11
Welding and Cutting

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11.1
Introduction

By the definition given by the American Welding Society (AWS) and Go Welding.Org, welding is a material joining process used in making structures consisting of two or more parts that must be structurally connected. It is usually applied to the joining of metals, but it does not have to be. The definition of welding is a localized coalescence (the joining together of the grain structure of materials being welded) of metals or non-metals by heating the materials to a suitable temperature with or without the application of pressure, and/or without the use of filler materials. In layman's terms, a weld is made when two pieces of material are joined together to form one, when heated to a high enough temperature to melt the two together (American Welding Society, 2012).

This chapter will cover the three most widely used welding processes: (1) "stick" or shielded metal ARC welding (SMAW), (2) "TIG" tungsten inert gas, and (3) "MIG" (metal inert gas) gas metal arc welding (GMAW). In doing so, the chapter will also cover the most important loss prevention engineering implications that must be considered and addressed in the welding processes:

- Stick welding (SMAW) can be an excellent and high quality way of joining metal, but it takes much practice and experience to achieve this level of quality.
- MIG (GMAW) is a fast and economical way to join metals and it takes less time and experience to use this process. By no means does that mean that anybody can pick up a MIG gun and start welding X-ray quality welds, it still takes some know-how and practice to make quality welds with this process.
- TIG (GTAW) is a clean, high quality way to join metals. It is generally used for thinner gauged metals, stainless steel, aluminum, and in making a "root pass" on high pressure pipes. It also requires much practice and experience to master this process. In this chapter, we will also discuss cutting metal with oxyfuel and plasma.

SMAW is performed by using an electrode that carries an electrical current to the metal to be welded and makes an electric arc that generates enough heat to

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melt both the electrode and the material being welded. The molten metal from the electrode and the molten metal from the work become fused together to form a weld. It is purified and protected by the slag that forms on top of the weld after the weld solidifies. Several types of electrodes are available and the type one employs depends on the type material that is to be welded and how thick the material is. A welding electrode is generally called a ''*welding rod*.'' It is a metal filled rod covered with a flux that burns off while the welding is accomplished. The flux purifies and protects the molten metal from the outside atmospheres. It solidifies on top of the weld and must be ''chipped'' away with a chipping hammer after the weld is made. A few of the mild steel flux coatings on the rod that solidify into slag are made from cellulose sodium, cellulose potassium, iron oxides, iron powder, hydrogen potassium, iron powder, and titania. When one is welding mild steel, the type of flux coating is of little concern. However, when welding metals used in curtained applications, such as stainless steel in high heat applications, more care should be exercised in choosing the right electrode for the job.

Although there are several types of welding rods, this chapter will only cover the most widely used rod types. They all have a designated number to inform the user of their composition. The most widely used electrodes are 6010, 6011, 6012, 6013, 7014, 7018, and 7024. The numbers indicate the strength, the position it can be used in, the strength of the welding current, and the type of flux it is coated with. The identification of the electrode is located on the top of the electrode, stamped on the flux.

For example, for 6012 the 60 means this particular rod has 60 000 pounds of tensile strength. Tensile strength refers to the property of a material that resists shear and tensile forces applied to pull metal apart. The third number refers to the position in which the metal is to be applied, whether it is ''overhead'' vertical, horizontal, or just flat. The number 1 means that this electrode can be welded in all positions. The last number indicates what type of current is to be used, and also what type of flux covering the rod has.

There are three types of currents used for welding: alternating current (AC), direct current reverse polarity (DCRP), and direct current straight polarity (DCSP). When the electrode is negatively charged and the work is positively charged, the base metal is at a higher temperature, so it is good for deeper penetrating welds into the base metal (DCRP). When the electrode is positively charged and the work is negatively charged, the electrode is hotter than the base metal, so choice of the electrode in this polarity is important. In this case, a slower burning flux should be used. However, this will create a jetting action. The ''jetting'' action forces metal and hot gases off the end of the electrode with enough velocity to force the metal to penetrate more deeply into the base metal. The choice of which polarity to use depends on the type of electrode used, and what type of weld is to be applied, the depth of weld penetration, or the amount of buildup desired, and so on.

