OBJECTIVES

After completing this chapter, the student should be able to:

- Explain the gas metal arc (GMA) welding process and discuss its advantages.
- Explain the purpose of a shielding gas and how it is delivered to the weld.
- Identify the various components that make up a GMA welding station.
- Define the common electrical terms associated with a welding power supply.
- Describe the path that the electrical current takes in the welding process.
- Compare the four major types of wire feed systems.
- List the parts of a GMAW gun and describe how it works.
- State the most commonly used shielding gases and gas blends and what factors should be considered when choosing one.
- Choose the correct gas flow rate using welding guides.
- Describe the four modes of metal transfer and what factors should be considered when selecting one.
- Discuss the various features of GMAW electrodes, including sizes, coatings, cast, and helix, and the proper handling of the electrodes.
- Explain the meaning of the letters and numbers in the American Welding Society (AWS) GMAW electrode classification code.
- Demonstrate how to properly set up a GWA welding installation.
- Demonstrate how to properly thread an electrode wire through a welding installation.

KEY TERMS

argon (Ar)  axial spray metal transfer  cast
argon-\( \text{CO}_2 \)  bird nesting  conduit liner
argon-oxygen  carbon dioxide (\( \text{CO}_2 \))  constant current (CC)
The early GMA welding process used only inert gases for shielding, so the name MIG welding applied. Today, there are many different gases used for GMA welding—some are inert, nonreactive under all conditions, and others are reactive and can combine under some conditions. To reflect the addition of reactive gases, the term MAG (metal active gas) has been added to the lexicon of welding terms. The American Welding Society’s standard term is gas metal arc welding (GMAW). However, in some industries the terms MIG and MAG are the most commonly used. The process has had other names through the years such as wire welding, but whatever the name, the process is the same.

The advantages of GMA welding over conventional electrode-type arc (stick) welding are numerous.

**INTRODUCTION**

GMA welding uses a solid welding wire that is fed automatically at a constant speed as an electrode. An arc is generated between the wire and the base metal, and the resulting heat from the arc melts the welding wire and base metal to join the parts together, Figure 11-1. This is a semiautomatic arc welding process because wire is fed automatically at a constant rate and you provide the gun movement. During the welding process, a shielding gas protects the weld from the atmosphere and prevents oxidation of the base metal. The type of shielding gas used depends on the base material to be welded.

This process is often referred to by its original name, MIG, which stands for metal inert gas welding.

![Figure 11-1: Gas metal arc welding.](image-url)
larger gaps and misfits. Gaps can be welded by making several short welds on top of each other.

- Out of position—GMA welding can easily be used in all positions because the weld pool is small and the metal is molten for a very short time.
- Tack welding—GMA welds are easily started in the correct spot because the wire is not energized until the gun trigger is depressed, so arc strikes outside of the weld groove can be avoided.
- Efficient—Some GMA welding procedures have a 98% efficiency of weld metal deposited as compared to shielded metal arc welding (SMAW), which is only 65% efficient under the most ideal conditions.

GMA welding is flexible and can be used for both new construction and repair work. Almost any welding that would be done with either an arc or gas welder can be done faster with GMA welding. In addition, it is possible to weld high-strength steel (HSS), high-strength low-alloy (HSLA), aluminum, stainless steel, and many other metals.

GMA WELDING EQUIPMENT

Although every manufacturer’s GMA welding equipment is designed differently, it is all set up in a similar manner. Figure 11-3 identifies the various components that make up a GMA welding station.
Amperage or amps (A) is the measurement of the total number of electrons flowing, in the same way that gallons is a measurement of the amount of water flowing.

- Electrical current means the same thing as amperage and is usually expressed by using the term current (C or I). The terms amperage, amps, and current can all be interchanged when referring to electrical flow.

GMA welding power supplies produce a constant arc voltage. This type of machine is referred to as either constant voltage (CV) or constant potential (CP). Both CV and CP have the same meaning. This is in contrast to SMAW “stick” welding power supplies, which are constant current (CC)-type machines. It is impossible to make acceptable welds using the wrong type of power supply. GMA welding machines are available as the type that plug into the building power (transformer-rectifiers) or as engine-generators (portable welders), Figure 11-5. Some machines can produce both CV and CC welding currents. This enables them to be used for both GMA and SMA welding by simply flipping a switch.

**Power Supply**

The main piece of equipment is the power source, which is often called the welder. It produces direct current (DC) welding power. Most GMA welding is performed with the electrode positive, direct current electrode positive (DCEP). Depending upon the machine’s capacity, its power can range from 40 to 600 amperes with 10 to 40 volts. Typical power supplies are shown in Figure 11-4.

Because of the long periods of continuous use, GMA welding machines have a 100% duty cycle. This allows the machine to be run for long periods of time or continuously without damage.

To better understand the terms used to describe the different welding power supplies you need to know the following electrical terms:

- Voltage or volts (V) is a measurement of electrical pressure, in the same way that pounds per square inch is a measurement of water pressure.
- Electrical potential means the same thing as voltage and is usually expressed by using the term potential (P or E). The terms voltage, volts, and potential can all be interchanged when referring to electrical pressure.

**Current Path**

The path of the welding current from the welding machine to the arc and back through the work cable to the welding machine is as follows. The current leaves the welding power source positive terminal. It then flows through a heavy flexible copper cable to the welding power terminal on the wire feed unit. This terminal is located on or close to the end of the welding gun assembly. The current passes through the gun assembly connector and is transferred through a stranded copper cable inside of the welding gun cable to the welding gun handle. In the welding handle, the stranded copper cable is clamped into one end of a connector block. In the other end of the connector block, the conductor tube is connected. The current passes through the conductor tube and is transferred to the gas diffuser. The gas diffuser transfers the current to the contact tube. The contact tube transfers the current to the welding wire. This means that the welding wire has to carry the full welding current only a short distance to the arc. Because of the very small diameter of the welding wire, it would be impossible for it to carry the full welding current for any distance.
without overheating. The current travels across the arc to the work, and it conducts the current back to the work clamp. The work clamp is connected to a welding cable, which returns the current back to the negative terminal on the welder, Figure 11-6.

The welding filler metal used in GMA welding is so small it is incapable of carrying the full welding current for more than a fraction of an inch. It is for this reason that the welding current is transferred through a number of components from the welding machine to the gun assembly, where it is finally transferred to the filler metal near the point of the actual welding arc. It is important to note that the welding current does travel back through the filler metal to
the spool on the wire feed unit. This means that the wire feed coil is actually connected to the electrode side of the welding circuit and would arc out if it accidentally comes into contact with the work side. Such arcing can more easily occur when metal-framed coils of filler metal are being used.

**Wire Feed Unit**

The purpose of the wire feeder is to provide a steady, uniform, and reliable supply of wire to the weld. It is very important that the wire be fed through the gun assembly smoothly and evenly because any change in the wire feed speed will result in a change in the weld produced. Even the slightest change or wire chatter can result in a weld bead defect or may even cause burn back. Burn back results when the wire momentarily stops feeding, and the arc backs up to fuse the welding contact tip, resulting in damage to the equipment, Figure 11-7.

The speed of the motor used in wire feed units can be continuously adjusted over the desired wire feed speed range. There are four major types of wire feed systems. They are push-type, pull-type, push-pull-type, and spool gun-type. The push, pull, and push-pull wire feed system names are descriptive based on how the wire is moved from the coil through the conduit to the gun.

