Welding

1. Arc Welding

1.1. Principles of Operation

The shielded metal arc welding process uses the heat of the electric arc to melt the consumable electrode and the work being welded. The welding circuit includes a power source, welding cables, an electrode holder, a work clamp and a welding electrode. One of the welding cables connects the power source to the electrode holder and the other cable connects to the workpiece. The welding begins when the welder initiates the arc by momentarily touching the electrode to the base metal, which completes the electrical circuit. The welder guides the electrode manually, controlling both the travel speed and the direction of travel. The welder maintains the arc by controlling the distance between the work material and the tip of the electrode (length of the arc). Some types of electrodes can be dragged along the surface of the work so that the coating thickness controls the arc length, which controls the voltage.

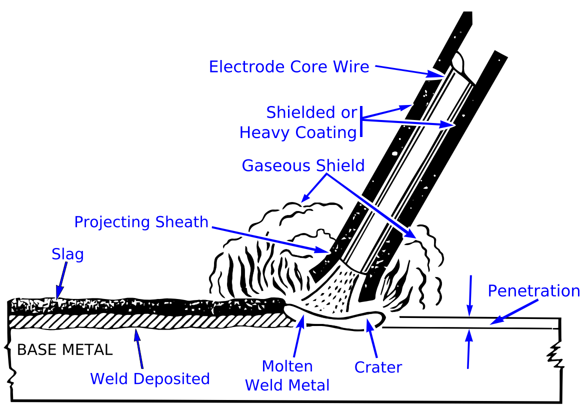


Figure 23. Shielded metal arc welding (SMAW)

1.2. Arc Systems

The constant current type of power source is best for shielded metal arc welding. The constant current welding machines provide a nearly constant welding current for the arc.

The constant current output is obtained with a drooping volt-ampere characteristic, which means that the voltage reduces as the current increases. The changing arc length causes the arc voltage to increase or decrease slightly, which in turn changes the welding current. Within the welding range, the steeper the slope of the volt-ampere curve, the smaller the current change for a given change in the arc voltage.

1.2.1. Electrical Terms

Many terms are associated with arc welding. The following basic terms are especially important.

Alternating current — Alternating current is an electrical current that has alternating negative and positive values. In the first half-cycle, the current flows in one direction and then reverses itself for the next half-cycle. In one complete cycle, the current spends 50 percent of the time flowing one way and the other 50 percent flowing the other way. The rate of change in direction is called frequency, and it is indicated by cycles per second. In the United States, the alternating current is set at 60 cycles per second.

Ampere — Amperes, sometimes called “amps,” refers to the amount of current that flows through a circuit. It is measured by an “amp” meter.

Conductor — Conductor means any material that allows the passage of an electrical current.

Current — Current is the movement or flow of an electrical charge through a conductor.

Direct current — Direct current is an electrical current that flows in one direction only.

Electrical circuit — Electrical circuit is the path taken by an electrical current flowing through a conductor from one terminal of the source to the load and returning to the other terminal of the source.

Polarity — Polarity is the direction of the flow of current in a circuit. Since current flows in one direction only in a DC welder, the polarity becomes an important factor in welding operations.

Resistance — Resistance is the opposition of the conductor to the flow of current. Resistance causes electrical energy to be changed into heat.

Volt — A volt is the force which is required to create the current flow in an electrical circuit. It can be compared to pressure in a hydraulic system. Volts are measured with a voltmeter.

Metal Transfer

The intense heat of the welding arc melts the tip of the electrode and melts the surface of the base metal. The temperature of the arc is about 9000°F (5000°C) which causes almost instantaneous melting of the surface of the work. Globules form on the tip of the electrode and transfer through the arc to the molten weld puddle on the surface of the work. When the detaching globules are small during the transfer, this is known as "spray type metal transfer". When the globules are relatively large during transfer, it is known as globular type metal transfer. Surface tension sometimes causes a globule of metal to connect the tip of the electrode to the weld puddle, causing an electrical short and making the arc go out. Usually, this is a momentary occurrence, but occasionally the electrode will stick to the weld puddle. When the short circuit occurs, the current builds up to a short circuit value and the increased current usually melts the connecting metal and reestablishes the arc.

1.3. The Basic Equipment for Welding

The equipment for the shielded metal arc welding process consists of a power source, welding cable, electrode holder, and work clamp or attachment. *Figure 24* shows a diagram of the equipment.

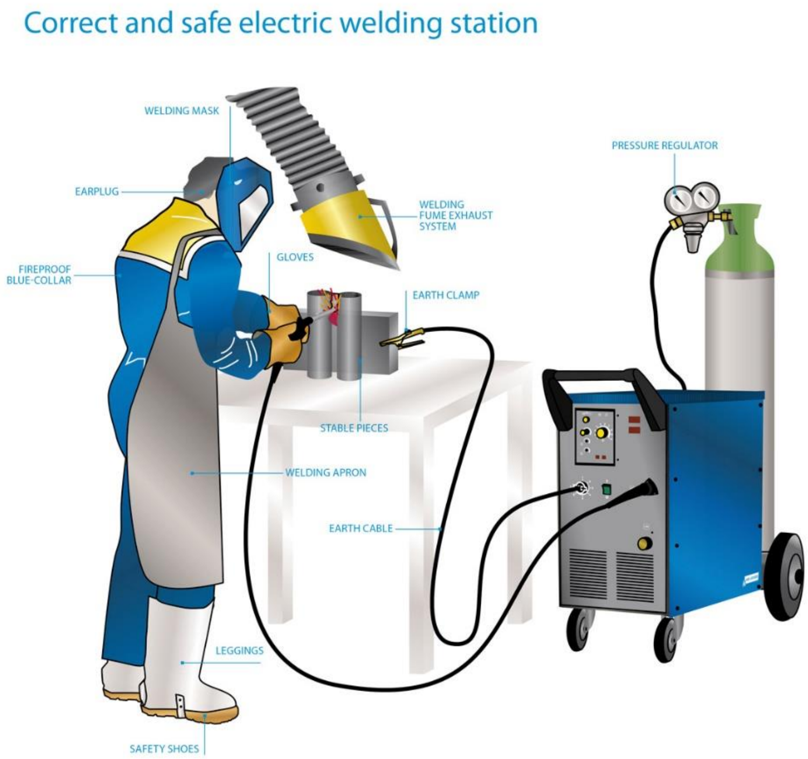


Figure 24. Equipment for shielded metal arc welding.

