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Fundamentals of Gas Cutting and Welding

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FUNDAMENTALS OF GAS WELDING & CUTTING



GAS WELDING AND CUTTING

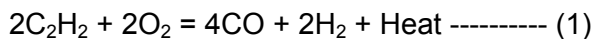
Oxy-fuel welding, commonly referred to as oxy welding or gas welding is a process of joining metals by application of heat created by gas flame. The fuel gas commonly acetylene, when mixed with proper proportion of oxygen in a mixing chamber of welding torch, produces a very hot flame of about 5700-5800°F. 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 like nature is added, the union is made even stronger than the original. This method is called oxy-acetylene welding.

Cutting with the oxy-fuel process is just the opposite from 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".

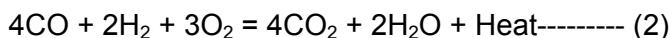
Traditionally oxy-fuel processes are used for brazing, fusion welding, flame hardening, metalizing, soldering, stress relieving, cutting and bending. The primary uses today are welding, brazing and cutting. This course describes the basic concepts of oxy-fuel welding and cutting including what equipment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

Chemistry of Oxy Acetylene Process

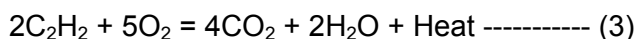
The most common fuel used in welding is acetylene. It has a two stage reaction; the first stage primary reaction involves the acetylene disassociating in the presence of oxygen to produce heat, carbon monoxide, and hydrogen gas.



A secondary reaction follows where the carbon monoxide and hydrogen combine with more oxygen to produce carbon dioxide and water vapor.



When you combine equations (1) and (2) you will notice that about 5 parts of oxygen is necessary to consume 2 parts of acetylene



Or we can say about 2.5 parts of oxygen is necessary to achieve complete combustion of acetylene. In operation, one part of oxygen is supplied through the torch and the remaining 1.5 parts is obtained from the surrounding air atmosphere (secondary reaction). When the secondary reaction does not burn all of the reactants from the primary reaction, the welding processes produces large amounts of carbon monoxide, and it often does. Because of the need for supplemental oxygen from the atmosphere, the acetylene oxygen flame cannot be used inside of pipes or structures subjected to oxygen depletion from gas welding. By varying the relative amounts of acetylene and oxygen, a welder can produce different flame atmospheres and temperatures as he requires.

Oxy Fuel welding Gases

Commercial fuel gases have one common property: they all require oxygen to support combustion. To be suitable for welding operations, a fuel gas, when burned with oxygen, must have the following:

- a. High flame temperature
- b. High rate of flame propagation
- c. Adequate heat content
- d. Minimum chemical reaction of the flame with base and filler metals

Among the commercially available fuel gases such as propane, liquefied petroleum gas (LPG), natural gas, propylene, hydrogen and MAPP gas, “**Acetylene**” most closely meets all the above requirements.

Acetylene is a hydrocarbon, just as are propane, methane, and virtually all the components which make up gasoline and fuel oils. However, it differs from those hydrocarbons in a way that its molecule is made up of two carbon atoms and two hydrogen atoms, the carbon atoms are joined by what chemists call a “triple bond”. When acetylene reaches its kindling* temperature; the bond breaks and releases energy. In other hydrocarbons, the breaking of the bonds between the carbon atoms absorbs energy. The triple bond is the reason that when acetylene and oxygen are mixed and ignited, the flame can reach the temperature of 5700°F to 6300 °F, highest among commonly used gaseous fuels.

The other property of acetylene which you must remember is that acetylene/air mixtures can be ignited when they contain anywhere from 2.5 percent acetylene to 80 percent acetylene. Mixtures of methane (the principal component of natural gas) and air are flammable when they contain as little as 5% methane and not more than 15% methane.

* Kindling Temperature – Kindling temperature is the lowest temperature at which a substance bursts into flame.

The other two gases suitable for welding and cutting are:

- a) MAPP
- b) Hydrogen

MAPP gas is a registered product of the Dow Chemical Company. It is liquefied petroleum gas mixed with methylacetylene-propadiene (acetylene + propane). It has the storage and shipping characteristics of LPG and has a heat value a little less than acetylene. Because it can be shipped in small containers for sale at retail stores, it is used by hobbyist. MAPP gas can be used at much higher pressures than acetylene, sometimes up to 40 or 50 psi in high-volume oxy-fuel cutting torches which can cut up to 12 inch thick steel. A MAPP gas leak is easy to identify because of its particularly terrible odor.

Hydrogen produces low-temperature flame and is best for aluminum. Hydrogen flame is non-luminous, commonly used for underwater welding (can be used at higher pressure than acetylene).

Gasses suitable for cutting but NOT welding:

- a) Propane
- b) Methane
- c) LPG

Hydrocarbon gases, such as propane, butane, city gas, and natural gas, are NOT suitable for welding ferrous materials due to their oxidizing characteristics. Although propane has a very high number of BTUs per cubic feet in its outer cone, it does not burn as hot as acetylene in its inner cone and therefore not very useful for welding operations. However with a right torch (injector style), propane can make a faster and

cleaner cutting and is much more useful for heating and bending applications than acetylene. In some instances, many nonferrous and ferrous metals can be braze welded with care taken in the adjustment of flare and the use of flux.

Characteristics of Acetylene:

- 1) Hydrocarbon - It burns in two stages with primary combustion zone (cone flame) and secondary combustion zone (envelope flame);
- 2) Acetylene is a colorless gas with a very distinctive, nauseating odor that is highly combustible when mixed with oxygen.
- 3) Acetylene gas is formed by the mixture calcium carbide and water and is composed of carbon and hydrogen having the chemical formula C_2H_2 .
- 4) Neutral flame temperature of $5420^{\circ}F$ at the end of the inner cone. This can be increased to a maximum of about $5800^{\circ}F$ by increasing the oxygen quantity through the torch (oxidizing flame);
- 5) Combustible intensity is 12700 BTU/sec. /sq. ft. of cone area in a one to one mixture of acetylene and oxygen through the torch;
- 6) Net heat value of 1433 BTU per cubic foot;

Advantages of Oxyacetylene Process

- 1) Does not require electricity;
- 2) The equipment is portable, easy to transport;
- 3) Welder has considerable control over the rate of heat input, the temperature of the weld zone, and the oxidizing or reducing potential of the welding atmosphere;
- 4) Oxyacetylene process is ideally suited to the welding of thin sheet, tubes, and small diameter pipe. It is also used for repair work, maintenance and in body shops;
- 5) Dissimilar metals can easily be joined;
- 6) Can also be used for preheating, cutting metal, case hardening, soldering and annealing.

Limitations of Acetylene

- 1) Acetylene becomes extremely dangerous if used above 15 pounds pressure. Pure acetylene is self-explosive if stored in the free state under a pressure of 29.4 pounds per square inch (psi);
- 2) The process is typically slower than the electrical arc-welding processes;

We will learn more about the oxyacetylene process and equipment in this course. The course is divided into 4 sections:

Section -1 Oxy-Acetylene Apparatus

Section -2 Oxy-Acetylene Welding

Section -3 Oxy-Acetylene Cutting

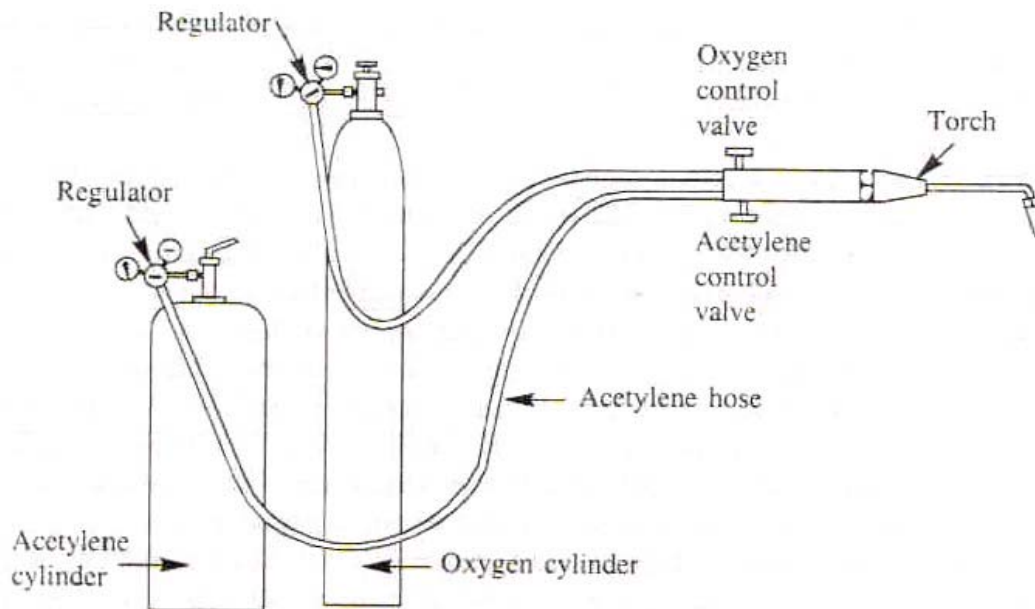
Section -4 Oxy-Acetylene Safety & Precautions including case study

Annexure -1 Terminology

SECTION - 1 OXY-ACETYLENE APPARATUS

Before discussing how the system works, it is important to know the name of the components that makes the oxy-fuel apparatus.

