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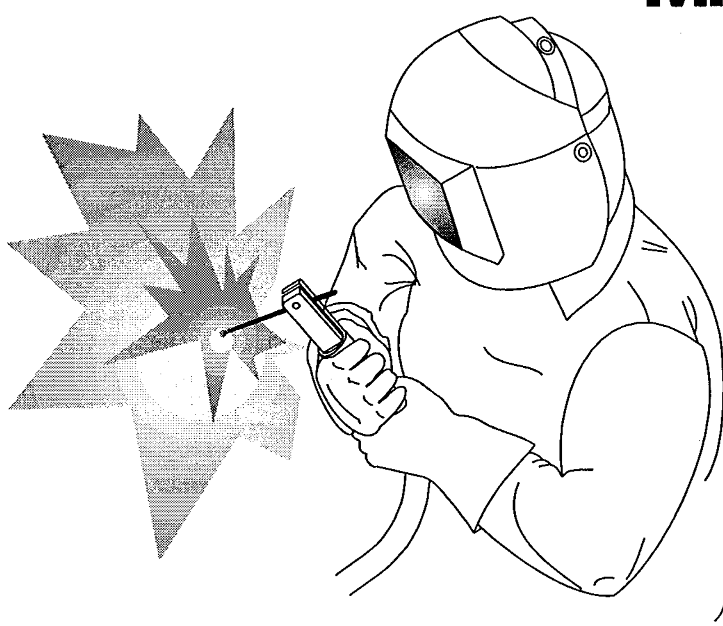


PRINCIPLES OF SHIELDED METAL ARC WELDING (SMAW)

WARNING:

This document contains general information about the topics discussed herein. This document is not an application manual and does not contain a complete statement of all factors pertaining to those topics.

The installation, operation, and maintenance of arc welding equipment and the employment of procedures described in this document should be conducted only by qualified persons in accordance with applicable codes, safe practices, and manufacturer's instructions.

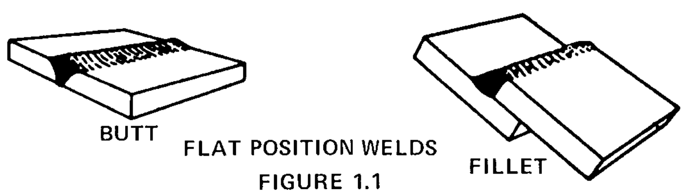
Always be certain that work areas are clean and safe and that proper ventilation is used. Misuse of equipment, and failure to observe applicable codes and safe practices, can result in serious personal injury and property damage.

PRINCIPLES OF ARC WELDING

Shielded metal-arc welding with the transformer welding machine depends upon this fundamental fact: that when one side of the welding circuit is attached to a piece of steel, a welding electrode connected to the other side and the two brought into contact, an arc will be established. If the arc is properly controlled, the metal from the electrode will pass through the arc and be deposited on the steel. When the electrode is moved along the steel at the correct speed, the metal will deposit in a uniform layer called a bead. The electrodes used in welding are carefully manufactured to produce strong, sound welds. They consist of a core of steel wire, usually called mild since it contains a low (0.10-0.14) percentage of carbon. Around this core is applied a special coating which assists in creating the arc and at the same time protects the molten steel as it transfers across the arc.

In order to utilize these principles in metal-arc welding, some means of controlling the power is essential. The power in a welding circuit is measured by the voltage and current. However, the voltage is governed by the arc length and in turn depends on the electrode diameter. Therefore, the practical measure of the power, or heat, is in terms of the current, generally measured in amperes. Obviously a small electrode requires less current than a large one. To simplify operations the scale on the front of the welding machine is marked off for the various current values.

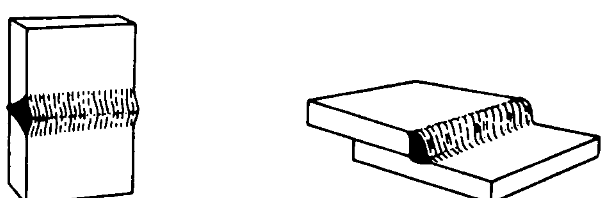
The exact current selected for a job depends upon the size of the pieces to be welded and the position of welding. Generally a lower current will be sufficient for welding on a small part than would be necessary to weld on a large piece of the same thickness. Similarly with a given size of electrode a lower current should be used on thin metals than on the heavier sections.



FLAT POSITION WELDS

FIGURE 1.1

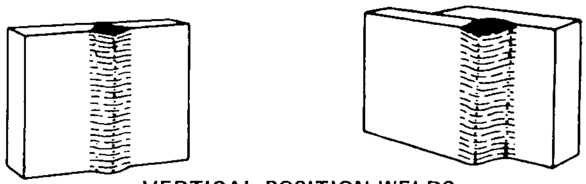
While it is always a good policy to weld on work in the flat position, as shown in Figure 1.1, occasionally, when working on ma-



HORIZONTAL POSITION WELDS

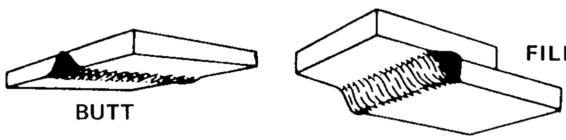
FIGURE 1.2

chines or other large units it will be necessary to weld in a vertical, horizontal or overhead position as shown in Figures 1.2, 1.3, and 1.4, respectively. Generally, under these difficult conditions it is helpful to reduce the current from the value used on welding in the flat position.



