

## GAS SHIELDED-ARC WELDING

The primary goal of any welding operation is to make a weld that has the same properties as the base metal. The only way to produce such a weld is to protect the molten puddle from the atmosphere. In gas shielded-arc welding, briefly discussed in chapter 3,

you use a gas as a covering shield around the arc to prevent the atmosphere from contaminating the weld. Gas shielding makes it possible to weld metals that are otherwise impractical or difficult to weld by eliminating atmospheric contamination from the molten puddle. Figure 8-1 shows the basic principle of gas shielded-arc welding.

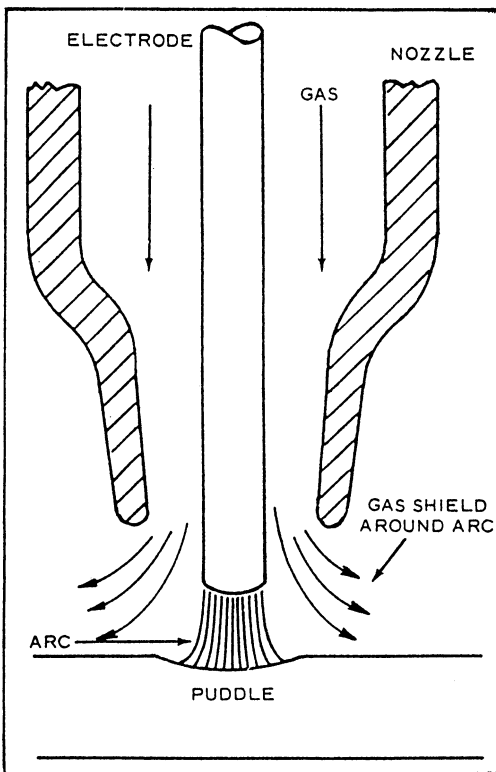


Figure 8-1.—Gas shielded-arc welding principle.

The two general types of gas shielded-arc welding processes are gas tungsten-arc welding (GTA) and gas metal-arc welding (GMA). GTA is often tilled *TIG* (tungsten inert gas) and GMA is referred to as *MIG* (metal inert gas). The term *inert* refers to a gas that will not combine chemically with other elements.

### GAS TUNGSTEN-ARC WELDING—GTAW

Gas tungsten-arc welding is basically a form of arc welding; however, in gas tungsten-arc welding, the electrode is used only to create the arc. The electrode is not consumed in the weld as in the shielded metal-arc process. The gas tungsten-arc welding process generally produces welds that are far superior to those produced by metallic arc welding electrodes. Especially useful for welding aluminum, it also may be used for welding many other types of metals. The GTA process is most effective for joining metals up to 1/8 inch thick, although you can use it to weld thicker material.

As shown in figure 8-2, the basic GTA process involves an intense arc between the base metal and a

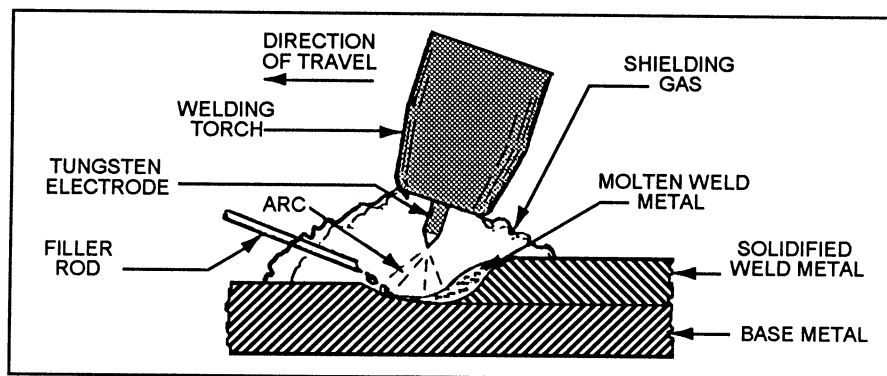


Figure 8-2.—GTA welding process.

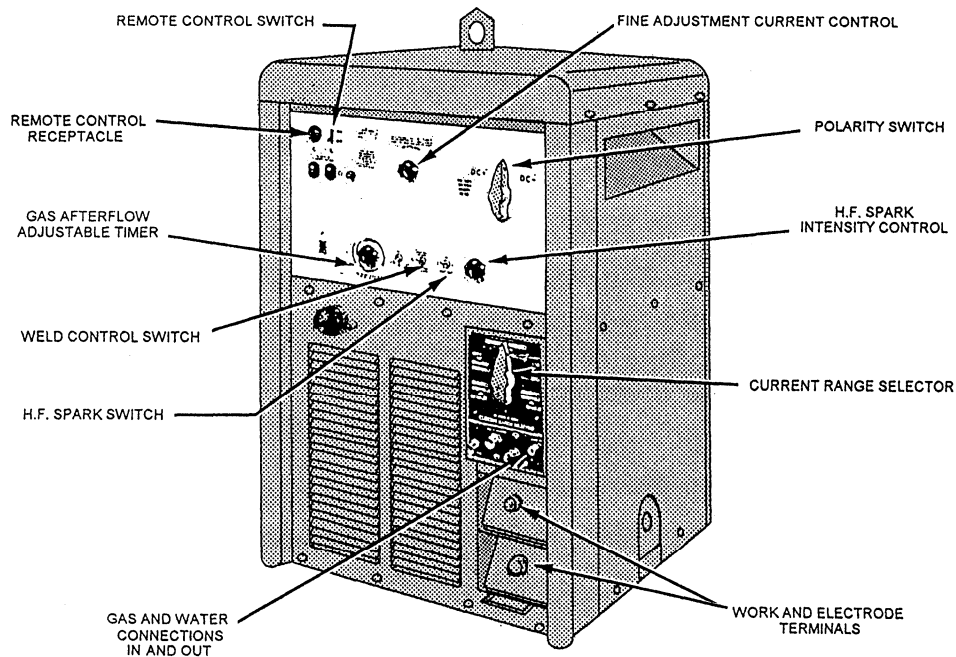


Figure 8-3.—Power supply unit specifically designed for gas tungsten-arc welding.

tungsten electrode. The arc, the electrode, and the weld zone are surrounded by an inert gas (usually either helium or argon or a mixture of the two) that displaces the air and eliminates the possibility of weld contamination by the oxygen and nitrogen present in the atmosphere. The tungsten electrode has a high melting point that makes it virtually nonconsumable.

Specific advantages of gas tungsten-arc welding include the following:

- Welding can be done in all positions.
- The weld is usually equal to the base metal in composition.
- Flux is not used; therefore, finished welds do not require cleaning of corrosive residue.
- Smoke or fumes are not present to obscure vision; therefore, you can easily see the welding process.
- Distortion of the base metal is minimal because the heat is concentrated in a small area.
- No splatter is produced because metal is not transferred across the arc.

## GTA WELDING EQUIPMENT AND SUPPLIES

The equipment and supplies required for gas tungsten-arc welding consist of an electric power unit, shielding gas, a pressure-reducing regulator and flowmeter, an electrode holder (commonly called a torch), nonconsumable tungsten electrodes, filler rods, a supply of cooling water (when required), and personal protective gear.

### Electric Power Unit

Most welding power sources can provide the current needed for GTA welding. The common welding machines, whether alternating current (ac) or direct current (dc), have their advantages in certain welding applications; however, they can be cumbersome and their hose and cable connections can create difficulties. Because of this, specially designed machines with all the necessary controls are available for gas tungsten-arc welding (fig. 8-3).

GTA power units are equipped with solenoid valves that turn the flow of shielding gas and cooling water on and off. They are also equipped with a hand- or foot-operated remote-control switch that turns the water and gas on and off. Some of these remote-control devices

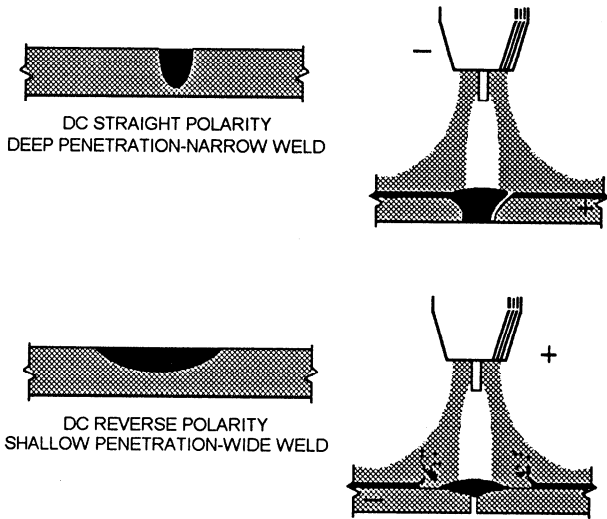


Figure 8-4.—Effects of polarity on the weld.

also turn the main welding current on and off at the same time. This not only allows the operator to start and stop without leaving the work but also to adjust the current while welding.

Most of these welding machines can produce both ac and dc current. The choice of ac or dc depends on the welding characteristics required.

**DIRECT CURRENT.**— As you learned in chapter 7, a direct-current welding circuit may be either straight or reverse polarity. When the machine is set on straight polarity, the electrons flow from the electrode to the plate, concentrating most of the heat on the work. With reverse polarity, the flow of electrons is from the plate to the electrode, thus causing a greater concentration of heat at the electrode. Because of this intense heat, the electrode tends to melt off; therefore, direct-current reverse polarity (DCRP) requires a larger diameter electrode than direct-current straight polarity (DCSP).

The effects of polarity on the weld are shown in figure 8-4. Notice that DCSP produces a narrow, deep weld. Since the heat is concentrated on the work, the welding process is more rapid and there is less distortion of the base metal. Overall, straight polarity is preferred over reverse polarity because you can achieve better welds.

DCRP forms a wide and shallow weld and is rarely used in the GTAW process. The exception to this is when it is used to weld sections of aluminum or magnesium. DCRP has excellent cleaning power that results from the

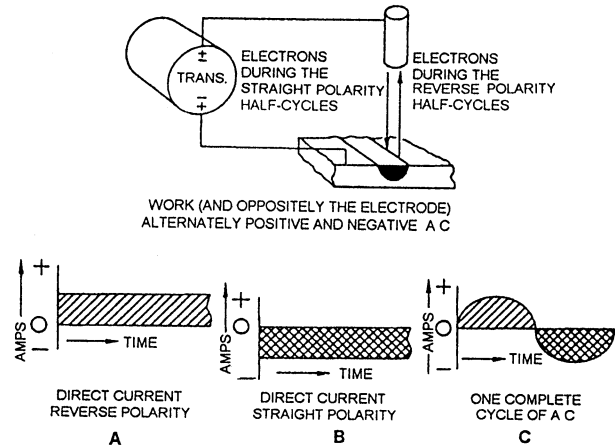


Figure 8-5.—The ac welding cycle.