Oxy-fuel apparatus consists of two cylinders (one oxygen and one acetylene) equipped with two regulators, pressure gauges, two lengths of hose, and a blow torch. The regulators are attached to cylinders and are used to reduce and maintain a uniform pressure of gases at the torch. The gases at reduced pressure are conveyed to the torch by the hoses. The regulators include high pressure and low pressure gauges to indicate the contents of the cylinder and the working-pressure on each hose. When the gases reach the torch they are there mixed and combustion takes place at the welding tip fitted to the torch.



Oxy-acetylene welding outfit

The basic equipments used to carry out gas welding are:

1. Oxygen gas cylinder (green)
2. Acetylene gas cylinder (maroon/red)
3. Oxygen pressure regulator
4. Acetylene pressure regulator
5. Oxygen gas hose(Blue)

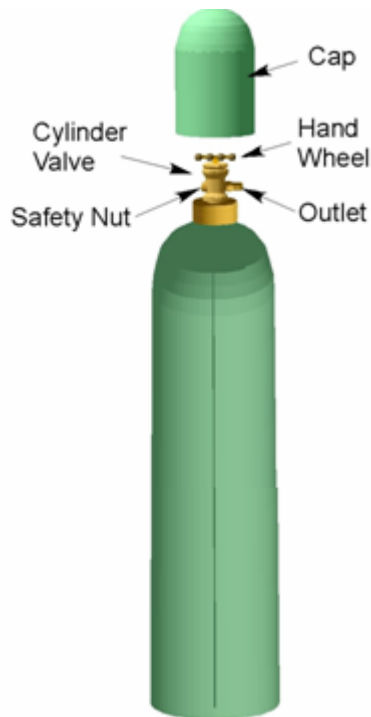
6. Acetylene gas hose(Red)
7. Welding torch or blow pipe with a set of nozzles and gas lighter
8. Trolleys for the transportation of oxygen and acetylene cylinders
9. Set of keys and spanners
10. Filler rods and fluxes
11. Protective clothing for the welder (e.g., asbestos apron, gloves, goggles, etc.)

OXYGEN GAS CYLINDER

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

- 244 cu ft (for industrial plants);
- 122 cu ft;
- 80 cu ft

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



The oxygen volume in a cylinder is directly proportional to its pressure. In other words, if the original pressure of a full oxygen cylinder drops by 10% during welding, it means 1/10th of the cylinder contents have been consumed.

Oxygen cylinders are usually painted green and are screwed right handed.

Oxygen Cylinder Valves

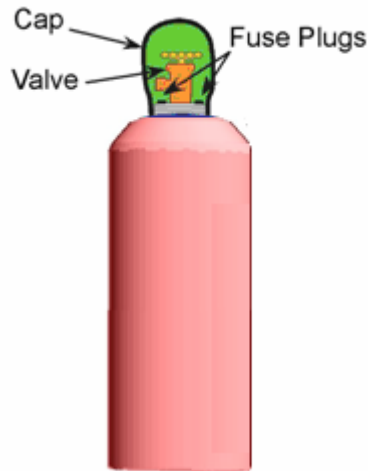
The oxygen cylinder valve is made largely of brass with **right hand** threads. Its outlet is threaded and machined to comply with standards set by the Compressed Gas Association (CGA) and the American National Standards Institute (ANSI). All oxygen regulators sold in the U.S and Canada for use on industrial oxygen cylinders carry a mating inlet nut and nipple. The connection is designated “CGA 540”. Every oxygen cylinder valve is also equipped with a *bursting disk* which will rupture and release the contents of the cylinder if cylinder pressure should approach cylinder test pressure (as it might in case of a fire). In order to protect cylinder valve from getting damaged, a removable steel cap is screwed on the cylinder at all times when the cylinder is not in use. The cylinder valve is kept closed when the cylinder is not in use and even when cylinder is empty.

Caution

- The valve shall never be left exposed. It must always have the regulator attached or the cap on.
- The valve must be opened all the way when in use.

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 grooved hex on nut or shank).



Acetylene is extremely **unstable** in its pure form at pressure above 15 PSI. This instability places special requirements on the storage of acetylene. Acetylene cylinders are packed with porous material (balsa wood, charcoal, corn pith, or portland cement) that is 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 normal pressure. Being a liquid, acetone can be drawn from an acetylene cylinder when it is not upright.

Here are two very important things to remember about dissolved acetylene cylinders:

First, acetylene cylinders should always be stored in the upright position to prevent the acetone from escaping thus causing the acetylene to become unstable.

Second, CGA G-1 calls for a withdrawal rate “not to exceed 1/10(one-tenth) of the capacity of the cylinder per hour during intermittent use. For full withdrawal of the contents of the cylinder on a continuous basis, the flow rate should be no more than 1/15 (one-fifteenth) of the capacity of the cylinder per hour.” If acetylene is withdrawn too rapidly, quite a lot of acetone may come with it, in vapor or droplet form, and the cylinder may cool down so much that it cannot sustain the high rate. This will affect your torch

flame, and will mean that your supplier must replenish the acetone in the cylinder more frequently.

Many acetylene cylinder valves are not equipped with hand wheels, and must be operated by a wrench. The wrench should always be left in place while the cylinder valve is open. Acetylene cylinders should be opened only 1/3 to 1/4 of a turn when in use.

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 @ 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 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. 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.

Safety Devices on Acetylene Cylinder

An acetylene cylinder is protected by 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 top and bottom 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.

Note: Acetylene cylinders are equipped with fusible metal safety plugs and NOT rupture-disk safety devices, as in oxygen and nitrogen gas cylinders.

Caution

- DO NOT adjust, alter, change, build, or do any experimental work on cylinders, regulators, torches, or any other gas equipment;
- DO NOT lift cylinders by the caps or valves;
- DO NOT transport the cylinders without the caps in place;
- Cylinders must be stored in **upright** position;
- KEEP valves closed on empty cylinders;
- MAKE sure, cylinders are regularly re-tested using hydrostatic (NDE) while in service.

Cylinder Transportation

- NEVER transport cylinders without the safety caps in place. When using fuel and oxygen tanks they should be fastened securely upright to a post or a portable cart. An oxygen tank is especially dangerous for the reason that the oxygen is at a pressure of 3000 PSI when full and if the tank falls over and its valve strikes something and is knocked off, the tank will effectively become an extremely deadly flying missile propelled by the compressed oxygen;
- NEVER transport with the regulators in place;
- NEVER allow bottles to stand freely. Always chain them to a secure cart or some other object that cannot be toppled easily.

Manifold System for Gas Welding

While a great deal of oxy-acetylene welding and cutting is done using gases supplied by a single pair of cylinders, there are many situations where considerable gas welding is done and at several places or where rate of gas consumption is high, it is much advantageous to use a manifold system.

In a manifold system, instead of having gas cylinders at each place of work, they are assembled at one centralized position in specially designed racks and connected by a manifold. The gas is then distributed by means of a pipeline to different workplaces.

The manifold distributes welding gases at a reduced pressure. There are separate manifolds for oxygen and acetylene gas supplies. An oxygen manifold system differs from acetylene manifold in the following ways:

1. There is no anti flashback device in an oxygen manifold system.

2. Oxygen supply line is a copper pipe whereas acetylene supply line is a steel pipe.
3. An oxygen pressure regulator is used in an oxygen manifold system.

Advantages of Using Manifolds –

Since gas cylinders have not been scattered throughout the work area, rather, they have been kept at a central place:

- a) The possibility of accidents is reduced.
 - More space is available at each workplace.
 - In case of fire, one can easily reach the cylinders.
- b) Cylinders are transported by less distance.
- c) There is no replacement of cylinders inside the workshop.

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 welding torch. Desired pressure at the welding torch may be somewhere up to 35 psig 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 shows the reduced pressure at which the gas is going out.



Gas Regulator

Gas pressure regulators may be classified as:

- a) Single stage Regulator
- b) Two stage Regulator

In single stage regulator, reduction of pressure from the cylinder pressure to the welding pressures takes place in single stage. A single stage regulator is all that actually is needed for both oxygen regulation and acetylene regulation for oxyacetylene welding. However, a single stage regulator tends to freeze in cold weather. This is because a sudden expansion and resulting drop in initial pressure causes rapid cooling of the gas involved. The moisture present in the gas, thus, results in the formation of ice on or near the regulator nozzle which causes irregular seating of the seat on the nozzle and therefore substantial pressure fluctuations.

The principle of pressure reduction in a two stage regulator is exactly the same as in a single stage regulator, but here the pressure is reduced in two stages instead of one, using two diaphragms and two control valves, so that the pressure reduction ratio is less abrupt.

Good regulators are essential to ensure the even flow of gas to the blowpipe. Acetylene regulators are constructed much more sensitively than the oxygen regulators, to take care of the lower pressure of gas. Acetylene regulators **cannot** be interchanged with

oxygen regulators for they will not stand the pressure demanded in the first place, and in the second if a small quantity of acetylene gas left in the regulator and oxygen introduced, an inflammable mixture would be formed which is not advisable on account of its explosiveness. In many instances oxygen regulators are put out with the copper diaphragms, whereas another metal must be used on the acetylene regulators, because acetylene gas attacks copper and usually a German silver or rubber diaphragm is used. On account of the lower pressures used in charging the acetylene cylinders, lower pressure gauges are used with acetylene regulators.

Difference between Oxygen and Acetylene Pressure Regulators -

Acetylene Regulator: The cylinder and hose connections have left handed threads on the acetylene regulator.

Oxygen Regulator: There are right hand threads in this case.

Acetylene Regulator: Acetylene connection nuts have chamfers or grooves cut in them.

Oxygen Regulator: Nuts are plain, i.e., with no chamfer or grooves.

Acetylene Regulator: Color band on acetylene regulator in maroon or red.