**Push-Type Wire Feed System**

The drive rollers are made of hardened steel and have a groove cut into the surface. The groove size must match the welding wire size. The rollers are interchangeable to accommodate different sizes of welding wires. Depending on the type of wire feed unit being used, there may be one or two sets of rollers. Within the set of rollers, one or both rollers may be driven or power rollers. These are the rollers that actually move the wire through the system. When only one roller is a drive roller, the other roller is referred to as an idler. The advantage of having two drive rollers in a roller set is that the wire can be pushed through a longer gun cable.

The wire feed rollers are clamped securely against the wire to provide the necessary friction to push the wire through the conduit to the gun. The clamping pressure applied on the wire can be adjusted. One or both of the rollers will be grooved. The groove in the roller aids in wire alignment and lessens the chance of slippage. The wire must be held in alignment with the out feed guide. Most manufacturers provide rollers with smooth or knurled U-shaped or V-shaped grooves, Figure 11-8. Knurled rollers (knurling is a series of ridges cut into the groove) help grip larger diameter wires. They are mainly used when additional roller traction is needed to provide a smooth filler wire feed. Soft wires, such as aluminum and copper, are easy to damage if knurled rollers are used. U-grooved rollers should be used when feeding soft wires. Even V-grooved rollers

![FIGURE 11-7](image1.png) Excessive heat can damage the contact tube. Larry Jeffus

![FIGURE 11-8](image2.png) Feed rollers. © Cengage Learning 2012
can distort the surface of soft wire, causing wire feed problems. V-grooved rollers are best-suited for hard wires, such as mild steel and stainless steel.

The groove in the feed roller must be properly sized to fit the filler wire diameter being fed. The size of the filler wire to be used with a roller is usually stamped on the side of the roller, Figure 11-9. If the groove on the roller is too small for the wire being fed, the wire may wander out of the groove and may not be fed in proper alignment to the out feed guide. If the groove in the roller is too large, the wire may not make firm enough contact with the roller to be fed smoothly, Figure 11-10.

In the pull-type system, a small motor is located in the gun to pull the wire through the conduit. Using this system, it is possible to move even soft wire over great distances. A disadvantage is that the gun is slightly heavier and a may be a little more difficult to use.

Push-Pull-Type Wire Feed System

The push-pull-type wire feed system has two motors, one located at each end. One motor is located at the wire feed end and is pushing the wire, while the other motor is located at the gun end pulling the wire. These motors work together so that the wire is being both pushed and pulled at the same time. This type of wire feed system provides very smooth and reliable wire feeding, which reduces welding defects and burn back, which are common problems with some push-feed systems.

Spool Gun-Type

A spool gun is a compact, self-contained wire feed unit consisting of a small drive motor and a wire supply, Figure 11-11. This system allows you to move more freely around a job with only a power lead and
shielding gas hose connecting it to the power supply. The major control system is usually mounted on the welder. The feed rollers and motor are found in the gun just behind the nozzle and contact tube. Because of the short, straight distance that the wire must be moved, very soft wires such as aluminum and copper can be used. A small spool of welding wire is located just behind the feed rollers.

**Feed Roller Tension**

The feed rollers clamp onto the filler wire, and as the rollers spin, they push or pull the wire from the reel to the welding gun. For the feed rollers to properly grip and feed the filler metal, they must have proper tension applied. This tension is normally adjustable. It can usually be adjusted by turning a screw, bolt, or hand wheel, Figure 11-12. If the tension is too light, the wire feed can be erratic and may actually stop momentarily as you manipulate the welding gun. Too tight a wire feed pressure can result in bird-nesting of the filler wire if the wire becomes jammed at the tip or in the liner, Figure 11-13. To set the proper adjustment, press the gun’s trigger and allow the wire to feed. The wire is electrically charged with the welding current and it can short out, so be careful and do not allow the wire to come in contact with the work or other grounded metal objects. As the wire is being fed, increase the roller tension until the wire feeds smoothly. To be sure the wire is not tensioned too tight, gently apply pressure to the wire spool with your hand. The wire feed roller is tensioned properly when the wire spool can be stopped without excessive pressure. A secondary advantage of not having excessive wire feed roller pressure is that if a welding cable, shielding gas hose, or other such item becomes tangled in the filler metal spool, the spool will be stopped before damage might occur to the wire, hose, or other tangled objects.
Reel Tension

The spindle that the reel or coil is mounted on has a friction adjustment. This adjustment allows the wire spool to be stopped quickly and not to coast once the welding trigger is released. Spool coasting after the trigger is released can result in two potential problems. One problem is that the loose wire can become tangled as welding is resumed. A more serious problem that occurs virtually each time that the slack is taken up is a momentary stoppage of the wire feed. This stoppage can result in burn back of the contact tube. To prevent coasting, the tension on the spindle must be properly set. It is set properly when the spool stops almost immediately each time that the welding gun trigger is released. Excessively high drag tension can result in wire feed problems also. To set the tension, use the gun trigger to start and stop the wire feed. Increase or decrease the wire feed tension while starting and stopping the feed until a smooth stop and restart occur without wire feed hesitation.

Wire Feed Guide

The out feed guide is a small pointed tube that guides the wire from the feed rollers into the beginning of the wire liner.

The steel, copper, brass, or plastic wire guides are such a simple component of the feeder system that it is easy to forget about them. They allow the wire to smoothly enter and exit the drive rolls.

The out feed guide should be aligned so that it is set as close as possible to the feed roller and in a straight line with the groove, Figure 11-14. The farther away the guide is from the feed roller, the more likely you are to have misfeed problems. Any misalignment of the out feed guide increases drag on the filler metal, which can lead to erratic wire feeding. On some copper-clad or softer filler wires, small amounts of copper cladding or slivers of the soft metal may be scraped away by the misaligned guide. These small particles are then carried into the wire conduit liner where they can accumulate, resulting in wire feed problems that can be remedied only by replacing the conduit liner itself.

Conduit Wire Liner

The conduit liner is a flexible hollow tube through which the wire is fed from the wire feed unit to the gun. It is positioned through the body of the gun and into the gun conductor tube. Most conduit liners are springlike in appearance because they are made from a hardened steel wire that is wound in a continuous spiral. Liners used with aluminum and other soft alloys often have a Teflon® liner to reduce the wire friction to allow the wire to feed more smoothly.

Replacement conduit liners can be ordered to fit individual guns, or they may be cut to length to fit some gun lengths from the feed unit to the GMAW gun.

GMAW Guns

The main part of the GMA gun is called the gun body. The gun body is made of a heat-resistant plastic. It is connected to the end of the welding cable. Its major parts are the gun trigger, gun body, conductor tube, conduit, gas diffuser, contact tube, and gas nozzle, Figure 11-15.

The gun trigger is a toggle switch (off/on switch) and is attached to the gun body. When the trigger is pressed, electrical contact is made, activating the wire feeder. This simultaneously starts the wire feed, weld current, and shielding gas so that the welding arc can begin. As long as the trigger is not depressed, the arc will not be struck. So, you can hold the gun with the wire touching the metal being welded without an arc starting until the trigger is pulled. This feature of GMA welding helps you to always start the weld exactly where you need it.
make. Sometimes you may find that one angle of conductor tube gives you better access to the weld joint, or you may find one type of conductor tube more comfortable to use than the others. The conductor tube is hollow so both the electrode liner and the shielding gas can pass through it. The conductor tube connects to the welding power cable in the handle, and it conducts the welding current to the end of the gun assembly; therefore, it is heavily insulated to prevent accidental arcing.