The types of electrodes most commonly used in the field today start with the 6010. As noted above, the 60 means 60 000 lb of tensile strength and the 1 means that it can be used for welding components in all positions. This electrode can be used in flat, vertical up, vertical down, horizontal, or overhead positions. It is an acceptable electrode to use for welding a joint that is contaminated with paint or oil or is rusted steel. Therefore, if, for any reason, the joint to be welded cannot be cleaned, the 6010 is the electrode to use. It is also an acceptable electrode for the root pass on pipe weld (''the root pass'' refers to the first pass on a particular joint when multiple passes are needed). It is generally run in a whipping motion to burn away any oil, paint, or rust that may be present in the joint. The 6010 electrode is designed to be run with DCRP.

As with the 6010 electrode, the 6011 electrode has 60 000 lbs tensile strength and, again, the 1 means that it too can be welded in all positions. The fourth number indicates the type of flux and that it can be used in AC reverse polarity or DCRP. It is so similar to the 6010 that the 6011 is known as the 6010 sister electrode because it has many of the same welding characteristics. Because of an added stabilizer, it is generally preferred over the 6010. In addition, in the case of any arc blow present, it can be switched to AC polarity. Arc blow occurs when electrons flow and create lines of magnetic forces (called *magnetic flux lines*) that circle around the line of flow. The line of flow refers to the direction of welding leads. When this happens, the arc becomes unstable and is forced away from the ground cable. It is like putting two negative sides of a magnet together – as we all know, they repel each other. It is the same with the welding arc and the ground cable. To limit arc blow, the weld leads should be kept as straight as possible, and two ground cables should be used, with each lead clamped to opposite sides of the joint to be welded. In this case, when possible, one should use AC polarity. AC polarity does not allow the flux line to build long enough to bend the arc before the current changes. With experience and practice a welder can teach him or herself how to control arc blow.

The 6012 electrode is an AC or DC polarity electrode. It is a less forceful arc, resulting in less penetration. It has a stable arc and is mainly used for sheet metal applications. It is also good for poorly fitting joints with less penetration and one is less likely to ''burn through.'' Owing to its good stability, it makes for an attractive weld.

The 6013 electrode is designed to be used with AC or DC either straight or reverse. It too has a stable arc and is used in many of the same applications as the 6012. It has slightly lower penetration than the 6012 and can be used on even thinner metal.

The 7014 electrode can be run on either DC polarity or on AC. It has almost the same type of flux as the 6012 and 6013, that is, titania, but has iron powder added and this creates more weld buildup. With more weld buildup, the weld can be made at a faster travel speed and, in the author's opinion; it also has a very attractive bead. It can be used in most low-carbon steel applications.

The 7018 electrode is designed to be run on either AC reverse polarity or DCRP, but in the author's opinion it is difficult to run this electrode in AC. The electrode tends to stick to the base metal while welding. It has a low hydrogen-based flux with iron powder added. Sometimes a foreman or coworker asks a welder that a particular piece be ''welded with low hydrogen rods.'' In the author's experience, this is the best of all welding rods. It has decent penetration, but should not be

Figure 11.1 Welding rods showing identification numbers.

used on any open joint as the weld is only protected by the flux. It is not protected by rapidly expanding gases from the burn-off; therefore, the back side of the weld is not protected from the atmosphere. This causes porosity in the weld or small holes in the weld made when the weld is not protected from the atmospheric contact.

The 7024 electrode is designed to be used with either an AC or DC power source and it has deep penetration characteristics. It has a high rate of buildup; therefore, it can be used to fill deep V-groove joints, but only in the flat or horizontal positions. It is an easy rod to weld with if it is held at the proper angle to the weld bead and the proper arc length. Arc length is discussed below.

These are the most common mild steel welding electrodes in use today. There are many more available to the welder – in fact an entire book could be written about all of the electrodes and their characteristics. This chapter introduces the reader to the most basic ones in most common use. Figure 11.1 shows the electrodes and where they are stamped for identification (Jeffas, 2012).