1.3.1. Power Sources

The purpose of the power source or welding machine is to provide the electric power of the proper current and voltage to maintain a welding arc. Many different sizes and types of power sources are designed for shielded metal arc welding. Most power sources operate on 230-volt or 460-volt input electric power, but power sources that operate on 200 or 575-volt input power are also available.

1.3.2. Types of Current

Shielded metal arc welding can use either direct current (DC) or alternating current (AC). Electrode negative (straight polarity) or electrode positive (reverse polarity) can be used with direct current. Each type of current has distinct advantages, but the selection of the type of welding current used usually depends on the availability of equipment and the type of electrode which is selected. Direct current flows in one direction continuously through the welding circuit. The advantage it has over alternating current is that direct current is better at low currents and with small-diameter electrodes.

All classes of covered electrodes can produce satisfactory results. Arc starting is generally easier with direct current.

Maintaining a short arc is easier. Direct current is easier to use for out-of-position welding because lower currents can be used.

Direct current is easier to use for welding sheet metal. It generally produces less weld spatter than alternating current.

Polarity or direction of current flow is important in the use of direct current. Electrode negative (straight polarity) is often used when shallower penetration is required. Electrode positive (reverse polarity) is generally used where deep penetration is needed. Normally, a negative electrode negative provides higher deposition rates than electrode positive. The type of electrode often governs the polarity to be used.

1.3.3. Power Source Duty Cycle

Duty cycle is the ratio of arc time to total time. For a welding machine, a 10-minute time period is used. Thus, for a 60% duty cycle machine, the welding load would be applied continuously for 6 minutes and would be off for 4 minutes. Most industrial type constant current machines are rated at 60% duty cycle. The formula for determining the duty cycle of a welding machine for a given load current is:

$$\%Duty\ Cycle = \frac{(Rated\ Current)^2}{(Load\ Current)^2} \times \%Rated\ Duty\ Cycle$$

For example, if a welding machine is rated at a 60% duty cycle at 300 amperes, the duty cycle of the machine when operated at 350 amperes would be:

$$\%Duty\ Cycle = \frac{(300)^2}{(350)^2} \times 60\% = 44\%$$

1.3.4. Selecting a Power Source

Selecting a welding machine is based on:

- The amount of current required for the work.
- The power available to the job site.
- Convenience and economic factors.
- The size of the machine is based on the welding current and duty cycle required. Welding current, duty cycle, and voltage are determined by considering weld joints, weld sizes, and welding procedures. The incoming power available

dictates this fact. Finally, the job situation, personal preference, and economic considerations narrow the field to the final selection. Consult with the local welding equipment supplier to help make your selection. Be knowledgeable of the following data when selecting a welding power source:

- Rated load amperes (current)
- Duty cycle
- Voltage of power supply (incoming)
- Frequency of power supply (incoming)
- Number of phases of power supply (incoming)

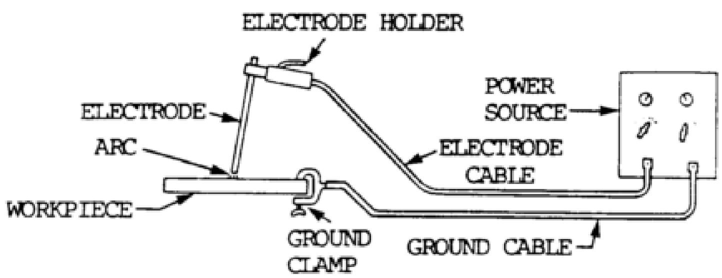


Figure 25. Arc welding setup

1.3.5. Controls

The controls are usually located on the front panel of the welding machine. These usually consist of a knob or tap switch to set the rough current range and a knob to adjust the current within the set range. On DC welding machines there is usually a switch to change polarity, and on combination AC-DC machines, there is usually a switch to select the polarity or AC current. An On-Off switch is also located on the front of the machine. Arc Force Control is a function of amperage triggered by a preset (internal module) voltage. The preset trigger voltage is 18 volts. What this means is that anytime the arc voltage drops from normal welding voltage to 18 volts or less, the drop triggers the arc force current, which gives the arc a surge of current to keep the arc from going out. When an arc is struck, the electrode is scratched against the work. At that point, the voltage goes to -0- which triggers the arc force current and the arc is initiated quickly.

On a standard machine without arc force control, arc striking is difficult and electrode sticking may occur. After the arc is established, a steady burn-off is desired. As the electrode burns and droplets of metal are transferred from the end of the electrode to the workpiece, there is a time period when the droplet is still connected to the end of the electrode but is also touching the workpiece. When this occurs, the machine is, in effect, in a "dead-short. The voltage drops, the arc force is triggered, and the droplet is transferred. On machines without arc force, the burn-off is the same; however, without the arc force to help, an arc outage may occur, and the electrode will stick in the puddle. In tight joints, such as pipe welding, the arc length is very short and with standard machines, it is difficult to maintain the arc since it wants to "short-out" against the sidewalls or bottom of the joint. The arc force control can be adjusted on this type application to prevent electrode sticking; whenever the voltage drops, the drop triggers the arc force current and the sticking doesn't happen because the current surge occurs.

1.3.6. Electrode Holder

An electrode holder, commonly called a stinger, is a clamping device for holding the electrode securely in any position. The welding cable attaches to the holder through the hollow insulated handle. The design of the electrode holder permits quick and easy electrode exchange. Two general types of electrode holders are in use: insulated and non-insulated . The non-insulated holders are not recommended because they are subject to accidental short-circuiting if they bump against the workpiece during welding. For safety reasons, try to ensure that only insulated stingers are used on the job site.