The gas diffuser screws into the conductor tube and is electrically hot when the trigger is depressed. The gas diffuser allows the shielding gas to be dispersed or diffused around the contact tube, enveloping the entire weld area for greater protection, Figure 11-17.

The contact tube is screwed into the gas diffuser. The contact tube is a short replaceable copper conductor that transfers the electricity from the gun to the electrode wire. Over time the hole in the contact tube wears out and spatter builds up on the outside, resulting in the need for the contact tube to be replaced. Contact tubes come in a variety of sizes to fit the various diameter electrode wires. A contact tube with the proper inside diameter must be selected. It is important that the contact tube be sized correctly for the filler wire being used. Too large a contact tube does not provide adequate electrical conductivity from the contact tube to the wire, which can result in the contact tube overheating and the wire becoming stuck in the tube. Too small a contact tube creates excessive drag on the wire, which may result in the wire sticking in the tube. If the wire sticks for any reason, a burn back will occur, destroying the contact tube.

The contact tube may get as hot as 300°F (150°C) when you are welding with an air-cooled GMAW torch. Larger diameter, heavy-duty contact tubes are

**NOTE:** On some small home/hobby-type GMA welding machines, the gun trigger starts and stops only the electrode feed motor. It may not start and stop the welding current, so the electrode is electrically charged all the time. Therefore, any time you touch the electrode to the work an arc will occur.

The insulated conductor tube, sometimes called the gun neck, is attached to the body of the gun. Conductor tubes are available as straight, 45°, 90°, and/or flexible, Figure 11-16. The most commonly used conductor tubes have a 45° angle. The choice of the angle of the conductor tube on the job is usually yours to
available from some manufacturers. You may want to consider using these heavier-duty tubes when welding with high-amperage settings because they can withstand the higher heat input better than the standard contact tubes.

When welding aluminum, it is very important to properly size the contact tube. You may want to try several different sized tubes to find the one that works best for your application. On any filler wire, but particularly with aluminum wire, the contact tube can be removed and cleaned with a set of oxyacetylene torch tip cleaners to extend the useful life of the contact tube.

To keep the electrically hot components from accidentally arcing, an insulating device called the gun nozzle insulator is used, Figure 11-18. The insulator is screwed onto the gas diffuser. On some types of GMA welding guns, the insulator ring can accidentally be screwed on backward. If the insulator is screwed on backward, the nozzle will not slide on far enough, the electrode extension will be excessively long, and poor welding will result.

The nozzle is the hollow metal tube located at the end of the gun assembly through which the welding wire passes and the shielding gas flows. Most nozzles are made of copper, although other materials such as brass and chrome plating are also used. Copper nozzles resist welding spatter and can withstand the welding heat. Chrome-plated nozzles are significantly more expensive but do resist weld spatter buildup much better than copper nozzles.

Nozzles come in a variety of diameters. The larger diameter nozzles provide better gas shielding for the weld but restrict the visibility significantly more than the smaller diameter nozzles. The nozzle size also affects the shielding gas flow rate. Obviously, the larger diameter nozzles require a higher shielding gas flow rate than the smaller diameter ones. In most cases, you can pick the size nozzle you prefer using; however, some welding procedures may specify the nozzle size and shielding gas flow rate that must be used.

Figure 11-19 shows an exploded view of a GMAW gun so that you can identify the various components of the guns. Although there are many brands of welding guns, the names used for the parts are generally the same.

**Work Lead**

It is important that the work clamp be securely connected to the work. GMA welding is very sensitive to changes in arc voltage. A loose or poor connection results in increased circuit resistance and a decrease in the arc's voltage. Voltage changes affect GMA weld quality. A more significant welding problem occurs when this resistance varies during the course of a weld. Such variations can dramatically adversely affect your ability to maintain weld bead control. GMA welding is more significantly affected by changes in the arc voltage than is SMAW (stick) welding. To be sure that you have a good work connection, remove any paint, dirt, rust, oil, or other surface contamination at the point where the work clamp is connected to the weldment.

Another problem that can cause resistance at the work clamp is when the clamp's internal spring...
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by opening a small valve at the base of the flowmeter. Some flowmeters indicate the flow rate by comparing the height that a small ball floats on top of the gas stream to a vertical scale on the transparent tube on the meter. Others flowmeters use a dial or digital display.

On ball-type flowmeters, if the tube is not vertical, the reading is not accurate. Less dense gases, such as helium and hydrogen, will not support the ball on as high a column with the same flow rate as a denser gas, like argon. So, to get accurate readings, be sure that the gas being used is read on the proper flow scale.

Welder Connections

Many smaller GMA welding units and some larger commercial units have the wire feed mechanism built into the welder so that no connections are required, Figure 11-20. Some types of GMA welding machines and wire feed units come as separate devices, Figure 11-21. These units require some connections before the welder can be used.

NOTE: The work clamp may become hot because it is connected to the part being welded. However, one way of determining that the work clamp is not clamping tightly enough is when it becomes hot during welding and it is not connected to a hot piece of metal. In this case, the clamp is becoming hot because of electrical resistance due to its poor connection to the work. Getting hot like this is a good indication that it needs to be repaired or replaced.

Shielding Gas Flowmeter

The shielding gas flowmeter measures the **flow rate** in cubic feet per hour (CFH) or in metric measure as liters per minute (L/min). The flow is controlled

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**FIGURE 11-19** Accessories and parts selection guide for a GMA welding gun. ESAB Welding & Cutting Products
Gas Metal Arc Welding Equipment and Materials

reducing wire feed problems. There are fewer problems to having longer interconnecting power and control cables between the welding machine and wire feed units as compared to the limitations on the wire feed cable.

• Flexibility—Having the wire feed unit separate allows you to change the wire feed assembly without the necessity of purchasing another complete welding machine. This makes it easier to use different types of wire feed units for special applications. Wire feed units such as a standard wire feed system, spool gun, and machine welding assembly can all be easily interchanged with the same welding power supply when they are separate units.

• Space savings—Welding machines can be located so that they are out of the way such as under a welding table, some distance from the welding area, or even overhead. The wire feed unit can be suspended at the end of a specially designed boom, Figure 11-22. This keeps both the welder and the wire feed unit out of the way of the operation and clear of sparks and hot metal.

• Equipment replacement—By having separate components it is easier to upgrade either the welding power supply or wire feed unit when such changes become necessary.

GMAW SHIELDING GASES

The GMA shielding gas can be provided from a compressed gas cylinder or from a central gas piped manifold system. Individual cylinders provide the greatest portability, while the manifold system can offer the greatest potential savings by reducing the number of cylinders a shop must rent.

The most commonly used gases are carbon dioxide (CO₂), argon (Ar), and helium (He). Sometimes a blend of these gases is used to obtain the best possible welding performance. And occasionally a trace of oxygen (O) can be added to the mixture for making welds on some ferrous (steel) alloys.

Often codes, standards, and weld specifications give a range of gas flows and choices of gases or blends to be used for a weld. So, you will need to make some shielding gas choices even when there are welding specifications.