11.2 Basic Equipment for Welding Comfortably and Safely

11.2.1 Eye Protection

Appropriate protection starts with the hood or welding helmet (Figure 11.2). The hood, which shields the face and eyes, is designed to flop down across a welder's face (and eyes) with a flick of the head in a downward motion when they are ready to strike an arc. It can be adjusted to stop right in front of one's eyes. The lens shield is the device that protects eyes from arc burn, a painful injury involving temporary damage to the cornea. The lenses in the hood filter the light energy from the arc before it reaches the eyes. There are different shades of lenses that offer different levels of protection. The lower the number of shade, the less protection the lens offers from ultraviolet (UV) radiation generated by the arc. Lower number shade lenses are normally used for cutting, that is, ∼"5," and the higher number

Figure 11.2 Welder's helmet.

Figure 11.3 Gloves and protective sleeves.

shades are for welding, that is, ~"11." The number is shown at the top corner of the lens. One should never arc weld with anything less than a number 10 welding lens. While the higher numbered lens offers better protection, because the lens is darker it makes it more difficult to see the weld. This can increase the likelihood of an error. Therefore, one should use the darkest shade lens that still allows him or her to see the weld. UV rays can also burn the skin on any exposed areas of the body. Some hoods do not offer adequate protection for the neck area, so when purchasing a hood the welder should ask about neck protection, ensuring that the bottom of the hood extends far enough to protect the neck from burning. This added protection can be afforded by a long front on the hood or a leather flap connected to the bottom of the hood.

11.2.2
Hand Protection

Gloves are an important piece of protective equipment required by a welder (Figure 11.3). Gloves with a high wrist of all-leather and a cloth liner for insulation should be used for the hottest work. Low wrist leather gloves can be used for more flexibility and they are often used for more precise work, for example, TIG welding.

11.2.3 Body Protection

Welding jackets, leggings, and boots are needed to protect the body from burns. Some welding jobs require more protection than others. Some jobs require the welder to lie in awkward positions exposing their body to the harmful UV rays, and weld spatter. In these cases, full body protection is recommended. Other smaller jobs may not present the same level of hazard and, therefore, may not require full body protection. However, full body protection is still recommended if there is a reasonable probability of any skin area being exposed. This again is for protection against exposure to UV rays and weld spatter protection.

Common sense should be used when dressing for a welding job. Clothing that will easily burn or melt should not be used. Wool clothing is the best choice, 100% cotton is a good second choice. In addition, darker colored clothes are best for stopping UV rays from burning the skin.

11.2.4 Respiratory Protection

Welding can produce a significant amount of metal fumes. Inhaling metal fumes can cause metal fume fever (flue-like symptoms in the short term and possibly worse with long-term or chronic exposure). The flu-like symptoms of metal fume fever include fever, chills, nausea, headache, fatigue, muscle aches, joint pain, shortness of breath, and vomiting. Some cases may require medical attention for low blood pressure. But in most cases it just requires removing the welder from the source of the fumes. Recovery should take place in about 24 h. A traditional treatment known among the welding community (not necessarily a sanctioned medical treatment) for metal fumes fever is drinking large quantities of milk to force the metals to chelate out of the bloodstream. This method is not often used today.

All welding should be carried out in a well-ventilated area. Natural ventilation is the best, but when that cannot be accomplished forced ventilation may be required with fans and blowers (Figure 11.4). Never expose the head directly over or in the line of the fumes burning off the weld. Some of the most common

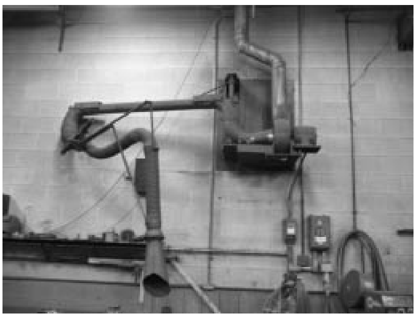

Figure 11.4 Example of local exhaust ventilation equipment.

metals involved in this exposure are zinc oxide, which burns off from galvanized steel (very common), chromium, which burns off when welding stainless steel, and cadmium, which is in silver solder. For more information on the causes and preventions of metal fumes fever, refer to *http://www.freeoshainfo.com/pubpages/Files/welding/metalfumefever.pdf*.

11.3 The Welding Process

Four things are important to the actual SMAW process. The first important performance variable is welding speed. The speed with which one travels across the joint is critical to the quality of the weld. It determines how much filler metal is deposited in the filler joint. Too much will lead to less penetration and result in an unacceptable appearance.