1.3.7. Welding Cables

The welding cables and connectors connect the power source to the electrode holder and to the work. These cables are normally made of copper or aluminum. The cable that connects the work to the power source is called the work lead. The work leads are usually connected to the work by pincher clamps or a bolt. The cable that connects the electrode holder to the power source is called the electrode lead. The welding cables must be flexible, durable, well insulated, and large enough to carry the required current. Use only cable specifically designed for welding, and always use a highly flexible cable for the electrode holder connection. This is necessary so the operator can easily maneuver the electrode holder during the welding process. The work lead cable need not be so flexible because once it is connected, it does not move. Two factors determine the size of the welding cable to use: the amperage rating of the machine and the distance between the work and the machine. If either amperage or distance increases, the cable size must also increase. Cable sizes range from the smallest at ***AWG*** No.8 to AWG No. 4/0 with amperage ratings of 75 amperes and upward. *Table 8-1* shows recommended cable sizes for use with different welding currents and cable lengths. The best size cable is one that meets the amperage demand but is small enough to manipulate easily. As a rule, the cable between the machine and the work should be as short as possible. Use one continuous length of cable if the distance is less than 35 feet. If you must use more than one length of cable, join the sections with insulated lock-type cable connectors. Joints in the cable should be at least 10 feet away from the operator.

1.3.8. Welding Electrodes

When a piece of metal is heated in the atmosphere it combines with the oxygen and nitrogen to form oxides and nitrides which combine with the metal. If these were allowed to form in the weld it would result in a poor quality, weak and brittle weld. It is, therefore, necessary to protect the weld area from the air. This can be done either by surrounding the weld area by an inert gas or via the use of suitable fluxes. It is common with manual metal arc welding to use coated electrodes, for example. These electrodes consist of a metal core surrounded by a layer of suitable flux coating.

1.3.8.1. Covered electrodes

The covered electrode provides both the filler metal and the shielding for the shielded metal arc welding process. Covered electrodes have different compositions of the core wire and a wide variety of types of flux coverings that perform one or all of the following functions, depending upon the type of electrode:

1. Forming a slag blanket over the molten puddle and solidified weld

2. Providing shielding gas to prevent atmospheric contamination of both the arc stream and the weld metal

3. Providing ionizing elements for smoother arc operation

4. Provides deoxidizers and scavengers to refine the grain structure of the weld metal

5. Providing alloying elements such as nickel and chromium for stainless steel

6. Providing metal such as iron powder for higher deposition rates

1.3.8.2. Functions of the Electrode Coating

The six main functions of the electrode coating are as follows:

1. To act as a flux and remove the impurities from the surfaces being welded.

2. To form a protection layer (slag) over the weld, which prevents contact with the air as it starts to cool down. This prevents the weld from becoming brittle and provides a smoother surface by preventing ripples caused during the welding process.

3. It forms a neutral gas atmosphere, which helps to protect the molten weld pool from oxygen and nitrogen in the surrounding air.

4. It helps to stabilize the arc, allowing Alternating Current (AC) to be used.

5. It can add certain constituents to the weld by replacing any that are lost during the welding process.

6. It can speed up the welding process by increasing the speed of melting the metal and the electrode.

The first two functions listed prevent the pickup of nitrogen and oxygen into the weld puddle and the red-hot solidified weld metal. The nitrogen and oxygen form nitrides and oxides which cause the weld metal to become brittle.

1.3.8.3. Electrodes Classification

The classification system for covered electrodes used throughout the industry in the United States was devised by the American Welding Society. In this system, designations for covered electrodes consist of the letter E (for electrode) and four (or five) digits for carbon steel and low-alloy steel covered electrodes. Sometimes a suffix appears on the end as well. These digits have specific meanings, which are:

1. The first two (or three) digits indicate the minimum tensile strength in 1,000 psi, of the weld metal deposited. Figure 26 lists the different digits used.

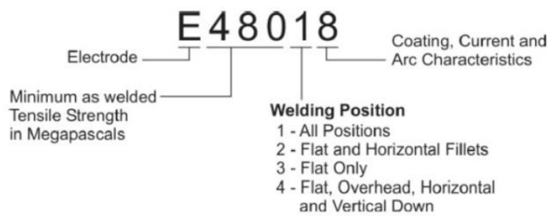
2. The third (or fourth) digit indicates the welding positions in which the electrode can be used. Table 8-3 lists the use of the different digits.

3. The fourth (or fifth) digit indicates the current characteristics and the types of electrode coating.

Table 8-4 describes what the different digits indicate.

4. A suffix is sometimes added to the EXXXX designation (it does not apply to the E60XX

classification). The suffix indicates the chemical composition of the deposited weld metal.



CSA W48.1M1991 electrode classification system.

Digit position indicating tensile and yield strength.

CLASSIFICATION	MINIMUM TENSILE STRENGTH[a] PSI (MPa)	MINIMUM YIELD STRENGTH[a] PSI (MPa)
E60XX	62,000 (425)	50,000 (345)
E70XX	70,000 (485)	57,000 (395)
E80XX	80,000 (550)	67,000 (460)
E90XX	90,000 (620)	77,000 (530)
E100XX	100,000 (690)	87,000 (600)
E110XX[b]	110,000 (760)	95,000 (655)
E120XX[b]	120,000 (825)	107,000 (740)

a- Refer to appropriate specification for exact property requirements.
b- E110XX and E120XX use low hydrogen type of coating only.

Digit indicating position electrode can be used in.

CLASSIFICATION	POSITIONS
EXX1X	Flat, Horizontal, Vertical, Overhead
EXX2X	Flat, Horizontal - Fillet
EXX4X	Flat, Horizontal, Vertical - Down, Overhead

Digits indicating electrode arc and coating characteristics.