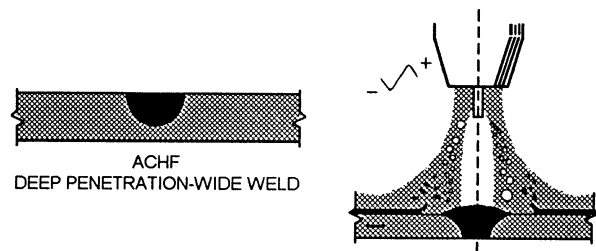


Figure 8-6.—ACHF combines the desired cleaning action of DCRP with the good penetration of DCSP.

action of positive-charged gas ions. When these gas ions strike the metal, they pierce the oxide film and form a path for the welding current to follow. This same cleaning action occurs in the reverse polarity half of an alternating-current welding cycle.

**ALTERNATING CURRENT.**— As shown in figure 8-5, ac welding is actually a combination of DCSP and DCRP; however, the electrical characteristics of the oxides on the metal often prevent the current from flowing smoothly in the reverse polarity half of the cycle. This partial or complete stoppage of current flow (*rectification*) causes the arc to be unstable and sometimes go out. Ac welding machines were developed with a high-frequency current flow unit to prevent this rectification. The high-frequency current pierces the oxide film and forms a path for the welding current to follow. The effects of alternating current high-frequency (ACHF) are shown in figure 8-6. Notice that ACHF offers both the advantages of DCRP and DCSP. ACHF is excellent for welding aluminum.

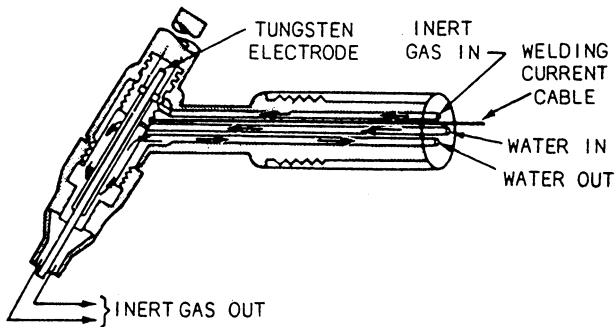
**Table 8-1.—Current Selection Guide for GTA Welding of Common Metals**

Material	Alternating Current With High-Frequency Stabilization	With High-Frequency Starting Current	
		Straight Polarity	Reverse Polarity
Aluminum-up to 3/32 inch thick	1	2	N.R.
Aluminum-over 3/32 inch thick	1	N.R.	N.R.
Aluminum castings	1	N.R.	N.R.
Brass alloys	2	1	N.R.
Silcon copper	N.R.	1	N.R.
Monel	2	1	N.R.
Stainless steel	2	1	N.R.
Hard-surfacing alloys	2	1	N.R.
Key: 1. Excellent Results 2. Good Results N.R. Not Recommended			

You can use table 8-1 as a guide for selecting the current for welding some of the more common metals. For more specific information, refer to the operator's manual for the specific machine you are using.

**Torches**

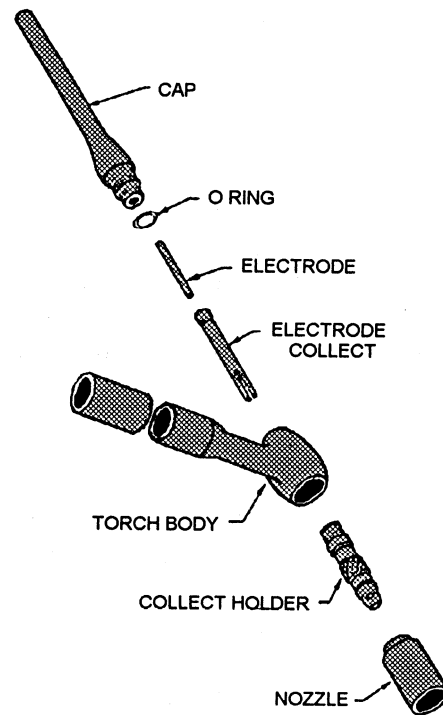
GTA welding torches are designed to conduct both welding current and inert gas to the weld zone. The torches can be either air or water cooled, depending on the welding current. Air-cooled torches are used for welding light-gauge materials at relatively low-current settings. Water-cooled torches are recommended for currents above 200 amperes. A sectional view of a GTA water-cooled torch is shown in figure 8-7. When you are using this type of torch, a circulating stream of water flows around the torch to keep it from overheating.



**Figure 8-7.—GTA water-cooled torch.**

NOTE: To avoid torch overheating caused by clogging and flow restrictions, you must keep the water clean.

The GTA welding torch carries the welding current and directs the gas to the weld area. The torch must have



**Figure 8-8.—GTA torch parts.**

**Table 8-2.—Approximate Cup Size for GTA Welding**

TUNGSTEN ELECTRODE diameter (inches)	CUP ORIFICE diameter (inches)
1/16	1/4-3/8
3/32	3/8-7/16
1/8	7/16-1/2
3/16	1/2-3/4

**Table 8-3.—Approximate Current Ranges for Tungsten Electrodes**

Electrode Diameter Inches	Current, Amperes	
	Standard Tungsten Electrodes	Thoriated Tungsten Electrodes
0.04	10-60	15-80
1/16	40-120	60-150
3/32	100-160	140-250
1/8	150-210	225-350
5/32	190-275	300-450
3/16	250-350	400-550
1/4	300-490	500-800
5/16	450-600	

the proper insulation for the maximum current ranges to ensure operational safety. Current is transmitted from the weld-rig machine through the power cable to a collet holding the tungsten electrode. A variety of collet sizes are available, depending on the diameter of the electrode. Figure 8-8 shows the various parts of a typical GTA torch.

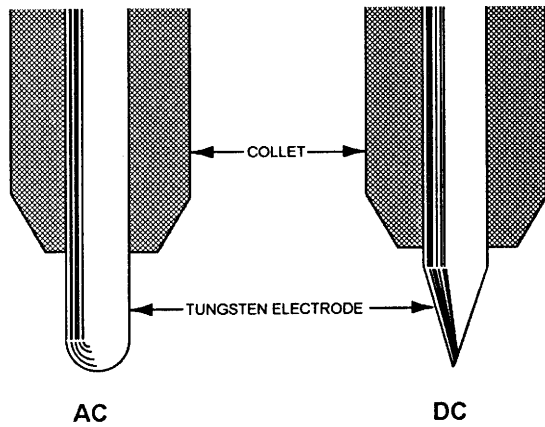
Gas is fed to the welding zone through the torch nozzle that consists of a ceramic cup. Nozzles also are made of steel (chrome plated), plastic, and glass (Pyrex) materials. These nozzles (gas cups) vary in size, depending upon the type and size of torch and the diameter of the electrode. See table 8-2 for sizes.

### Electrodes

The electrode should extend beyond the end of the gas cup a distance equal to its diameter for butt welding and slightly further for fillet welding. Selecting the right size electrode for each job is important to prevent electrode damage and poor welds caused by too high or too low a current. Excessive current causes tungsten particles to transfer to the weld, while not enough current allows the arc to wander emetically over the end of the electrode.

The diameter of the electrode selected for GTA welding is governed by the amount of welding current used. Remember: DCRP requires larger electrodes than DCSP. Recommended electrode sizes for various ranges of welding current are shown in table 8-3. These current ranges are broad. You should refer to the manufacturer's recommendations for specific current ranges and electrode sizes based on the type of material you are welding.

Basic diameters of nonconsumable electrodes are .040, 1/16, 3/32, and 1/8 of an inch. They are either pure tungsten or alloyed tungsten. The alloyed electrodes are of three types: 1% thorium alloy, 2% thorium alloy, and zirconium alloy. Pure tungsten is routinely used with ac welding and is sufficient for most GTA welding operations. The thoriated types are normally used for DCSP welding. These electrodes give slightly better penetration and arc-starting characteristics over a wider range of current settings. The zirconium alloy is excellent for ac welding and has high resistance to contamination. The electrodes alloyed with thorium and zirconium are primarily used for critical weldments in the aircraft and missile industries.



**Figure 8-9.—Tungsten electrode shapes for ac and dc welding.**

Tungsten electrodes are usually color-coded at one end. A green color indicates that the rod is pure tungsten; yellow indicates a 1-percent thoriated tungsten rod; red indicates a 2-percent thoriated tungsten rod; and brown indicates that the rod is alloyed with zirconium.

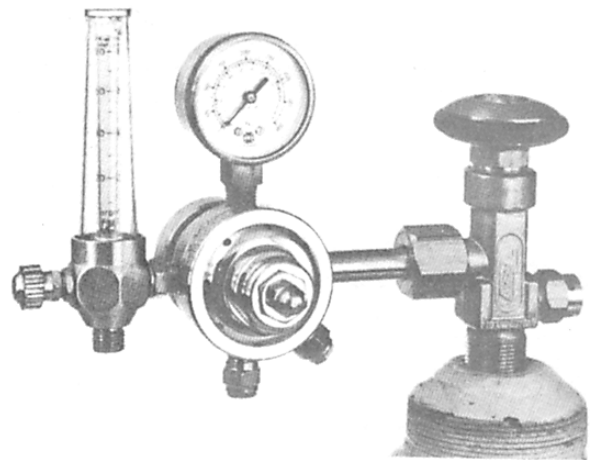
To produce good quality welds with the GTA process, you must shape the electrode properly. The general practice is to use a pointed electrode with dc welding and a spherical end with ac welding (fig. 8-9).

### Shielding Gas

Shielding gas for GTA welding can be argon, helium, or a mixture of argon and helium. Argon is by far the most popular. When compared to helium, argon has greater cleaning action and provides a more stable arc. Argon is heavier than air; therefore, it provides a blanket over the weld that protects it from contaminants. Helium, being lighter than air, requires a higher gas flow than argon and is therefore more expensive to use. However, as a shielding gas, helium - allows greater penetration and faster welding speeds because the arc is hotter in the helium atmosphere than in the argon atmosphere. The opposite is true for GMA welding; therefore, a mixture of argon and helium is sometimes used in welding metals that require a higher heat input. Table 8-4 lists a selection of shielding gases recommended for various metals for both the GTA and GMA welding processes. Notice that for most GTA welding operations, you use pure argon.