Oxygen Regulator: It is either blue or black on the oxygen regulator.

Acetylene Regulator: The inlet or high pressure gauge on the regulator reads up to 8bar.

Oxygen Regulator: The inlet or high pressure gauge on the regulator reads up to 100bar.

Acetylene Regulator: The outlet or low pressure gauge on the regulator reads up to 1bar.

Oxygen Regulator: The outlet or low pressure gauge on the regulator reads up to 4.8bar.

Caution

- NEVER use oxygen or fuel gas from a cylinder except through an approved pressure-reducing regulator.
- NEVER attempt to use a regulator except for the gas and service for which it is designed. Generally speaking, the inlet connections installed by the regulator manufacturer make mismatching impossible. However, that cannot always be the case, since there just are not enough mechanically distinct connections to permit each gas to have individual treatment. Therefore, some gases – for example, the

inert gases and certain fuel gases – are treated in groups. A propane regulator will fit many acetylene cylinders, but should not be so used.

- Oil or other petroleum products must never be used around oxygen regulators because these products will either cause a regulator explosion or fire.

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. Hose used for light work has a 3/16 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 5/16 inch and three to five plies of fabric. 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.



Rubber flexible hose

Oxygen hoses are **green** in color and have right hand thread. Acetylene hoses are **red** in color with left hand 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 to prevent hoses from being hooked up the wrong way.

Some precautions are to be taken when using reinforced rubber hoses:

- a) Only one gas should be used in a hose. For example, using an oxygen hose to carry acetylene could cause a serious accident.
- b) The hose should never be patched or repaired.
- c) Hot metal (job) should never be placed on the hose.

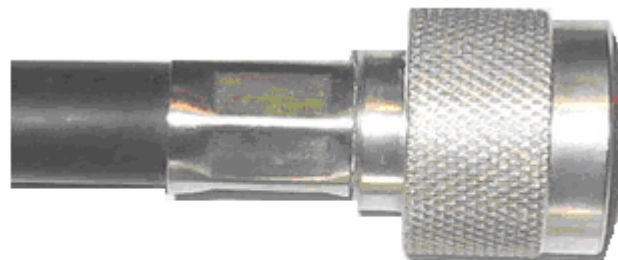
The length of hose you use is important. The delivery pressure at the torch varies with the length of the hose. A 20-foot, 3/16-inch hose maybe adequate for a job, but if the same hose was 50 feet long, the pressure drop would result in insufficient gas flow to the torch. Longer hoses require larger inside diameters to ensure the correct flow of gas to the torch. When you are having problems welding or cutting, this is one area to check

Hose Clamps:

A metal clamp is used to attach the welding hose to a nipple. There are basically two types of connections that can be used. The first is using a jubilee clip. The second option is using a crimped connector. The second option is probably safer as it is harder for this type of connection to come loose. The hoses should also be clipped together at intervals approximately 3 feet apart.



Jubilee Clip



Crimped Connector

Check Valve

A check valve lets gas flow in one direction only and is positioned at the torch inlet, and at the regulator outlet. The purpose of check valve is to prevent flame or oxygen-fuel mixture being pushed back into cylinder and causing backfire, flashback and explosion.

Backfire: A backfire is caused by the flame going out suddenly on the torch. A backfire may occur when:

- o The tip is touched against the work piece;

- If the flame setting is too low;
- If the tip is dirty, damage or loose, or;
- If the tip is overheated.

When a torch backfires, it could cause a flashback.

A flashback is a condition in which the flame burns inside the tip, the torch, or the hose. Flashbacks are caused by the improper mixture of the gases, which increases the rate of flame propagation to such an extent that the flame will flash back to the mixing chamber. If it is not stopped, the flame will ignite the mixture and will travel backwards from the torch, along the hoses, through the regulator and into the cylinder. To prevent such occurrence, a **flash arrestor** shall be installed. Flashback arrestor (not to be confused with a check valve) prevents the shock waves from downstream coming back up the hoses and entering the cylinder (possibly rupturing it), as there are quantities of fuel/oxygen mixtures inside parts of the equipment (specifically within the mixer and blowpipe/nozzle) that may explode, if the equipment is incorrectly shut down; and acetylene decomposes at excessive pressures or temperatures. The flashback arrestor will remain switched off until someone resets it.

(Refer to Section -4 “Safe Working Practices” illustrating a case study of safety incident in UK.)

Note - Combination Check/ Flashback Valves can be placed at the torch or regulator.

WELDING TORCH & BLOW PIPE

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

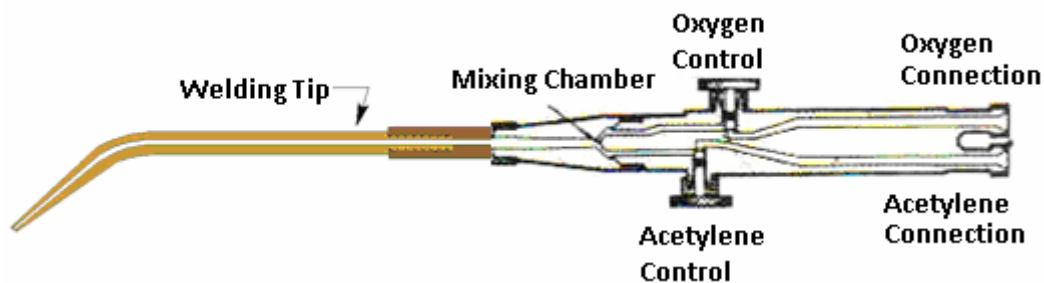
There are two types of welding torches, namely:

- 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 high pressure blow torch, 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.



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 appropriately.

NOTE: The real tool of the oxy-acetylene welding process is the flame, NOT the torch. When we come to oxygen cutting, we must consider the pure oxygen jet as a second tool, working hand-in-hand with the flame. To produce only the flame, we use a welding torch, fitted with the appropriate size welding head or tip. To produce both flames and the oxygen jet, we use a cutting torch or cutting attachment, equipped with the appropriate cutting nozzle or tip.

Welding Nozzles or Tips

The welding nozzle or tip is that portion of the torch which is located at the end of the torch and contains the opening through which the oxygen and acetylene gas mixture passes prior to ignition and combustion. Depending upon the design of the welding torch, the interchangeable nozzles may consist of:

- a) Either, a set of tips which screw onto the head of the blowpipe, or
- b) As a set of gooseneck extensions fitting directly onto the mixer portion of the blowpipe.

A welding nozzle enables the welder to guide the flame and direct it with the maximum ease and efficiency. The following factors are important in the selection of appropriate welding nozzle:

- a) The position of the weld
- b) The type of joint
- c) Job thickness and the size of welding flame required for the job
- d) The metal/alloy to be welded.

To provide for different amounts of heat, to weld metals of different thicknesses, welding tips are made in various sizes. The size of a welding tip is determined by the diameter of the opening or orifice in the tip. As the orifice size increases, greater amounts of the welding gases pass through and are burnt to supply a greater amount of heat.

The choice of the proper tip size is very important to good welding. For welding thicker material large sized tip is used which will supply more combustible gases and more heat. A chart giving sizes of tips for welding various thicknesses of metal along with oxygen and acetylene pressures used is generally provided by the manufacturers.

Care of Welding tips

- a) All welding tips are made of copper and may be damaged by careless handling.
- b) Nozzles should never be dropped or used for moving or holding the work.
- c) Nozzle seat and threads should be absolutely free from foreign matter in order to prevent any scoring when tightening on assembly.
- d) Nozzle orifice should only be cleaned with tip cleaners specially designed for this purpose.

Filler Metals:

Filler metals are used to supply additional material to the pool to assist in filling the gap (or groove) and it forms an integral part of the weld. Filler rods have the same or nearly the same chemical composition as the base metal and are available in a variety of compositions (for welding different materials) and sizes. These consumable filler rods may be bare, or they may be coated with flux. The purpose of the flux is to retard oxidation of the surfaces of the parts being welded, by generating gaseous shield around the weld zone. The flux also helps to dissolve and remove oxides and other substances

from the work piece and so contributes to the formation of a stronger joint. The slag developed protects the molten metal puddles of metal against oxidation as it cools.

Characteristics of good flux

The melting point of a flux must be lower than that of either the metal or the oxides formed, so that it will be liquid. The ideal flux has exactly the right fluidity when the welding temperature has been reached. The flux will protect the molten metal from atmospheric oxidation. Such a flux will remain close to the weld area instead of flowing all over the base metal for some distance from the weld.

Composition of Fluxes

Fluxes differ in their composition according to the metals with which they are to be used. In cast iron welding, a slag forms on the surface of the puddle. The flux serves to break this up. Equal parts of a carbonate of soda and bicarbonate of soda make a good compound for this purpose. Nonferrous metals usually require a flux. Copper also requires a filler rod containing enough phosphorous to produce a metal free from oxides. Borax which has been melted and powdered is often used as a flux with copper alloys. A good flux is required with aluminum, because there is a tendency for the heavy slag formed to mix with the melted aluminum and weaken the weld. For sheet aluminum welding, it is customary to dissolve the flux in water and apply it to the rod. After welding aluminum, all traces of the flux should be removed.

Gas Lighter

A gas (spark) lighter provides a convenient, safe and inexpensive means of lighting the torch. Match sticks should never be used for this purpose because the puff of the flame produced by the ignition of the acetylene flowing from the tip is likely to burn the welder's hand. Spark lighters are constructed from flint and steel.

