate contact with both plate edges to avoid trapped slag at the root, Figure 6.

Weld Reinforcement

On a butt joint, a nominal weld reinforcement (approximately $1/16''$ above flush) is all that is necessary, Figure 7, left. Additional buildup, Figure 7, right, serves no useful purpose, and will increase the weld cost.

Care should be taken to keep both the width and the height of the reinforcement to a minimum.

2. EDGE PREPARATION

The main purpose of a land, Figure 8, is to provide an additional thickness of metal, as opposed to a feather edge, in order to minimize any burn-through tendency. A feather edge preparation is more prone to burn-through than a joint with a land, especially if the gap gets a little too large, Figure 9.

A land is not as easily obtained as a feather edge. A feather edge is generally a matter of one cut with a torch, while a land will usually require two cuts or possibly a torch cut plus machining.

A land usually requires back gouging if a 100% weld is required. A land is not recommended when welding into a backup strip, Figure 10, since a gas pocket would be formed.

Plate edges are beveled to permit accessibility to all parts of the joint and insure good fusion throughout the entire weld cross-section. Accessibility can be gained by compromising between maximum bevel and minimum root opening, Figure 11.

Degree of bevel may be dictated by the importance of maintaining proper electrode angle in confined quarters, Figure 12. For the joint illustrated, the minimum recommended bevel is 45°.

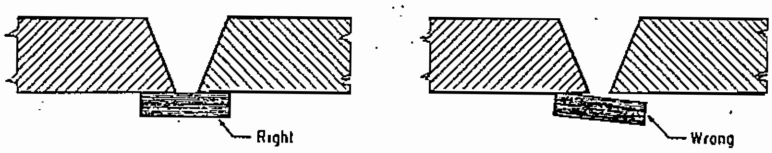


FIGURE 6

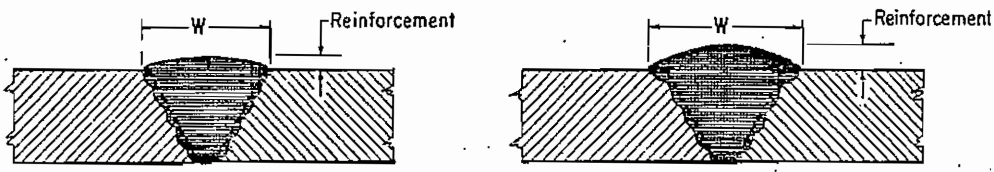


FIGURE 7

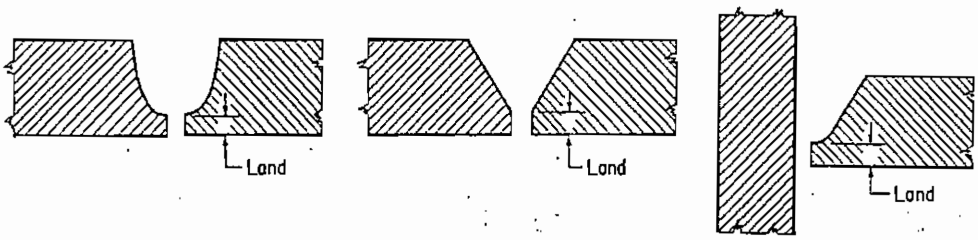


FIGURE 8

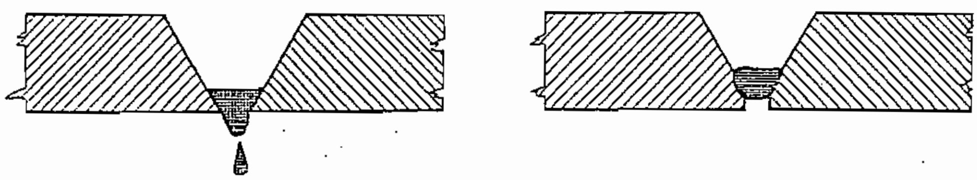


FIGURE 9

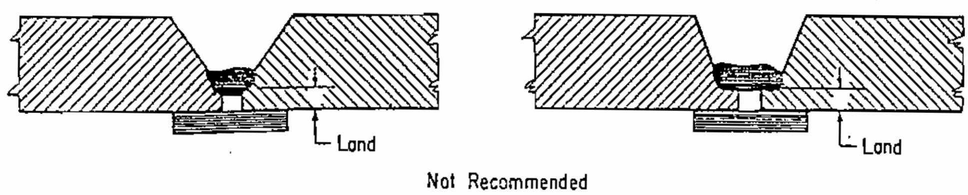


FIGURE 10

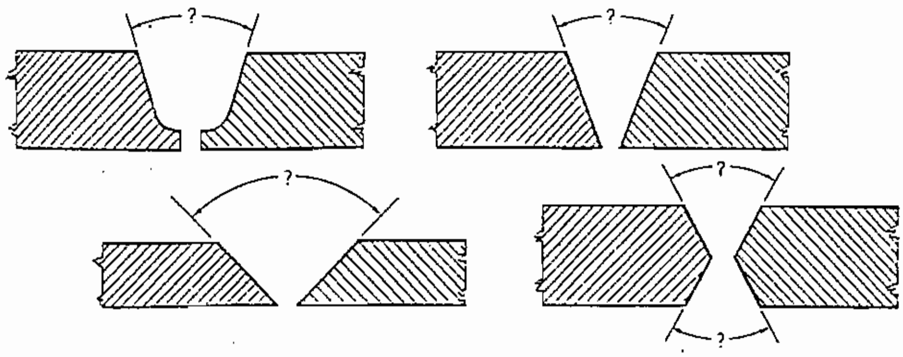


FIGURE 11

U and J versus Vee Preparations

J and U preparations are excellent to work with but economically they have little to offer because preparation requires machining as opposed to simple torch cutting. Also a J or U groove requires a land, Figure 13, and thus back gouging.