The second important performance variable is the angle at which the rod is held relative to the bead. A trailing angle weld is the best for achieving the best quality weld. This is accomplished when the welder holds the electrode at about a 15° angle (from horizontal) away from the weld bead. Holding this angle forces molten metal away from the leading edge of the puddle, so more heat is delivered to the base plate, resulting, therefore, in more penetration. The 15° angle is the ideal angle to hold the electrode when welding plate steel. Flat, overhead, horizontal, and vertical is a little different. There will be times when the welder needs a different angle. As a welder works, he/she can make electrode angle adjustments and these electrode manipulations are done with practice and knowing what qualities the particular weld bead needs as welding is in progress. Penetration, buildup, width, and so on are critical angle determinants, but also so is knowing if you are getting undercut or slag inclusions. Consequently, a welder will have to gain experience or have adequate supervision to know how to manipulate the electrode to obtain a weld bead of acceptable quality.

Undercut is the melting away of the base metal along the outer edge of the joint. A severe undercut can cause concentration of stress and can cause the weld to fail. Undercut is usually caused by improper techniques, and/or by a high welding current. Another problem that can occur is slag inclusions, where slag or oxides or metallic materials become trapped in the weld bead. Inclusions can also cause a concentration of stress that weakens the weld. Inclusions are caused by not allowing adequate time to burn the slag or oxides out of the weld, and also not having enough room for the correct rod manipulation.

The third performance variable is arc length. Arc length is distance between the unmelted portion of the electrode and the base metal being welded. In some cases, the welder will need to change the arc length depending on the angle he or she is holding the electrode. The further the welder holds the electrode away from the weld, the flatter the resulting bead. Holding a tight arc length allows more buildup, but the welder has to ensure that he or she is not maintaining an excessive arc length or there will be less penetration. This is because the further away the electrode is from the bead the less voltage there is to melt the metal, resulting in a colder weld. The closer the electrode is to the work, the more voltage there is to melt the metal. This can be helpful when welding thinner metals; by moving the electrode in and out one can, to a limited extent, control the heat to the weld. But, to ensure a high quality weld that is less likely to fail, it is always best to maintain the same arc length throughout the entire weld. Only advanced, more experienced welders, should manipulate arc length. A general rule of thumb, in the author's opinion, is that the arc length should be no more than $^{1}/_{8}$ in when welding SMAW.

The fourth most important point when welding using any type of welding (not just SMAW) is the amount of heat delivered to the base metal and to the rod. The diameter of the electrode, thickness of the base metal, and position of the work are all factors that determine the heat needed for a better quality weld (heat is also a function of the amount of current). The smaller the electrode diameter, the lower the current requirement needed to heat the weld to an adequate temperature. Conversely, a larger diameter electrode requires more current. To determine how to adjust current takes practice and experience, but a few rules of thumb are: if the weld has rounded ripples, it is cooling uniformly, so the current is too low; if the ripples are pointed, the weld is cooling too slowly, because there is too much heat; and if the ripples are evenly spaced, uniform, and are rounded on a leading edge, the current setting is correct.

11.3.1
Gas Metal Arc Welding (MIG)

MIG welding is a fast, highly productive method of welding. It is semi-automatic and requires a welding machine, a wire feeder, welding gun, leads, and shielding gas. There are, however, a few other methods of welding MIG that do not require the use of shielding gas. One is called *flux core*, but in this chapter only basic hard-wired, shield gas MIG welding is discussed. It is carried out by feeding wire through the lead, from a wire spool in the wire feeder, through the MIG gun. See Figure 11.5 for GMAW set up and Figure 11.6 for a welder using the GMAW or

Figure 11.5 Example of a MIG welding machine.

Figure 11.6 A welder using the MIG welding technique.

MIG technique. Wire will automatically feed from the gun when the operator pulls the trigger on the gun. The shield gas from the cylinder also travels to the gun from its source.