Gas Cylinder Trolleys

Trolleys should be capable of accommodating one oxygen cylinder and one acetylene cylinder required for gas welding. Normally cylinders can be mounted on a trolley side by side, but where work has to be done on plant with access only by narrow gangways the, has an advantage. Trolleys may have rubber tires or steel rim wheels. The gas cylinders are held in place with chains and supported on the bottom with a steel platform.

Goggles

They are used to protect the eyes of the operator from harmful heat and radiation of infrared and ultraviolet rays produced during the welding.

Apron, Gloves & Safety Goggles

The molten metal has a tendency to pop and splatter as heat is applied and oxygen reacts with the superheated metal. It is critical that operators using the oxy-acetylene welding or cutting process wear proper gloves and use approved safety goggles or face shield. The goggles and/or face shield protect the eyes from sparks and flying hot metal particles. The goggles or face shield use special lenses to protect the eyes from light damage. A variety of lenses are used depending on the type of welding or cutting that needs to be done, the type of material, and the thickness of the material. If protective eye shielding is not used, painful burns can occur on the surface of the eye, and could result in permanent damage.

SECTION - 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 sometimes used to prevent oxidation and to facilitate the metal union.

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:

- The use dual oxygen and acetylene gases stored under pressure in steel cylinders;
- Its ability to switch quickly to a cutting process, by changing the welding tip to a cutting tip;
- The high temperature the gas mixture attains (~5800°F);
- The use of regulators to control gas flow and reduce pressure on both the oxygen and acetylene tanks;
- The use of double line rubber hoses to conduct the gas from the tanks to the torch;
- Melting the materials to be welded together;
- The ability to regulate temperature by adjusting gas flow.

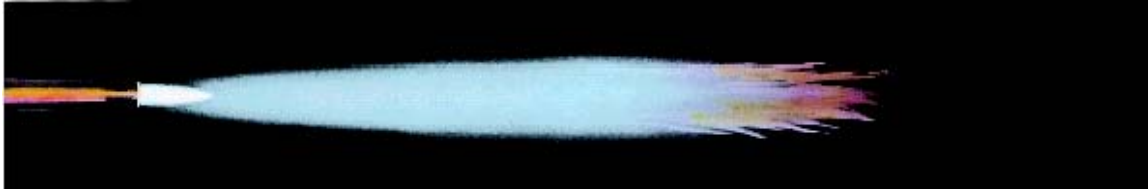
Types of Welding Flames

In oxyacetylene welding, flame is the most important tool. All the welding equipment simply serves 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 on 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 5900°F.

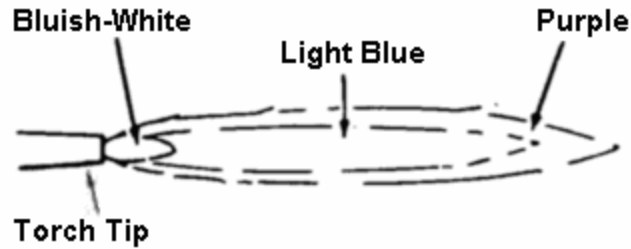


Neutral Flame (5850°F).

For Fusion welding of steel and cast iron

Characteristics of Neutral flame:

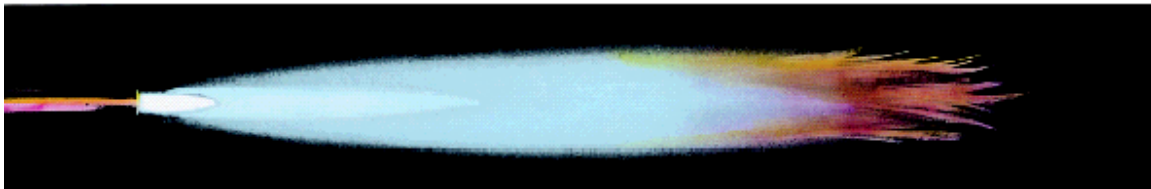
- a) The neutral flame is obtained when approximately one volume of oxygen and one volume of acetylene are mixed. It's termed "neutral" because it will usually have no chemical effect on the metal being welded. It will not oxidize the weld metal; it will not cause an increase in the carbon content of the weld metal.
- b) Neutral flame is obtained by gradually opening the oxygen valve to shorten the acetylene flame until a clearly defined inner cone is visible. For a strictly neutral flame, no whitish streamers or feathers should be present at the end of the cone.
- c) Neutral flame is used for most welding operations and for preheating during cutting operations. When welding steel with neutral flame, the molten metal puddle is quiet and clear; the metal flows easily without boiling, foaming, or sparking.
- d) There are two clearly defined zones in the neutral flame. The inner zone consists of a luminous cone that is bluish-white. The inner cone is where the acetylene and the oxygen combine. Surrounding this is a light blue flame envelope or sheath. This neutral flame is obtained by starting with an excess acetylene flame in which there is a "feather" extension of the inner cone. When the flow of acetylene is decreased or the flow of oxygen increased the feather will tend to disappear. The neutral flame begins when the feather disappears.



- e) The tip of the inner is the hottest part of the flame and is approximately 5850°F, while at the end of the outer sheath or envelope the temperature drops to approximately 2300°F. This variation within the flame permits some temperature control when making a weld. The position of the flame to the molten puddle can be changed, and the heat controlled in this manner.
- f) The neutral flame is commonly used for the welding of:
- Mild steel
 - Stainless steel
 - Cast Iron
 - Copper
 - Aluminum

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.

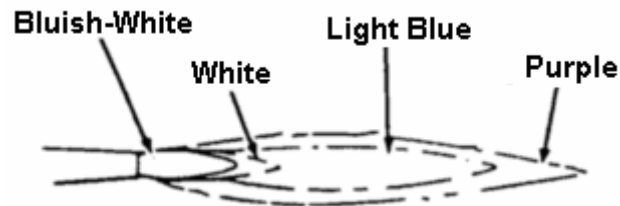


Carburizing Flame (Excess acetylene with oxygen, 5700°F)

Used for hard facing and welding white metal.

Characteristics of Reducing or carburizing flame:

- a) An excess of acetylene creates a carburizing flame. The reducing or carburizing flame is obtained when slightly less than one volume of oxygen is mixed with one volume of acetylene. This flame is obtained by first adjusting to neutral and then slowly opening the acetylene valve until an acetylene streamer or "feather" is at the end of the inner cone. The length of this excess streamer indicates the degree of flame carburization. For most welding operations, this streamer should be no more than half the length of the inner cone.
- b) The carburizing flame is characterized by three flame zones; the hot inner cone, a white-hot "acetylene feather", and the blue-colored outer cone. This is the type of flame observed when oxygen is first added to the burning acetylene. The feather is adjusted and made ever smaller by adding increasing amounts of oxygen to the flame. A welding feather is measured as 2X or 3X, with X being the length of the inner flame cone. This type of flare burns with a coarse rushing sound. It has a temperature of approximately 5700°F (3149°C) at the inner cone tips.



The feather is caused by incomplete combustion of the acetylene to cause an excess of carbon in the flame.

- c) The carburizing flame may add carbon to the weld metal and will tend to remove the oxygen from iron oxides which may be present, a fact which has caused the flame to be known as a "reducing flame". With iron and steel it produces very hard, brittle substance known as iron carbide. This chemical change makes the metal unfit for many applications in which the weld may need to be bent or stretched. Metals that tend to absorb carbon should NOT be welded with reducing flame.
- d) The reducing flame is typically used for welding high carbon steel and hard facing operations or backhand pipe welding techniques. When used in silver solder and soft solder operations, only the intermediate and outer flame cones

are used. They impart a low temperature soaking heat to the parts being soldered.

- e) Since this flame provides a strong reducing atmosphere in the welding zone, it is useful for those materials which are readily oxidized like oxygen free copper alloys. It is also used for high carbon steels, cast iron and hard surfacing with high speed steel and cement carbides. A reducing flame has an approximate temperature of 5500°F (which is lowest among all the three flames). A reducing flame may be distinguished from a carburizing flame by the fact that a carburizing flame contains more acetylene than a reducing flame. A carburizing flame is used in the welding of lead and for carburizing (surface hardening) purposes. A reducing flame, on the other hand, does not carburize the metal; rather it ensures the absence of the oxidizing condition. It is used for welding with low alloy steel rods and for welding those metals, (e.g. non ferrous) 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 to give an excess of oxygen. This flame type is observed when welders add more oxygen to the neutral flame.



Oxidizing Flame (Acetylene and excess oxygen, 6300°F)

For braze welding with Bronze rod.

The presence of excess oxygen in this flame creates undesirable oxides to the structural and mechanical detriment of most metals. It is useful for welding copper base alloys, zinc base alloys, cast iron, manganese steel etc.

Characteristics of an Oxidizing flame:

- a) The oxidizing flame is produced when slightly more than one volume of oxygen is mixed with one volume of acetylene. To obtain this type of flame, the torch should first be adjusted to a neutral flame. The flow of oxygen is then increased

- until the inner cone is shortened to about one-tenth of its original length. When the flame is properly adjusted, the inner cone is pointed and slightly purple. An oxidizing flame can also be recognized by its distinct hissing sound. The temperature of this flame is approximately 6300°F (3482°C) at the inner cone tip.
- b) An oxidizing flame can be recognized by the small white cone which is shorter, much bluer in color and more pointed than that of the neutral flame. The outer flame envelope is much shorter and tends to fan out at the end on the other hand the neutral and carburizing envelopes tend to come to a sharp point.
 - c) An oxidizing flame burns with a decided loud roar. An oxidizing flame tends to be hotter than the other two flames. This is because of excess oxygen which causes the temperature to rise as high as 6300°F and not heat up as much thermally inert carbon.
 - d) When applied to steel, an oxidizing flame especially at high temperatures tends to combine with many metals to form hard, brittle, low strength oxides. This indicates that the excess oxygen is combining with the steel and burning it. Moreover, an excess of oxygen causes the weld bead and the surrounding area to have a scummy or dirty appearance. This flame will ruin most metals and should be avoided, except as noted below.
 - e) 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 most
 - o Copper base metals
 - o Zinc base metals, and
 - o A few types of ferrous metals, such as manganese steel and cast iron

A stronger oxidizing flame is used in the welding of brass or bronze. The oxidizing atmosphere, in these cases, creates a base metal oxide that protects the base metal. For example, in welding brass, the zinc has a tendency to separate and fume away. The formation of a covering copper oxide prevents the zinc from dissipating.