CLASSIFICATION	TYPE OF CURRENT USED	PENETRATION	COATING
EXXX0	DCEP	Deep	Cellulose, Sodium
EXXX1	AC, DCEP	Deep	Cellulose, Potassium
EXXX2	AC, DCEN	Medium	Rutile, Sodium
EXXX3	AC, DCEP, DCEN	Light	Rutile, Potassium
EXXX4	AC, DCEP, DCEN	Light	Rutile, Iron Powder
EXXX5	DCEP	Medium	Low Hydrogen, Sodium
EXXX6	AC, DCEP	Medium	Low Hydrogen, Potassium
EXXX7	AC, DCEP, DCEN	Medium	Iron Powder, Iron Oxide
EXXX8	AC, DCEP	Medium	Low Hydrogen, Iron Powder
EXXX9	AC, DCEN, DCEP	Medium	Iron Oxide, Titania, Potassium

For example, the E8018-B1 designation indicates an electrode that deposits metal that has a minimum tensile strength of 80,000 psi (550 ***MPa***), can be used in all welding positions, has a low hydrogen iron powder classification, and has chemical composition in the weld deposit of .12 C, .90 Mn, .03 P, .04 S, .BO Si, .40-.65 Cr and .40-.65 Mo.

Figure 26. Electrode classification

2. Air Carbon-Arc Cutting

Air carbon-arc cutting (ACC) is a process of cutting, piercing, or gouging metal by heating it to a molten state and then using compressed air to blow away the molten metal. The equipment consists of a special holder that uses carbon or graphite electrodes and compressed air fed through jets built into the electrode holder. A push button or a hand valve on the electrode holder controls the air jet. The air jet blows the molten metal away and usually leaves a surface that needs no further preparation for welding. The electrode holder operates at air pressures between 60 and 100 psi.

3. Gas Welding

Oxy-fuel welding, commonly referred to as oxy welding or gas welding, is a process of joining metals by application of heat created by a gas flame. The gas is commonly acetylene, which when mixed with a proper proportion of oxygen in a mixing chamber with a welding torch, produces a very hot flame of about 5700-5800°F. With this flame, it is possible to bring any of the so-called commercial metals, namely: cast iron, steel, copper, and aluminum, to a molten state and cause a fusion of two pieces of like metals in such a manner that the point of fusion will very closely approach the strength of the metal fused. If more metal of a like nature is added, the union is made even stronger than the original. This process is called oxy-acetylene welding.

Cutting with the oxy-fuel process is essentially just the opposite form of welding. Oxy-fuel cutting uses acetylene and oxygen to preheat metal to red hot and then uses pure oxygen to burn away the preheated metal. Because this is achieved by oxidation, it is only effective on metals that are easily oxidized at this temperature. Such metals are mild steel and low allow steels. Oxy-fuel cutting can be used to cut thicknesses from 2/8” to up to 12”.

Traditionally oxy-fuel processes are used for brazing, fusion welding, flame hardening, metalizing, soldering, stress relieving, cutting and bending. The primary uses today are welding, brazing, and cutting. This course describes the basic concepts of oxy-fuel welding and cutting including what equipment and safety precautions are needed.

3.1. Oxy-Acetylene Apparatus

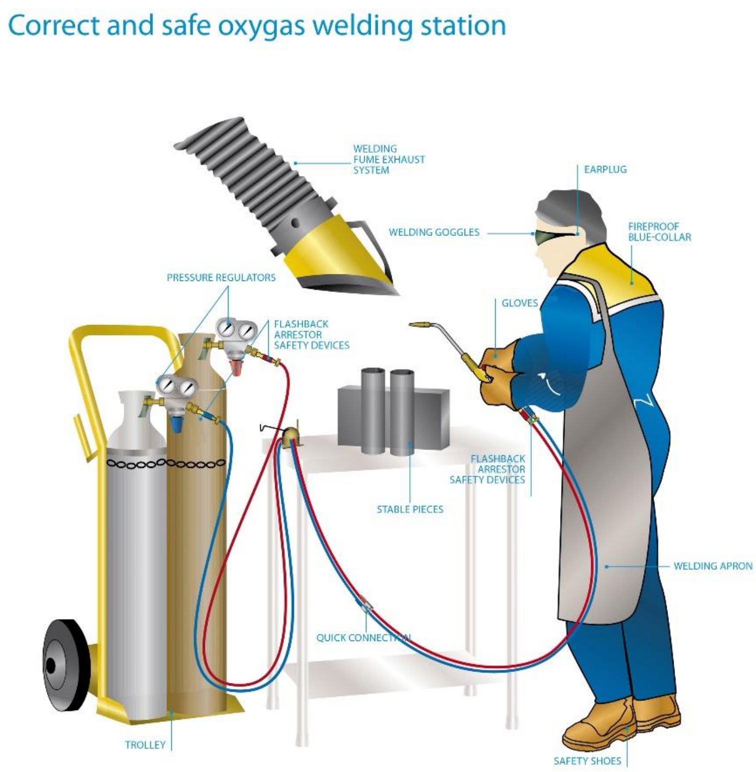


Figure 26. Equipment for Oxy-acytelene welding

The basic equipment used to carry out gas welding and cutting is:

1. Oxygen gas cylinder (green)

2. Acetylene gas cylinder (maroon/red)

3. Oxygen pressure regulator

4. Acetylene pressure regulator

5. Oxygen gas hose(Blue)

6. Acetylene gas hose(Red)

7. Welding torch or blowpipe with a set of nozzles and gas lighter

8. Trolleys for the transportation of oxygen and acetylene cylinders

9. Set of keys and spanners

10. Filler rods and fluxes

11. Protective clothing for the welder (e.g. asbestos apron, gloves, goggles, etc.)

3.1.1. Oxygen Gas Cylinder

An oxygen cylinder is drawn from a piece of high-strength steel plate and is available in common sizes of:

1.- 244 cu ft (for industrial plants);

2.–122 cu ft;

3.- 80 cu ft

Oxygen is stored within cylinders at a pressure of 2200 psi when filled at 70°F and is capable of retaining a pressure of almost twice the fill pressure.