Back Gouging

To consistently obtain complete fusion when welding a plate, back gouging is required on virtually all joints except "vees" with feather edge. This may be done by any convenient means: grinding, chipping, or arc-air gouging. The latter method is generally the most economical and leaves an ideal contour for subsequent beads.

Without back gouging, penetration is incomplete, Figure 14. Proper back chipping should be deep enough to expose sound weld metal, and the contour should permit the electrode complete accessibility, Figure 15.

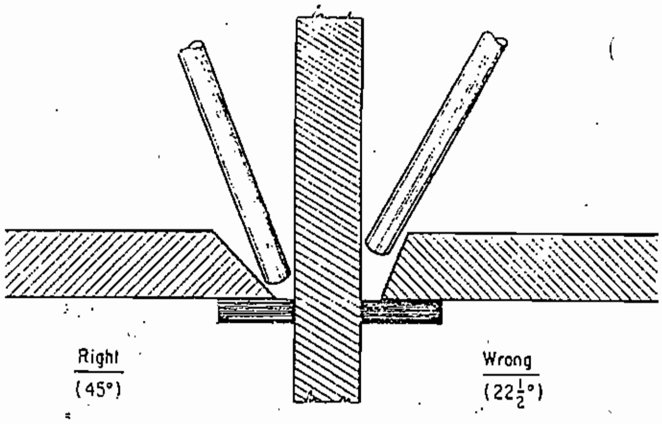


FIGURE 12

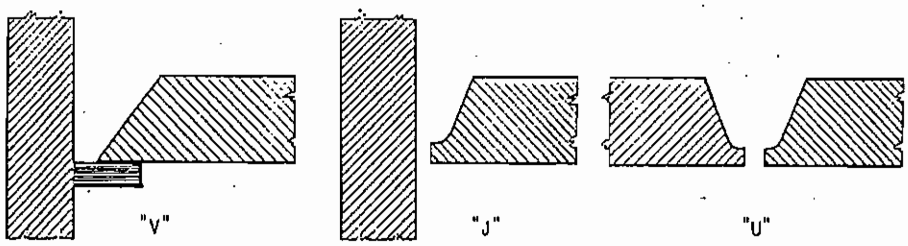


FIGURE 13

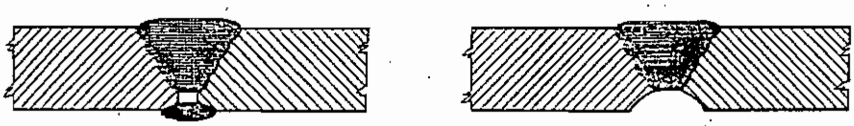


FIGURE 14

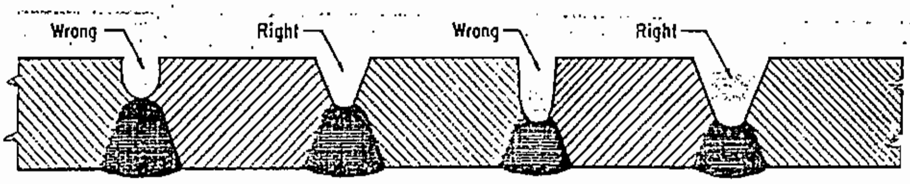
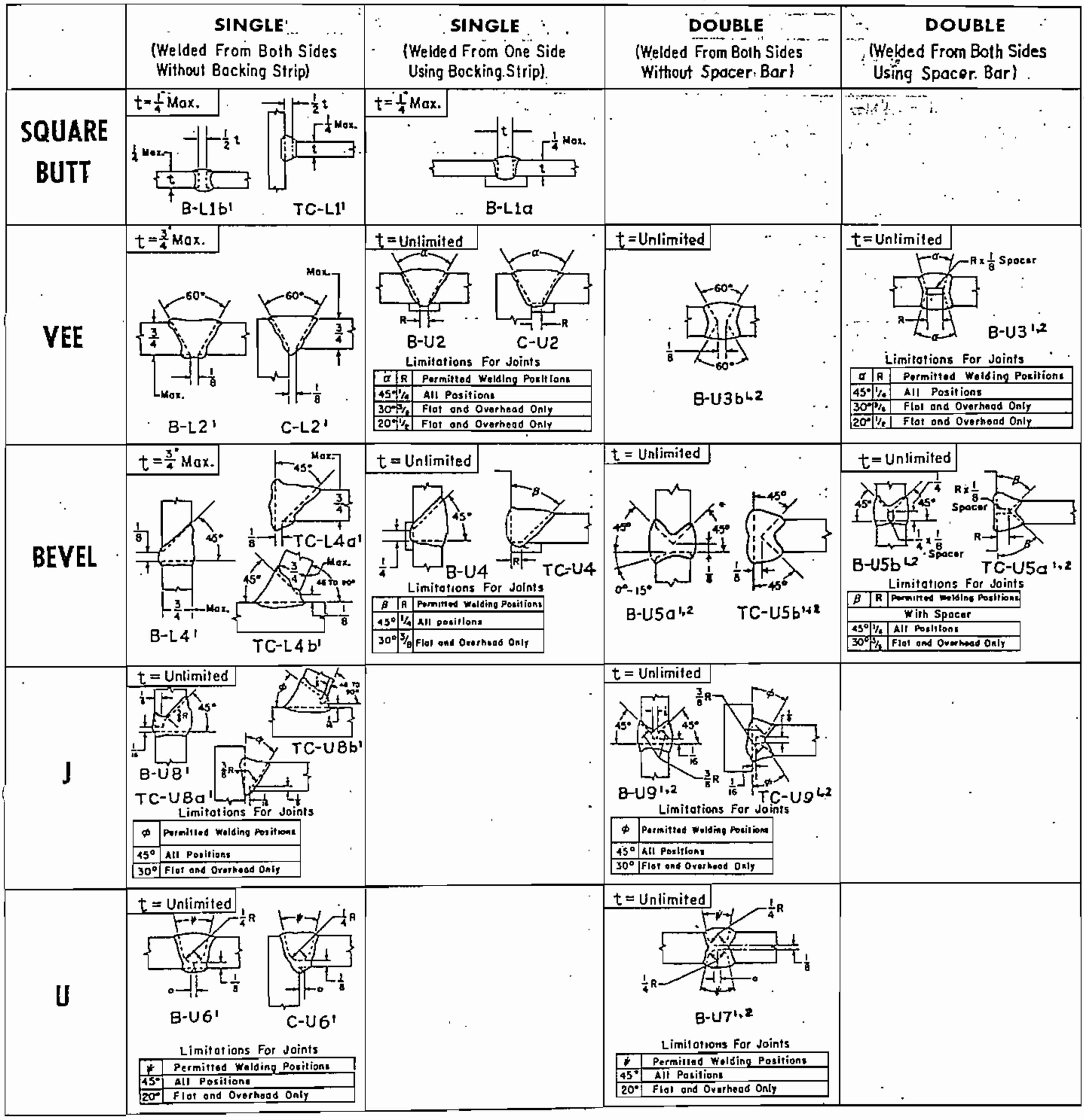