BUTT VERTICAL POSITION WELDS FILLET

FIGURE 1.3



FILLET

BUTT

OVERHEAD POSITION WELDS

FIGURE 1.4

STRIKING THE ARC - RUNNING BEADS

In learning to weld there are certain fundamental steps which must be mastered before one can attempt to weld on actual work. Preparatory to the actual striking of an arc, it is necessary to insert the electrode in the holder, as shown in Figure 2.1. For striking an

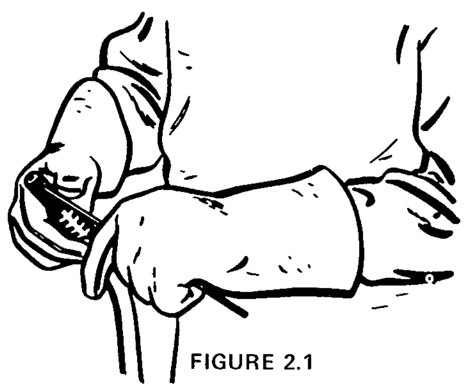


FIGURE 2.1

arc, Figure 3.1 illustrates what is commonly known as the "scratching technique." In this method the striking end of the electrode is dragged across the work in a manner much the same as striking a match. When the electrode touches the work, the welding current starts. If held in this position, the electrode would "freeze" or weld itself to the work and to overcome this, the electrode is withdrawn from the work immediately after contact has been made.

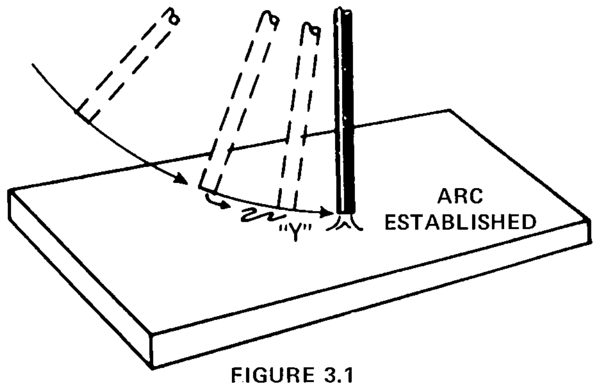


FIGURE 3.1

The amount that the electrode is withdrawn is small and depends upon the diameter; this distance is known as the arc length. If in striking an arc, the electrode freezes, it may be freed by a quick twist of the wrist.

Another method of establishing the arc is available. It is known as the "tapping method" and is shown in Figure 4.1. In this the electrode in the holder is brought straight down on the work and immediately after contact, is withdrawn to the proper arc length.

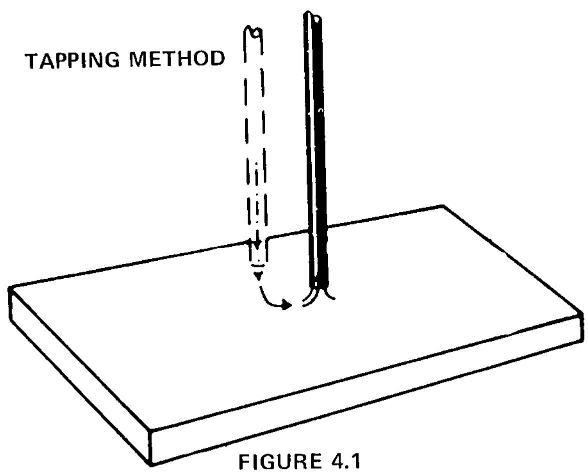


FIGURE 4.1

Practice striking the arc using both methods. Generally the scratching method is preferred for a-c welding.

Determination of the correct arc length is difficult since there is no ready means of measuring it. As a preliminary guide, use about 1/16" arc length on 1/16" and 3/32" electrode; for 1/8" and 5/32" electrodes use about 1/8" arc length. When skill is acquired, the sound of the arc will be a good guide. A short arc with correct current will give a sharp, crackling sound. Examination of the deposited bead will give a further check.