Earlier in the chapter, the flux from the welding rod protecting the molten metal from the atmosphere was discussed and the same applies with MIG welding. As there is no flux on hard wire MIG wire, it requires a cover gas to protect the molten metal. There are several combinations of cover gases; here only cover gases for mild steel will be discussed. Argon is widely used for MIG welding and there are also many cover gases that are mixed with argon. When choosing a shield gas, rely on the gas cylinder label. The label shows a percentage of argon, and a percentage of the mix gases, such as CO_2 andO_2. The label will read, for example, AG 95%, O_2 5% or AG 98%, CO_2 2%, or just plain argon. In the author's opinion, the best shield gas for mild steel is AG 95%, O_2 5%. The 5% O_2 gives it more penetration and allows a better side-wash on the outer edges of the weld. Side wash allows the molten weld to "wash out" on the side of the weld puddle, making for a more even weld with less buildup in the middle of the weld. When setting up the shield gas for welding, the cylinder must be chained to either the welding machine or somewhere solid and stable. In the USA it is against US Federal Occupational Safety and Health Administration regulations (Occupational Safety and Health Administration, 2009) to have a high-pressure cylinder unchained.

The same methods apply when welding with MIG as does with SMAW (stick welding). Angle, speed, and stick-out are considerations for MIG as well. Stick out with MIG is the same as arc length when referring to stick welding. MIG is much faster than SMAW welding, and there is no need to chip away the slag when the weld is finished. The angle that the gun will be held while welding varies, depending on the type of welding being performed. It takes experience to know what angle is required. Keeping a consistent stick-out or arc length will yield a more uniform weld. Experience is necessary to know when and how much to change the stick out as the weld progresses.

Cover gas flow rate must vary as a function welding conditions, such as outdoor welding or the type of gun being used. With the proper regulator a welder adjusts the flow rate as the weld progresses. First, pull the trigger on the MIG gun, this will allow the gas to flow through the regulator, allowing the flow rate to be adjusted. A welder would start at 35 cfh (cubic feet per hour) and go from there. Experience allows one to determine the best setting for the particular purpose. Flow rate is affected by many variables, such as wind or draft from a nearby fan and so on. This will blow cover gas away and cause unacceptable porosity in the weld. This is so critical to the quality of the weld that it is nearly impossible to MIG weld even with a small breeze coming from anywhere.

11.3.2 Tungsten Inert Gas Welding (TIG)

The TIG welding process uses an arc from a tungsten electrode, which is non-consumable, to produce an arc with a high temperature. Its slow travel speed makes it impractical for most high production welding jobs. This section covers the basics of TIG welding and set-up. The same principles that were important to stick and MIG welding are also important for TIG welding, that is the variables of speed, angle, heat, and stick out are also critical to TIG welding.

TIG uses a TIG torch or "gun." Figures 11.7 and 11.8 give an example of a TIG torch and welding machine, respectively. The TIG rod projects through the torch end and is usually ground to a point, which where the arc originates.

Figure 11.7 Example of a TIG torch.

Figure 11.8 Example of a TIG machine.

TIG welding is accomplished in two ways: scratch start and high frequency. With scratch-start welding, one must scratch the tungsten on the work to acquire an arc. The heat setting cannot be changed unless it is changed from the machine, with high frequency (the welding machine must be equipped with this capability). One makes this change by compressing a foot peddle and the arc will jump from the tungsten to the work without touching the work. The more the foot peddle is compressed the higher the heat generated; however, the heat can never exceed the setting on the welding machine. High frequency TIG welding is considerably easier than the scratch start method, because the welder is able to change the heat setting as the welding progresses. As with MIG, one must use a cover gas, usually 100% argon; other inert gases can be used but argon is the most popular. Experience gives the welder greater ability in determining and setting the proper flow rate. This setting is adjusted by the welder as he or she is able to determine the necessary setting by the appearance of the weld. Like MIG and stick welding, there is a filler rod, but in some cases one can weld with TIG without welding this way. This is called *fusing* and this is usually performed on thinner gauged metals.

The filler rod used must be the proper type of metal for the base metal to be welded. For example, for a 304 stainless steel base metal the filler rod should be 304 stainless steel. The TIG torch is held in one hand and the filler metal, held in the other hand, is dipped into the weld puddle to produce the weld bead. The filler rod and weld puddle must be kept inside the protective zone of the shielding gas that is supplied by a gas cylinder much in the same way as with MIG. If removed from that protective zone while hot (above 400°F or ~244 °C) it will become oxidized, which will contaminate the weld. If the end of the filler rod becomes oxidized, it should be cut off before welding again. There are settings on the TIG welding machine to keep the cover gas flowing for a few seconds after welding is stopped. This is called *post-flow setting*, so one should hold the torch over the weld and filler rod for a few seconds after welding is stopped to keep the weld puddle, including the tungsten, from oxidizing, which would potentially lead to a weld failure. The tungsten should be kept from touching the molten puddle or the filler rod. This is a common mistake that is made by inexperienced welders.