The most commonly used gases for ferrous metals are CO₂, argon with 2 to 5% oxygen added, and argon with 25% CO₂ added. Most nonferrous metals are
Argon (Ar)

The atomic symbol for argon is Ar, and it is an inert gas. Inert gases do not react with any other substance and are insoluble in molten metal. One hundred percent argon is used on nonferrous metals such as aluminum, copper, magnesium, nickel, and their alloys, welded using inert gases such as argon, helium, or a blend of argon and helium. To better make a selection of which shielding gas or shielding gas blends to use, you must consider many factors. Table 11-1 lists common GMA welded metals and some of the shielding gases and gas blends that can be used. It also lists the commonly used GMA welding gases and gas blends as they relate to metals and welding processes. The specific shielding gas or gas blend used affects the GMA weld being produced. Factors to be considered when selecting a shielding gas or blend may include the following:

- Metal transfer method
- Weld bead shape, penetration, and width of fusion zone
- Welding speed
- Weld discontinuities
- Weld spatter
- Metal transfer efficiency
- Type of base and filler metals
- Welding position
- Cost of the gas
- Total welding cost

Argon (Ar)
### GMAW Metals, Shielding Gases, and Gas Blends

<table>
<thead>
<tr>
<th>Metals</th>
<th>Gases Blends of Two Gases</th>
<th>Gases Blends of Three Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Argon + Oxygen</td>
<td>Argon + Carbon Dioxide</td>
</tr>
<tr>
<td></td>
<td>Ar + 1% O₂</td>
<td>Ar + 5% CO₂</td>
</tr>
<tr>
<td>Aluminum</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Copper Alloys</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Nickel Alloys</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

### GMAW Shielding Gases, Gas Blends, Metals, and Welding Process

<table>
<thead>
<tr>
<th>Gases/Blend</th>
<th>Gas Reaction</th>
<th>Application</th>
<th>Remarks</th>
<th>Gas/Blend</th>
<th>Gas Reaction</th>
<th>Application</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon (Ar)</td>
<td>Inert</td>
<td>Nonferrous metals</td>
<td>Provides spray transfer</td>
<td>CO₂</td>
<td>Oxidizing</td>
<td>Mild, low alloy steels and stainless steel</td>
<td>Least expensive gas, deep penetration with short-circuiting or globular transfer</td>
</tr>
<tr>
<td>Helium (Me)</td>
<td>Inert</td>
<td>Aluminum and magnesium</td>
<td>Very hot arc for welds on thick sections, usually used in gas blends to increase the arc temperature and penetration</td>
<td>Nitrogen</td>
<td>Almost inert</td>
<td>Copper and copper alloys</td>
<td>Has high heat input with globular transfer</td>
</tr>
<tr>
<td>Ar + 1% O₂</td>
<td>Oxidizing</td>
<td>Stainless steel</td>
<td>Oxygen provides arc stability</td>
<td>Ar + 25% He</td>
<td>Inert</td>
<td>Al, Mg, copper, nickel, and their alloys</td>
<td>Higher heat input than Ar, for thicker metal</td>
</tr>
<tr>
<td>Ar + 2% O₂</td>
<td>Oxidizing</td>
<td>Stainless steel</td>
<td>Oxygen provides arc stability</td>
<td>Ar + 50% He</td>
<td>Inert</td>
<td>Al, Mg, copper, nickel, and their alloys</td>
<td>Higher heat in arc use on heavier thickness with spray transfer</td>
</tr>
<tr>
<td>Ar + 5% O₂</td>
<td>Oxidizing</td>
<td>Mild and low alloy steel</td>
<td>Provides spray transfer</td>
<td>Ar + 75% He</td>
<td>Inert</td>
<td>Copper, nickel, and their alloys</td>
<td>Highest heat input</td>
</tr>
<tr>
<td>Ar + 5% CO₂</td>
<td>Oxidizing</td>
<td>Low alloy steel</td>
<td>Pulse spray and short-circuit transfer in out-of-position welds</td>
<td>Ar + CO₂ + O₂</td>
<td>Oxidizing</td>
<td>Low alloy steel and some stainless steel</td>
<td>All metal transfer for automatic and robotic applications</td>
</tr>
<tr>
<td>Ar + 10% CO₂</td>
<td>Oxidizing</td>
<td>Low alloy steel</td>
<td>Same as above with a wider, more fluid weld pool</td>
<td>Ar + CO₂ + N</td>
<td>Almost insert</td>
<td>Stainless steel</td>
<td>Excellent toughness, excellent arc stability, wetting characteristics, and bead contour; little spatter with short-circuiting transfer</td>
</tr>
<tr>
<td>Ar + 25% CO₂</td>
<td>Oxidizing</td>
<td>Mild, low alloy steels and stainless steel</td>
<td>Smooth weld surface, reduces penetration with short-circuiting transfer</td>
<td>Ar + 7.5% Ar + 2.5% CO₂</td>
<td>Almost insert</td>
<td>Stainless steel and some low alloy steels</td>
<td>All metal transfer, excellent for thin gauge material</td>
</tr>
</tbody>
</table>

### Table 11-1

(A) Metals Compared to GMAW Shielding Gases and Gas Blends (B) GMAW Shielding Gases and Gas Blends Compared with Metals
Argon Gas Blends

Oxygen, carbon dioxide, helium, and nitrogen can be blended with argon to change argon’s welding characteristics. Adding reactive gases (oxidizing) such as oxygen or carbon dioxide to argon tends to stabilize the arc, promote favorable metal transfer, and minimize spatter. As a result, the penetration pattern is improved, and undercutting is reduced or eliminated. Adding helium or nitrogen gases (non-reactive or inert) increases the arc heat for deeper penetration.

The amount of the reactive gases, oxygen or carbon dioxide, required to produce the desired effects is quite small. As little as a half percent change in the amount of oxygen produces a noticeable effect on the weld. Most of the time, blends containing 1 to 5% of oxygen are used. Carbon dioxide may be added to argon in the range of 20 to 30%. Blends of argon with less than 10% carbon dioxide may not have enough arc voltage to give the desired results. The most commonly used argon-CO₂ blend is 25% CO₂.

When you are using oxidizing shielding gases with oxygen or carbon dioxide added, a suitable filler wire containing deoxidizers should be used to prevent porosity in the weld. The presence of oxygen in the shielding gas can also cause some loss of certain alloying elements, such as chromium, vanadium, aluminum, titanium, manganese, and silicon.

Helium (He)

The atomic symbol for helium is He, and it is an inert gas that is a product of the natural gas industry. It is removed from natural gas as the gas undergoes separation (fractionation) for purification or refinement.

Helium is lighter than air, thus its flow rates must be about twice as high as argon’s for acceptable stiffness in the gas stream to be able to push air away from the weld. Proper protection is difficult in drafts unless high flow rates are used. It requires a higher voltage to ionize, which produces a much hotter arc. There is a noticeable increase in both the heat and temperature of a helium arc. This hotter arc makes it easier to make welds on thick sections of aluminum and magnesium.

Small quantities of helium are blended with other heavier gases. These blends take advantage of the heat produced by the lightweight helium and weld coverage by the other heavier gas. Thus, each gas is contributing its primary advantage to the blended gas.

Carbon Dioxide (CO₂)

Carbon dioxide is a compound made up of one carbon atom (C) and two oxygen atoms (O₂), and its molecular formula is CO₂. One hundred percent carbon dioxide is widely used as a shielding gas for GMA welding of steels. It allows higher welding speed, better penetration, and good mechanical properties and costs less than the inert gases. The chief drawback in the use of carbon dioxide is the less-steady-arc characteristics and a considerable increase in weld spatter. The spatter can be kept at a minimum by maintaining a very short, uniform arc length. CO₂ can produce sound welds provided a filler wire having the proper deoxidizing additives is used.