3.1.2.Acetylene Gas Cylinder

An acetylene cylinder is also a solid drawn steel cylinder and the common sizes are 300, 120, and 75 cubic feet. Cylinder pressure is 250 PSI when filled. An acetylene cylinder is painted maroon and the valves are screwed **left-handed** (with a grooved hex on the nut or shank).

Acetylene is extremely **unstable** in its pure form at a pressure above 15 PSI. This instability places special requirements on the storage of acetylene. Acetylene cylinders are packed with porous materials (balsa wood, charcoal, corn pith, or Portland cement) which are saturated with acetone to allow the safe storage of acetylene. These porous filler materials aid in the prevention of high-pressure gas pockets forming in the cylinder.

Acetone, a colorless, flammable liquid, is then added to the cylinder until about 40 percent of the porous material is saturated. Acetone is a liquid chemical that dissolves large portions of acetylene under pressure without changing the nature of the gas, and is a liquid capable of absorbing **25** times its own volume of acetylene gas at a normal pressure. Being a liquid, acetone can be drawn from an acetylene cylinder when it is not upright.

3.1.3. Pressure Relationship

In an oxygen cylinder, there is a precise relationship between cylinder pressure and cylinder contents. A standard oxygen cylinder that contains 244 cu-ft at 2200 psi at 700°F will contain 122 cu-ft when the pressure has dropped to 1100 psi at 700°F. In contrast, an acetylene cylinder will not be precisely half-full when its pressure drops to that of half. Note that the changes in temperature affect the pressure in an acetylene cylinder at a much faster rate than it affects the pressure in an oxygen cylinder. The pressure in an oxygen cylinder will go up or down only about 4 percent for each 20-degree change in temperature (F) from 70 deg. A full acetylene cylinder which has a pressure of 250 psi at 700°F will have a pressure of 315 psi at 900°F and a pressure of 190 psi at 500°F. You must always take temperature into account when estimating how much acetylene the cylinder contains.

3.1.4. Safety Devices on Acetylene Cylinder and oxygen cylinder

An acetylene cylinder is protected by a number of fusible plugs which melt at 220°F (104°C). These plugs melt and release the pressure in case the cylinder is exposed to excessive heat. Small cylinders (the 10 cu-ft. and 40 cu-ft. sizes) have one fusible metal channel located in the cylinder valve. The large cylinders normally used in welding and cutting, with capacities ranging up to nearly 300 cubic feet of acetylene, have two to four plugs, located in both the tops and bottoms of the cylinders. If a cylinder is exposed to a fire, one or more safety devices will melt and allow the acetylene and acetone to escape and burn gradually. If it did not have such a safety device, a full acetylene cylinder exposed to a fire would rupture and release its contents all at once, perhaps explosively.

a.- DO NOT adjust, alter, change, build, or do any experimental work on cylinders, regulators, torches, or any other gas equipment;

b.-DO NOT lift cylinders by the caps or valves;

c.-DO NOT transport the cylinders without the caps in place;

d.- Cylinders must be stored in an **upright** position;

e.- KEEP valves closed on empty cylinders;

f.- MAKE sure that cylinders are regularly re-tested using hydrostatic testing (NDE) while in service.

3.1.5. Oxygen & Acetylene Pressure Regulators

The pressure of the gases obtained from cylinders is considerably higher than the gas pressure used to operate the welding torch. The purpose of using a gas pressure regulator is:

• to reduce the high pressure of the gas in the cylinder to a suitable working pressure, and

• to produce a steady flow of gas under varying cylinder pressures.

A pressure regulator is connected between the cylinder/generator and the hose leading to the welding torch. The desired pressure at the welding torch may be somewhere up to 35 psig (psi gauge) for oxygen and 15 psig for acetylene.

Cylinder	Cylinder pressure	(Max on the gauge)	Working pressure	(Max on the gauge)
Oxygen	2200 psi	(4000 psi)	1 to 35 psi	(150 psi)
Acetylene	250 psi	(400 psi)	1 to 12 psi	(30 psi)

A pressure regulator is fitted with two pressure gauges. One indicates the gas pressure in the cylinder and the other displays the reduced pressure at which the gas is going out.

Figure 27. Gas pressure regulator

3.1.6. Gas Hoses & Clamps

The hoses used to make the connections between the torch and the regulators must be strong, nonporous, light, and flexible enough to make torch movements easy. The most common type of cutting and welding hose is the twin or double hose that consists of the fuel hose and the oxygen hose joined together side by side.

Size is determined by the inside diameter, and the proper size to use depends on the type of work for which it is intended. The hose used for light work has a 3/1 6 or 1/4 inch inside diameter and one or two plies of fabric. For heavy-duty welding and cutting operations, use a hose with an inside diameter of 5/1 6 inches and three to five plies of fabric. A single hose is available in the standard sizes as well as 1/2-, 3/4-, and 1-inch sizes. These larger sizes are for heavy-duty heating and for use on large cutting machines.

Oxygen hoses are **green** in color and have right-handed thread. Acetylene hoses are **red** in color with left-handed thread. The nut on the acetylene connection has a notch that runs around the center, distinguishing it from the nut on the oxygen connection. This is a safety precaution which prevents hoses from being hooked up the wrong way.

3.1.7. Welding Torch & Blow Pipe

A welding torch mixes oxygen and acetylene in the desired proportions, burning the mixture at the end of the tip and providing a means for moving and directing the flame.

There are two types of welding torches, namely:

a) High pressure (or equal pressure) type

b) Low pressure (or injector) type

High-pressure blowpipes or torches are used with (dissolved) acetylene stored in cylinders at a pressure of 117 psi. Low-pressure blowpipes are used with acetylene obtained from an acetylene generator at a pressure of 8 inch - head of water (approximately 0.3 psi).