The polarity for most metals used for TIG welding is DCSP. Aluminum, however, requires AC polarity. There are different types of tungsten. Choosing the proper tungsten is important. Pure tungsten has many properties that make it an excellent electrode for TIG welding. Although pure tungsten is used for certain processes, it can be improved by adding thoria or zirconia (in small amounts of up to 2%). This addition, and resulting composition, helps with the arc starting, adds resistance to contamination, and increases the current carrying capacity, which allows lower temperatures to be used, which in turn keeps metal distortion to a minimum. Tungsten rods are color coded. Table 11.1 shows the America Welding Society classification system (AWS A5.12, 1998) and color codes for tungsten.

Table 11.1 Tungsten color coding classification system.

AWS classification	Types	Tip color
EWP	Pure tungsten	Green
EWTH-1	1% thorium added	Yellow
EWTH-2	2% thorium stripe added	Red
EWTH-3	1 or 2% thorium stripe added	Blue
EWZr	$^1/_4$ or $^1/_2$% zirconium added	Brown

More information on composition and other requirements for tungsten is available from AWS publication A5.12, 1998, Specification for Tungsten and Tungsten-Alloy Electrodes for Arc Welding and Cutting.
Adapted from AWS Classification System.

11.4 Cutting

Oxy-fuel gas cutting (OFC) is the process of using high heat from oxy fuel flame to heat the metal to the melting point and then providing a burst of oxygen at high pressure to blow the molten metal away.

Acetylene is the most common fuel gas used in the field today. But there are other types of fuels used such as MAPP. MAPP is a fuel gas made up of a mixture of methylacetylene and propadiene; the name MAPP is its trademark name, which is derived from the original chemical composition (MethylAcetylene ProPadiene). Propane, natural gas, and hydrogen are also used, but acetylene is the most common in the industry today. The type of torch tip and regulator must be right for the type of fuel used. Being able to make a good clean cut using oxyfuel is a matter of using the right size tip, right gas pressure, and a steady hand. The choice of torch tip is determined by the thickness of the base metal. There are charts to help the welder determine what size tip to use for how thick the metal to be cut is. All torches are different, so it is important to consult the manufacturer via their web site. For proper tip size to thickness ratio and proper gas pressure for their particular product, also consult the manufacturer's web site.

There are many steps involved in preparing the equipment to cut and it is important for the welder to ensure the steps are followed to ensure a safe operation. For example:

1) Make sure the adjuster screws are fully extended.
2) Turn the gas on slowly, about a half a turn, wait a moment, and then another half turn. This is done to make sure there is no buildup of pressure already in the regulator, when this happens it raises the temperature, and if there is a piece of dirt or some oil stuck inside, it can ignite, causing RBO (regulator burn out). Oxygen flows out, saturating the welder's clothes, possibly, igniting them.
3) When turning on the oxygen regulator, stand an arm's length away, and face the opposite direction.

4) Turning on the fuel involves less risk of fire, due to the lower pressure; however, this step should be done slowly.
5) Set the gas pressure, by turning the adjuster screw on the regulator, to the desired pressure.

As one can see, this process involves flammable material, fire-supporting oxygen, and high pressure. There is much for a loss prevention engineer to consider in overseeing this type of work.

One rule of thumb for acetylene is that the oxygen pressure should be seven times the pressure setting of the acetylene. For example, if acetylene pressure is set at 5 psi (pounds per square inch) the oxygen pressure should be set at 35 psi. The acetylene pressure should never be higher than 15 psi. The withdrawal rate becomes too fast and makes the gas become unstable, also increasing the risk of fire. Acetylene is kept stable in the cylinder with the use of acetone. Acetone is included to absorb the gas; when the acetylene is drawn off for use, it evaporates of the acetone. Excessively high withdrawal rates will cause the acetylene to boil; this rapid boiling can cause a portion of the liquid acetone to be drawn off with the acetylene, causing the acetylene in the cylinder to become unstable and, thereby, increasing the risk of fire. The draw off rate should not exceed one-seventh of the total cylinder capacity per hour – any setting above 15 psi could cause the welder to exceed the maximum withdrawal rate.