*To **conclude**, for most welding operations the Neutral Flame is correct, but the other types of flames are sometimes needed for special welds, e.g., non-ferrous alloys and high carbon steels may require a reducing flame, whilst zinc bearing alloys may need an oxidizing flame for welding purposes.*

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 slag produced by the welding operation.

Safety check

- 1) Read carefully the safety considerations;
- 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 hot;
- 4) Always have a suitable fire extinguisher near 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.

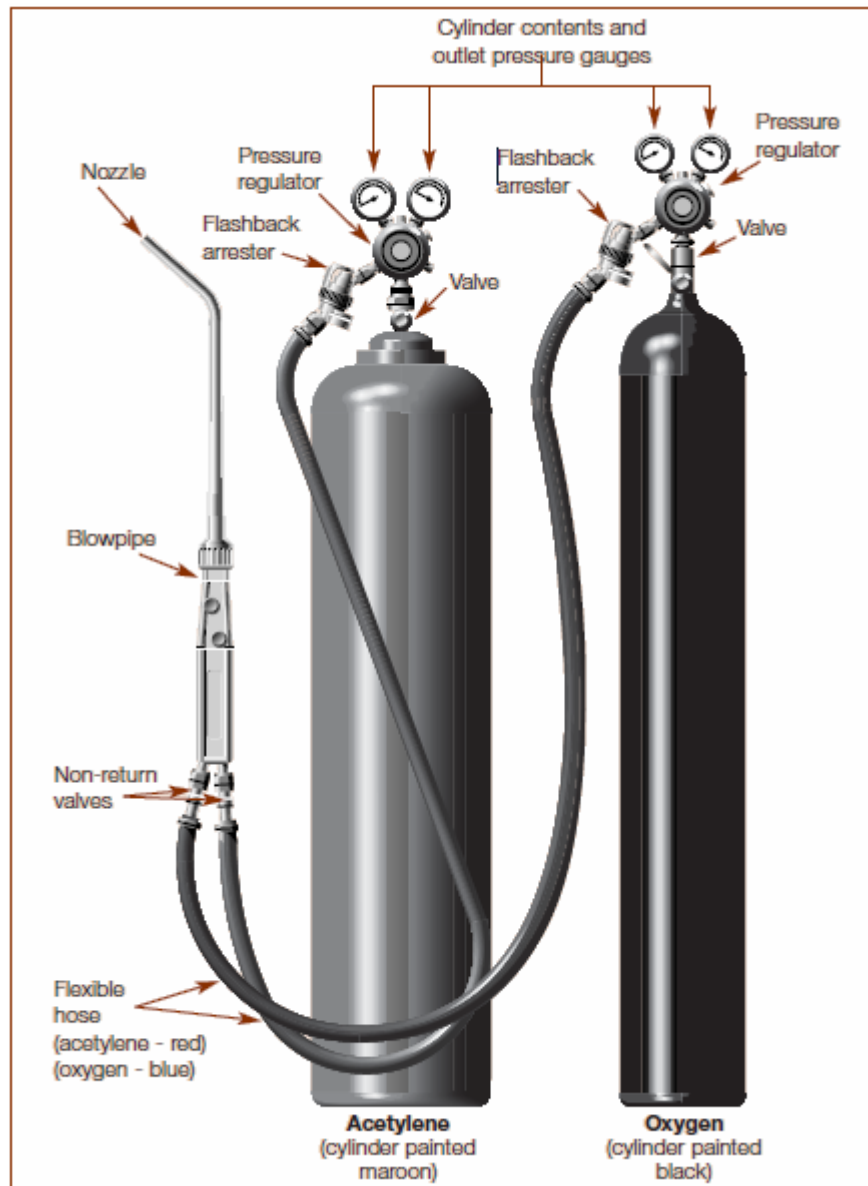
Caution

- 1) If a cylinder falls over and breaks the main valve off, the cylinder will become a missile and cause extreme damage.
- 2) Wear a leather apron or similar protective clothing and welding gloves when using an oxyacetylene torch.
- 3) Always use proper welding goggles. Do not use sunglasses because they do not filter the extreme ultraviolet light as effectively. The plastic used in sunglass lenses will not protect your eyes from sparks. Use face mask and valved respirators.
- 4) Never point the lighted flame toward another person or any flammable material.
- 5) Always light the oxyacetylene torch with the striker. A cigarette lighter or match would put your hand too close to the igniting tip.
- 6) Wherever possible, use a heat shield behind the component you are heating. This will prevent nearby objects from becoming hot.

- 7) After heating a piece of metal, label it as "HOT" with a piece of chalk so that others will not attempt to pick it up.

Component identification

It is important to learn the names of all associated equipment and auxiliaries related to oxy-acetylene process. Some parts of this illustration are labeled.



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, the other 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 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 right hand thread and the acetylene connector is a left hand 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 tables below.

Low Pressure or Injector Type Torch

Tip Size No.	Oxygen, psi	Acetylene, psi
0	9	1
1	9	1
2	10	1
3	10	1
4	11	1
5	12	1
6	14	1
7	16	1
8	19	1
10	21	1
12	25	1
15	30	1

Equal Pressure Type Torch

Tip Size No.	Oxygen, psi	Acetylene, psi
1	2	2
3	3	3
4	3	3
5	3.5	3.5
6	3.5	3.5
7	5	5
8	7	7
9	9	9
10	12	12

The choice of the tip size depends on the thickness of the metal to be joined. Larger torch tip sizes cause higher amount of oxygen and fuel to flow out causing the release of more heat.

Notes:

1. Tips are provided by a number of manufacturers, and sizes may vary slightly.

2. Oxygen pressures are approximately the same as acetylene pressures in the balanced pressure type torch. Pressures for specific types of mixing heads and tips are specified by the manufacturer.

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 to open the valve. The oxygen tank valve is a backstop valve and should be opened all the way in order to completely seal. 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 ultra violet rays, which will damage your eyes. It is absolutely vital that you are wearing the right safety gear: gloves and tinted goggles or face mask. So put them on and adjust them comfortably.

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 in to increase the pressure and out 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

Caution

- Check all connections before lighting the torch.
- NEVER use a match or butane lighter to light the flame. Always use a flint and steel spark lighter to light the oxygen acetylene flame.
- BEFORE LIGHTING TORCH, be positive that hose, tanks, or any inflammable material will not be exposed to heat, flame, or sparks.

- Never stand directly in front of or behind a regulator when opening the cylinder valve.
- Turn both cylinders off immediately when the torch flashes back or is burning on the inside: first oxygen and then acetylene.
- Never open both fuel (acetylene) and oxygen valves before lighting the preheat flame. ALWAYS turn the oxygen cylinder valve all the way open.
- Open the acetylene cylinder valve not more than one turn. One-half turn is preferred.

Adjust the flame

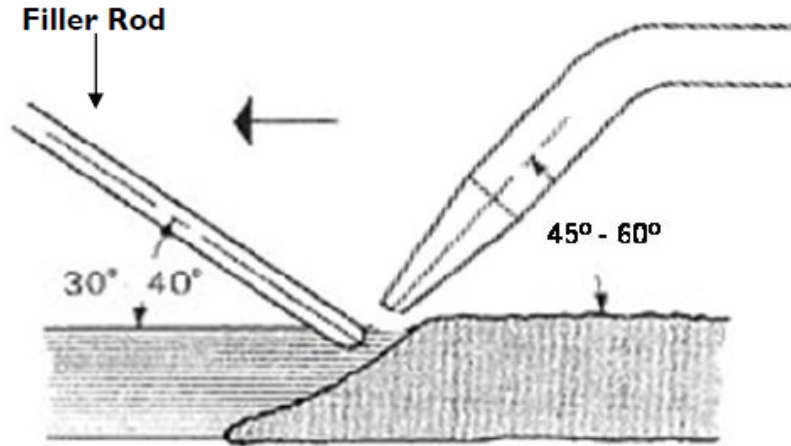
As you open the oxygen valve, you will see the color of the flame change. The pure acetylene flame is yellow, and it will change to blue as you add the oxygen. Continue to open the oxygen valve until you can observe a small, sharp blue cone in the center of the torch flame. This is the “neutral” flame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

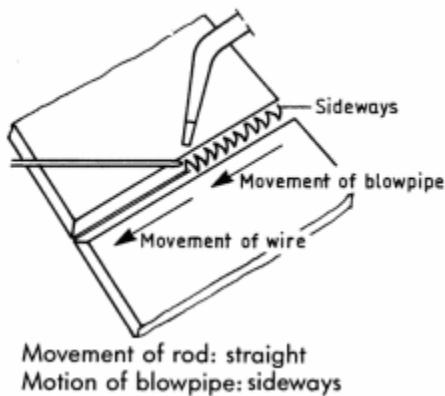
The torch tip should be positioned above the metal plate so that the white cone is at a distance of 1.5 to 3.0 mm from the plate. The torch should be held at an angle of 45 to 60° from the horizontal plane.