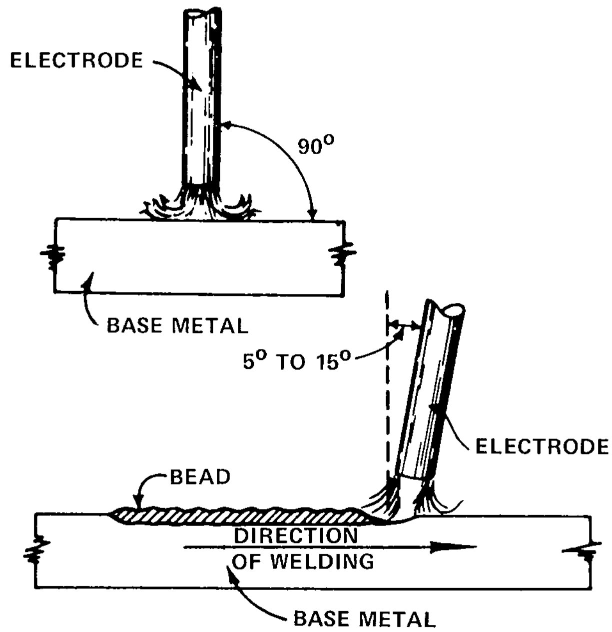


FIGURE 5.1

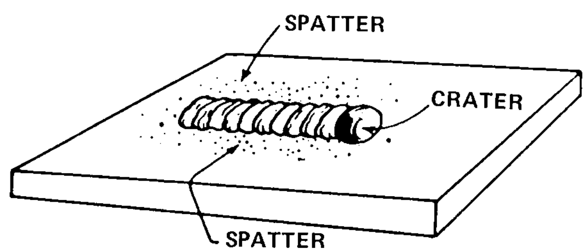


FIGURE 6.1

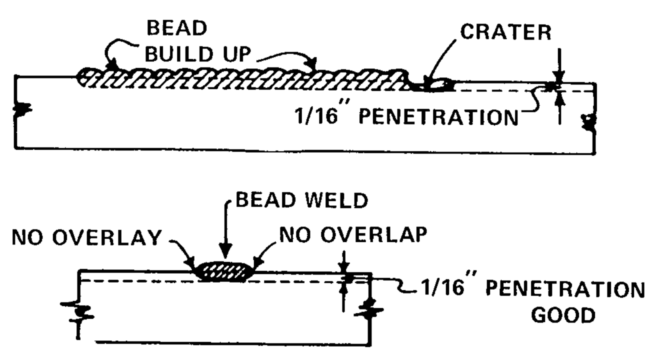


FIGURE 7.1

Once the knack of starting and holding an arc has been learned, turn next to depositing weld metal. In the beginning it is best to run beads of weld metal on flat plates using a full electrode. Practice moving from left to right and from right to left. The electrode should be held more or less perpendicular to the work, except that tilting it ahead, in the direction of travel will prove helpful. The correct position is shown in Figure 5.1. A proper bead is shown in Figure 6.1 while Figure 7.1, illustrates a cross-section through the bead and identifies the various terms used in describing a weld. To produce these results it is necessary to hold a short arc, travel at a uniform speed, and feed the electrode downward at a constant rate as it melts.

Probably the first attempts in the practice will fall short of the results shown. Too long an arc will be held or the travel speed will vary from slow to fast and the welds will look like the one in Figure 8.1. A cross-section through such a weld is given in Figure

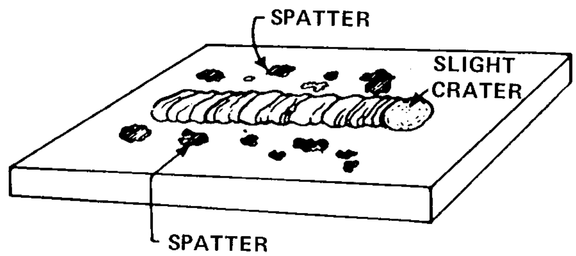


FIGURE 8.1

9.1. In addition the weld will probably be spongy (porous) and of low strength.

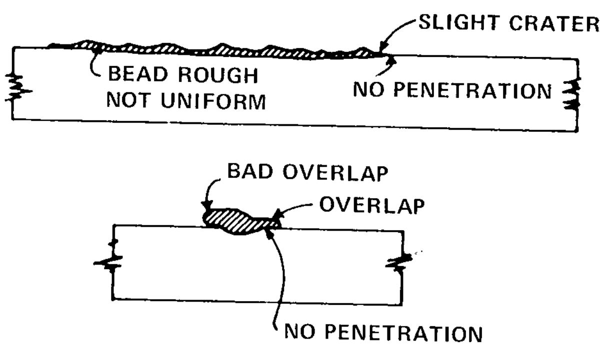


FIGURE 9.1

Continue practicing until uniform beads as shown in Figure 6.1 can be produced every time. A good method of practicing is to deposit a series of beads, one next to the other until the plate is covered. Then deposit another series of beads at right angles to the first, thus building up the plate to a greater thickness.

WEAVING

When it is necessary to cover a wider area in one pass of the electrode, a method known as weaving is employed. In this the electrode is moved or oscillated from side to side in a set pattern. In order to be sure of uniform deposits, it is necessary to use a definite pattern such as those illustrated in Figure 10.1. While weaving is helpful, particularly when building up metal, it should be limited to weaves not exceeding 2-1/2 times the diameter of the electrode.

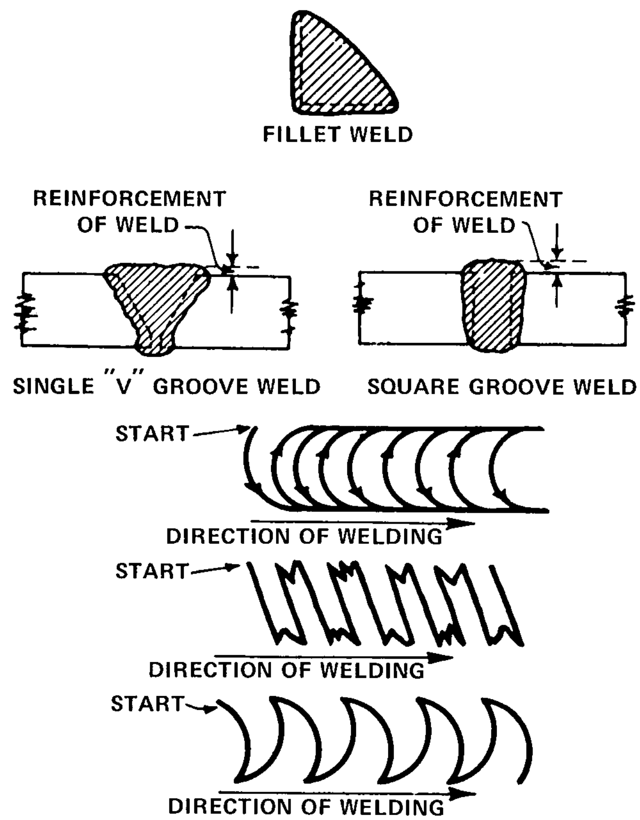
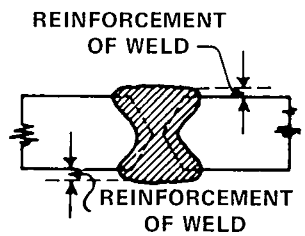


FIGURE 10.1

BUTT JOINTS

Up to this point the discussion has covered only the deposit of beads on the flat plates. While such operations are helpful in building up worn parts or applying hard-facing materials, they do not help in learning to weld pieces together. For this purpose, other types of welds as illustrated in Figure 11.1 are necessary.

In making bead welds, previously described, it was probably noted that the depositing of weld metal on one side of the plate caused it to "curl" up towards the weld; this is called distortion and will almost always be found when heat is applied locally to a



DOUBLE "V" GROOVE WELD

FIGURE 11.1

metal plate. Similarly in making a butt weld distortion will cause the edges of the plate to draw together ahead of welding. This is caused by the contraction of the deposited weld metal on cooling. It may be overcome by spreading the edges apart on a long taper of about 1/8" per foot.