FIGURE 15

FIGURE 16A—Prequalified AWS Building Joints (Manual Welding)
Complete Penetration Groove Welds—Par. 209

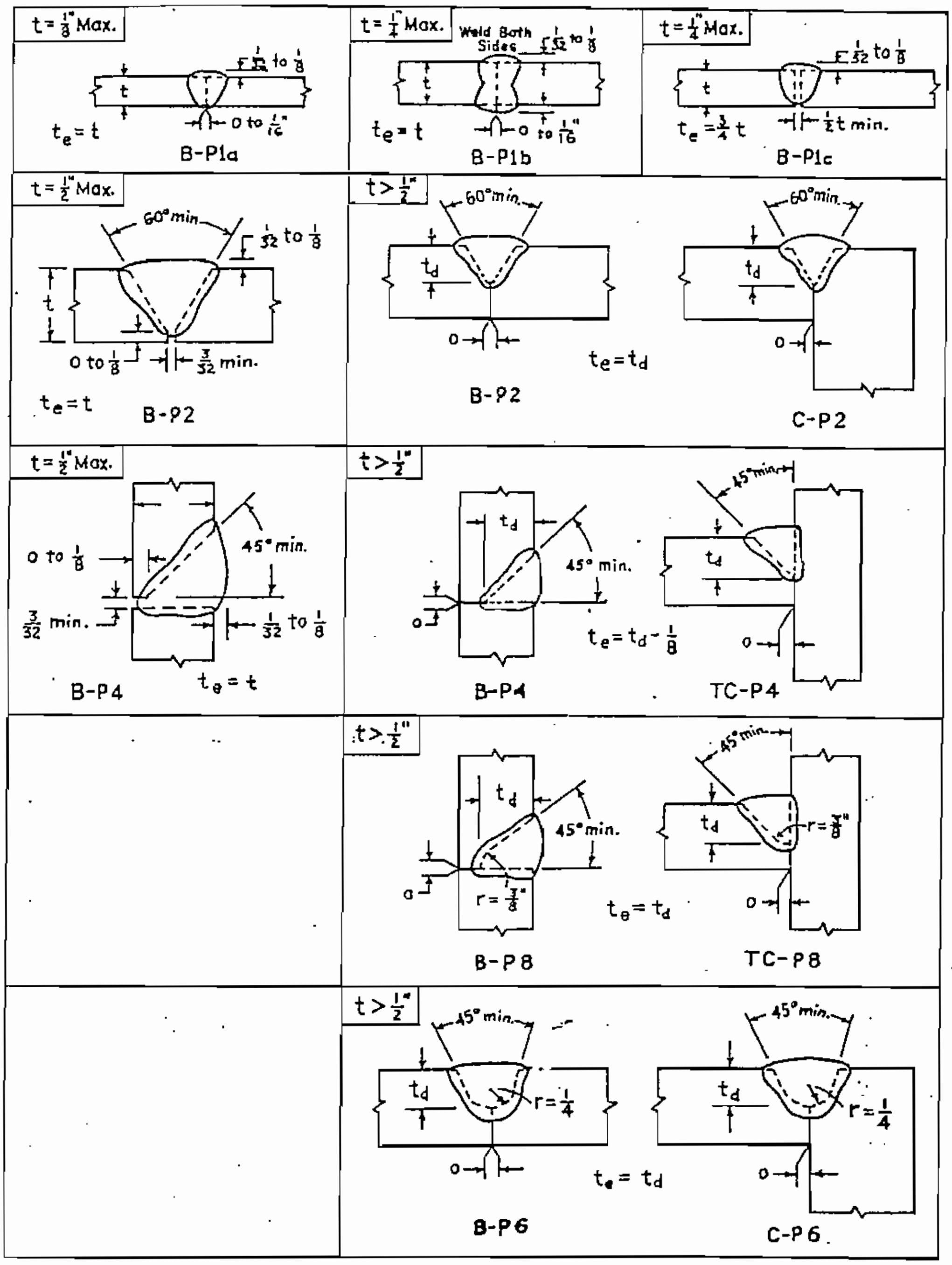


NOTE: The size of the fillet weld reinforcing groove welds in Tee and corner joints shall equal t/4 but shall be 3/8" max.