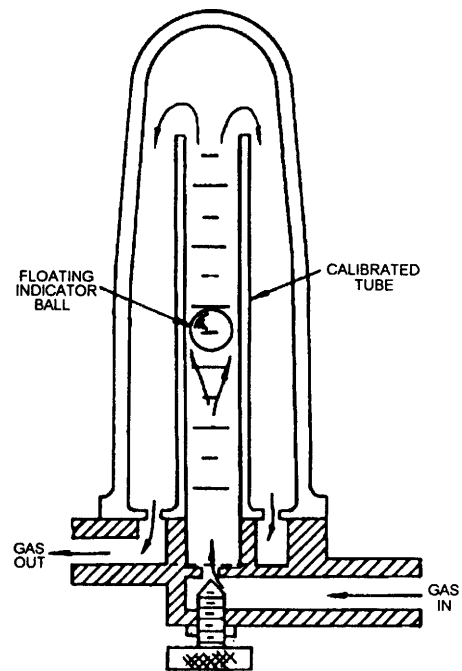
### Regulators

The primary difference between the regulators used for oxyfuel welding and for GTA/GMA welding is that the working pressure on the oxyfuel regulators is shown in pounds per square inch (psi) while the regulators used



127.286

**Figure 8-10.—Combination regulator and flowmeter.**



**Figure 8-11.—Cross section of flowmeter.**

for GMA/GTA show the flow of shielding gas in cubic feet per hour (cfh) or liters per minute (lpm). Regulators used for GMA/GTA welding have a flowmeter instead of a working pressure gauge along with the cylinder pressure gauge. See figure 8-10.

The flowmeter consists of a plastic or glass tube that contains a loosely fitting ball. As the gas flows up the tube, it passes around the ball and lifts it up. The more

Table 8-4.—Selection of Shielding Gases for Various GMAW and GTAW Applications

METALS	ARGON	HELIUM	CO <sub>2</sub>	O <sub>2</sub>	H <sub>2</sub>	N <sub>2</sub>	METHOD		POLARITY
							(GTAW)	(GMAW)	
Aluminum Alloys	100							*	DCRP
	100						*		ACHF
		100						*	DCSP
	25	75						*	
Aluminum Bronze	100						*	*	DCSP
Copper	25	75					*	*	DCSP
	100							*	
		100					*		
	95					5			
Magnesium	100							*	DCRP
	100						*		ACHF
Nickel	100						*	*	ACHF
	20	80							DCSP
		100					*A		
Silicon Bronze	100						*	*	ACHF
	100							*	
Steel mild	100						*		DCSP
	75		25					*	DCRP
		100					*A		
			100					*	
	98				2				*
Low alloy	97			3				*	DCRP
	95			5				*	
	80				20				
	80		20						
Stainless	99			1				*	DCRP
	95			5				*	DCSP
	80				20		*		
	100						*		
		100						*A	
Titanium	100							*	DCSP
	100						*		
		100					*A		
Dissimilar Metals Backup Gas	100						*		DCSP
					5	80			

gas that moves up the tube, the higher the ball is lifted. Figure 8-11 shows a cross section of the flowmeter.

The shielding gas regulator has a constant outlet pressure to the flowmeter of about 50 psig. This is important because the flowmeter scales are accurate only if the gas entering them is at that approximate

pressure. If you use higher inlet pressures, the gas flow rate will be higher than the actual reading. The reverse is true if the inlet pressure is lower than 50 psig; therefore, it is important to use accurately adjusted regulators. With an accurate flowmeter, these regulators can deliver inert gas flows up to 60 cfh. You should read the scale by aligning the top of the ball with the cfh desired.

Table 8-5.—Suggested Inert Gas Flow Rates for Various Metals

METAL		GAS FLOW CU. FT./HR. (CFH)		
KIND	THICKNESS	ARGON	HELIUM	*CO <sub>2</sub>
Steel	.035-3/32	8-10	20-30	8-10
Cast Iron	1/4	16	40	---
Stainless Steel	1/16-1/8	11	30	---
Stainless Steel	3/16-1/4	13	32	---
Copper	1/16-1/4	15	38	---
Magnesium	1/16-1/8	10	25	---

\* Pure CO<sub>2</sub> is currently used exclusively on steel.

To obtain an accurate reading, you must mount the meter in a vertical position. Any slant will create an off-center gas flow and result in an inaccurate reading. Also, because gas densities vary, you should use different flowmeters for different gases.

The flow of gas necessary for good GTA welding depends primarily on the thickness of the material. Other factors include the following: welding current, size of nozzle, joint design, speed of welding, and a draft-free area in the location the welding is done. This last factor can affect gas coverage and use considerably. Table 8-5 shows the approximate gas flow rates for various types of metals.

### Filler Rods

Normally you do not require filler metal when GTA welding light-gauge materials since they tend to flow together easily. Thick material and thin material that needs reinforcing should be welded using a filler metal.

Special filler rods are available for GTA welding; therefore, you should not use welding rods designed for oxyfuel welding because they can contaminate the tungsten electrode. You should use filler rods that have the same composition as the base metal; for example, use mild steel rods to weld low-carbon steel and aluminum rods for welding aluminum. Additionally, there are many different compositions of the same metal; therefore, you should select a filler metal of the same composition as the metal you are welding.

### Personal Protective Equipment

A welding hood like the one used in shielded metal-arc welding should be used for gas tungsten-arc

welding. The correct shade of lens depends on the intensity of the arc. Chapter 3 provides a chart of recommended lens shades based on the current setting of the machine. For normal GTA welding at current ranges of 76 to 200 amperes, a shade No. 10 lens is satisfactory. Eye fatigue indicates you should use a different shade of lens or there is leakage around the protective filter glass.

In addition to the welding hood, protective clothing, such as gloves and an apron, should be worn. Bare skin should never be exposed to the rays of the welding arc because painful burns may result.

### GTA WELDING PREPARATION

Although it can produce outstanding results, GTA welding can be expensive. The equipment, electrodes, and shielding gas are costly and the material you weld is usually much more expensive than the material welded by other welding processes. To avoid costly mistakes, you should take the time to prepare for each welding operation fully. Preparation is the key to producing quality weldments.

Specific information on the different manufacturers of GTA welding equipment is not provided in this training manual. You should read the manufacturer's instructional pamphlets for specific information on your machine. The following suggestions are considered general and you can apply them to any GTA welding operation:

- Prepare the joint according to the welding procedure you are performing. Refer to chapter 3 of this training manual for specific information about joint preparation.



- Clean the metal of all oxidation, scale, oil, dirt, or other foreign matter. Regardless of the type of joint used, proper cleaning of the metal is essential. For best results, use a stainless steel wire brush.
- Check all electrical circuit connections to make sure they are properly connected and all fittings are tight.
- Be sure the torch is the right type and capacity for the current at which most of the welding will be done. Some manufacturers offer different torches for different ranges of welding current.
- Check the size, appearance, and position of the tungsten electrode in the torch. Ensure that the electrode diameter and nozzle size meet the manufacturer's recommendations. The tip should be properly shaped as discussed earlier (refer to figure 8-9). The electrode should extend beyond the end of the gas cup a distance ranging from 1/8 to 3/16 of an inch for butt welding and 1/4 to 3/8 of an inch for fillet welding. Check the electrode for positioning and good electrical contact. The electrode should be clean and silvery. A dirty tungsten electrode can usually be cleaned satisfactorily with a fine emery cloth. If severely contaminated, the electrode should be replaced or the tip broken off and dressed on a grinding wheel. A contaminated tungsten electrode and a good tungsten electrode are shown in figure 8-12.
- Check the ground cable connections to the workpiece. The connections should be periodically checked after welding begins because they tend to work loose. When this happens, the welding current varies.
- Set the machine for the correct welding amperage. (Follow manufacturer's recommendations.)
- Open the cylinder valve and adjust the gas flow. Before welding, check the connections on the gas supply for leaks with soapy water.
- If using a water-cooled torch, turn on the water. Be sure the water pressure is not higher than recommended by the torch manufacturer.

## GTA WELDING PROCEDURES

As we discussed in chapter 3, the detailed methods and practices used to prepare a particular weldment are called the *welding procedure*. We also said that the

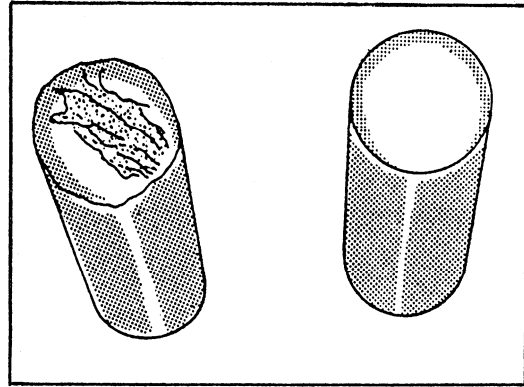


Figure 8-12.—Contaminated and good tungsten electrode.

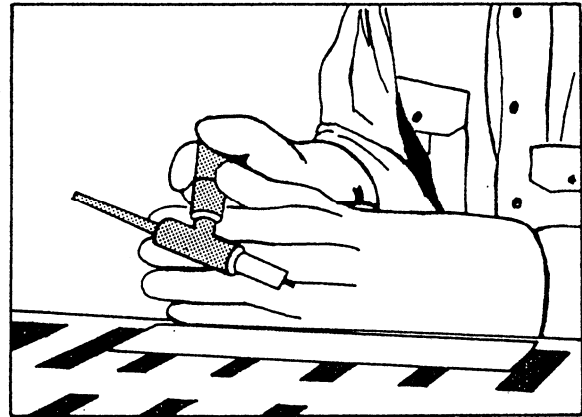


Figure 8-13.—Torch position for the starting swing to strike the arc.

procedure for a particular welded joint includes many variables. The same variables that must be considered for other welding processes also must be considered for gas shielded-arc welding. Some of the variables that you must consider include the following: type of base metal, the joint design, the welding position, the type of shielding gas, and the welding machine setting.

### Starting the Arc

Before starting the arc, you should form a ball on the end of the electrode for ac welding. To do this, simply set the current to DCRP and strike an arc for a moment on a piece of carbon or a piece of copper. The ball diameter should be only slightly larger than the original diameter of the tungsten electrode.

When starting the arc with an ac high-frequency current, you do not have to bring the electrode into contact with the workpiece. To strike the arc, you must hold the torch in a horizontal position about 2 inches above the work surface, as shown in figure 8-13. Then

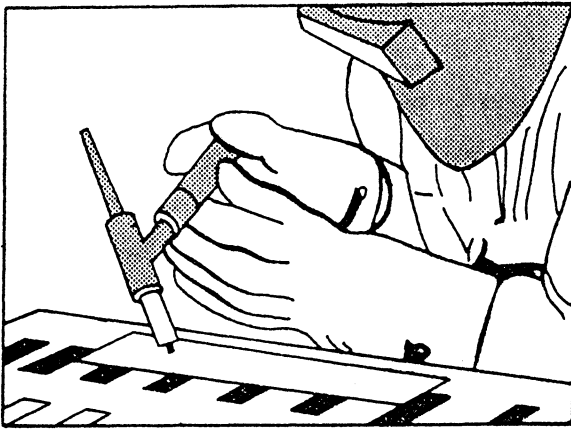


Figure 8-14.—Torch position at the end of the swing when the arc strikes.