Nitrogen (N)

The atomic symbol for nitrogen is N. It is not an inert gas but is relatively nonreactive to the molten weld pool. It is often used in blended gases to increase the arc’s heat and temperature. One hundred percent nitrogen can be used to weld copper and copper alloys.

GAS FLOW RATE

The correct flow rate can be set by checking welding guides that are available, Table 11-2. These welding guides list the gas flow required for various nozzle sizes and welding amperage settings. Some welders
feel that a higher gas flow provides better weld coverage, but that is not always the case. High gas flow rates both waste shielding gases and may lead to contamination. The contamination comes from turbulence in the gas at high flow rates. Air is drawn into the gas envelope by the venturi effect around the edge of the nozzle. Also, the air can be drawn in under the nozzle if the torch is held at too sharp an angle to the metal, Figure 11-23.

**NOTE:** If you need more shielding gas coverage in a windy or drafty area, use both a larger diameter gas nozzle and a higher gas flow rate. The larger the nozzle size, the higher the permissible flow rate without causing turbulence. Larger nozzle sizes may restrict your visibility of the weld. You might also consider setting up a wind barrier to protect your welding from the wind, Figure 11-24.

### Shielding Gas Cost

The price of the gas is not the only factor that must be considered when selecting a shielding gas for GMA welding. For example, using CO₂ will produce the most spatter and the average efficiency will be about 93%. Using a 75% argon and 25% CO₂ gas mixture results in somewhat less spatter and an efficiency of approximately 96%. A 98% argon and 2% oxygen mixture will produce even less spatter, and the average efficiency will be about 98%. The loss of filler metal in the weld...
CHAPTER 11

WELD METAL TRANSFER METHODS

The GMAW process is unique in that there are several modes of transferring the filler metal from the wire to the weld. Each mode of metal transfer has its own unique characteristics. The mode of metal transfer is the mechanism by which the molten filler metal is transferred across the arc to the base metal. The modes of metal transfer are short-circuit transfer (GMAW-S), axial spray transfer, globular transfer, and pulsed-arc transfer (GMAW-P). To change from one metal transfer mode to another, all you have to do is make the necessary changes in the voltage and amperage settings. In other words, it is the equipment setup and not the equipment or filler metal that determines the GMAW mode of metal transfer. Therefore, it is possible to make welds with each of the metal transfer modes by simply changing the voltage and amperage without even having to change the type of filler wire. In some cases, it may be necessary to change the shielding gas; for example, CO₂ cannot be used to make welds in all three transfer modes, but Ar + O₂ can.

Selecting the mode of metal transfer used depends on the welding power source, the wire electrode size, the type and thickness of material, the type of shielding gas used, and the best welding position for the task.

Short-Circuit Transfer—GMAW-S

In short-circuit metal transfer, the electrode actually momentarily comes in contact with the base metal surface, and the arc is momentarily shorted out. That is why it is called short-circuit metal transfer because at the moment that the electrode comes in contact with the surface, it electrically shorts out the arc and that is when a small drop of molten metal is transferred to the weld.

NOTE: The terms short or short circuit is often confused with the terms for an open or broken circuit. When someone flips on a light switch and the light does not come on, it is incorrect to say that it must be shorted. If the light did not come on, you have an open circuit. An open circuit is one that does not have any current flow. However, in a short circuit all the possible power available tries to flow. When two wires bump together creating a shower of sparks, you have a short. So, if you switch on the light and a shower of sparks flies from the light fixture, you would be correct in saying you have a short. When you turn a switch on and nothing happens, you have an open circuit; if sparks fly, you have a short circuit; and if your light comes on, you have a closed circuit.

The following description explains the short-circuit metal transfer process in detail. As the gun trigger is depressed, the wire feed unit is energized. An arc is established between the electrode and the base metal surface, forming a small molten weld pool. The wire electrode is fed out faster than the arc can melt the end away. This results in the electrode advancing and bridging the gap between the contact tube and the
All welding positions can be used for short-circuit transfer. It is the most widely used of the metal transfers for general repairs to mild steel. The amperage range may be from as low as 35 for materials of 24 gauge, to amperages of 225 for materials up to 1/8 in. (3 mm) in thickness on square groove weld joints. Thicker base metals can be welded if edges are properly prepared and cut at an angle (beveled) to provide a complete joint weld penetration.

A properly functioning short-circuit weld makes a smooth frying sound.

The short-circuit mode of transfer is the most common process used with GMAW. It is used on thin or properly prepared thick sections of material, and when joining thick to thin materials. GMAW-S can be used with a wide range of electrode diameters and shielding gases.

The 0.023-, 0.030-, 0.035-, and 0.045-diameter (0.6-, 0.8-, 0.9- and 1.2-mm) wire electrodes are commonly used for the manual short-circuit welding mode. The common shielding gases used on carbon steel are 100% carbon dioxide, a blend of 25% carbon dioxide and 75% argon, or a blend of argon with a trace of oxygen.

Globular transfer is generally used on thin materials and at a very low current range. In globular transfer, the arc melts the end of the electrode, forming a molten ball of metal. When the ball of metal becomes large enough, its surface tension cannot hold it onto the end of the wire. It falls across the arc, landing in the molten weld pool. Because there is little control over where the glob of metal lands and the weld pool tends to be a small landing target, this process is rarely used by itself. It is used more commonly in combination with pulsed spray transfer. With this

SPARK YOUR IMAGINATION

The speed at which the short-circuit metal transfer method occurs is so fast that it cannot be seen. It literally happens in less time than the blink of your eye. List some other things that happen so fast that they may look like they are standing still or you cannot see a single part.

Globular Transfer

Globular transfer is generally used on thin materials and at a very low current range. In globular transfer, the arc melts the end of the electrode, forming a molten ball of metal. When the ball of metal becomes large enough, its surface tension cannot hold it onto the end of the wire. It falls across the arc, landing in the molten weld pool. Because there is little control over where the glob of metal lands and the weld pool tends to be a small landing target, this process is rarely used by itself. It is used more commonly in combination with pulsed spray transfer. With this
This process generally uses larger diameter wire electrodes, so it requires a higher amperage range. The higher the amperage range, the faster the weld bead progresses and the joint filled. Increased current flow combines with the high percentage of argon, causing a **pinch effect** on the molten ball of wire electrode much like the effect that pinching has on a rubber water hose. When you pinch the end of the rubber water hose, the water exits the hose in a spray pattern. That is what happens to the end of the electrode in axial spray transfer.

The axial spray transfer process is very hot and virtually free of any spatter. The sound produced by axial spray transfer is a quiet, hissing sound, unlike the short-circuit process that makes a raspy, frying sound. A disadvantage of axial spray transfer is that it produces a very fluid weld pool that may be difficult to control in out-of-position welds. The high welding current produces a great deal of UV light, so combination of processes, the molten weld pool is larger and the glob is more likely to land in the molten pool, Figure 11-26.

**Axial Spray Transfer**

The GMA **axial spray metal transfer** mode uses the highest voltage and amperage settings compared to other processes. Often this process is referred to simply as **spray transfer**. The current setting is high enough so that the end of the electrode is melted away rapidly and only small molten droplets are formed, Figure 11-27. These small droplets are transferred down the center axis of the arc to the molten weld pool. Axial spray transfer is a popular process used in manufacturing where high-deposition rates are required and deep weld joint penetration is desired. On ferrous metals it can use a blend of 95 to 98% argon and 2 to 5% oxygen. The added percentage of oxygen allows greater weld penetration. On nonferrous metals, 100% argon or blends of argon with helium or nitrogen are used.