In making welds in a butt joint, preparation of the edges may be necessary to insure good results. In metal arc welding it is common practice to weld thin materials up to 3/16" thick without any special preparation using the square groove butt joint. For thickness of 3/16" and over the "V" groove either single or double is employed. Generally the single "V" groove will be satisfactory on thicknesses up to 3/4" and in those cases, regardless of thickness, where one can work on the weld from one side only.

BEVELING

The best means for beveling steel for welding is by means of the oxyacetylene cutting torch. The work may be done with a hand guided torch or special oxyacetylene cutting machine. However, in performing this cutting, a scale will adhere to the plates. This must be removed by grinding or chipping before welding as it is likely to become entrapped and thus produce an unsound weld. Where oxyacetylene cutting equipment is not available, grinding will probably be the best means of preparing bevels. The angles of these bevels should be about 30 degrees and the bottom edge may be left square for a distance of about 1/16". See Figure 12.1.

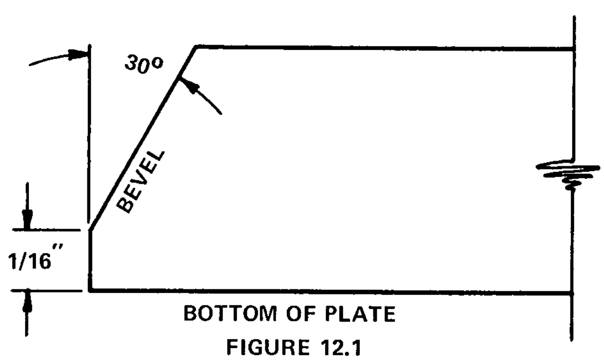


FIGURE 12.1

Practice making butt welds starting on thin material about 1/8" thick. Avoid very thin material (around 1/16" thick) in the beginning as this requires a fair degree of skill. Separate the squared edges of the 1/8" material about 1/16" and make a butt weld all the way through with a 1/8" electrode. Probably the first attempts will fail to penetrate the sheet or may burn through. Keep trying, adjusting the current within the recommended range; also vary the travel speed to give the desired weld. Having mastered the 1/8", proceed to a similar exercise on 1/4". This time, however, deposit a bead on each side of the joint and try to fuse one to the other. Since the weld from one side is in effect on 1/8" thickness, no bevel is needed.

Next make a single "V" groove on 1/4" plate beveled 30 degrees. Start with a 1/8" electrode for the first bead or layer and finish with a 5/32" electrode. Be sure to penetrate about 1/32" beyond the bottom of the "V" (called the root). When skill has been acquired on the 1/4" material, proceed to 3/8" and then to 1/2". On these, particularly the 1/2", make also the double "V" butt joints. Generally speaking, it will be necessary to deposit a bead or layer for each 1/8" thickness. On the heavier plates weaving of the top layers may be necessary to fill the groove completely.

When making practice butt welds it is wise to check the results occasionally. When elaborate testing equipment is not available, this may be done with a hammer and vise. Grip a short, welding piece with the weld just above the jaws. Hammer it in a direction that tends to open the bottom, root side of the weld, in the manner shown in Figure 13.1. A good weld will not break under this test

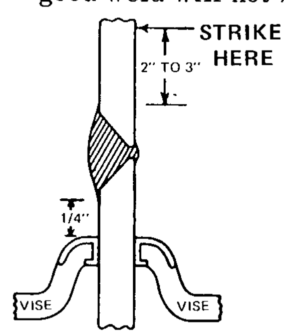


FIGURE 13.1

but will bend over. If the weld breaks, examine it to determine the cause. If there are a large number of holes - the weld looks spongy - it is porous and this is probably due to holding too long an arc. If there are bits of slag in the weld perhaps the arc was too short or the electrode was manipulated incorrectly thus permitting the molten slag from the coating to be trapped. This is quite likely to happen on a "V" joint made in several layers and calls for thorough cleaning between layers. Perhaps on breaking it will be found that the original surface of the bevel is still evident. That means that it was not melted and the cause is quite likely to be found in too fast a travel speed or insufficient heat.

TEE AND LAP JOINTS

The other basic type of weld, the fillet weld, is used for making tee and lap joints. For this type of welding, no special preparation, other than squared edges, is necessary. Typical welded tee and lap joints are pictured in Figures 14.1 and 15.1 respectively.

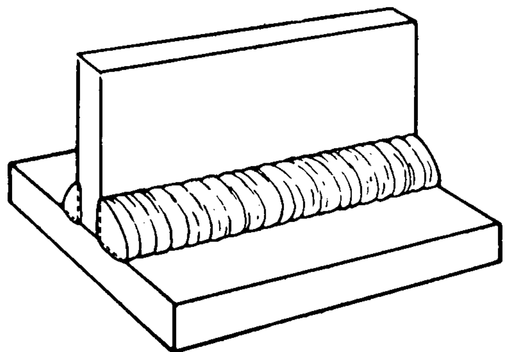


FIGURE 14.1

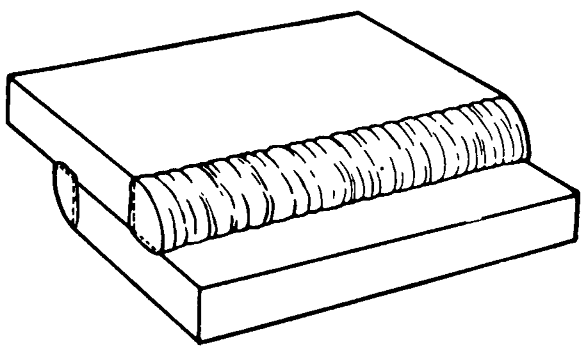


FIGURE 15.1

Considering the tee joint first, it will be seen immediately that the different locations of the pieces creates a problem. The method of holding the electrode for butt welds will not be satisfactory. To deposit a single pass fillet weld hold the electrode as shown in Figure 16.1. This will provide fusion into the corner and a fillet, the sides of which will be approximately equal. For maximum strength a fillet weld should be deposited on each side of the upright section. When a heavier fillet is needed, deposit a second layer as indicated in Figure 17.1, using any of the weaving patterns shown in Figure 17.2.