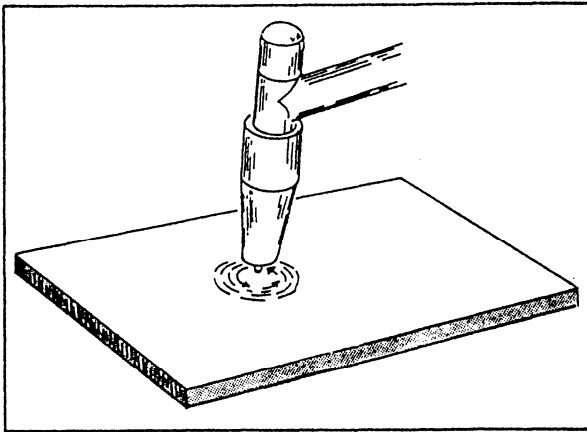


Figure 8-15.—Forming a molten puddle with a GTA torch.

rapidly swing the electrode end of the torch down to within 1/8 of an inch of the work surface. The high-frequency arc will then jump the gap between the electrode and the plate, establishing the arc. Figure 8-14 shows the torch position at the time the arc strikes.

If you are using a dc machine, hold the torch in the same position, but touch the plate to start the arc. When the arc is struck withdraw the electrode so it is about 1/8 of an inch above the plate.

To stop the arc, quickly swing the electrode back to the horizontal position. If the machine has a foot pedal, gradually decrease the current before stopping the arc.

## Welded Joints

In the following paragraphs the different types of joints and the procedures used to weld them is discussed.

**BUTT JOINTS.**— After you strike the arc, hold the torch at a 90-degree angle to the workpiece surface, and

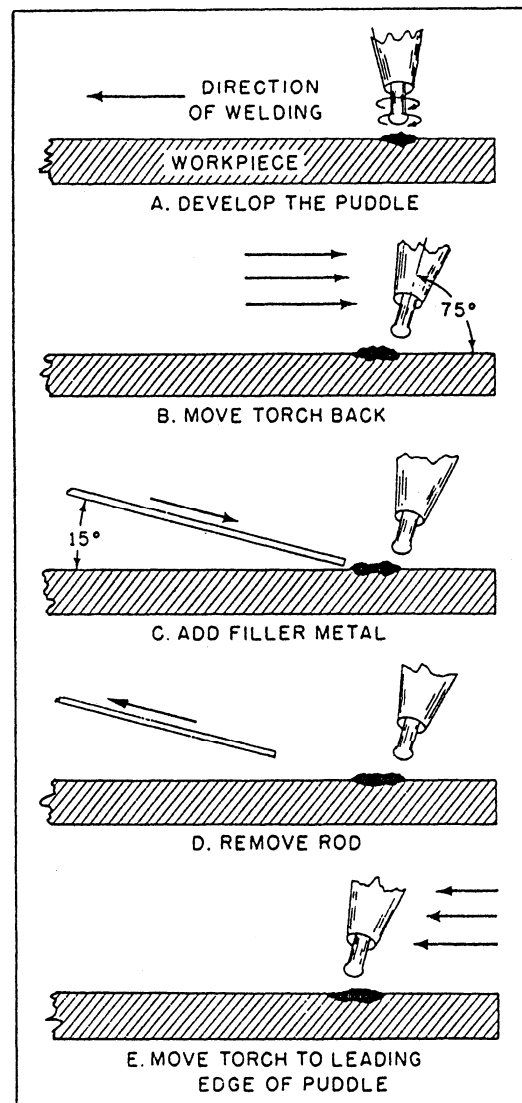


Figure 8-16.—Addition of filler metal in the flat position.

with small circular motions, as shown in figure 8-15, form a molten puddle. After you form the molten puddle, hold the torch at a 75-degree angle to the work surface and move it slowly and steadily along the joint at a speed that produces a bead of uniform width. Move the torch slowly enough to keep the puddle bright and fluid. No oscillating or other movement of the torch is necessary except the steady forward movement.

When you must use a filler metal, form the molten puddle as described previously. When the puddle becomes bright and fluid, you should move the arc to the rear of the puddle and add the filler metal by quickly touching the rod to the front edge of the puddle. Hold the rod at about a 15-degree angle from the work. Because the electrode is pointing toward the filler metal or pushing it, it is known as the *push angle*. Remove the

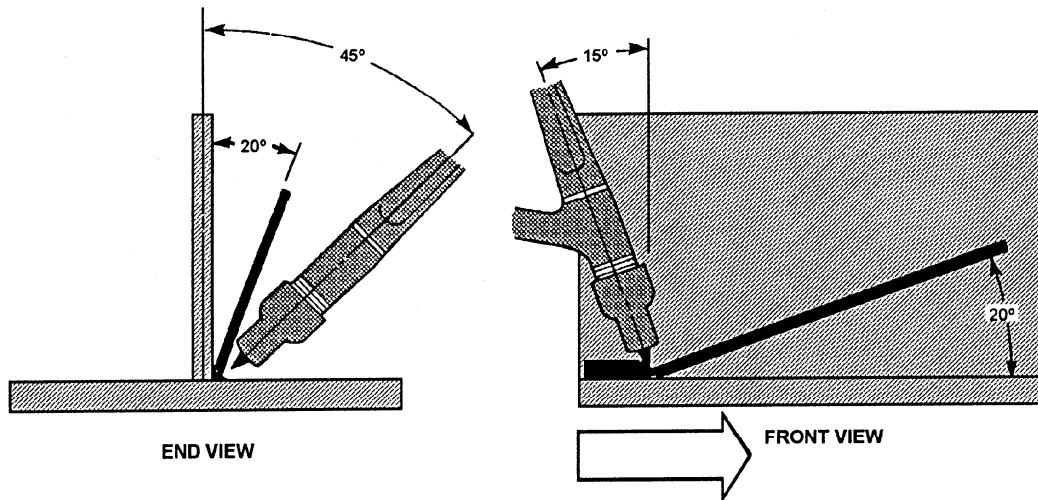


Figure 8-17.—GTA welding a tee joint.

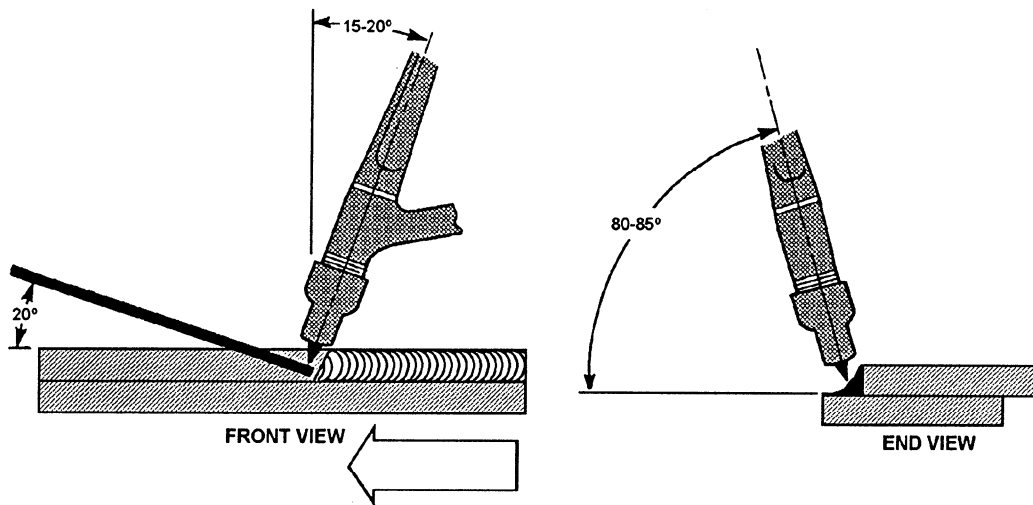


Figure 8-18.—GTA welding a lap joint.

filler rod and bring the arc back to the front edge of the puddle. When the puddle becomes bright and fluid again, you should repeat the steps as described before. Figure 8-16 shows the correct procedures for adding filler metal. Continue this sequence until the weld joint has been completed. The width and height of the weld bead is determined by the speed of travel, by the movement of the torch, and by the amount of filler metal added.

In welding practice, it is again stressed that good (GTA welding depends on following this definite procedure—form the molten pool and then feed filler rod intermittently to the leading edge of the pool as you move the torch forward. DO NOT feed the filler rod into

the arc. You should practice making single-pass butt welds until you can produce satisfactory welds.

**LAP AND TEE JOINTS.**— In chapter 3, we said that lap and tee joints are welded using the fillet weld. Fillet welds are slightly awkward to make using the GTA welding process because of the gas nozzle. Once you establish the arc, you should pay close attention to the molten puddle. Figures 8-17 and 8-18 show the correct torch and rod angles for the tee and lap joints.

In welding a tee or lap joint, the puddle forms a V-shape. The center of the V is called a *notch*, and the speed at which you fill the notch governs how fast you should move the torch. Do NOT get ahead of the notch. If you do, the joint will have insufficient fusion and penetration. As you weld along the joint, dip the rod in

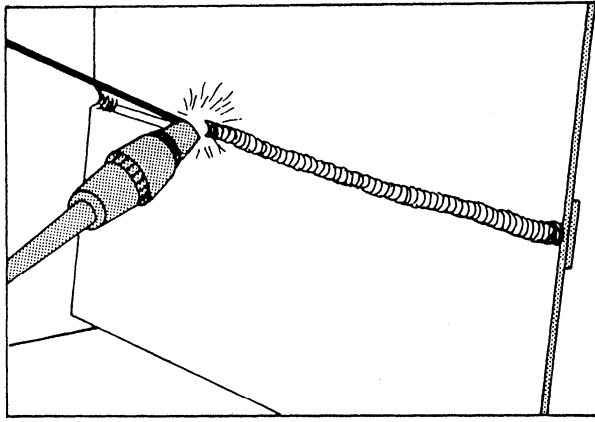


Figure 8-19.—GTA welding in the horizontal position.

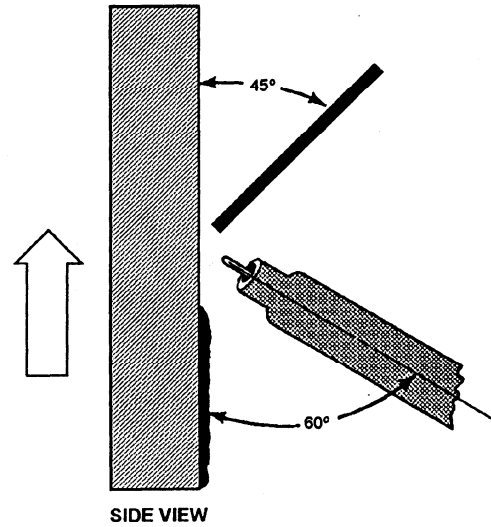


Figure 8-21.—GTA welding vertical upward.