![Figure 11-26 Globular transfer](image)

![Figure 11-27 Axial spray metal transfer](image)
The lower total current and heat input provided by the pulsed-arc transfer permits its use on thinner-gauge base metals. It is also easier to use for out-of-position welding than the straight axial spray process. Pulsed arc produces less spatter and higher weld speeds than does the short-circuit metal transfer. The graph in Figure 11-28 shows the relationship between welding current, deposition, and the time for the pulses of a typical pulsed-arc transfer.

GMAW ELECTRODES

The electrode used with GMAW is a very long coil of solid wire. It is a filler wire electrode and is continuously fed off a reel attached to the wire feed unit. A series of drive rolls, guide tubes, a conduit liner, and a contact tube make the delivery of the electrically charged electrode seem effortless. When the electrode makes contact with the base metal, an arc is established, and the end of the electrode melts to produce the weld bead.

Although there is no flux or slag associated with GMA welding, you will occasionally notice an intermittent brown, tan, or black glass-like substance on the surface of the solidified weld bead. These are impurities that have been floated to the weld surface as they combine with the deoxidizers in the electrode. Deoxidizers, such as manganese and silicone, can be added to the electrode wire in small amounts to help remove impurities in or on the metal being welded.
The glass-like substance can pop off the weld bead as it cools and does not cause any damage to the weld surface.

**CAUTION**

Always wear your safety glasses when looking at the surface of the cooling weld bead.

**Electrode Diameters**

Wire electrodes are produced with diameters of 0.023, 0.030, 0.035, 0.045, and 0.062 (0.6, 0.8, 0.9, 1.2, and 1.6 mm). Other larger diameters are available for production work and can include sizes such as 5/64, and 7/64 in. (2.0 and 2.8 mm).

Some wire electrodes have a thin copper coating. This coating provides some protection to the electrode, preventing it from rusting; and improves the electrical contact between the wire electrode and the contact tube. Electrodes with this coating may look like copper wire because of the very thin copper cladding. The amount of copper is so thin that it either burns off or is diluted into the weld pool with no significant reaction.

**Electrode Cast and Helix**

The electrode wire is wound (rolled) on spools, reels, or coils made of formed metal, wood, pressed fiber, or plastic, Figure 11-29. All of them are collectively called the electrode package. Sometimes drums are used, with the wire coiled inside of the drum.

The **cast** is the diameter of the circle formed by an unrestricted coil of wire. The **helix** is the twist in the wire. To see the cast and helix of a GMA welding wire, snip off several feet of electrode. Let it fall to the floor and observe how it forms a circle. One complete circle or the diameter across the circle is known as the cast of the wire. You will notice that the wire electrode does not lie flat and one end will be slightly higher than the other. This is caused by the twist or helix of the wire. The helix is measured in height and is the maximum height from the flat surface to the highest point of the wire from the flat surface.

The manufacturer purposely puts the cast and helix in the wire as part of the manufacturing process. The slight bend of the cast in the electrode wire ensures a positive contact with the energized contact tube. The helix twists the wire, causing a rubbing effect on the inside of the contact tube. If the wire as not twisted, the contact tube would quickly wear a groove where the cast caused it to rub, but by twisting the wire, a more uniform wear pattern occurs inside the contact tube, Figure 11-30.
Electrode Handling

Wire electrodes may be wrapped in plastic sealed bags, wrapped in a special paper, or sealed in cans or cardboard boxes to protect the electrode from the elements. A small bag of a moisture-absorbing material, crystal desiccant, is sometimes placed in the shipping containers. This material is included in the packing to protect the wire electrode from rust-causing moisture.

Mishandling of the electrode wire can result in wire feed problems and in some cases cause weld contamination. The wire can become tangled if the electrode package is thrown, dropped, or mishandled. Oxidation or even rusting may occur if the electrode is stored in a damp location. Always keep the electrode wire dry, and handle it carefully.

GMAW ELECTRODE CLASSIFICATION

The American Welding Society (AWS) has a standardized method of identifying GMA welding electrodes. This standard uses a series of letters and numbers to group filler metals into specific classifications. The AWS specification is for the chemical and physical properties of the weld produced by the filler metal and not the specific composition of the wire. This allows manufacturers to make slight changes in the electrode composition as long as the weld produced with the electrode meets the group specifications.

Most manufacturers of filler metals have trade names unique to their products. A comparison chart is available from each manufacturer that lists its product names as they relate to specific AWS-numbered electrodes. These charts are helpful when it is necessary to make sure that a particular wire meets a code or standard or when you are changing from one supplier to another.

Carbon Steel and Low-Alloy Wire Electrodes

ER70S-2 is an example of the American Welding Society’s classification system for mild steel GMAW filler metals. The E in the prefix shows that the wire is classified as an electrode. The R indicates that this particular filler metal could also be provided as a cut length or rod for GTA or OF welding.

The 70 that follows the ER designates the minimum tensile strength of the deposited weld metal in thousands. For example, ER70 indicates that the weld metal, as deposited, will have a minimum tensile strength of 70,000 pounds per square inch.

The S that follows the ER70 indicates that this electrode is a solid wire electrode. The letter T means that it is tubular, and those wires are used for flux cored arc welding (FCAW).

The last position in the example ER70S-2 consists of a number or letter ranging from 1 to 7, or the letter G. This number and letter system indicates the electrode’s filler metal composition and the manufacturer’s recommendations for the current setting and shielding gas.

GMAW electrodes come in a variety of packaging sizes—reels, spools, or drums. The weight of each of these packages varies depending on the type of filler metal. For example, a 7-in. (178-mm) reel of steel filler wire weighs a lot more than a 7-in. (178-mm) reel of aluminum filler wire.

The following are examples of the various types of carbon steel and low-alloy steel filler metals that are available.

ER70S-2

With ER70S-2, the 2 indicates that the electrode is a deoxidizing mild steel filler wire and can be used on metal that has a light cover of rust or oxide. This electrode is a general-purpose electrode that can be used in all weld positions. The weld pool is not very fluid, making this electrode filler a good choice for out-of-position welding or when short arc metal transfer is selected. Shielding gases such as CO₂, Ar/CO₂, and Ar/O₂ gas blends may be used with this wire electrode.

ER70S-3

With ER70S-3, the 3 indicates that this electrode does not have the deoxidizers needed for welding over a metal surface that has rust or mill scale on it. The weld area must be ground sanded or sandblasted clean. It is recommended for use on thinner steels of low to medium carbon content where the tensile strength will exceed the strength of the base metal. It maintains a degree of ductility in the weld. The weld pool is more fluid than ER70S-2, but the electrode can still be used in all positions. ER70S-3 can be used with either CO₂, Ar/CO₂, or Ar/O₂ shielding gases.
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ER70S-4

With ER70S-4, the 4 indicates that the wire electrode contains a higher level of a deoxidizer like silicone than ER70S-3. This electrode is commonly used when welding on structural steel, pipe systems, ships, and in many metal fabricating job shops. Metal transfer can be accomplished by either the short-circuit axial spray, or with pulsed-arc transfer methods. The ER70S-4 electrode performs well in all welding positions, but it is difficult to weld out of position when using the axial spray transfer method. Under the same conditions, the weld bead will be flatter and slightly wider than beads made with other fillers. This electrode also works well with CO₂, Ar/CO₂, or Ar/O₂ shielding gases.