1. Gouge root before welding second side (Par 505i)
2. Use of this weld preferably limited to base metal thickness of 5/8" or larger.

* When lower plate is bevelled, first weld root pass this side.

FIGURE 16B—Prequalified AWS Building Joints (Manual Welding)
Partial Penetration Groove Welds—Par. 210 $t_e \geq \sqrt{\frac{t}{6}}$



NOTE: 1. Gouge root before welding second side (Par. 505i)
2. Use of this weld preferably limited to base metal thickness of 5/8" or larger.
* When lower plate is bevelled, first weld root pass this side.

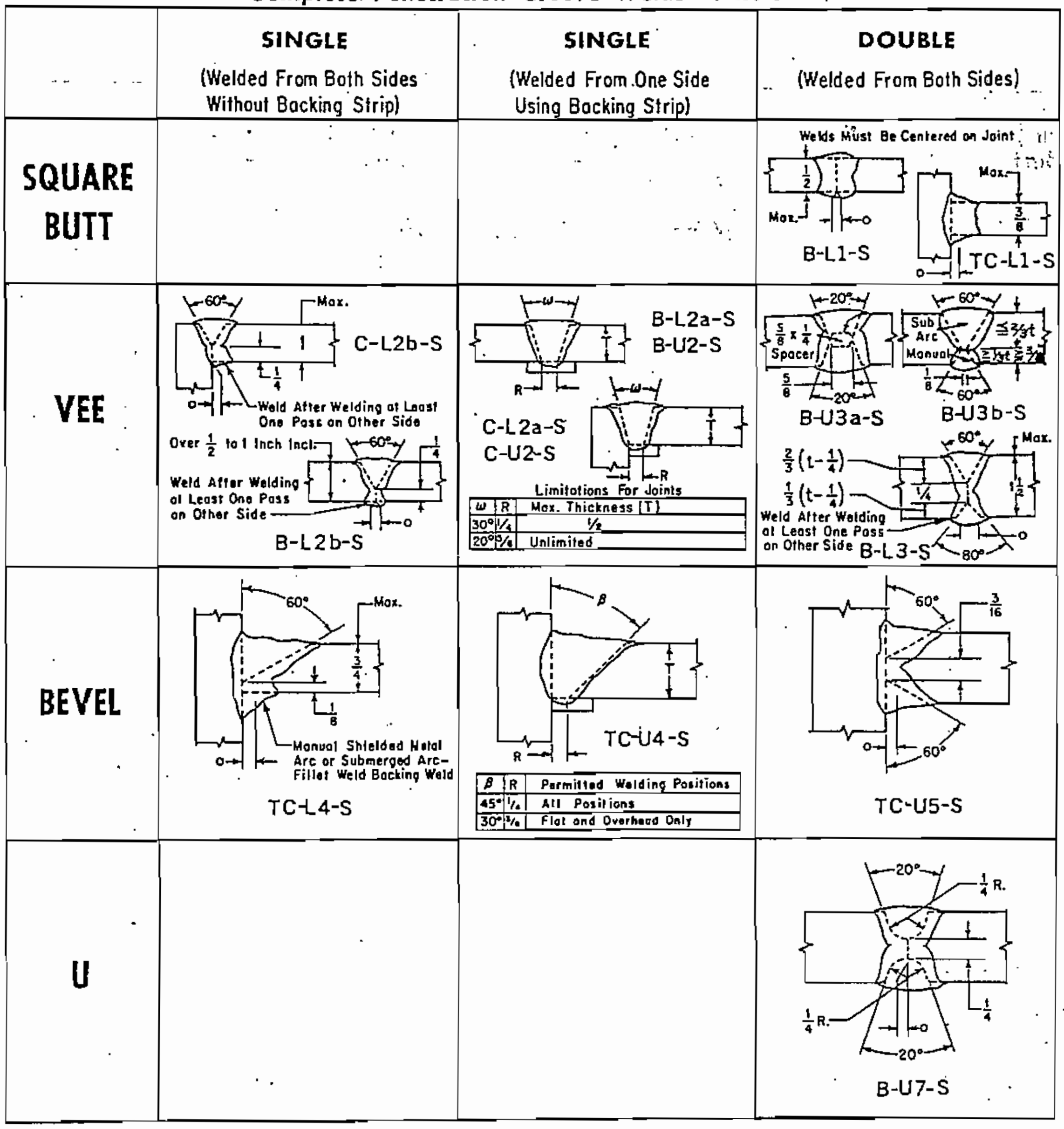
3. TYPES OF JOINTS

The type of joint to be made depends on the design condition and may be one of the following: groove, fillet, plug or T joint. These joints may be made using various edge preparations, such as: square butt, Vee, bevel, J, or U. Certain of these joints have been prequalified by the American Welding Society (AWS) and are illustrated in two charts, Figure 16 for manual welding and in Figure 17 for submerged-arc automatic welding.

The choice between two or more types of joint

FIGURE 17A—Prequalified AWS Building Joints (Submerged-Arc Automatic Welding)

Complete Penetration Groove Welds—Par. 211



ω	R	Max. Thickness (T)
30°	1/4	1/2
20°	5/8	Unlimited

β	R	Permitted Welding Positions
45°	1/4	All Positions
30°	3/8	Flat and Overhead Only

NOTE: The size of the fillet weld reinforcing groove welds in Tee and corner joints shall equal t/4 but shall be 3/8" max.

1. Gouge root before welding second side (Par 505i)
2. Use of this weld preferably limited to base metal thickness of 5/8" or larger.