When lighting the torch, the lower oxygen valve is opened. The welder should make sure the upper valve is off. It is then time to open the acetylene valve about a half a turn. At this point, the torch can be lit with a striker. After the torch is lit, the welder is to slowly open the acetylene valve until the flame starts to fan out about an inch away from the end of the tip. At this point, the upper oxygen valve is opened slowly until several small blue flames form at the end of the torch tip. The welder adjusts the blue flames until they are neutral, not too blue and not a faded blue feather at the end. When there are dark blue flames, there is too much oxygen present and we have what is called a *oxidizing flame*, when there is a long feather at the front of the blue flames there is not enough oxygen present and we have what is called a *carburizing flame*.

Once a neutral flame is set, the welder places the flame over the spot to be cut, and preheats the spot until it becomes molten. Once this is accomplished, he or she depresses the oxygen lever and begins to cut. Cutting requires proper planning by the loss prevention engineer and project engineer and proper implementation by the welder to reduce the risk of fire or explosion. Figures 11.9 and 11.10 give an example of an oxygen/acetylene regulators and torch, respectively.

11.4.1 Safety

At least a number 5 lens should be used to protect the eyes and the proper clothing should be worn to prevent burns. The same type of protective clothing worn for welding is required for cutting as well. A welder is instructed never to use an acetylene cylinder after it has been lying on its side for 24 h or more. This

Figure 11.9 Example of oxygen acetylene regulators.

Figure 11.10 Example of an oxygen acetylene torch.

destabilizes the gas and it becomes explosive. Cylinders of flammable gases have a fusible plug at the top of the cylinder to relieve high pressure and minimize the risk of catastrophic failure of the cylinder. This plug will melt at temperatures of 212°F (100 °C). Appropriate ventilation is to be used to minimize exposure to metal fumes or other toxic gases.

11.4.2 Plasma Cutting

Plasma cutting is a process that severs metal by melting a localized area with a constricted arc and removes the molten material with a high velocity jet of hot ionized gas ensuing from the TIP orifice. It is a similar process to oxyfuel cutting as it melts the metal and blows it away. Most of the same principles apply when cutting with plasma as with oxyfuel; for example, tip travel speed is the most important. Plasma cutting leaves a cleaner cut edge than oxyfuel and oxyfuel cannot be used when cutting stainless steel, aluminum, and several other metals that plasma cutting can do with ease. A plasma cutting machine is required as is a high-pressure air source, along with leads (Figures 11.11 and 11.12). A safety lens of at least a number 8 should be used for eye protection and the proper protective clothes are required to minimize burn risk.

Figure 11.11 Example of a plasma cutting machine.

Figure 11.12 Example of a plasma cutting torch.

11.5 Conclusion

There are many other welding and cutting aspects subjects that could be covered but the reference handbook nature of this book limits the scope. This chapter gives just a basic overview of this field and some basic knowledge of what to look for when getting started. Welding should be carried out by an experienced welder, and should not be taking lightly. Weld failure is a common problem in industry today. Weld failures can cause equipment failure, loss of production, and, worst of all, loss of life, so one must take much care when getting ready for a welding or cutting job. Obtain the proper knowledge and experience before getting started.

References

AWS (American Welding Society) (1998) Standard AWS A5.12. *Specification for Tungsten and Tungsten-Alloy Electrodes for Arc Welding and Cutting*, American Welding Society, Miami, FL.

American Welding Society *http://www.aws.com* (accessed 1 June 2012).

Free OSHA Info *http://www.freeoshainfo.com/Pubpages/Files/welding/metalfumefever.pdf* (accessed 1 June 2012).

Jeffas, L.F. (2012) *Welding Principals and Applications*, 7th edn, Delmar, Cengage Learning, Clifton Park, NY.

Occupational Safety and Health Administration (2009) Regulation 29CFR Subpart H, 1910.101.