ER70S-5

With ER70S-5, the 5 indicates that this electrode is used in the flat position only. The weld pool will be extremely fluid. You can weld over mill scale or rusty surfaces and maintain weld quality with this electrode. Short-circuit weld metal transfer should not be used. This filler electrode is excellent for axial spray arc metal transfer with a larger diameter wire electrode used in the flat position on heavy or thick materials. ER70S-5 has very good deoxidizing characteristics and works best with Ar/O₂ or Ar/CO₂ shielding gases.

ER70S-6

With the ER70S-6, the 6 indicates that this is an electrode with the highest levels of manganese and silicone for strength and deoxidation. This electrode is used on thick or thin sections. It works well over rusty surfaces, mill scale or areas that cannot be easily cleaned, and light-gauge metals used in the automotive industry. It can be used in the short-circuit metal transfer method in all positions. ER70S-6 welds a smooth bead with a uniform appearance. It can be used with CO₂, Ar/CO₂, or Ar/O₂ shielding gases.

ER70S-7

With the ER70S-7, the 7 indicates that this is a high manganese carbon steel electrode with a balanced level of silicone. This electrode can be used over a wide range of welding parameters in all positions. It can be used over moderate amounts of rust and mill scale. ER70S-7 welds have excellent mechanical properties, and the electrode is widely used in the automotive industry, for welding heavy equipment and with robotic welding. It can be used with CO₂ or Ar/C0₂ shielding gases.

ER70S-G

With the ER70S-G, the G indicates that this is a non-standard electrode. That means that different manufacturers can produce this electrode with special properties to meet an industry’s need. You must refer to that manufacturer’s literature to determine the properties, applications, and shielding gas requirements for its product. Manufacturers of electrodes in this classification usually have a trade term for their product.

ER80S-Ni1

The addition of nickel (Ni) to this electrode increases its strength and atmospheric corrosion-resistance for welding on weathering steels.

ER80S-D2

The addition of molybdenum provides strength after the weldment has been postweld heat-treated. This is an ideal filler wire for use on high-temperature piping, flanges, and pressure vessels, all of which may be postweld stress-relieved by some type of heat treatment.

Stainless Steel Wire Electrodes

The AWS specification for stainless steel bare wire electrodes and welding rods is A5.9. ER308L is an example of a GMAW filler metal electrode that uses the A5.9 system for stainless steel. As with the mild steel electrodes, the AWS uses the ER prefix. Following the prefix, the American Iron and Steel Institute’s (AISI) three-digit stainless steel number for the specific alloy is used. This number indicates the type of stainless steel in the filler metal. The letter L may be added to the right of the AISI number to indicate a low-carbon stainless welding electrode. The letters Si may be added to indicate the addition of silicone deoxidizer.

The following are examples of the various types of stainless steel filler metals that are available.

ER308L and ER308LSi

The ER308L and ER308LSi filler metals can be used to weld on all 18-8-type stainless steels such as 301, 302, 302B, 303, 304, 305, 308, 201, and 202. The 308...
ductility and a high-resistance to cracking during welding. ER4043 can be used to weld on the following rolled or drawn alloys—2014, 3003, 3004, 4043, 5052, 6061, 6062, 6063—and these cast alloys: 43, 355, 356, and 214.

**ER5356**

The ER5356 filler metal has 4.5 to 5.5% magnesium added to improve the tensile strength. The weld has high ductility but only an average resistance to cracking during welding. ER5356 can be used to weld on the following rolled or drawn alloys: 5050, 5052, 5056, 5083, 5086, 5154, 5356, 5454, and 5456.

**ER5556**

The ER5556 filler metal has 4.7 to 5.5% magnesium and 0.5 to 1.0% manganese added to produce a weld with high strength. The weld has high ductility and average resistance to cracking during welding. ER5556 can be used to weld on the following rolled or drawn alloys: 5052, 5083, 5356, 5454, and 5456.

### Aluminum and Aluminum Alloy Wire Electrodes

The AWS specification for aluminum and aluminum alloy filler metals is A5.10 for bare welding rods and electrodes. Filler metals classified within A5.10 use the prefix *ER* with the Aluminum Association number for the alloy.

**ER1100**

The ER1100 filler metal can be used to weld 1100- and 3003-grade aluminum. The filler wire is relatively pure. ER1100 produces welds that have good corrosion-resistance and high ductility with tensile strengths ranging from 11,000 to 17,000 psi. The weld deposit has a high-resistance to cracking during welding. The 1100 aluminum has the lowest percentage of alloying agents of all of the aluminum alloys, and it melts at 1215°F (657°C). It is commonly used for items such as food containers, food processing equipment, storage tanks, and heat exchangers.

**ER4043**

The ER4043 filler metal is a general purpose welding filler metal. It has 4.5 to 6.0% silicone added, which lowers its melting temperature to 1155°F (624°C). The lower melting temperature helps promote a free-flowing molten weld pool. The welds have high ductility and a high-resistance to cracking during welding. ER4043 can be used to weld on the following rolled or drawn alloys—2014, 3003, 3004, 4043, 5052, 6061, 6062, 6063—and these cast alloys: 43, 355, 356, and 214.

**ER5356**

The ER5356 filler metal has 4.5 to 5.5% magnesium added to improve the tensile strength. The weld has high ductility but only an average resistance to cracking during welding. ER5356 can be used to weld on the following rolled or drawn alloys: 5050, 5052, 5056, 5083, 5086, 5154, 5356, 5454, and 5456.

**ER5556**

The ER5556 filler metal has 4.7 to 5.5% magnesium and 0.5 to 1.0% manganese added to produce a weld with high strength. The weld has high ductility and average resistance to cracking during welding. ER5556 can be used to weld on the following rolled or drawn alloys: 5052, 5083, 5356, 5454, and 5456.
spatter, undercut, overlap, porosity, and poor weld bead contours. Setup becomes even more important for out-of-position welds. Making quality vertical and overhead welds can be difficult for a student welder with a properly setup system, but it becomes impossible with a system that is out of adjustment.

Learning to set up and properly adjust the GMA welding system allows you to produce high-quality welds at a high level of productivity.

GMAW is set up and manipulated in a similar manner to FCAW. The results of changes in electrode extension, voltage, amperage, and torch angle are essentially the same with both processes.

Although every manufacturer designs its GMA welding equipment differently, the equipment is all set up in a similar manner. It is always best to follow the specific manufacturer’s recommendations regarding setup as provided in the equipment literature. You will find, however, that in the field, the manufacturer’s literature is not always available for the equipment you are asked to use. It is, therefore, important to have a good general knowledge and understanding of the setup procedure for GMA welding equipment. Figure 11-32 shows all of the various components that make up a GMA welding station.

**PRACTICE 11-1**

**GMAW Equipment Setup**

For this practice, you need a GMAW power source, welding gun, electrode feed unit, electrode supply, shielding gas supply, shielding gas flowmeter regulator, electrode conduit, power and work leads, shielding gas hoses, assorted hand tools, spare parts, and any other required materials. In this practice you will properly set up a GWA welding installation.