* When lower plate is bevelled, first weld root pass this side.

is not always dictated solely by the design function. The choice often directly affects the cost of welding. For example, Figure 18 illustrates this influence. The choice is to be made between 45° fillet welds or some type of T groove joints.

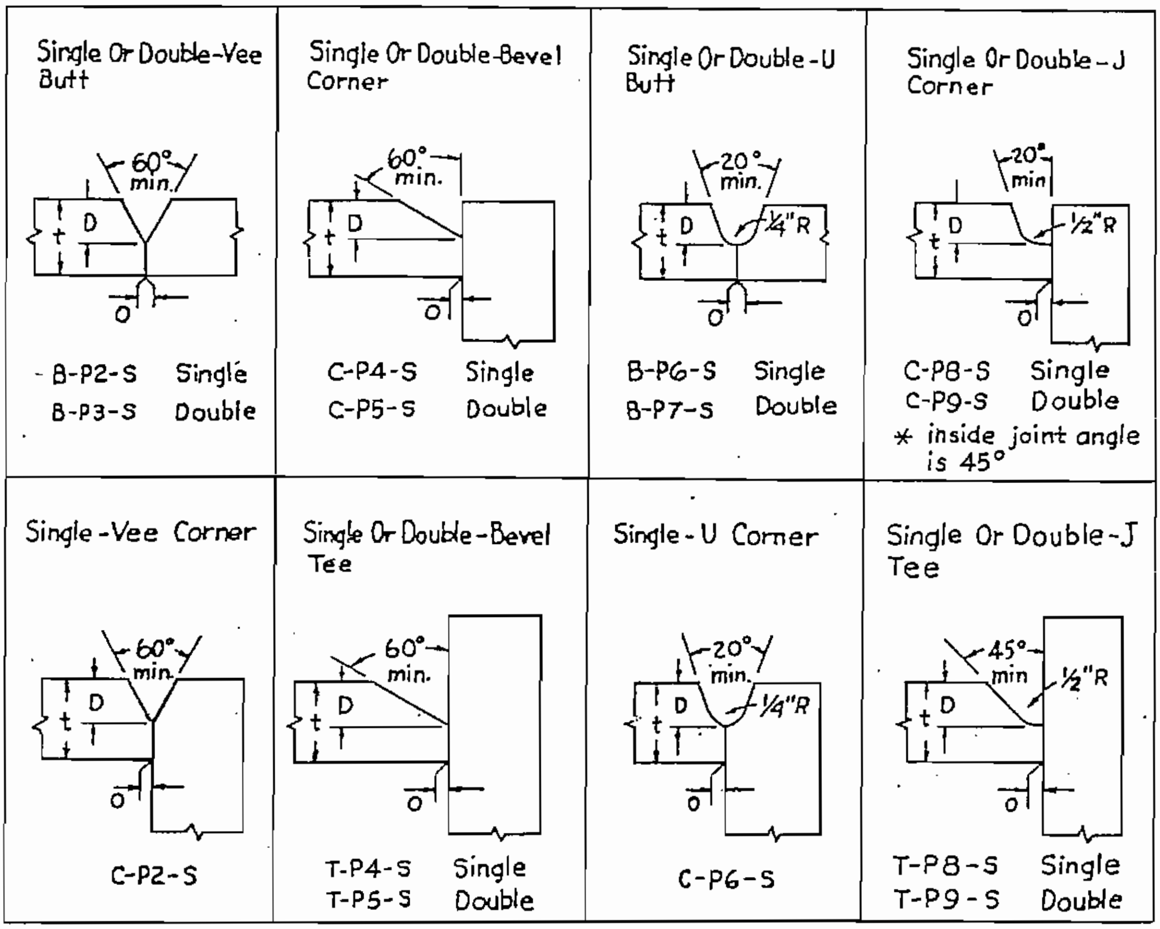
(a) For full-strength welds, the leg of the fillet weld must be about 75% of the plate thickness.

(b) Full strength may also be obtained by double beveling the edge of the plate 45° and spacing the plate so the root opening is ⅛" to allow for complete penetration. The amount of weld metal compared to the conventional fillet weld varies from 75% for a 1" plate to 56% for a 4" plate. For plates up to about 1½" thickness, the extra cost of beveling the plate and the probable need to use lower welding current in the 45° groove tend to offset the lower cost of weld metal for this type of joint. But for heavier plate the reduction in weld metal is great enough to overcome any extra preparation cost.

(c) Full strength may also be obtained by bevel-

FIGURE 17B—Prequalified AWS Building Joints
(Submerged-Arc Automatic Welding)

Partial Penetration Groove Welds—Par. 212



NOTES:

- Welded in the flat position.
- If root face is less than 1/4", there should be at least one manual bead to prevent burnthrough.
- Minimum effective throat $= \sqrt{t/6}$, where t is thickness of thinner part.
- Plate thickness: single groove joint $t \geqq \frac{3}{4}$"; double groove joint $t \geqq 1\frac{1}{4}$".
- Effective throat $= t_d$.

ing the edge of the plate 60° so as to place some of the weld within the plate; a 60° fillet is then placed on the outside. The minimum depth of bevel and the additional leg of fillet are both equal to 29% of the plate thickness. For all plate thicknesses, the amount of weld metal is approximately half that of the conventional fillet. This joint has the additional advantage that almost high welding current may be used as in the making of the fillet weld.

All of this is shown in the graph, Figure 18. The cross-over point in this chart between the conventional fillet welds and the 45° full penetrated T groove joint is about 1½" plate. The 60° bevel, partly penetrated joint, with 60° fillets appears to be the lowest in cost above 1" in thicknesses. The relative position of these curves will vary according to the welding and cutting costs used.