The lap joint, while involving the same fundamental weld type, the fillet, has metal distributed differently and therefore requires still another technique. The details of the application are given in Figure 18.1, for a single pass weld. For a two pass weld Figure 18.2 provides the details.

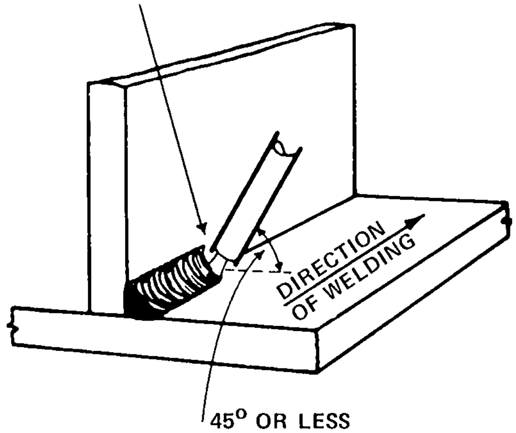


FIGURE 16.1

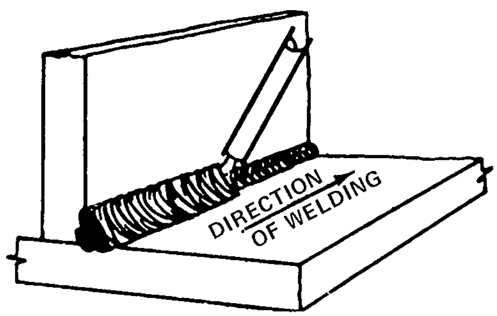


FIGURE 17.1

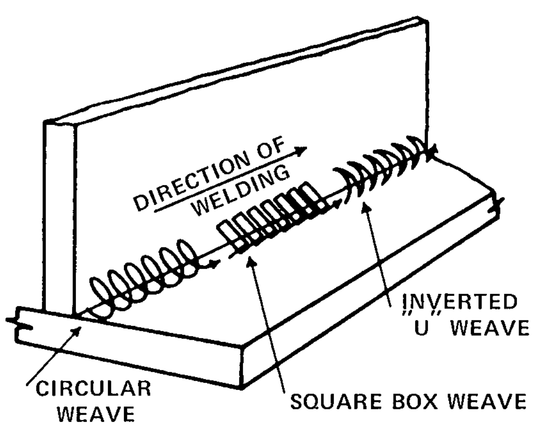


FIGURE 17.2

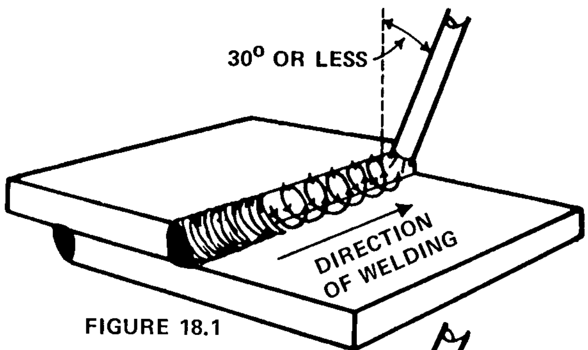


FIGURE 18.1

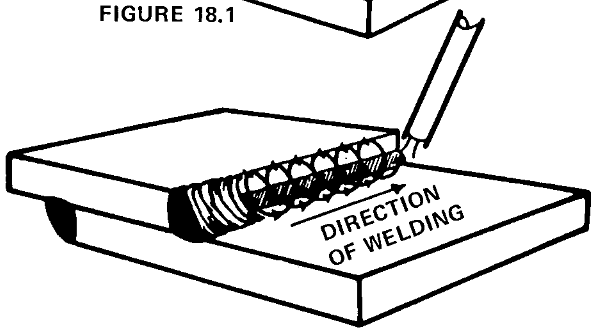


FIGURE 18.2

WELDING VERTICALLY, HORIZONTALLY AND OVERHEAD

The importance of welding in the flat position, whenever possible, cannot be stressed too strongly. The quality of the weld is better, the operation easier and faster. However, occasions will arise when it is necessary to work on parts fixed in position under which condition welds must be deposited horizontally, vertically and overhead. It must be realized at the very beginning that welding in these positions is difficult and will require constant practice to develop skill.

As in the case of welding in the flat position, it is best to start practicing by first running bead welds in the various positions. Then as facility is gained on these operations practice may be continued on butt and fillet welds (tee and lap joints) in these positions.

One of the first facts noted when welding in these positions is that the force of gravity tends to cause the molten metal to drip (fall) down. The technique used, therefore, must be designed to overcome this and since it is difficult it is best to approach this by steps. To accomplish this, start by making horizontal bead welds on plates inclined at 45 degrees as shown in Figure 19.1. When this has been mastered so that uniform beads can be made consistently, practice on welding vertically may be started. Again begin with an easy operation such as running beads vertically on plates set at 45 degrees - see Figure 20.1.