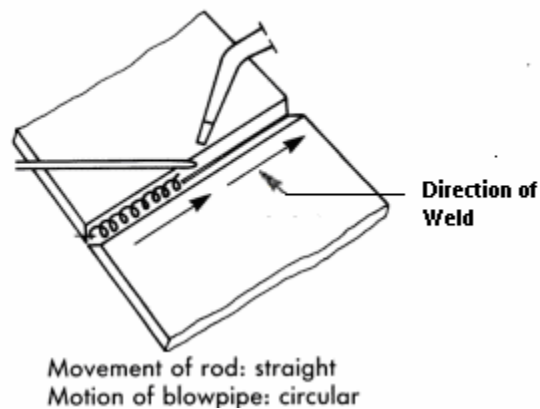
The torch movement along the joint should be either oscillating or circular. In forehand welding, the torch is moved in the direction of the tip. This tends to preheat before the white cone of the tip melts it. In backhand welding the torch moves backwards. The outer blue flames are directed on the already welded joint. This allows the joint to be continuously annealed relieving the welding stresses. This welding allows a better penetration as well as form 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.

Forehand



Backhand Welding



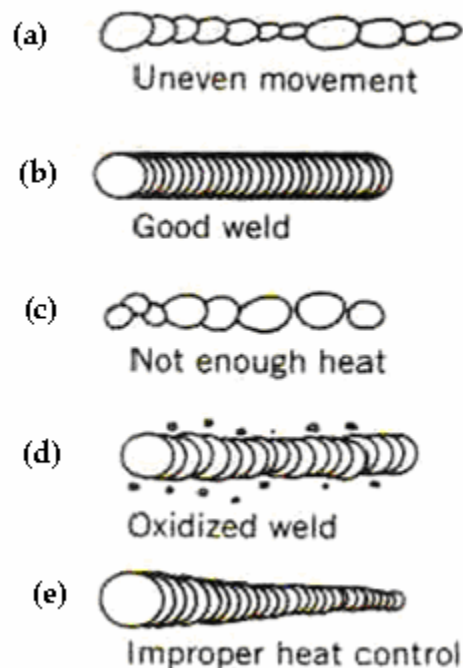
Oxy-fuel welding can be used for all the types of joints in all positions. Overhead usage requires additional skill to safeguard the welder. The various butt joint edge preparations are shown in the adjacent figure.

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.

Weld Appearances

Welding gas pressures are set in accordance with the manufacturer's recommendations. The welder will modify the speed of welding travel to maintain a uniform bead width. Trained welders are taught to keep the bead the same size at the beginning of the weld as at the end. If the bead gets too wide, the welder increases the speed of welding travel. If the bead gets too narrow or if the weld puddle is lost, the welder slows down the speed of travel. Welding in the vertical or overhead positions is typically slower than welding in the flat or horizontal positions.

The welder must add the filler rod to the molten puddle. The welder must also keep the filler metal in the hot outer flame zone when not adding it to the puddle to protect filler metal from oxidation. Do not let the welding flame burn off the filler metal. The metal will not wet into the base metal and will look like a series of cold dots on the base metal. There is very little strength in a cold weld. When the filler metal is properly added to the molten puddle, the resulting weld will be stronger than the original base metal.



Weld Appearances

To Extinguish the Flame and Stop Welding

1. When the welding or cutting operation is finished, close the torch acetylene valve first and then turn off the torch oxygen valve.
2. Close the oxygen cylinder valve.
3. Release the pressure in the hose and regulator by opening the oxygen control valve on the torch.
4. Release the pressure on the oxygen regulator diaphragm by turning the regulator to the minimum pressure position.
5. Close the oxygen control valve on the torch.
6. Repeat the same procedure for purging acetylene.

Caution

- ALWAYS weld at least 5 feet from the cylinders
- ALWAYS place the welding tip so that it points to the side of the torch to which the acetylene hose is attached
- DO NOT use any oil or grease on any oxygen or acetylene connections
- NEVER hammer on oxygen or acetylene regulators or stuck valves
- BEWARE OF HIGH ACETYLENE PRESSURE. NEVER USE ACETYLENE GAS WHEN THE PRESSURE IS GREATER THAN 15 POUNDS PER SQ. IN. (acetylene gas when compressed to more than 15 pounds per sq. in. become a very high explosive.)
- DO NOT hold welding or cutting tip too close to your work
- NEVER LEAVE TORCH BURNING AND GO AWAY FROM IT
- NEVER leave torch valves open

Perfecting the Weld

There are several factors that impact on the quality of weld. These factors include:

- Tip size
- Rod size

- Flame size
- Preparation of metal
- Torch or rod angle
- Distance between torch and work
- Speed and method of torch movement
- Maintenance of equipment

Tip and rod size

You need to select the proper tip size for the job to get the correct heat for the metal being welded. Some general guidelines include:

- Tips need to be selected to match the size of filler rod used and the thickness of the gauge metal being welded. The larger the filler rod, the thicker the metal, the higher the number of tip to be used.
- As a basic rule of thumb, choose a rod size that is the same thickness as the metal that you are welding.
- Tip sizes 3, 5 and 7 are common sizes to use for steel between 1/16" and 1/8" thick.

Flame Size

If the puddle is not moving properly, it may be because of incorrect tip size or it may mean you need to adjust your torch valve setting slightly. Remember that you also need to have the torch set for the correct flame type – usually neutral.

Preparation of Metal

Metal should be free of rust, grease, oil and paint. Use a grinder or wire brush to remove rust or paint. Anything that has had oil or grease on it should be avoided as it is potentially toxic and flammable when heated.

Torch or Rod Angle

The angle between the torch flame and the steel helps you to move the weld puddle where you want it. Change the angle that you are working until you find the angle that works best, usually 45 to 60 degrees.

Distance between torch and work

The closer you hold the torch to your work, the more heat is created. The greater heat increases the depth of penetration of the weld and makes the weld puddle narrower.

Speed and method of torch movement

Slower speed will make a wider weld with a deeper penetration. The object is to get a flat weld. To achieve that you may need some slight back and forth or oval motions with the torch. A steady, even speed and movement is important to achieving a quality weld.

Maintenance of equipment

If your tip becomes plugged, the flame will go sideways and splutter or go out. You need to be sure that your tips are kept clean with a tip cleaner.

The tip wears, becomes blackened, and pitted as you work with it. The tip cleaning tool has a flat file you can use to file the tip flat again. The cleaning tool has tip cleaners for each size of the tip. Be sure to use the right size of cleaner for the tip you are cleaning as you may damage it. Be very careful when using these cleaners as they can break off inside the tip.

Advantages of Gas Welding –

- 1) Welder has considerable control over the rate of heat input, the temperature of the weld zone, and the oxidizing or reducing potential of the welding atmosphere;
- 2) As the source of heat and filler metal are separated, the metal deposition can be easily controlled and heat properly adjusted giving rise to a satisfactory weld;
- 3) Welding equipment is portable and can be operated at remote places. Besides gas welding, the equipment can be used for preheating, post heating, braze welding, torch brazing and it is readily converted to oxygen cutting;
- 4) Weld bead size and shape and weld puddle viscosity are also controlled in the welding process because the filler metal is added independently of the welding heat source;
- 5) Gas welding is ideally suited to the welding of thin sheet, tubes, and small diameter pipe. It is also used for repair welding. Thick section welds, except for repair work, are not economical.

Limitations of gas welding:

- 1) Gas flame takes a long time to heat up the metal than an arc;

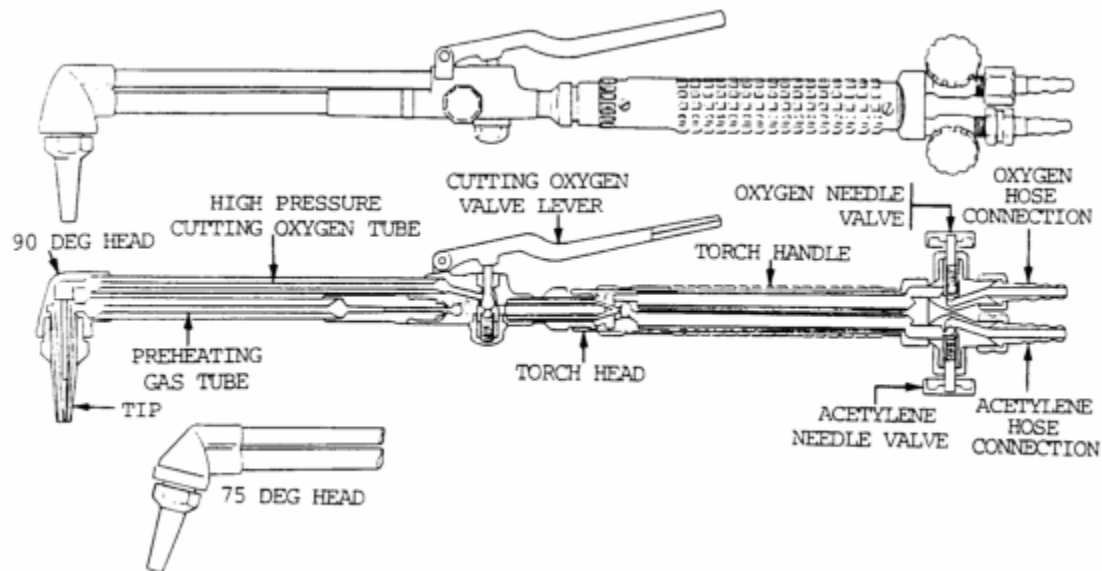
- 2) Flame temperature is less than the temperature of the arc;
- 3) Slower speed of welding compared electric arc welding;
- 4) Heavy sections cannot be joined efficiently;
- 5) For heavy sections proper penetration may not be achieved;
- 6) Refractory metals (e.g., tungsten, molybdenum, tantalum, etc.) and reactive metals (e.g., titanium and zirconium) cannot be gas welded;
- 7) Flux used in the filler metal provides fumes which are irritating to the eyes, nose, throat and lungs;
- 8) More safety is recommended in gas welding;
- 9) Acetylene and oxygen are expensive gases;
- 10) Prolonged heating of the joint may results in large HAZ. This often leads to increased grain growth, more distortion and, in some cases, loss of corrosion resistance.