It would be a good idea for each company to make a similar cost study of the welding in their shop for guidance of their engineers in quickly selecting the most economical weld. Naturally the various costs (labor, welding, cutting, handling, assembly, etc.) will vary with each company.

4. WELDING SYMBOLS

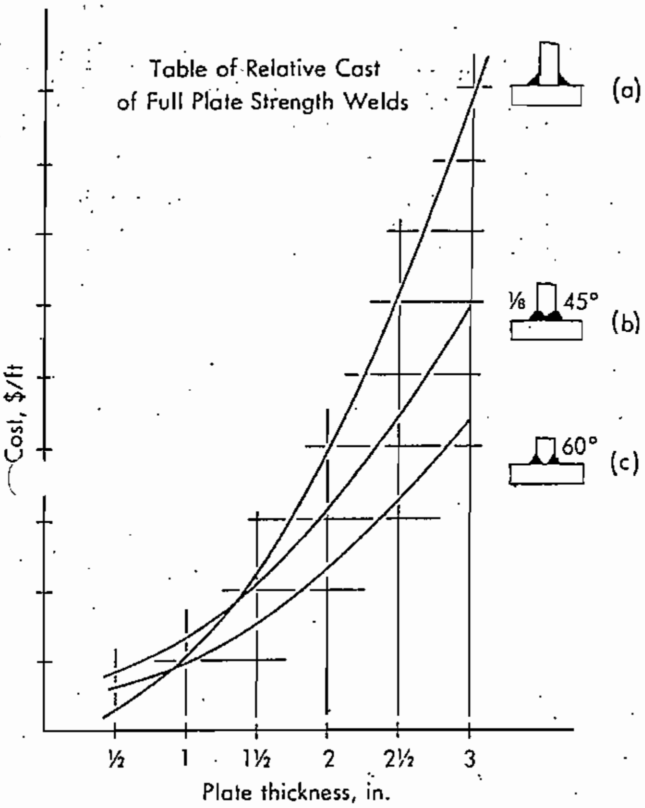


FIGURE 18

The symbols in the chart, Figure 19, denoting the type of weld to be applied to a particular weldment have been standardized and adopted by the American Welding Society. Like any systematic plan of symbols, these welding notations quickly indicate to the designer, draftsman, production supervisor, and weldor alike, the exact welding details established for each joint or connection to satisfy all conditions of material strength and service required. Adapting this system of symbols to your engineering department will assure that the correct welding instructions are transmitted to all concerned and prevent misinterpretation of instructions, and resulting production cost increases.

Although at first it may appear that many different symbols are involved, the system of symbols is broken down into basic elements or fundamentals. Any combination of these elements can then be built up to conform to any set of conditions governing a welded joint.

Therefore, it is wise in the initial stages to limit the use of symbols to just fillet welds and simple groove welds and to detail any special welds on the drawings. After the shop and draftsmen get used to these simple symbols, then they can branch into the ones that are more rarely used. Figure 20 shows the practical application of these symbols to various typical joints.