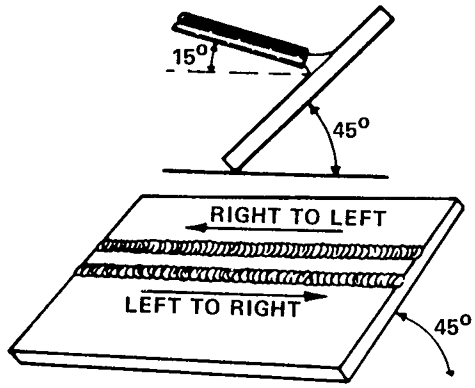


FIGURE 19.1

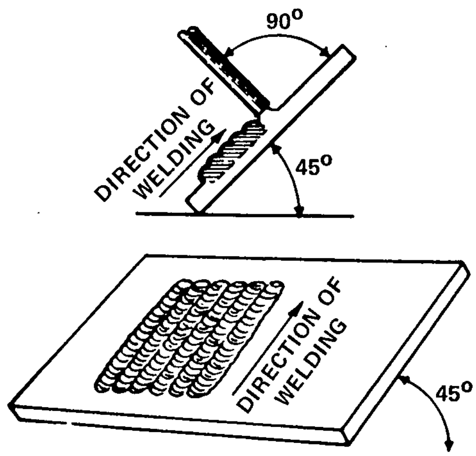


FIGURE 20.1

To progress with this practice it is necessary now to move the plates into vertical position. The details of horizontal bead welds are given in Figure 21.1.

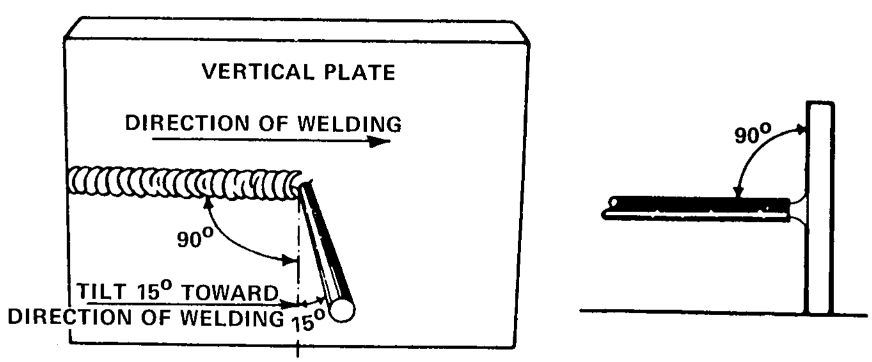


FIGURE 21.1

Welding vertically may be performed either by carrying the weld upward or starting from the top and welding down. It is generally conceded that working upward is easier and therefore, bead welds in this manner should be practiced. A method for making weave beads is illustrated in Figure 22.1.

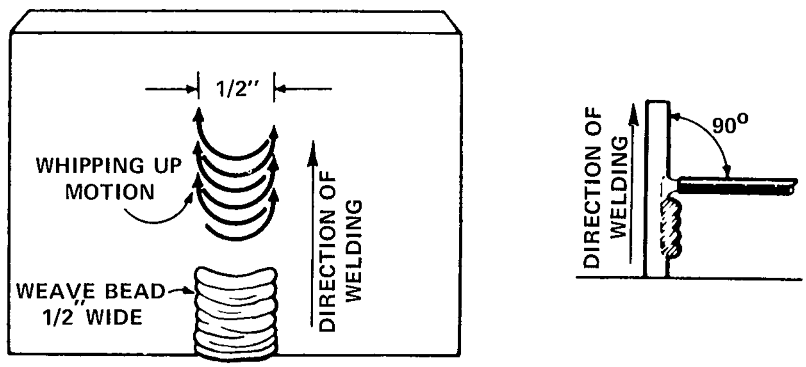


FIGURE 22.1

Since bead welds are of limited practical value, this experience must be extended by practicing on butt welds in the vertical and horizontal patterns.

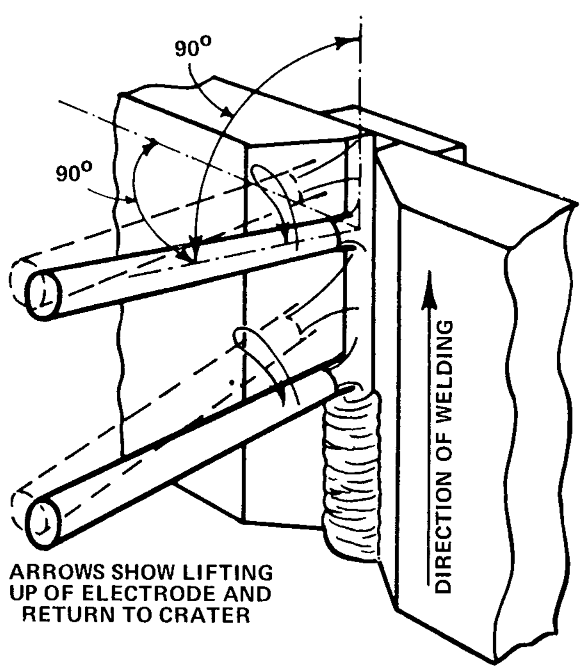


FIGURE 23.1

Figure 23.1 provides information suitable for a single pass vertical butt weld or the first pass of a multiple layer deposit. Two methods of depositing the subsequent layers are given in Figures 24.1 and 24.2