In a high-pressure blowtorch, both the oxygen and acetylene are fed at equal pressures and the gases are mixed in a mixing chamber prior to being fed to the nozzle tip. The high-pressure torch, also called the equal pressure torch, is most commonly used because:

a) it is lighter and simpler;

b) it does not need an injector;

c) in operation, it is less troublesome since it does not suffer from backfires to the same extent.

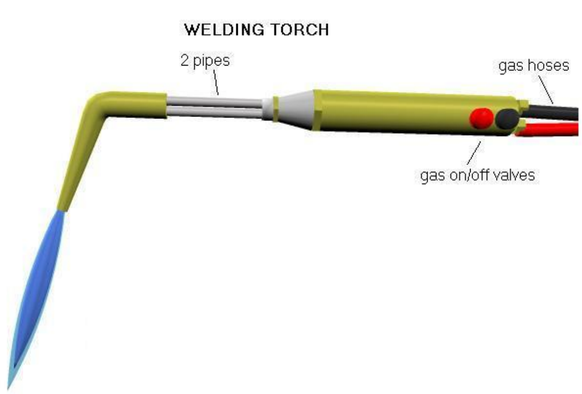


Figure 28. Welding torch

To change the power of the welding torch, it is only necessary to change the nozzle tip (size) and increase or decrease the gas pressures accordingly.

3.2. Oxy-Acetylene Welding

The oxyacetylene welding process uses a combination of oxygen and acetylene gas to provide a high-temperature flame. The high-temperature flame melts the metal faces of the work-pieces to be joined, causing them to flow together. A filler metal alloy is normally added and is sometimes used to prevent oxidation while facilitating the union of the metal.

The amount of heat applied to the metal is a function of the welding tip size, the speed of travel, and the welding position. The flame size is determined by the welding tip size and the proper tip size is determined by the metal thickness and the joint design.

Characteristics of the oxy-acetylene welding process include:

a.-The use of dual oxygen and acetylene gases stored under pressure in steel cylinders;

b.-Its ability to switch quickly to a cutting process, by changing the welding tip to a cutting tip;

c.-The high temperature the gas mixture attains (~5800°F);

d.- The use of regulators to control gas flow and reduce pressure on both the oxygen and acetylene tanks;

e.- The use of double line rubber hoses to conduct the gas from the tanks to the torch;

f.-Melting the materials to be welded together;

g.-The ability to regulate temperature by adjusting gas flow.

3.2.1. Types of Welding Flames

In oxyacetylene welding, the flame is the most important tool; all the welding equipment is simply there in order to maintain and control the flame. The flame must be of the proper size, shape, and condition in order to operate with maximum efficiency. Three distinct types of flames are possible in adjusting the proportions of acetylene and oxygen:

1. Neutral Flame (Acetylene oxygen in equal proportions)

2. Oxidizing Flame (Excess of oxygen)

3. Reducing Flame (Excess of acetylene)

Neutral Flame

A neutral flame is produced when the ratio of oxygen to acetylene, in the mixture leaving the torch, is almost exactly one-to-one. The temperature of the neutral flame is of the order of about 5900ºF.

The tip of the inner flame is the hottest part of the flame and is approximately 5850ºF, while at the end of the outer sheath or envelope the temperature drops to approximately 2300ºF. This variation within the flame permits some temperature control when making a weld. The position of the flame relative to the molten puddle can be changed, and the heat is controlled in this manner.

Carburizing or Reducing Flame:

If the volume of oxygen supplied to the neutral flame is reduced, the resulting flame will be a carburizing or reducing flame, i.e. rich in acetylene. A reducing flame can be recognized by acetylene feather which exists between the inner cone and the outer envelope. The outer flame envelope is longer than that of the neutral flame and is usually much brighter in color.


Figure 28. Carburizing flame

Carburizing Flame (Excess acetylene with oxygen, 5700°F) Used for hard-facing and welding white metal.

It is used for welding with low alloy steel rods and for welding those metals, (e.g. nonferrous metals) that do not tend to absorb carbon. This flame is very well used for welding high carbon steel.

Oxidizing Flame

The oxidizing flame is the third possible flame adjustment. It occurs when the ratio of oxygen to acetylene required for a neutral flame is changed in order to give an excess of oxygen. This flame type is observed when welders add more oxygen to the neutral flame.

Figure 29. Oxidizing flame

An oxidizing flame is of limited use in welding. It is not used in the welding of steel. A slightly oxidizing flame is helpful when welding:

a.- Copper-based metals

b.-Zinc-based metals, and

c.- a few types of ferrous metals, such as manganese steel and cast iron.

3.2.2. Setting up an Oxyacetylene Torch

Before you begin a welding operation, make a thorough inspection of the area. Ensure that there are no combustible materials in the area that could be ignited by the sparks or the slag produced by the welding operation.

Safety check

1) Read the safety considerations carefully;

2) Oxygen and acetylene cylinders must be securely stored in an upright position;

3) An oxyacetylene torch can produce a large amount of heat. Be aware that any objects you direct the flame towards will become very hot;

4) Always have a suitable fire extinguisher nearby in your work area;

5) Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your supervisor.

3.2.3. Step – by – Step Instruction

Check equipment

First, make sure that the gas flow from both the oxygen and the acetylene cylinders is turned off tightly. The two cylinders are secured in an upright position. This is usually on a wheeled trolley. Look at the hose pressure and cylinder pressure gauges on top of each cylinder. Both gauges on each cylinder should read zero. If both gauges do not read zero, turn the main cylinder valve on the top of the cylinder clockwise, to close it completely. Then you must purge the system of any gas.

Purge the system

It is recommended that you purge the gas lines before use to ensure that no oxygen is in the acetylene line and vice versa. Ensure that you have adequate ventilation.

To purge the system, make sure the main cylinder valve is closed tightly. Pick up the torch handle and note that it has two hoses attached. One hose supplies acetylene, while the other supplies oxygen. Turn the oxygen regulator under the gauges clockwise, and open the oxygen valve on the handle. This will purge any gas that may still be in the system and the gauges should both drop back to zero. For a 20-foot hose, open the torch valve for 5 seconds to allow oxygen to bleed from the line acetylene line. For a longer hose, consult a welding reference. Repeat this procedure with the acetylene cylinder.