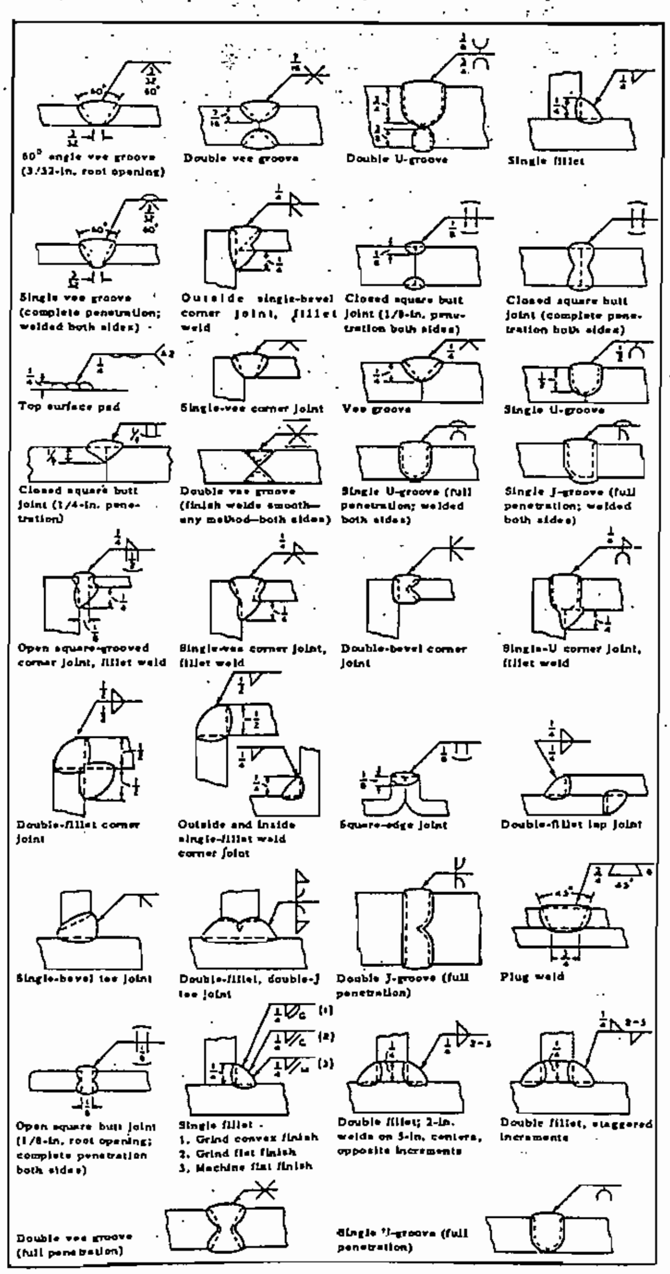
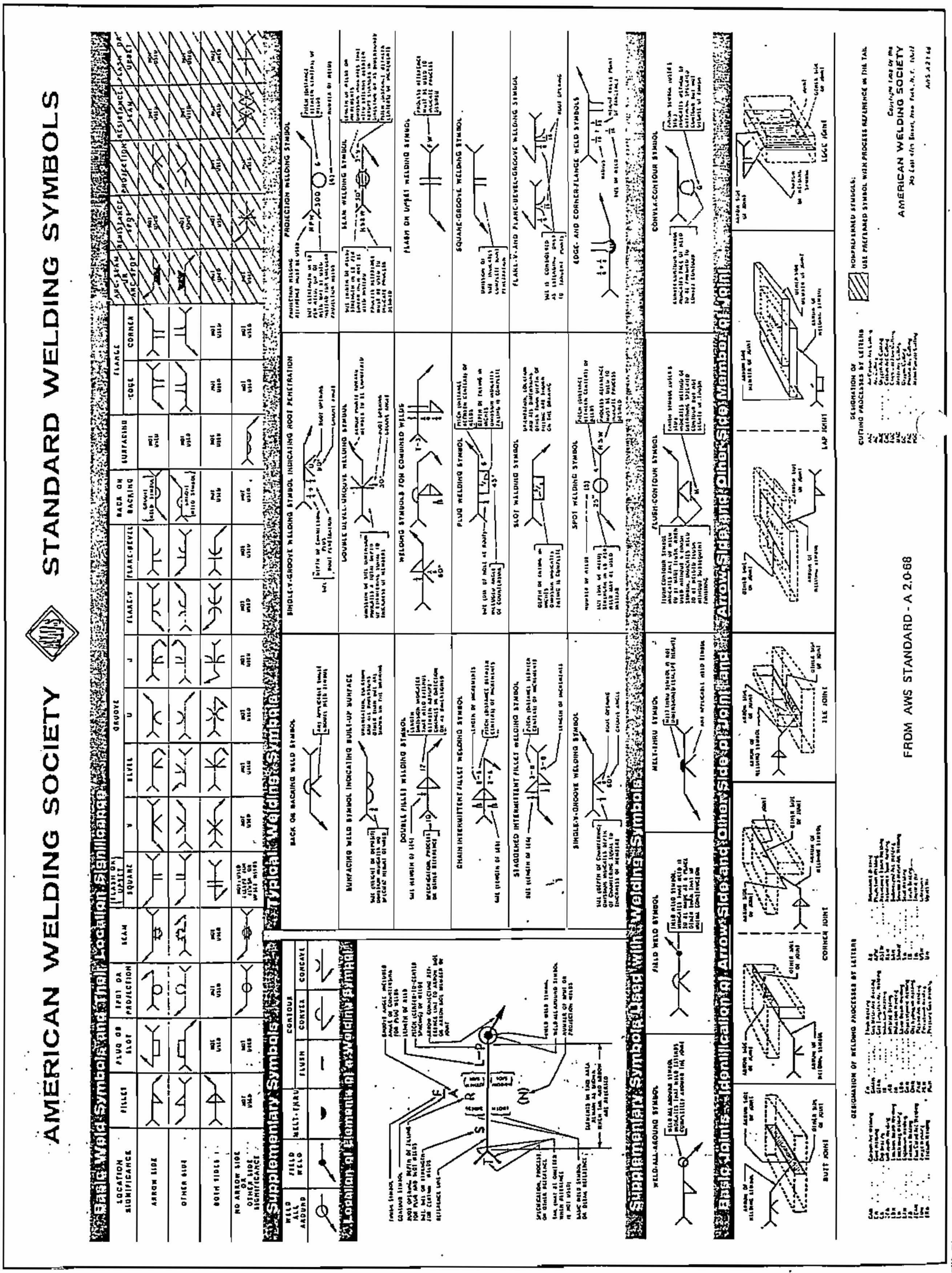
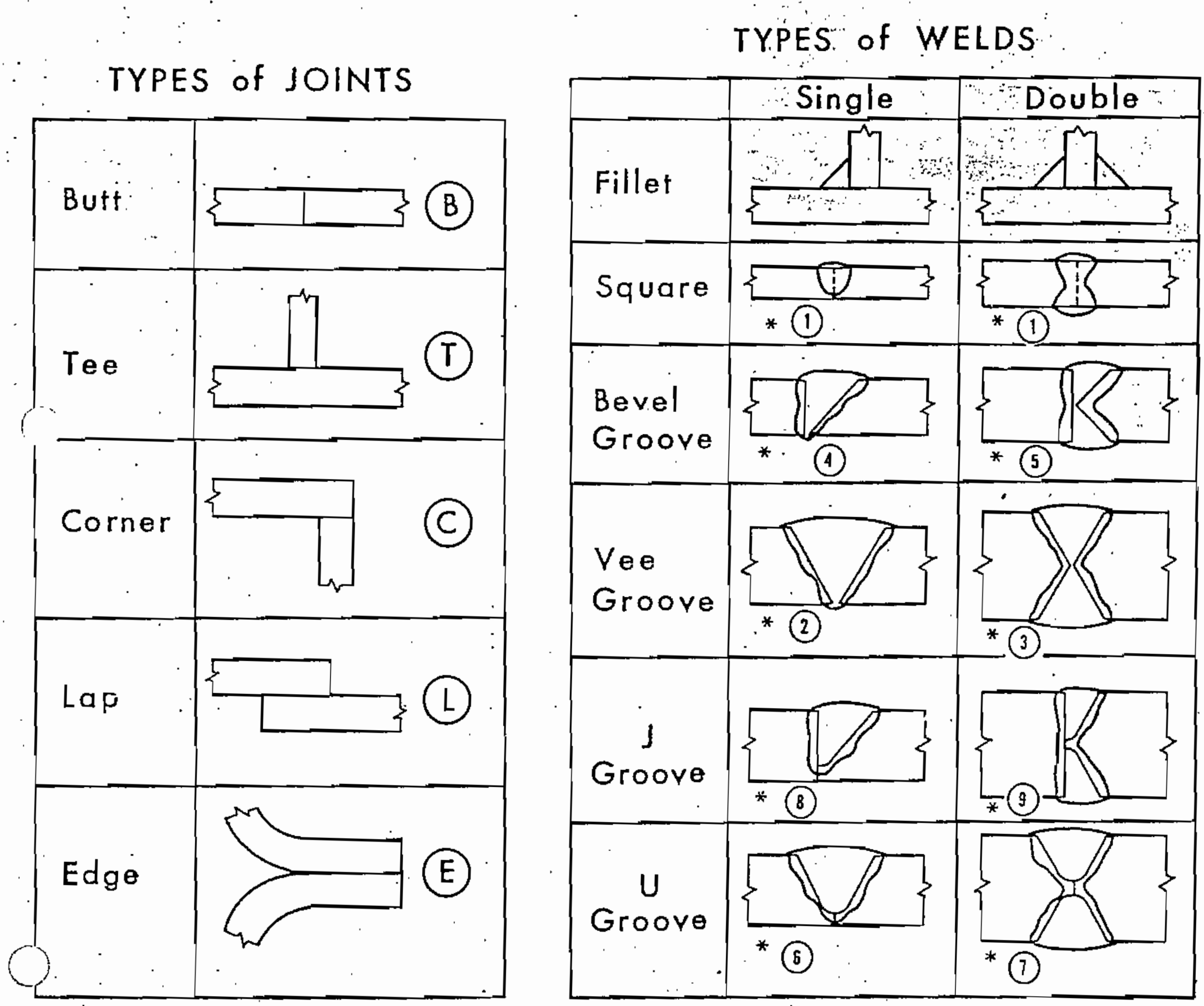