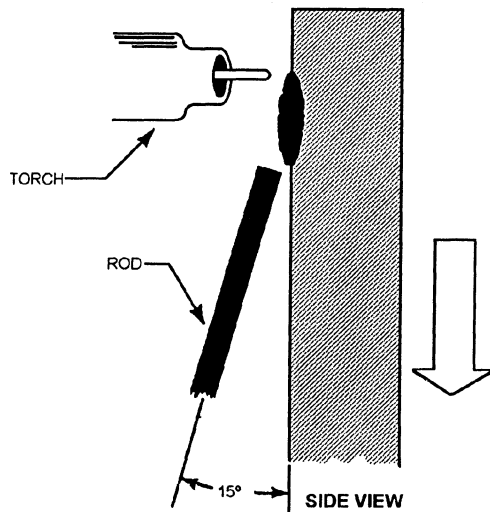


Figure 8-20.—GTA welding vertical downward.

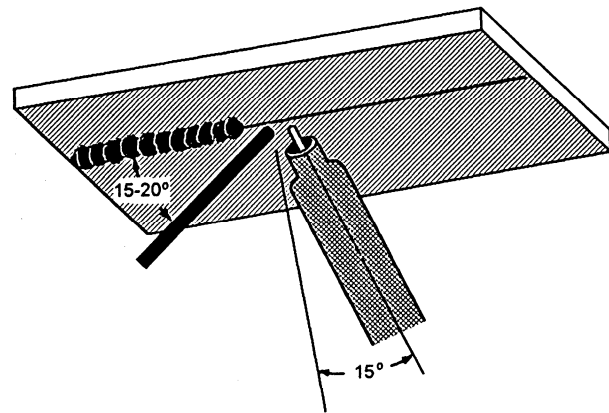


Figure 8-22.—GTA welding overhead.

and out of the puddle about every 1/4 of an inch of travel. If you add the filler rod to the molten puddle at just the right time uniform welds result every time.

### Out-of-Position Welding

Rules for quality welding in the flat position also must be followed for out-of-position GTA welding. Cleanliness, good joint fit-up, preheat, sufficient shielding gas, and correct welding current are important. In addition, you should not use high welding current or deposit large weld beads. Direct the arc so there is no overheating at anyone area that could cause sagging or undercutting. The adding of filler metal, bead size, and sequence must be done correctly to ensure complete fusion between passes.

**HORIZONTAL WELDING.**— When welding in the horizontal position, start the arc on the edge of the

joint. Then hold the torch at a work angle of 15 degrees and a push angle of 15 degrees. After you establish the puddle, dip the rod into the front edge of the puddle on the high side as you move the torch along the joint (fig. 8-19). Maintain an arc length as close as possible to the diameter of the electrode. Correct arc length coupled with the correct speed of travel helps prevent undercutting and permits complete penetration.

**VERTICAL WELDING.**— When welding thin material with the GTA welding process, you should weld from the top, moving downward (fig. 8-20). This helps you produce an adequate weld without burning through the metal. Filler material is not normally needed for welding downward.

On heavier materials, you should weld from the bottom, upwards (fig. 8-21). This enables you to achieve adequate penetration. When welding upward, you normally need to use a filler rod.

**OVERHEAD WELDING.**— When GTA welding in the overhead position, you should lower the welding current by 5 to 10 percent of what normally is used for flat welding. This reduced welding current enables you to maintain better control of the welding puddle. Conversely, you need a higher flow of shielding gas. Hold the torch and the rod as you do for flat welding (fig. 8-22). You should try to maintain a small weld puddle to avoid the effects of gravity. Most inexperienced welders find overhead welding awkward; therefore, try to get in as comfortable and relaxed a position as possible when welding. This helps you to maintain steady, even torch and filler rod manipulation.

## **GTA WELDING COMMON METALS**

The actual welding technique for gas tungsten-arc welding common metals is virtually the same; however, each of the metals that we discuss has its own unique welding characteristics. In this section we discuss some of those characteristics. It is not the scope of this training manual to provide you with an in depth study of the welding procedures required to weld all types of metals. This chapter is merely an introduction to gas shielded-arc welding. For more information, refer to the manufacturer's literature for the specific welding equipment you use or any of the references listed in this book.

### **Aluminum**

Steelworkers use the gas tungsten-arc welding procedure more for aluminum than for any other metal. Aluminum is available in a variety of compositions. Series 1000, 3000, and 5000 aluminum alloys are considered nonheat-treatable and are easily weldable. The heat-treatable alloys in the series 2000, 6000, and 7000 also can be welded; however, higher welding temperatures and speed are needed.

You can weld aluminum in all positions, but better welds are normally produced in the flat position. You should also use copper backup blocks whenever possible, especially on thin material. For best results use ACHF current and argon for shielding gas.

### **Stainless Steel**

In GTA welding of stainless steel, the welding techniques used are similar to those used with aluminum. The major differences are in the selection of the welding current and the type of tungsten electrode used. To get the best results in welding stainless steel, you should use DCSP welding current; however, ACHF can be used. The forehand welding technique should be used.

The amperage settings for GTA welding stainless steel are higher than for aluminum. The amperage used for different thicknesses of stainless should be according to the recommended settings that you can find in the manufacturer's technical manual or the information pamphlets provided with the equipment.

### **Copper and Its Alloys**

Pure copper is easily welded; however, as with any of the other metals we have discussed, it must be thoroughly cleaned before to welding. The GTA weldability of each copper-alloy group depends largely upon the alloying elements. Copper-silicon and copper-nickel alloys are weldable using the GTA process. Copper-zinc, copper-tin, and copper-lead alloys are difficult or impossible to weld by the GTA process. Plates up to 1/4 of an inch thick are generally prepared with a square edge. The forehand welding technique with DCSP is recommended for materials thicker than 0.050 of an inch. On lighter material, ACHF also can be used.

### **Cast Iron**

You can make sound welds using the GTA welding process in three principal grades of cast iron: gray, white, and malleable. Cast-iron parts must always be preheated before to welding. Gray cast iron should be preheated to a temperature ranging between 500°F to 1250°F. The required temperature depends on the size and shape of the workpiece.

In either GTA or GMA welding, you should allow the workpiece to cool slowly after welding. You can accomplish this by covering the workpiece in a bed of lime or ashes. This slow cooling prevents cracking and residual stresses.

### **Magnesium**

The welding characteristics of magnesium are comparable to those of aluminum. Both have high-heat conductivity, a low-melting point, high-thermal expansion, and both oxidize rapidly. Both DCRP and ac provide excellent cleaning action to the weld metal. DCRP can be used with helium gas to produce wide weld deposits, high heat, and shallow penetration. ACHF with helium, argon, or a mixture of the gases can be used to join metals ranging from 0.20 to over 0.25 of an inch. DCSP with helium produces deep penetration but no surface cleaning.

Most satisfactory results on magnesium are obtained by using the electrode in as nearly a vertical

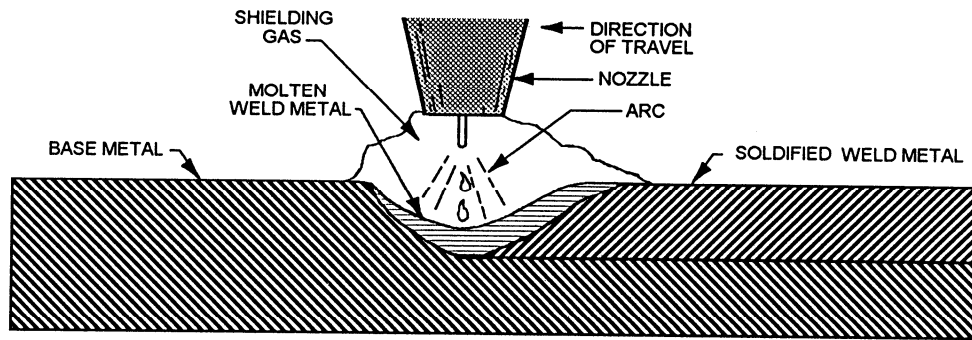


Figure 8-23.—GMA welding process.

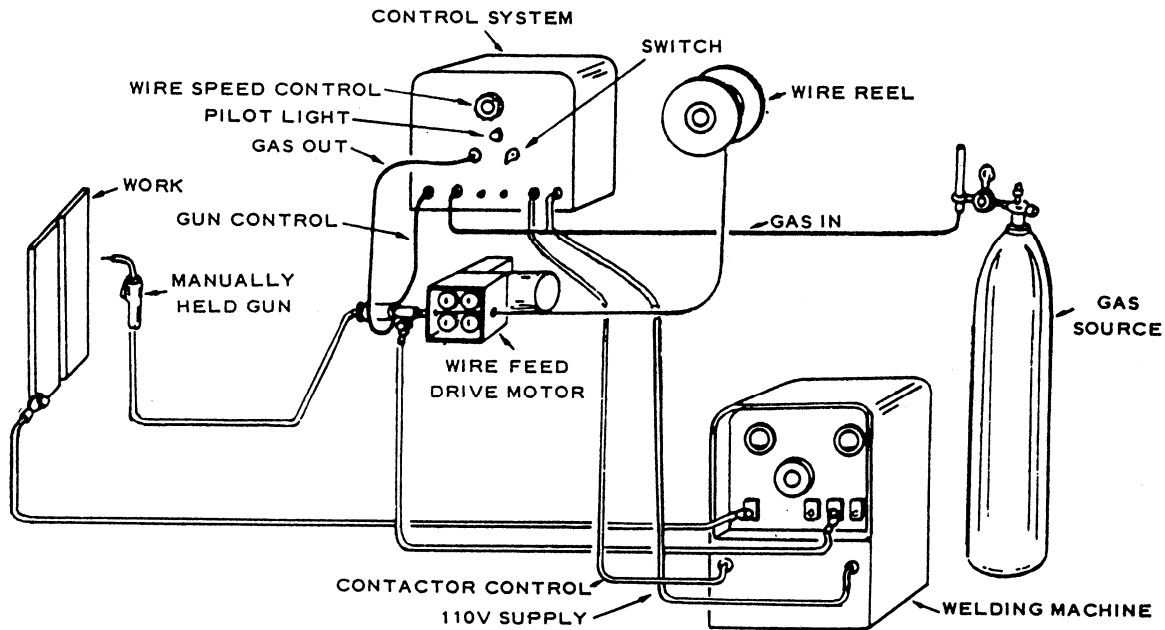


Figure 8-24.—Diagram of GMA welding equipment.

position as possible. The electrode is advanced along the line of weld, using the forehand technique.

### CAUTION

Always be sure there is good ventilation when welding. The fumes from some of these metals are highly toxic; therefore, a good ventilating system is essential.