Install the torch handle

The torch handle is the connection between the hoses and the working tips. It consists of a body and two taps. It's used for both welding and heating. Different attachments are connected to the handle so as to enable welding, heating, or cutting. Examine the connections - one connection is marked ”OX” and is for the oxygen hose. The other is marked “AC” and is for the acetylene hose.

Connect the hoses

As a further safety precaution, you'll find the oxygen connector is a right-handed thread and the acetylene connector is a left-handed thread.

Install the correct tip

Welding tips come in sizes that are stamped with a number. Number one is the smallest tip. The relation between the tip number and the diameter of the orifice may vary with different manufacturers. However, the smaller number always indicates the smaller diameter. For the approximate relation between the tip number and the required oxygen and acetylene pressures, see the tables below.

Adjust the pressure of the gas flow

You are now ready to adjust the gas pressure for heating. Look at the two valves on the torch handle. The valve next to the oxygen hose controls the flow of oxygen to the tip. Close it tightly clockwise. The valve next to the acetylene hose controls the flow of acetylene to the tip. Also close it tightly, clockwise.

Turn on the gases

Now that you're ready to use the torch, turn the main valve on the top of each cylinder counter-clockwise half a turn in order to open the valve. The oxygen tank valve is a backstop valve and should be opened all the way in order to completely seal it. The acetylene valve should only be opened 1/4 to 1/3 of a turn. The needle on the cylinder pressure gauge will rise to show you the pressure in the cylinder. Turn the oxygen regulator handle clockwise until the needle in the gauge registers 10 psi. Turn the acetylene regulator handle clockwise until the needle in the gauge registers 5 psi. This is your working pressure for heating.

Make sure the valves are easily accessible in case emergency shutdown is necessary.

Check the area

Before you light the torch, check the area you're working in to make sure there are no flammable materials or fluids nearby. Workmates should also be clear of the area. The welding flame is not only extremely hot; it also produces dangerous ultraviolet rays which can severely damage your eyes. It is absolutely vital that you are wearing the right safety gear: gloves and tinted goggles or a face mask. Put them on and adjust them until comfortable and secure.

Ignite the torch

Now you are ready to ignite the torch with the striker. The tip of the torch must be pointing downwards away from your body and away from the gas cylinders.

1.-Hold the striker against the tip of the torch with the lighter cup between the torch and you. Flick the striker to create the spark while opening the acetylene valve slightly (1/4 turn). This will ignite the gas at the tip of the torch.

2) Once the flame is lit, open the acetylene valve just until the flame stops smoking. You should get a flame about 8 inches long with a toothy splintering end.

3) Now introduce oxygen into the flame by opening the oxygen valve on the torch.

4) Adjust the two valves (cutting torch oxygen and acetylene) until you obtain a short, bright blue flame at the torch tip with no yellow.

5) Adjust the acetylene regulator to approximately 10 psi. Turn the screw inwards to increase the pressure and outwards to decrease it.

6) Adjust the oxygen regulator in the same manner to a pressure between 40 and 60 psi.

7) Adjust the acetylene and oxygen valves as necessary to maintain the correct flame. The actual adjustment of the flame depends on the type of material to be joined.

Flame Adjustment for Oxy-acetylene Welding

Metal	Flame
Mild Steel	Neutral
High Carbon Steel	Reducing
Grey Cast Iron	Neutral, Slightly Oxidizing
Alloy Steel	Neutral
Lead	Neutral
Aluminum	Slightly Carburizing
Brass	Slightly Oxidizing
Copper, Bronze	Neutral, Slightly Oxidizing
Nickel Alloy	Slightly Carburizing

Adjust the flame

As you open the oxygen valve, you will see the color of the flame change. The pure acetylene flame is yellow, and it will change to blue as you add the oxygen. Continue to open the oxygen valve until you can observe a small, sharp blue cone in the center of the torch flame. This is the “neutral” flame that you need for general heating.

The inner cone or vivid blue flare of the burning mixture of gases issuing from the tip is called the “working flare”. The closer the end of the inner cone is to the surface of the metal being heated or welded, the more effective the heat transfer from the flame to the metal. The flame can be made soft or harsh by varying the gas flow. Too low a gas flow for a given tip size will result in a soft, ineffective flame which is sensitive to backfiring. Too high a gas flow will result in a harsh, high-velocity flame that is hard to handle and will blow the molten metal from the puddle.

The chemical action of the flame on a molten pool of metal can be altered by changing the ratio of the volume of oxygen to acetylene issuing from the tip. Most oxyacetylene welding is done with a neutral flame, having approximately a 1:1 gas ratio. An oxidizing action can be obtained by increasing the oxygen flow, and a reducing action will result from increasing the acetylene flow. Both adjustments are valuable aids in welding.

Using the Torch

The torch tip should be positioned above the metal plate so that the white cone is at a distance of 1.5 to 3.0 mm from the plate. The torch should be held at an angle of 45 to 60° from the horizontal plane.

The torch movement along the joint should be either oscillating or circular. In forehand welding, the torch is moved in the direction of the tip. This tends to preheat before the white cone of the tip melts it. In backhand welding, the torch moves backward. The outer blue flames are directed on the already-welded joint. This allows the joint to be continuously annealed, thereby relieving the welding stresses. This welding allows a better penetration as well as forming a bigger weld. Backhand welding is generally used for thicker materials.

When the welding rod is used to provide filler material, it is necessary to hold it at a distance of 10 mm from the flame and 1.5 to 3.0 mm from the surface of the weld metal pool or puddle. This way the rod gets preheated and when dipped into the puddle would readily get melted.

Oxy-fuel welding can be used for all the types of joints in all positions. Overhead usage requires additional skill to safeguard the welder.

Thicker plates require more than one pass of the gas torch along the length to complete the joint. In multi-pass welding, the first pass (root pass) is very critical in any welding operation.