FIG. 20—Typical Applications of AWS Drafting Symbols for Welds.

FIGURE 19


AMERICAN WELDING SOCIETY
STANDARD WELDING SYMBOLS
Basic Weld Symbols and Their Location Significance
Supplementary Symbols
Typical Welding Symbols
Location of Elements of a Welding Symbol
Supplementary Symbols Used with Welding Symbols
Basic Joints - Identification of Arrow Side and Other Side of Joint
Arrow Side and Other Side Member of Joint
FROM AWS STANDARD - A 2.0-68
AMERICAN WELDING SOCIETY



*Same Number Used on AWS Prequalified Joints, See Figures 16A & B, 17A & B.

FIGURE 21

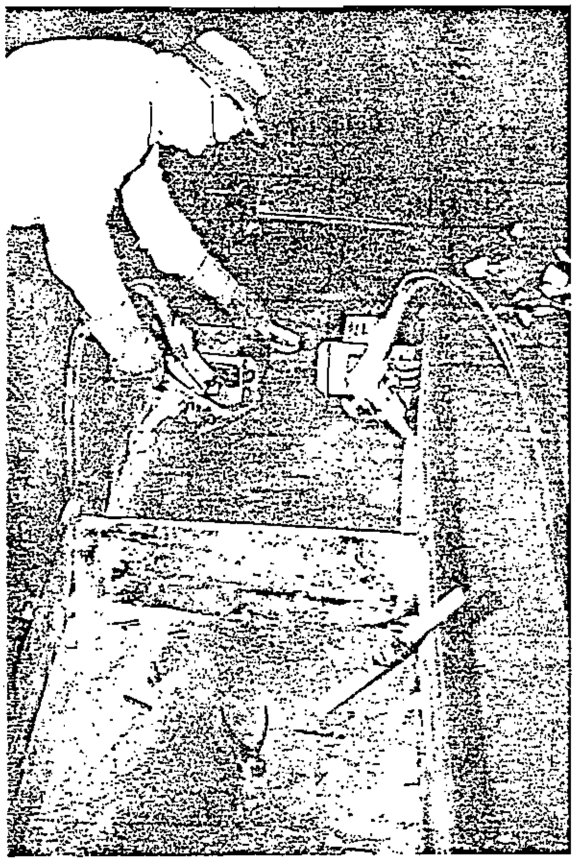
5. TERMINOLOGY

People who specify or are otherwise associated with welding often use the terms "joint" and "weld" rather loosely. For clarity in communication of instructions, it is desirable to keep in mind the basic difference in meaning between these two terms. This is illustrated by Figure 21.

The left-hand chart shows the five basic types of joints: butt, tee, corner, lap, and edge. Each is defined in a way that is descriptive of the relationship the plates being joined have to each other. Neither the geometry of the weld itself nor the method of edge preparation has any influence on the basic definition of the joint. For instance, the tee joint could be either fillet welded or groove welded.

The right-hand chart shows the basic types of welds: fillet, square, bevel-groove, V-groove, J-groove, and U-groove. The type of joint does not affect what we call the weld. Although the single bevel-groove weld is illustrated as a butt joint, it may be used in a butt, tee or corner joint.

The complete definition of a welded joint must include description of both the joint and the weld.



Efficient fabrication of large curved roof girders for the University of Vermont gymnasium was assured by submerged-arc welding, using semi-automatic guns mounted on self-propelled trackless tractors.

Here production of large box-section bridge girders is speeded by submerged-arc welding and self-propelled trackless trolley which follows the joint with minimum guidance.