### GAS METAL-ARC WELDING-GMAW

The gas metal-arc welding process (GMAW), often called *MIG*, has revolutionized arc welding. In this process, a consumable electrode (in the form of wire) is fed from a spool through the torch (welding gun) at a

preset controlled speed. As the wire passes through the contact tube of the gun, it picks up the welding current. The consumable wire electrode serves two functions: it maintains the arc and provides filler metal to the joint. The method of delivery of the filler metal allows GMAW welding to be basically a one-handed operation which does not require the same degree of skill as GTAW. Figure 8-23 shows the basic principle of gas metal-arc welding.

An important factor in the GMA welding process is the high rate at which metal can be deposited. This high rate of metal deposition and high speed of welding results in minimum distortion and a narrow heat-affected zone. When you are deciding whether to use GTA or GMA welding, the thickness of the material should

be a deciding factor. GMAW is often chosen for welding thicker material.

Like GTA welding, gas metal-arc welding also uses a shielding gas to protect the weld zone during welding. The inert gas is fed through the gun into the weld zone and prevents atmospheric contamination.

GMAW offers many of the advantages of GTAW. Since there is no flux, GMA welds are clean and there is no slag to remove. GMAW enables you to produce sound welds in all positions quickly. Now let's take a look at the equipment you will use for GMA welding.

## **GMA WELDING EQUIPMENT AND SUPPLIES**

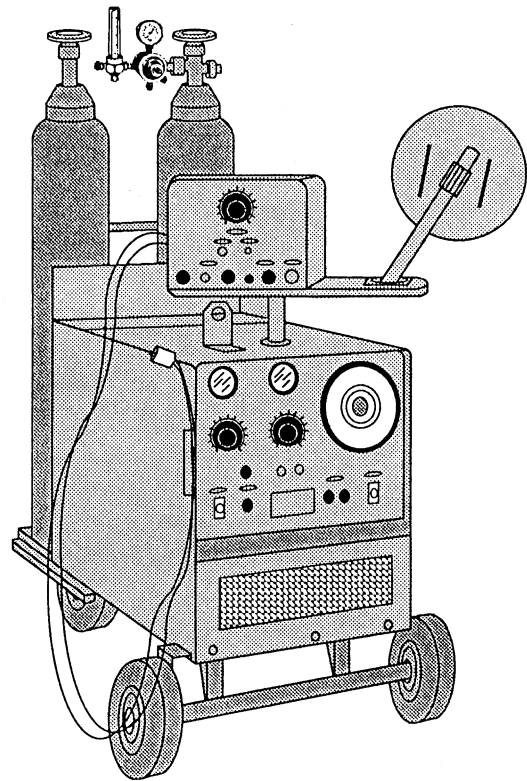
Gas metal-arc welding equipment basically consists of four units: the power supply, the wire feeding mechanism, the welding gun (also referred to as the torch), and the gas supply. Figure 8-24 shows atypical GMA welding outfit.

### **Welding Machine**

When you use a conventional type of welding machine for GMA welding, the voltage varies depending on the length of the arc. Whenever the nozzle-to-work distance changes, the arc length and the voltage changes. The only way to produce uniform welds with this type of power source is to maintain the arc length and voltage at a constant value. Besides producing nonuniform welds, this inconsistent voltage can cause the wire to burn back to the nozzle.

A *constant voltage (CV)* power source was developed to overcome the inconsistent voltage characteristics of a conventional welding machine, (See fig. 8-25). It can be either a dc rectifier or motor generator that supplies current with normal limits of 200 to 250 amperes.

The CV type power source has a nearly flat volt-ampere characteristic. This means that the machine maintains the same voltage regardless of the amount of current used. With this type of power source, you can change the wire-feed speed over a considerable range without causing the wire to burn back to the nozzle. When the wire-feed speed is set at a specific rate, a proportionate amount of current is automatically drawn. In other words, the current selection is based on the wire-feed speed. When the wire is fed faster, the current increases; when it is fed slower, the current decreases. With this type of power supply, variations in



**Figure 8-25.—Constant voltage (CV) power unit.**

the nozzle-to-work distance will not change the arc length and burn back is virtually eliminated.

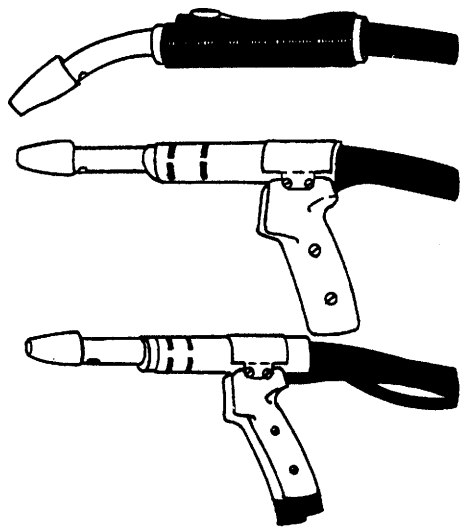
In gas metal-arc welding, direct-current reverse polarity (DCRP) is recommended. You should recall from the previous section that DCRP produces excellent cleaning action and allows for deeper penetration.

### **Wire Feed Drive Motor**

The wire feed drive motor is used to automatically drive the electrode wire from the wire spool through the gun up to the arc point. You can vary the speed of the wire feed by adjusting the controls on the wire-feed control panel. The wire feeder can be mounted on the power unit or it can be separate from the welding machine.

### **Welding Gun**

The function of the welding gun is to carry the electrode wire, the welding current, and the shielding gas to the arc area. The gun has a trigger switch that controls the wire feed and arc as well as the shielding gas. The welding operator directs the arc and controls the weld with the welding gun. GMA welding guns are available in many different styles, some of which are



**Figure 8-26.—GMA welding guns.**

shown in figure 8-26. When using these guns, the wire is fed to the torch by an automatic wire feeding machine which pushes the wire through a flexible tube to the arc point.

Figure 8-27 shows another type of GMA welding gun that Steelworkers could use. This model incorporates the drive motor and a small spool of wire inside the gun. This type of gun is attached directly to the welding unit and gas supply, eliminating the need for a separate control unit and wire drive assembly.

As with the GTA welding torch, the torch nozzle must be kept clean at all times. Also, you should clean the tube through which the electrode wire passes each time the electrode reel is changed.

### Shielding Gas

In gas metal-arc welding, as with gas tungsten-arc welding, the shielding gas can have a major effect on the properties of the base metal. Some of the shielding gases commonly used with the GMA process are pure argon, argon-helium, argon-oxygen, argon-carbon dioxide, and carbon dioxide. Refer to table 8-4 for a selection of shielding gases recommended for various metals for both the GMA and GTA welding processes. The smoothness of operation, weld appearance, weld quality, and welding speeds are affected in different ways with each type of metal, thickness, and gas mixture.

**ARGON.**— Earlier in this chapter, we said that argon provides greater cleaning action than other gases. Because it is heavier than air, argon blankets the weld from contamination. Also, when you are using argon as a shielding gas, the welding arc tends to be more stable. For this reason, argon is often used in combination with



127.258B

**Figure 8-27.—GMA welding torch with wire feed motor and wire spool inside.**

other gases for arc shielding. Argon reduces spatter by producing a quiet arc and reducing arc voltage that results in lower power in the arc and thus lower penetration. The combination of lower penetration and reduced spatter makes argon desirable when welding sheet metal.

Pure argon is seldom used for arc shielding except in welding such metals as aluminum, copper, nickel, and titanium. The use of pure argon to weld steel usually results in undercutting, poor bead contour, and the penetration is somewhat shallow.

**ARGON-OXYGEN.**— Small amounts of oxygen added to argon can produce excellent results. Normally oxygen is added in amounts of 1, 2, or 5 percent. When oxygen is added to argon, it improves the penetration pattern. It also improves the bead contour and eliminates the undercut at the edge of the weld. You use argon-oxygen mixtures in welding alloy steels, carbon steels, and stainless steel.

**HELIUM.**— Helium, like argon, is an inert gas. But there are few similarities between the two gases. Argon is heavier than air and helium is lighter than air. Helium has a high-voltage change as the arc length changes. When you use helium for GMA welding, more arc energy is lost in the arc itself and is not transmitted to the work. In the section on GTA welding, we said that helium produces good penetration and fast welding speeds. For GMA welding, the opposite is true. In GMA welding, helium produces a broader weld bead, but shallower penetration.

Because of its high cost, helium is primarily used for special welding tasks and for welding nonferrous metals, such as aluminum, magnesium, and copper. It is also used in combination with other gases.

**CARBON DIOXIDE (CO<sub>2</sub>).**— Argon and helium gases are composed of single atoms. Carbon dioxide, on the other hand, consists of molecules. Each molecule contains one carbon atom and two oxygen atoms. At



**Table 8-6.—Recommended Wire Diameters for GMA Welding Using Welding Grade CO<sub>2</sub> and a Wire Stick-out of 1/4 to 3/8 of an Inch**

(Manual travel, single pass, flat fillet welds)					
MATERIAL THICKNESS (inches)	ELECTRODE SIZE	WELDING DCRO (arc volts)	CONDITIONS (amperes)	GAS FLOW (cfh)	TRAVEL SPEED (ipm)
0.025	0.030	15-17	30-50	15-20	15-20
.031	.030	15-17	40-60	15-20	18-22
.037	.035	15-17	65-85	15-20	35-40
.050	.035	17-19	80-100	15-20	35-40
.062	.035	17-19	90-110	20-25	30-35
.078	.035	18-20	110-130	20-25	25-30
.125	.035	19-21	140-160	20-25	20-25
.125	.045	20-23	180-200	20-25	27-32
.187	.035	19-21	140-160	20-25	14-19
.187	.045	20-23	180-200	20-25	18-22
.250	.035	19-21	140-160	20-25	10-15
.250	.045	20-23	180-200	20-25	12-18

normal temperatures carbon dioxide is essentially an inert gas; however, at high temperatures it decomposes into carbon monoxide (CO) and oxygen (O<sub>2</sub>). Because the excess oxygen atoms can combine with carbon or iron in the weld metal, wires used with this gas must contain *deoxidizing* elements. A deoxidizing element has a great affinity for the oxygen and readily combines with it. Some of the more common deoxidizers used in wire electrodes are manganese, silicon, and aluminum.

Carbon dioxide is used primarily for the GMA welding of mild steel. Because of its low cost, CO<sub>2</sub> is often used in combination with other shielding gases for welding different types of metals. Direct-current reverse polarity (DCRP) is generally used with CO<sub>2</sub>. The current setting is about 25 percent higher with CO<sub>2</sub> than with other shielding gases.

Carbon dioxide produces a broad, deep penetration pattern. It also produces good bead contour and there is no tendency toward undercutting. The only problem with CO<sub>2</sub> gas is the tendency for the arc to be violent. This can lead to spatter problems; however, for most applications this is not a problem and the advantages of CO<sub>2</sub> far outweigh the disadvantages.