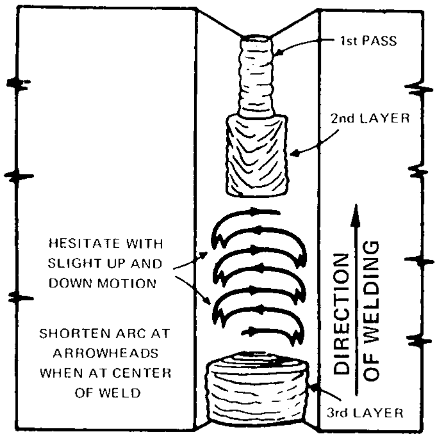


FIGURE 24.1

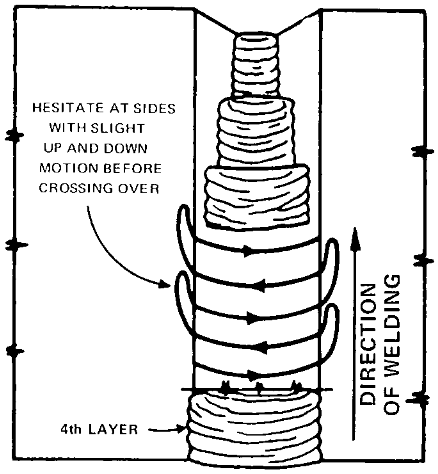


FIGURE 24.2

For horizontal welds the details are shown in Figures 25.1 through 25.8. Note that a strip of metal is shown at the root of the weld - this is known as the backing strip. Its use permits the securing of a sound root pass without great difficulty. In use, the beveled plate edges should be spaced on the backing strip and the strip tack welded to the plates on the reverse side.

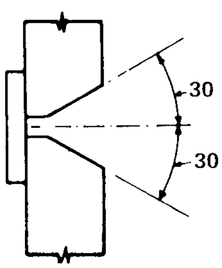


FIGURE 25.1

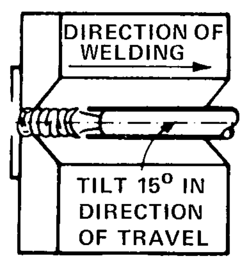


FIGURE 25.2

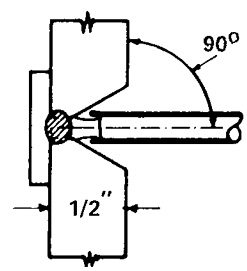


FIGURE 25.3

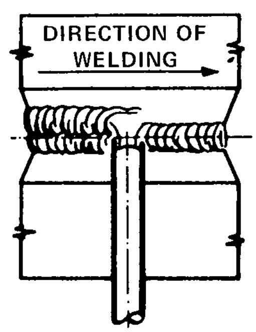


FIGURE 25.4

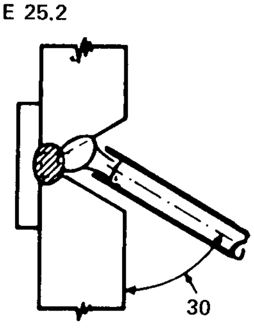


FIGURE 25.5

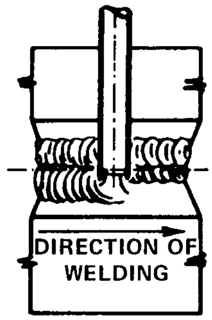


FIGURE 25.6

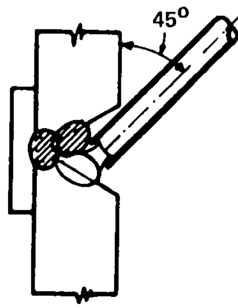


FIGURE 25.7

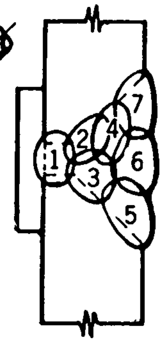


FIGURE 25.8

For fillet welds on tee joints the technique is shown in Figure 26.1. For vertical lap joints the same technique may be employed notwithstanding the difference in positions of the plates. Also, when depositing a multilayer fillet weld, this same method would be used to deposit the first layer on both lap and tee joints. For depositing

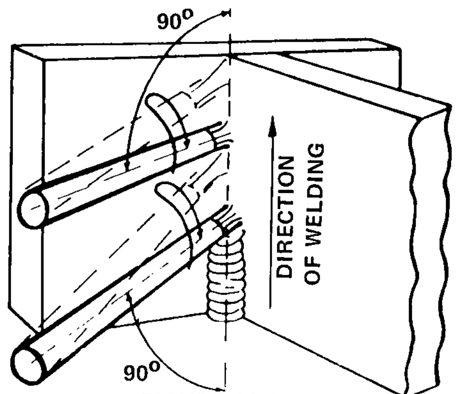


FIGURE 26.1

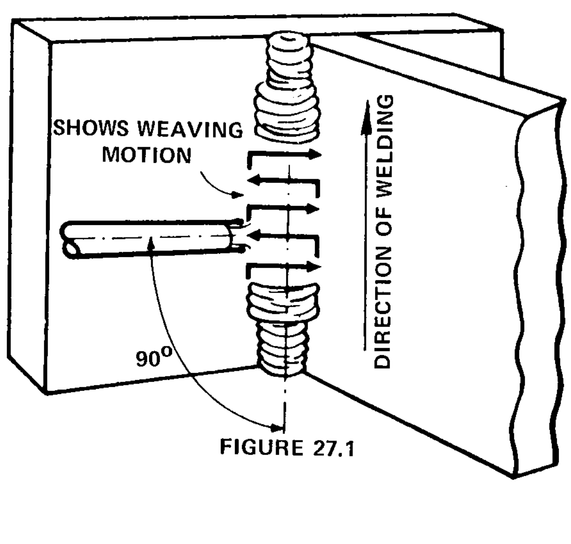


FIGURE 27.1

subsequent layers on tee joints two means are used and are shown in Figures 27.1 and 27.2. For the additional layers on lap joints a somewhat similar weave may be seen in Figure 28.1.