Applications of Gas Welding –

- 1) For joining of thin materials. The process is used extensively for soldering copper tubing;
- 2) For joining materials in whose case excessively high temperatures or rapid heating and cooling of the job would produce unwanted or harmful changes in the metal;
- 3) For joining materials in whose case extremely high temperatures would cause certain elements in the metal to escape into the atmosphere;
- 4) For joining most ferrous and nonferrous metals, e.g., carbon steels, alloy steels, cast iron, aluminum, copper, nickel, magnesium and its alloys, etc;
- 5) In automotive and aircraft industries. In sheet metal fabricating plants, etc.

SECTION – 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 $\frac{1}{4}$ " to more than 12.0" in thickness.



Cutting Torch

OPERATION OF CUTTING EQUIPMENT

Setting up the oxyacetylene equipment and preparing for cutting must be done carefully and systematically to avoid costly mistakes. Refer below the Step-by-Step instructions before any attempt is made to light the torch:

- 1) Secure the cylinders so they cannot be accidentally knocked over. A good way to do this is to either put them in a corner or next to a vertical column and then

secure them with a piece of line. After securing the cylinders, remove the protective caps.

- 2) Standing to one side, crack each cylinder valve slightly and then immediately close the valve again. This blows any dirt or other foreign matter out of the cylinder valve nozzle. Do not bleed fuel gas into a confined area because it may ignite. Ensure the valves are closed and wipe the connections with a clean cloth.
- 3) Connect the fuel-gas regulator to the fuel-gas cylinder and the oxygen regulator to the oxygen cylinder. Using a gang wrench, snug the connection nuts sufficiently to avoid leaks.
- 4) Back off the regulator screws to prevent damage to the regulators and gauges and open the cylinder valves slowly. Open the fuel-gas valve only one-half turn and the oxygen valve all the way. Some fuel-gas cylinders have a hand-wheel for opening the fuel-gas valve while others require the use of a gang wrench or T-handle wrench. Leave the wrench in place while the cylinder is in use so the fuel-gas bottle can be turned off quickly in an emergency. Read the high-pressure gauge to check the contents in each cylinder.
- 5) Connect the RED hose to the fuel-gas regulator and the GREEN hose to the oxygen regulator. Notice the left-hand threads on the fuel-gas connection.
- 6) To blow out the oxygen hose, turn the regulator screw in (clockwise) and adjust the pressure between 2 and 5 psig. After the hose has been purged, turn the screw back out again (counterclockwise) to shutoff the oxygen. Do the same for the fuel-gas hose, but do it ONLY in a well-ventilated place that is free from sparks, flames, or other possible sources of ignition.
- 7) Connect the hoses to the torch. The RED (fuel-gas) hose is connected to the connection gland with the needle valve marked "FUEL." The GREEN (oxygen) hose is connected to the connection gland with the needle valve marked "OXY."
- 8) With the torch valves closed, turn both regulator screws clockwise to test the hose connections for leaks. If none are found, turn the regulator screws counterclockwise and drain the hose by opening the torch valves.
- 9) Select the correct cutting tip and install it in the cutting torch head. Tighten the assembly by hand, and then tighten with your gang wrench.

- 10) Adjust the working pressures. The fuel-gas pressure is adjusted by opening the torch needle valve and turning the fuel-gas regulator screw clockwise. Adjust the regulator to the working pressure needed for the particular tip size, and then close the torch needle valve. To adjust acetylene gas, you should set the gauge pressure with the torch valves closed. To adjust the oxygen working pressure, you should open the oxygen torch needle valve and proceed in the same manner as in adjusting the fuel-gas pressure.
- 11) In lighting the torch and adjusting the flame, always follow the manufacturer's directions for the particular model of torch being used. This is necessary because the procedure varies somewhat with different types of torches and, in some cases, even with different models made by the same manufacturer. In general, the procedure used for lighting a torch is to first open the torch oxygen needle valve a small amount and the torch fuel-gas needle valve slightly more, depending upon the type of torch. The mixture of oxygen and fuel gas coming from the torch tip is then lighted by means of a spark igniter or stationary pilot flame. Adjust the preheating flame to neutral.
- 12) Hold the torch so that the cutting oxygen lever or trigger can be operated with one hand. Use the other hand to steady and maintain the position of the torch head to the work. Keep the flame at a 90 degree angle to work in the direction of travel. The inner cones of the preheating flames should be about 1/16 in. (1.6 mm) above the end of the line to be cut. Hold this position until the spot has been raised to a bright red heat, and then slowly open the cutting oxygen valve.
- 13) Cutting is initiated by heating the edge or leading face (as in cutting shapes such as round rod) of the steel to the ignition temperature (approximately bright red heat) using the pre-heat jets only, then using the separate cutting oxygen valve to release the oxygen from the central jet. The oxygen chemically combines with the iron in the ferrous material to instantly oxidize the iron into molten iron oxide, producing the cut. If the cut has been started properly, a shower of sparks will fall from the opposite side of the work. Move the torch at a speed which will allow the cut to continue penetrating the work. A good cut will be clean and narrow.
- 14) When cutting billets, round bars, or heavy sections, time and gas are saved if a burr is raised with a chisel at the point where the cut is to start. This small portion

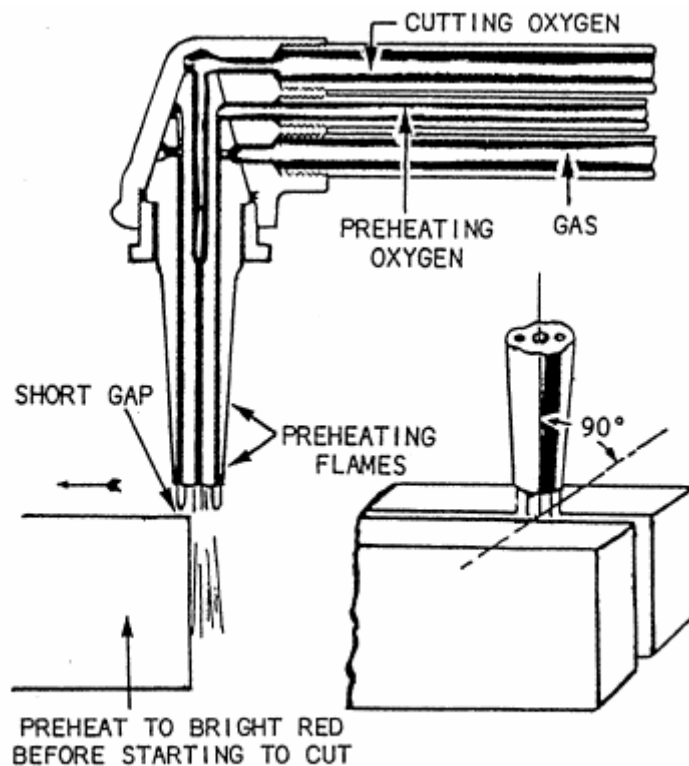
will heat quickly and cutting will start immediately. A welding rod can be used to start a cut on heavy sections. When used, it is called a starting rod.

Caution

NEVER use matches to light the torch; their length requires bringing the hand too close to the tip. Accumulated gas may envelop the hand and, upon igniting, result in a severe burn. Also, never light the torch from hot metal.

CUTTING MILD-CARBON STEEL

To cut mild-carbon steel with the oxyacetylene cutting torch, you should adjust the preheating flames to **neutral**. Hold the torch perpendicular to the work, with the inner cones of the preheating flames about 1/16 inches above the end of the line to be cut (refer figure below). Hold the torch in this position until the spot you are heating is a bright red. Open the cutting oxygen valve slowly but steadily by pressing down on the cutting valve lever.

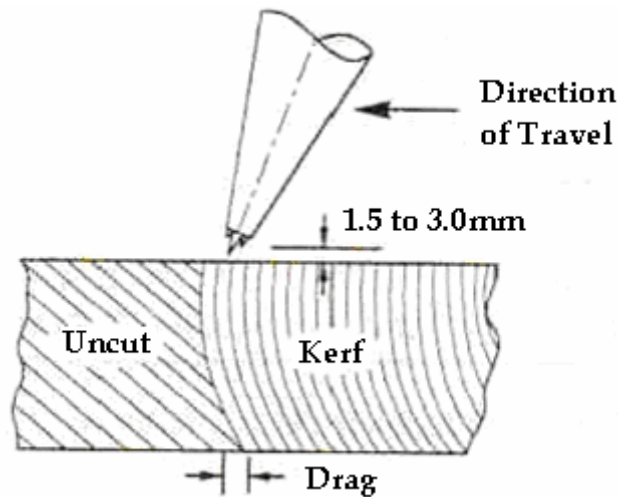


Position of torch tip for starting a cut

When the cut is started correctly, a shower of sparks will fall from the opposite side of the work, indicating that the flame has pierced the metal. Move the cutting torch forward

along the line just fast enough for the flame to continue to penetrate the work completely. If you have made the cut properly, you will get a clean, narrow cut that looks almost like it was made by a saw.