### Regulators

You should use the same type of regulator and flowmeter for gas metal-arc welding that you use for gas tungsten-arc welding. The gas flow rates vary, depending on the types and thicknesses of the material and the joint design. At times it is necessary to connect two or

more gas cylinders (manifold) together to maintain higher gas flow.

For most welding conditions, the gas flow rate is approximately 35 cubic feet per hour (cfh). This flow rate may be increased or decreased, depending upon the particular welding application. Final adjustments usually are made on a trial-and-error basis. The proper amount of gas shielding results in a rapidly crackling or sizzling arc sound. Inadequate gas shielding produces a popping arc sound and results in weld discoloration, porosity, and spatter.

### Filler Wires

The composition of the filler wire used for GMA welding must match the base metal. For mild steel, you should select mild steel wire; for aluminum, you should select aluminum wire. Additionally, you should try to select electrode wire that matches the composition of the various metals you are welding. For instance, when you are welding Type 308 aluminum, you should use an ER-308L filler wire.

Wires are available in spools of several different sizes. The wire varies in diameter from .020 to 1/8 of an inch. You should select the proper diameter of wire based on the thickness of the metal you are welding as well as the position in which you are welding. Wires of 0.020, 0.030, and 0.035 of an inch are generally used for welding thin materials. You also can use them for welding low- and medium-carbon steels and low-alloy/high-strength steels of medium thicknesses. (See table 8-6.) Medium thicknesses of metals are normally welded with

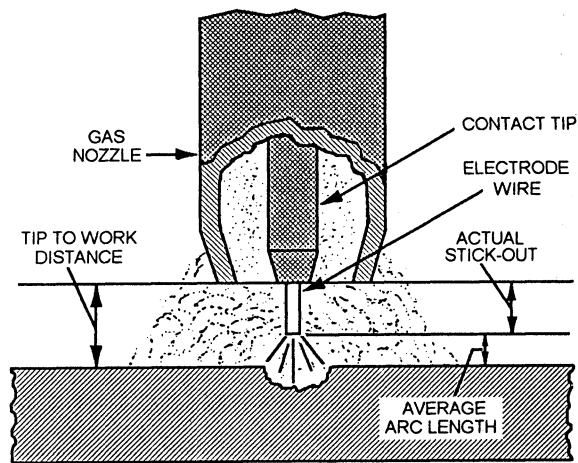


Figure 8-28.—Correct wire stick-out.

0.045-inch or 1/16-inch diameter wires. For thicker metals, larger diameter electrodes may be required.

As you learned earlier, the position of welding is a factor that must be considered. For instance, when you are welding in the vertical or overhead positions, you normally use smaller diameter electrodes.

Special attention must be given to ensure the wire is clean. Unsound welds result from the use of wire that is contaminated by oil, grease, dust, or shop fumes. You can obtain the best welding results with wire that has just been taken out of its carton. Wire should be stored in a hot locker or in a warm dry area, and should be kept covered. If welding is stopped for a long period of time, you should remove the wire and place it in its original carton to prevent contamination.

**WIRE STICK-OUT.**— In gas metal-arc welding, *wire stick-out* refers to the distance the wire extends from the nozzle of the gun (fig. 8-28). The correct amount of wire stick-out is important because it influences the welding current of the power source. Since the power source is self-regulating, the current output is automatically decreased when the wire stick-out increases. Conversely, when the stick-out decreases, the power source is forced to furnish more current. Too little stickout causes the wire to fuse to the nozzle tip, which decreases the tip life.

For most GMA welding, the wire stickout should measure from 3/8 to 3/4 of an inch. For smaller (micro) wires, the stick-out should be between 1/4 and 3/8 of an inch.

**WIRE-FEED SPEED.**— As we stated earlier, you can adjust the wire-feed drive motor to vary the

wire-feed speed. This adjustment is limited to a definite range, depending on the welding current used. (See table 8-6). The wire-feed speed is measured in inches per minute (ipm). For a specific amperage setting, a high wire-feed speed results in a short arc, whereas a low speed produces a long arc. You use higher speeds for overhead welding than with flat-position welding.

### Personal Protective Equipment

As with any other welding process, SAFETY is extremely important. A welding hood like the one used in shielded metal-arc welding should be used for gas metal-arc welding. The correct shade of lens depends on the intensity of the arc. Chapter 3 provides a chart of recommended lens shades based on the current setting of the machine. Eye fatigue indicates you should use a different shade of lens or there is leakage around the protective filter glass.

In addition to the welding hood, protective clothing, such as gloves and an apron, should be worn. Bare skin should never be exposed to the rays of the welding arc because it could result in painful burns.

### TYPES OF GMA WELDING

When using the GMA welding process, metal is transferred by one of three methods: spray transfer, globular transfer, or short-circuiting transfer. The type of metal transfer depends on the arc voltage, current setting, electrode wire size, and shielding gas.

#### Spray-Arc Welding

Spray-arc transfer is a high-current range method that produces a rapid disposition of weld metal. This type of transfer is effective for welding heavy-gauge metals because it produces deep weld penetration. The use of argon or a mixture of argon and oxygen are necessary for spray transfer. Argon produces a pinching effect on the molten tip of the electrode, permitting only small droplets to form and transfer during the welding process. Spray transfer is useful when welding aluminum; however, it is not practical for welding light-gauge metal.

#### Globular Transfer

Globular transfer occurs when the welding current is low. Because of the low current, only a few drops are

transferred per second, whereas many small drops are transferred with a higher current setting. In this type of transfer, the ball at the tip of the electrode grows in size before it is transferred to the workpiece. This globule tends to reconnect with the electrode and the workpiece, causing the arc to go out periodically. This results in poor arc stability, poor penetration, and excessive spatter.

Globular transfer is not effective for GMA welding. When it is used, it is generally restricted to thin materials where low heat input is desired.

### **Short-Circuiting Arc Transfer**

Short-circuiting arc transfer is also known as *short arc*. Short arc was developed to eliminate distortion, burn-through, and spatter when welding thin-gauge metals. It can be used for welding in all positions, especially vertical and overhead where puddle control is more difficult. In most cases, it is used with current levels below 200 amperes and wire of 0.045 of an inch or less in diameter. Small wire produces weld puddles that are small and easily manageable.

The shielding gas mixture for short-arc welding is 75% carbon dioxide and 25% argon. The carbon dioxide provides for increased heat and higher speeds, while the argon controls the spatter. Straight CO<sub>2</sub> is now being used for short-arc welding; however, it does not produce the excellent bead contour that the argon mixture does.

### **GMA WELDING PREPARATION**

Preparation is the key to producing quality weldments with the gas metal-arc welding process. As in GTA welding, the equipment is expensive; therefore, you should make every effort to follow the manufacturer's instruction manuals when preparing to use GMA welding equipment.

#### **Joints**

For the most part, the same joint designs recommended for other arc welding processes can be used for gas metal-arc welding (refer to chapter 3). There are some minor modifications that should be considered due to the welding characteristics of the GMA process. Since the arc in GMA welding is more penetrating and narrower than the arc for shielded metal-arc welding, groove joints can have smaller root faces and root openings. Also, since the nozzle does not have to be placed within the groove, less beveling of the plates is required.

GMA welding can actually lower material costs, since you use less weld metal in the joint.

### **Equipment**

The following suggestions are general and can be applied to any GMA welding operation:

- Check all hose and cable connections to make sure they are in good condition and are properly connected.
- Check to see that the nozzle is clean and the correct size for the particular wire diameter used.
- Make sure that the guide tube is clean and that the wire is properly threaded through the gun.
- Determine the correct wire-feed speed and adjust the feeder control accordingly. During welding, the wire-speed rate may have to be varied to correct for too little or too much heat input.
- Make sure the shielding gas and water coolant sources are on and adjusted properly.
- Check the wire stick-out.

### **GMA WELDING PROCEDURES**

As with any other type of welding, the GMA welding procedure consists of certain variables that you must understand and follow. Many of the variables have already been discussed. This section applies some of these variables to the actual welding procedure.

#### **Starting the Arc**

For a good arc start, the electrode must make good electrical contact with the work. For the best results, you should clean the metal of all impurities. The wire stick-out must be set correctly because as the wire stick-out increases, the arc initiation becomes increasingly difficult.

When preparing to start the arc, hold the torch at an angle between 5 and 20 degrees. Support the weight of the welding cable and gas hose across your shoulder to ensure free movement of the welding torch. Hold the torch close to, but not touching, the workpiece. Lower your helmet and squeeze the torch trigger. Squeezing the trigger starts the flow of shielding gas and energizes the welding circuit. The wire-feed motor does not energize until the wire electrode comes in contact with the workpiece. Move the torch toward the work, touching the wire electrode to the work with a sideways scratching

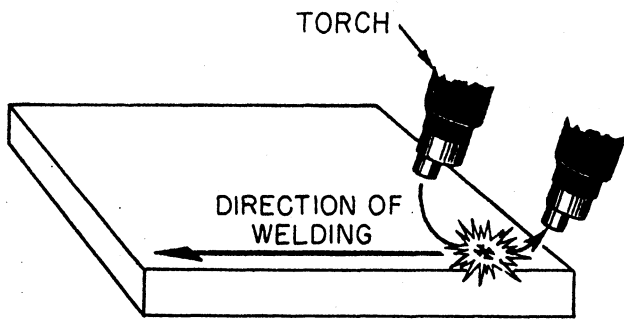


Figure 8-29.—Striking the arc (GMAW).

motion, as shown in figure 8-29. To prevent sticking, you should pull the torch back quickly, about 1/2 of an inch—the instant contact is made between the wire electrode and the workpiece. The arc strikes as soon as contact is made and the wire-feed motor feeds the wire automatically as long as the trigger is held.

A properly established arc has a soft, sizzling sound. Adjustment of the wire-feed control dial or the welding machine itself is necessary when the arc does not sound right. For example, a loud, crackling sound indicates that the arc is too short and that the wire-feed speed is too fast. You may correct this problem by moving the

wire-feed dial slightly counterclockwise. This decreases the wire-feed speed and increases the arc length. A clockwise movement of the dial has the opposite effect. With experience, you can recognize the sound of the proper length of arc to use.

To break the arc, you simply release the trigger. This breaks the welding circuit and de-energizes the wire-feed motor. Should the wire electrode stick to the work when striking the arc or during welding, release the trigger and clip the wire with a pair of side cutters.

### Welding Positions

In gas metal-arc welding, the proper position of the welding torch and weldment are important. The position of the torch in relation to the plate is called the work and travel angle. Work and travel angles are shown in figure 8-30. If the parts are equal in thickness, the work angle should normally be on the center line of the joint; however, if the pieces are unequal in thickness, the torch should angle toward the thicker piece.