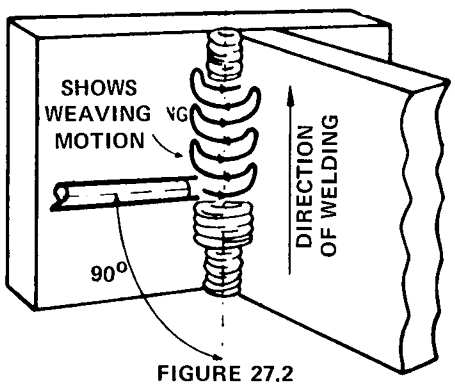


FIGURE 27.2

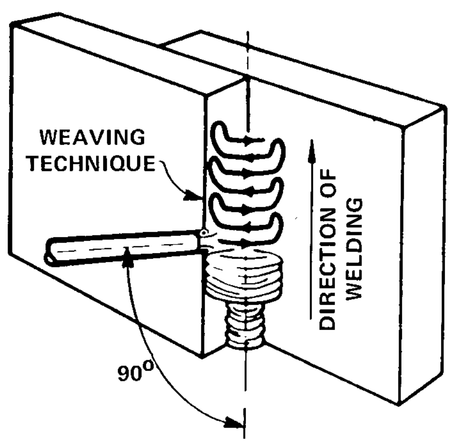


FIGURE 28.1

Welding in the overhead position is the final problem to master. Again proceed through the steps of making bead welds, the making of butt welds and finally the making of fillet welds. For bead welds the electrode position, Figure 29.1, will prove helpful. When weaving is necessary, the pattern in Figure 30.1 may be used. The technique for overhead butt welds is illustrated in Figure 31.1; this covers single pass welds or the first pass of multilayer welds. Sub-

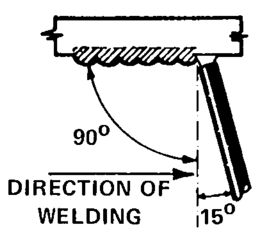


FIGURE 29.1

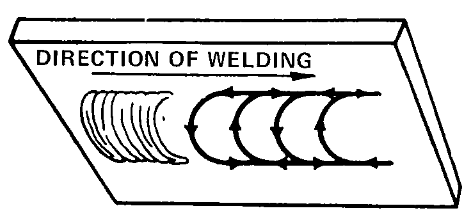


FIGURE 30.1

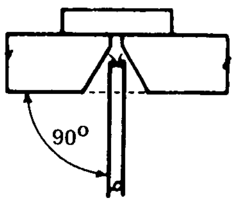


FIGURE 31.1

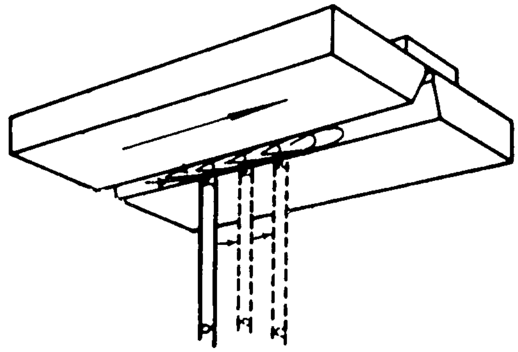


FIGURE 31.2

sequent beads may be deposited as shown in Figure 32.1. For depositing single layer fillets or the first layer of multiple fillets in the overhead position the technique in Figure 33.1 should be employed. The sequence for depositing beads on a multilayer fillet weld is provided in Figure 34.1. Note that single beads are recommended and for that reason use the same technique shown in Figure 33.1. Again the technique for fillet welds may be employed for welding lap joints.

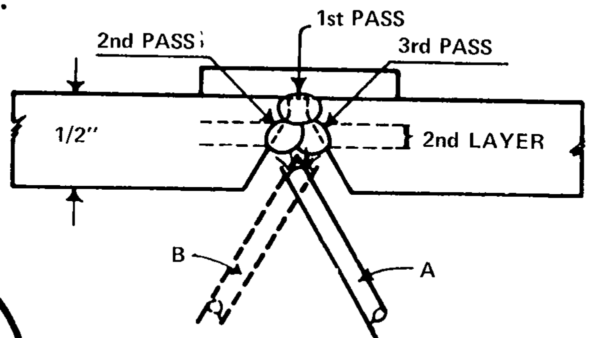


FIGURE 32.1

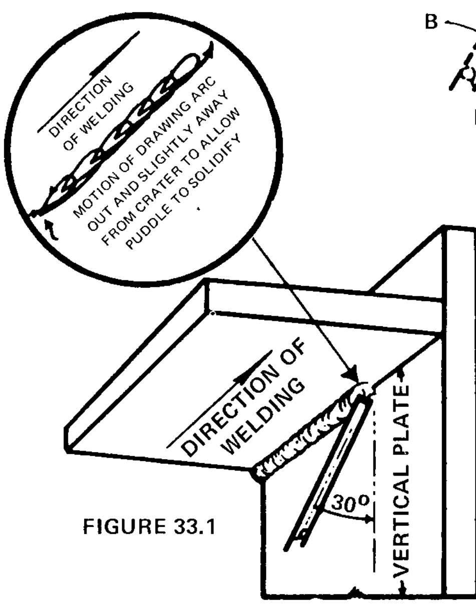


FIGURE 33.1

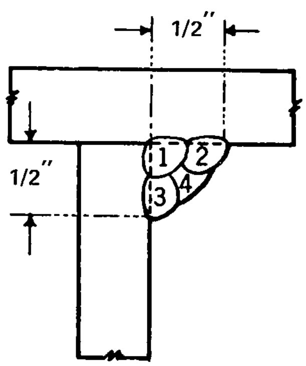


FIGURE 34.1

CONCLUSION

It may be appreciated that no printed instruction can impart to the beginner the skill necessary for successful welding. Personal instruction by an experienced welding operator is the best means devised to date for accomplishing this end. Therefore, an effort should be made to secure some facility for instruction and practice under competent supervision. In any event the beginner should at least secure the benefit of criticism of finished welds by a qualified welder.

CURRENT REQUIREMENTS FOR MILD STEEL ELECTRODES

Electrode	Amperage	
Diameter	Min.	Max.
5/64	20	50
3/32	40	80
1/8	65	125
5/32	90	160
3/16	120	180

NOTES

NOTES

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