If the shielding gas supply is a cylinder, it must be chained securely in place before the valve protection cap is removed, Figure 11-33. Standing to one side of the cylinder, quickly crack the valve to blow out any dirt in the valve before the flowmeter regulator is attached, Figure 11-34. Attach the correct hose from the regulator to the “gas-in” connection on the electrode feed unit or machine.
The welding gun should be securely attached to the main lead cable and conduit. There should be a gas diffuser attached to the end of the conduit liner to ensure proper alignment. A contact tube (tip) of the correct size to match the electrode wire size being used should be installed. A shielding gas nozzle is attached to complete the assembly.

Recheck all the fittings and connections for tightness. Loose fittings can leak; loose connections can cause added resistance, reducing the welding efficiency. Some manufacturers include detailed setup instructions with their equipment, Figure 11-35.

Complete a copy of the performance qualification test record in Appendix IV or use form provided by your instructor.

PRACTICE 11-2
Threading GMAW Wire

Using the GMAW machine that was properly assembled in Practice 11-1, you will turn the machine on and thread the electrode wire through the system.

Check to see that the unit is assembled correctly according to the manufacturer’s specifications. Switch on the power and check the gun switch circuit by depressing the switch. The power source relays, feed relays, gas solenoid, and feed motor should all activate.

Cut the end of the electrode wire free. Hold it tightly so that it does not unwind. The wire has a natural curve that is known as its cast. The cast is measured by the diameter of the circle that the wire would make if it were loosely laid on a flat surface. The cast helps the wire make a good electrical contact as it passes through the contact tube. However, the cast can be a problem when you thread the system. To make threading easier, straighten about 12 in. (305 mm) of the end of the wire and cut off any kinks.

Separate the wire feed rollers, and push the wire first through the guides, then between the rollers, and finally into the conduit liner. Reset the rollers so there is a slight amount of compression on the wire. Set the wire feed speed control to a slow speed. Hold the welding gun so that the electrode conduit and cable are as straight as possible.

Press the gun switch. Pressing the gun switch to start the wire feeder is called triggering the gun. The wire should start feeding into the liner. Watch to make certain that the wire feeds smoothly, and release the gun switch as soon as the end comes through the contact tube.

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With the wire feed running, adjust the feed roller compression so that the wire reel can be stopped easily by a slight pressure. If the roller pressure is too tight, it causes the wire to feed erratically. Too high a pressure can turn a minor problem into a major disaster. If the wire jams at a high roller pressure, the feed rollers keep feeding the wire, causing it to bird nest and possibly short out. With a light pressure, the wire can stop, preventing bird nesting. This is very important with soft wires. The other advantage of light pressure is that the feed will stop if something like clothing or gas hoses get caught in the reel.

With the feed running, adjust the spool drag so that the reel stops when the feed stops. The reel should not coast to a stop because the wire can easily snag. Also, when the feed restarts, a jolt occurs when the slack in the wire is taken up. This jolt can be enough to momentarily stop the wire, possibly causing a discontinuity in the weld.

When the test runs are completed, the wire can either be rewound or cut off. Some wire feed units have a retract button. This allows the feed driver...
to reverse and retract the wire automatically. To rewind the wire on units without this retract feature, release the rollers and turn them backward by hand. If the machine does not allow the feed rollers to be released without upsetting the tension, you must cut the wire.

Complete a copy of the performance qualification test record in Appendix IV or use form provided by your instructor.

**CAUTION**

Do not discard pieces of wire on the floor. They present a hazard to safe movement around the machine. In addition, a small piece of wire can work its way into a filter screen on the welding power source. If the piece of wire shorts out inside the machine, it could become charged with high voltage, which could cause injury or death. Always wind the wire tightly into a ball or cut it into short lengths before discarding it in the proper waste container.

**SUMMARY**

The speed, efficiency, and quality of welds produced with the GMA welding process make it the first choice for most welding fabrication. The ability to make long, uninterrupted, high-quality welds has significantly reduced the time and cost to manufacture weldments. In addition, you can make changes in the machine settings and shielding gases to permit you to weld on a wide range of metal thicknesses.

Properly setting up and adjusting the GMA welding equipment is the key to producing quality welds. Once you have mastered these skills, the only remaining obstacle to your producing consistent, uniform, high-quality welds is your ability to follow or track the joint consistently. Some welders find that lightly dragging their glove along the metal surface or edge of the fabrication can aid them in controlling the weld consistency.

Welder fatigue can become a problem when making long welds. To help avoid fatigue you should find a comfortable welding position that you can maintain for several minutes.

**REVIEW QUESTIONS**

1. Why is GMA welding called a semiautomatic process?
2. What is the purpose of the shielding gas during the GMA welding process?
3. What are some other terms that gas metal arc welding is referred to as?
4. What are the advantages of GMA welding over conventional electrode type arc (stick) welding?
5. What is the power source commonly referred to as?
6. What are three terms that refer to a measurement of electrical pressure?
7. What three terms refer to the total number of electrons flowing?
8. List the components for the welding current transferred through from welding machine to the gun assembly and back to the welder.
9. What is the purpose of the wire feeder?
10. What is burn back?
11. What are the four major types of wire feed systems?
12. What is the purpose of the groove in a wire feed roller?
13. What are knurled wire feed rollers and when should they be used?
14. What types of wire feed rollers should be used with soft wires?
15. How do you know what size of filler wire to use with a wire feed roller?
16. What type of wire feed system would be best to use when moving soft wire over a great distance?
17. Describe the push-pull-type wire feed system.
18. What is the purpose of the feed rollers?
19. What can happen if the feed roller tension is too light?
20. What can happen if the feed roller tension is too tight?
21. What are the three main parts of the GMAW gun?
22. What happens when the trigger is pressed on a GMAW gun?
23. What is the purpose of the gas diffuser on a GMAW gun?
24. Why is it important for the contact tube to be sized properly for the filler wire being used?
25. How does the size of the nozzle diameter affect the welding process?
26. How is GMA welding affected by changes in the arc voltage?
27. What are some advantages of having the wire feed assembly separate from the welding machine?
28. GMAW shielding gas can be supplied to the welding station by what two methods?
29. What are the most commonly used shielding gases?
30. What factors should you consider when selecting a shielding gas or blend?
31. What are inert gases?
32. How does argon gas shield the weld?
33. What other gases can be blended with argon?
34. Why does helium require a higher flow rate than argon?
35. What are advantages of using carbon dioxide (CO₂) as a shielding gas for GMA welding of steels?
36. What effect would adding nitrogen to a gas blend have?
37. How do you choose the correct flow rate?
38. What cost significance can weld spatter have?
39. What are four modes of metal transfer?
40. What factors should you consider when selecting the mode of metal transfer?
41. Describe the short-circuit metal transfer process.
42. What is the most common mode of transfer used with GMAW?
43. Describe the globular transfer mode of transfer.
44. Which mode of transfer uses the highest voltage and amperage settings?
45. How do higher voltage and amperage settings affect the transfer process?
46. Describe the pulsed-arc transfer mode.
47. Why is it important to wear safety glasses when looking at the surface of a cooling weld bead?
48. What kind of coating is on some wire electrodes, and what is its purpose?
49. What are the purposes of the cast and the helix that are manufactured into the wire?
50. What problems can occur if the electrode wire has been mishandled?
51. What information is provided by the series of letters and numbers that AWS uses to identify welding electrodes?
52. Identify what each of the letters and numbers represents in the following example of a carbon steel and low-alloy wire electrode: ER70S-2.
53. Identify what each of the letters and numbers represents in the following example of a stainless steel wire electrode: ER308L.
54. What equipment setup variables can affect the quality of a weld?