3.3. Gas Cutting

The equipment and accessories for oxy-gas cutting are the same as for oxy-gas welding, except that you use a cutting torch or a cutting attachment instead of a welding torch. The main difference between the cutting torch and the welding torch is that the cutting torch has an additional tube for high-pressure oxygen, along with a cutting tip or nozzle. The tip is provided with a center hole, through which a jet of pure oxygen passes. Mixed oxygen and acetylene pass through holes surrounding the center holes for the preheating flames. The number of orifices for oxyacetylene flames ranges from 2 to 6, depending on the purpose for which the tip is used. The cutting torch is controlled by a trigger or lever-operated valve. The cutting torch is furnished with interchangeable tips for cutting steel from less than ¼” to more than 12.0” in thickness.

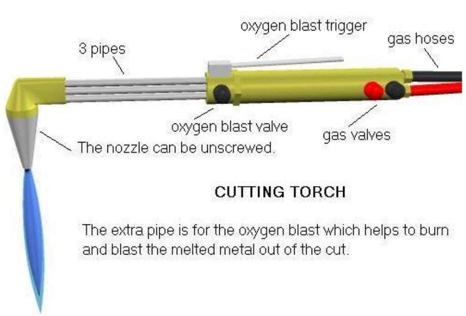


Figure 30. Cutting torch

3.3.1. Operation of Gas Cutting Equipment

Torch Body

While cutting torches are designed for a single purpose, most welding torches are designed so the body can accept a welding tip, heating tip (rosebud), or a cutting attachment. This type of torch is called a “combination torch”. The advantage of this type of torch is the ease in changing from one mode to another. With a combination torch, you do not need to disconnect the hoses; you just unscrew the welding tip and screw on the heating tip or cutting attachment which has the high-pressure oxygen-cutting lever on the now-attached torch handle.

Cutting Torch Tips

To do quality work and produce a clean cut, in cutting, as in welding, you must use the proper size tip for the appropriate fuel gas. The preheat flames must furnish the correct amount of heat, and the oxygen jet orifice must deliver the correct amount of oxygen at the right pressure and velocity. To add to this, you must also operate with a minimum consumption of oxygen and fuel gas. Inattentive workers or workers unfamiliar with correct procedures can inevitably waste both oxygen and fuel gas. This may not seem important in homeport working in a shop, but on deployment with long supply lead times, it can become critical to a project’s success. Manufacturers make many different types of cutting tips to serve multiple purposes and service the use of different gases. While orifice arrangements are relatively common based on the best configuration for a particular gas, and tip material is much the same among the manufacturers, the part of the tip that fits into the torch head often differs in design.

The gas cutting tips are available in four basic types: two for use with standard pressures and normal cutting speeds; two for use with high pressures and high cutting speeds. Only standard pressure tips, types *SP* and *FS,* will be presented, as they are the ones that Steelworkers are likely use. SP stands for standard pressure and FS stands for fine standard.

Table Recommended MAPP Tip Sizes and Oxyfuel Pressures

<table>
<tr><th>Material Thickness inches (millimeters)</th><th>Cutting Tip Number</th><th>Oxygen Cutting Pressure (psig)</th><th>MAPP Gas Pressure (psig)</th></tr>
<tr><td>1/8 (3)</td><td>75</td><td rowspan="6">40-50</td><td rowspan="9">2-10</td></tr>
<tr><td>3/16 (4.8)</td><td>72</td></tr>
<tr><td>1/4 (6.4)</td><td>68</td></tr>
<tr><td>1/2 (12.7)</td><td>61</td></tr>
<tr><td>3/4 (19)</td><td rowspan="2">56</td></tr>
<tr><td>1 (25.4)</td></tr>
<tr><td>1 1/4 (31.8)</td><td rowspan="2">54</td><td rowspan="5">50-60</td></tr>
<tr><td>1 1/2 (38)</td></tr>
<tr><td>2 (50.8)</td><td>52</td></tr>
<tr><td>2 1/2 (63.5)</td><td rowspan="2">48</td><td rowspan="3">6-10</td></tr>
<tr><td>3 (76)</td></tr>
<tr><td>4 (101)</td><td>46</td><td>60-70</td></tr>
</table>

3.3.2. Oxyfuel Cutting Operation

Before you begin any cutting operation, perform a thorough inspection of the area for any combustible materials that could be ignited by sparks or a slag. If you are burning into a wall, inspect the opposite side and post a fire watch as required.

When you use the oxyfuel cutting process, proceed as follows:

1. –Heat a spot on the metal to kindling or ignition temperature (1400°F to 1600°F for steels).

2. –The term for this oxyfuel flame is the *preheating flame.*

3. – Press the lever on the cutting torch to direct a jet of pure oxygen at the heated metal.

The oxygen causes a rapid chemical reaction known as *oxidation.*

This rapid oxidation is called *combustion* or *burning.* Slow oxidation is known as *rusting.* When you use an oxyfuel torch to cut metal, the oxidation of the metal is extremely rapid and part of the metal actually burns. Heat, liberated by the burning of the iron or steel, melts the iron oxide formed by the chemical reaction and accelerates the preheating of the object. The molten material runs off as slag, exposing more iron or steel to the oxygen jet. In oxyfuel cutting, only the metal in the direct path of the oxygen jet is oxidized, and the narrow slit formed as the cutting progresses is called the *kerf.* Most of the material removed from the kerf comes in the form of oxides (products of the oxidation reaction), while the remainder is molten metal blown out of the kerf by the force of the oxygen jet.

A quality cut leaves the kerf walls fairly smooth and parallel with no excess of slag. When you develop your torch handling skills, you should be able to keep the cut within close tolerances; guide the cut along straight, curved, or irregular lines, and cut bevels or other shapes that require holding the torch at an angle. Partial oxidation is a vital part of the oxyfuel cutting process. As a result, metals that do not oxidize readily are not suitable for oxyfuel cutting. Carbon steels are easily cut by the oxyfuel process, although special techniques are required for cutting many other metals.