The travel angle refers to the angle in which welding takes place. This angle should be between 5 and 25 degrees. The travel angle may be either a push angle or a drag angle, depending on the position of the torch.

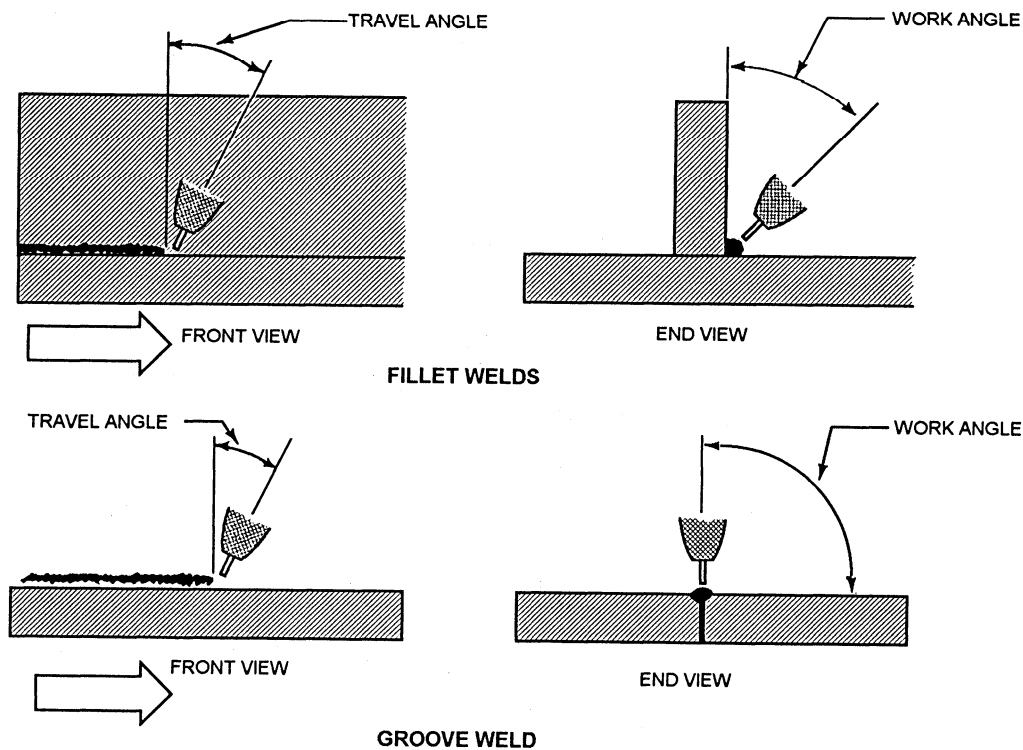


Figure 8-30.—Travel and work angle for GMA welding.

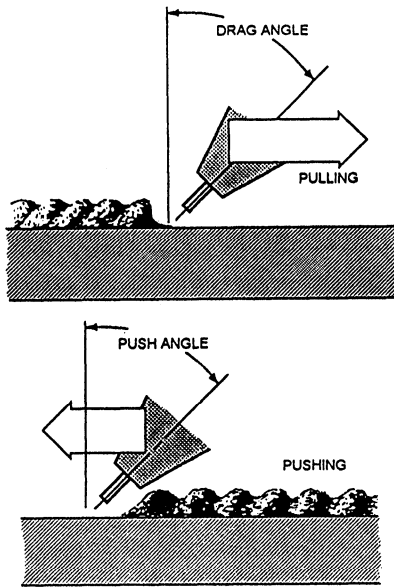


Figure 8-31.—Pulling and pushing travel angle techniques.

When the torch is ahead of the weld, it is known as pulling (or dragging) the weld. When the torch is behind the weld, it is referred to as pushing the metal (fig. 8-31).

The pulling or drag technique is for heavy-gauge metals. Usually the drag technique produces greater penetration than the pushing technique. Also, since the welder can see the weld crater more easily, better quality welds can consistently be made. The pushing technique is normally used for light-gauge metals. Welds made with this technique are less penetrating and wider because the welding speed is faster.

For the best results, you should position the weldment in the flat position. This position improves the molten metal flow, bead contour, and gives better shielding gas protection.

After you have learned to weld in the flat position, you should be able to use your acquired skill and knowledge to weld out of position. These positions include horizontal, vertical-up, vertical-down, and overhead welds. The only difference in welding out of position from the flat position is a 10-percent reduction in amperage.

When welding heavier thicknesses of metal with the GMA welding process, you should use the multipass technique (discussed in chapter 3). This is accomplished by overlapping single small beads or making larger beads, using the weaving technique. Various multipass welding sequences are shown in figure 8-32. The numbers refer to the sequences in which you make the passes.

### Common Weld Defects

Once you get the feel of welding with GMA equipment, you will probably find that the techniques are less difficult to master than many of the other welding processes; however, as with any other welding process, GMA welding does have some pitfalls. To produce good quality welds, you must learn to recognize and correct possible welding defects. The following are a few of the more common defects you may encounter along with corrective actions that you can take.

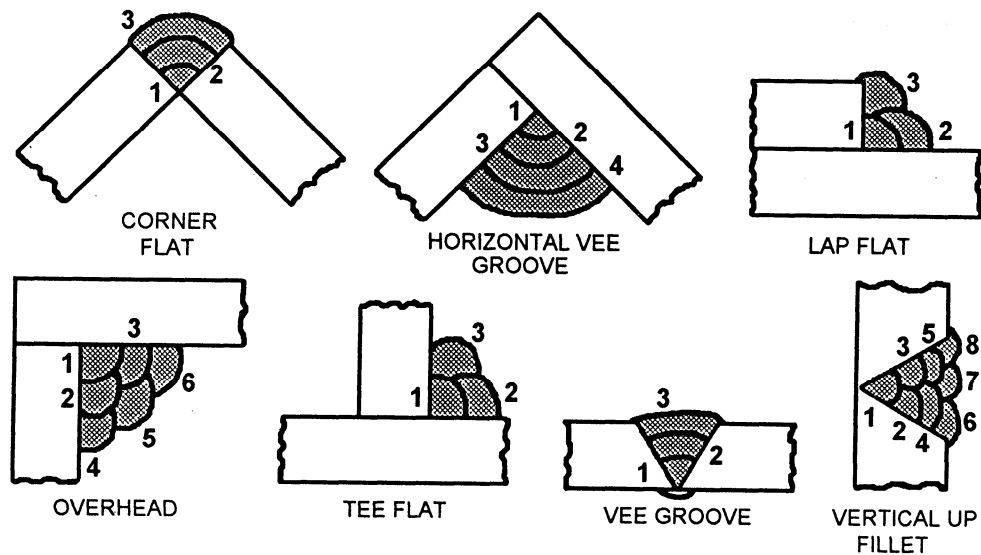


Figure 8-32.—Multipass welding.

**SURFACE POROSITY.**— Surface porosity usually results from atmospheric contamination. It can be caused by a clogged nozzle, shielding gas set too low or too high, or welding in a windy area. To avoid surface porosity, you should keep the nozzle clean of spatter, use the correct gas pressure, and use a protective wind shield when welding in a windy area.

**CRATER POROSITY.**— Crater porosity usually results from pulling the torch and gas shield away before the crater has solidified. To correct this problem, you should reduce the travel speed at the end of the joint. You also may try reducing the tip-to-work distance.

**COLD LAP.**— Cold laps often result when the arc does not melt the base metal sufficiently. When cold lap occurs, the molten puddle flows into an unwelded base metal. Often this results when the puddle is allowed to become too large. To correct this problem, you should keep the arc at the leading edge of the puddle. Also, reduce the size of the puddle by increasing the travel speed or reducing the wire-feed speed. You also may use a slight whip motion.

**LACK OF PENETRATION.**— Lack of penetration usually results from too little heat input in the weld zone. If the heat input is too low, increase the wire-feed speed to get a higher amperage. Also, you may try reducing the wire stick-out.

**BURN-THROUGH.**— Burn-through (too much penetration) is caused by having too much heat input in the weld zone. You can correct this problem by reducing the wire-feed speed, which, in turn lowers the welding amperage. Also you can increase the travel speed. Burn-through can also result from having an excessive amount of root opening. To correct this problem, you increase the wire stick-out and oscillate the torch slightly.

**WHISKERS.**— Whiskers are short pieces of electrode wire sticking through the root side of the weld joint. This is caused by pushing the wire past the leading edge of the weld puddle. To prevent this problem, you should cut off the ball on the end of the wire with side cutters before pulling the trigger. Also, reduce the travel speed and, if necessary, use a whipping motion.

## **GMA WELDING COMMON METALS**

You can use the welding equipment and techniques for gas metal-arc welding to join all types of metals; however, as we discussed in the GTAW process, each of the metals requires a unique welding method. In this

section, we discuss some of the welding methods associated with a few of the more commonly welded metals.

### **Carbon Steels**

The majority of welding by all methods is done on carbon steels. When you are using GMA to weld carbon steels, both the spray-arc and short-arc methods may be applied. For spray-arc welding, a mixture of 5-percent oxygen with argon is recommended. As we mentioned earlier, this mixture provides a more stable arc. Also you may use a mixture of argon and CO<sub>2</sub> or straight CO<sub>2</sub>. Straight CO<sub>2</sub> is often used for high-speed production welding; however, with CO<sub>2</sub> the arc is not a true spray arc. For short-arc welding, a 25-percent CO<sub>2</sub> and 75-percent argon mixture is preferred.

For GMA welding of thin materials (0.035 inch to 1/8 inch), no edge preparation is needed and a root opening of 1/16 of an inch or less is recommended. For production of adequate welds on thicker material, some beveling is normally required. When welding plates 1/4 of an inch or greater in thickness, you should prepare a single or double-V groove with 50- to 60-degree included angle(s).

### **Aluminum**

The joint design for aluminum is similar to that of steel; however, aluminum requires a narrower joint spacing and lower welding current setting.

The short-arc welding method is normally used for out-of-position welding or when welding thin materials because short-arc produces a cooler arc than the spray type arc. When welding thinner material (up to 1 inch in thickness), you should use pure argon.

The spray-arc welding method is recommended for welding thicker materials. With spray arc, more heat is produced to melt the wire and base metal. When you are welding thicker material (between 1 and 2 inches) a mixture of 90-percent argon and 10-percent helium is recommended. The helium provides more heat input and the argon provides good cleaning action.

### **Stainless Steel**

DCRP with a 1- or 2-percent oxygen with argon mixture is recommended for most stainless steel welding. In general, you weld stainless steel with the spray-arc welding method and a pushing technique. When welding stainless steel up to 1/16 of an inch in thickness, you should use a copper backup strip. For welding thin materials in the overhead or vertical positions, the short-arc method produces better results.