A good cut is characterized by very small or negligible drag. When the torch is moved too rapidly, the metal at the bottom does not get sufficient heat to get oxidized and cut and hence there is a large drag. When the torch is moved slowly, all the preheated metal is burnt away by the oxygen jet and a large amount of slag is generated.

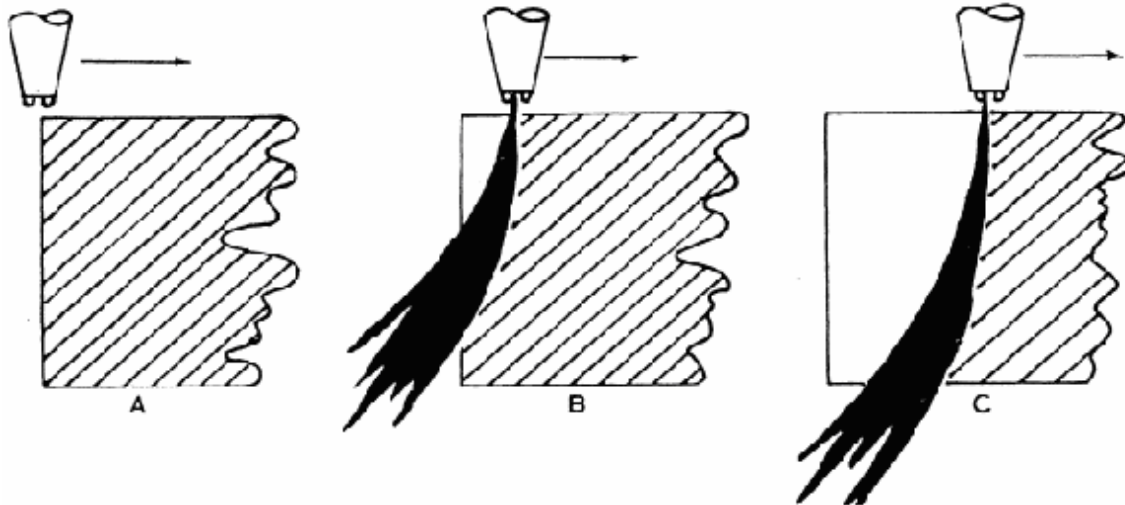


Drag Figure

***Kerf** - The narrow slit formed in metal as cutting progresses. The ideal kerf is a narrow gap with a sharp edge on either side of the work piece; overheating the work piece and thus melting through it causes a rounded edge.

Cutting Thick Steel

Steel, that is greater than 1/8 inch thick, can be cut by holding the torch so the tip is almost vertical to the surface of the metal. If you are right-handed, one method to cut steel is to start at the edge of the plate and move from right to left. Left-handed people tend to cut left to right. Both directions are correct and you may cut in the direction that is most comfortable for you. Figure below shows the progress of a cut in thick steel.



Progress of a cut in thick steel

After heating the edge of the steel to a dull cherry red, open the oxygen jet all the way by pressing on the cutting lever. As soon as the cutting action starts, move the torch tip at an even rate. Avoid unsteady movement of the torch to prevent irregular cuts and premature stopping of the cutting action.

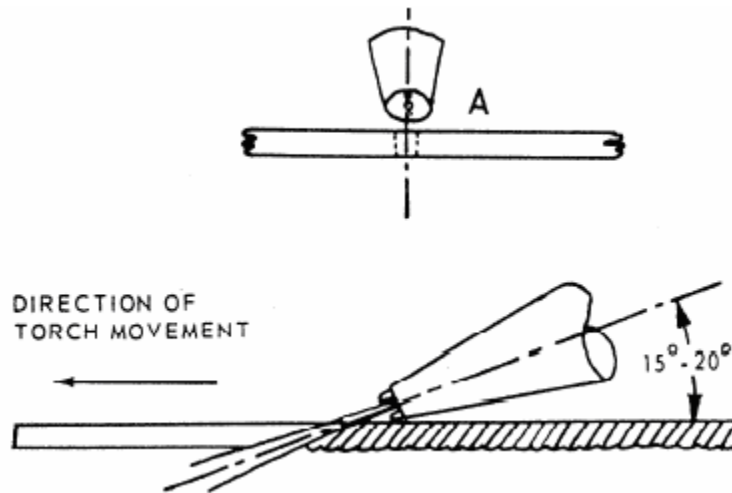
To start a cut quicker in thick plate, you should start at the edge of the metal with the torch angled in the opposite direction of travel. When the edge starts to cut, bring the torch to a vertical position to complete the cut through the total thickness of the metal. As soon as the cut is through the metal, start moving the torch in the direction of travel.

Two other methods for starting cuts are used. In the **first** method, you nick the edge of the metal with a cold chisel at the point where the cut is to start. The sharp edges of the metal upset by the chisel will preheat and oxidize rapidly under the cutting torch, allowing you to start the cut without preheating the entire edge of the plate. In the **second** method, you place an iron filler rod at the edge of a thick plate. As you apply the preheat flames to the edge of the plate, the filler rod rapidly reaches the cherry red temperature. At this point, turn the cutting oxygen on and the rod will oxidize and cause the thicker plate to start oxidizing.

Cutting Thin Steel

Though the gas cutting is more useful with thick plates, thin sheets (1/8 inch or less) can also be cut by this process taking special precautions. Tip size chosen should be as small as possible. If small tips are not available, then the tip is inclined at an angle of 15 to 20 degrees and point the tip in the direction the torch is traveling. By tilting the tip, you

give the preheating flames a chance to heat the metal ahead of the oxygen jet, as shown in figure below. If you hold the tip perpendicular to the surface, you decrease the amount of preheated metal and the adjacent metal could cool the cut enough to prevent smooth cutting action.



Torch position for cutting thin sheets

Common gauge settings for cutting

- 1/4" material - Oxygen: 30-35psi; Acetylene: 3-9 psi
- 1/2" material - Oxygen: 55-85psi; Acetylene: 6-12 psi
- 1" material - Oxygen: 110-160psi; Acetylene: 7-15 psi

General Cutting Info

There is a wide variety of cutting tip styles and sizes available to suit various types of work. The thickness of the material to be cut generally governs the selection of the tip. The cutting oxygen pressure, cutting speed, and preheating intensity should be controlled to produce narrow, parallel sided kerfs. Cuts that are improperly made will produce ragged, irregular edges with adhering slag at the bottom of the plates. Table below identifies cutting tip numbers, gas pressures, and hand-cutting speeds used for cutting mild steel up to 12 in. (304.8 mm) thick.

Oxyacetylene Cutting Information

Plate thickness (inches)	Cutting tip (size number)	Oxygen (psi)	Acetylene (psi)	Hand cutting speed (inches per minute)
1/4	0	30	3	16 to 18
3/8	1	30	3	14.5 to 16.5
1/2	1	40	3	12 to 14.5
3/4	2	40	3	12 to 14.5
1	2	50	3	8.5 to 11.5
1 1/2	3	45	3	6 to 7.5
2	4	50	4	5.5 to 7
3	5	45	4	5 to 6.5
4	5	60	5	4 to 5
5	6	50	5	3.5 to 4.5
6	6	55	6	3 to 4
8	7	60	6	2.5 to 3.5
10	7	70	6	2 to 3
12	8	70	6	1.5 to 2

Note: Check the torch manufactures data for tip identification number and optimum pressure settings

Safety Precautions in Cutting Operations

1. Never use a cutting torch where sparks will be a hazard;
2. Sweep floors clean and wet them before cutting;
3. Provide a bucket of water or sand to catch dripping slag;
4. Use fire-resistant guards, partitions or screens if necessary;
5. Take extra precautions while working in greasy, dirty, or gaseous atmosphere to prevent explosions;
6. Keep combustible materials at least 35 ft. away from cutting operations;
7. Never cut near ventilators;
8. Never use oxygen to dust off clothing or work pieces or as a substitute for compressed air;

9. Locate the nearest fire extinguisher before performing any welding or cutting operation;
10. Purge oxygen and acetylene hoses before lighting torch;
11. Never move cylinders without protective caps in place;
12. Wear personal protective equipment. Wear welding gloves, helmet, leather apron, welding chaps, leather shoes, welding goggles, and other personal protective equipment to help prevent weld burns and injury. Make sure the welding goggles or face shield have at least a No. 4 filter lens;
13. Do not wear clothing made of synthetic fibers while welding;
14. Fasten cylinders securely. Do not handle cylinders roughly. Chain cylinders in an upright position to a wall or cart. When regulators are not on cylinders, keep safety caps in place. Caps will prevent damage to cylinder valves;
15. Never use oil on welding equipment. Oil and grease may ignite spontaneously, when in contact with oxygen;
16. Open cylinder valves correctly. Open the valve on the acetylene cylinder no more than three-fourths of a turn (maximum one turn) so it can be closed quickly in case of emergency. Open the valve on the oxygen tank fully. While welding or cutting, leave the valve wrench in position;
17. Keep the tip pointed away from your body. Do not saturate your clothing with oxygen or acetylene. Before and while lighting the flame, keep the tip pointed away from your body;
18. Light the flame with an approved lighter. Using matches to light the torch brings fingers too close to the tip;
19. Set the operating pressure carefully. Never use acetylene at a pressure over 15 psi;
20. Do not leave the work area until the cylinder valves are closed. Be sure the cylinder valves are closed and pressure is relieved from the hoses before you leave the work area;
21. Do not cut on containers that have held flammable materials;

22. Store oxygen cylinders away from acetylene cylinders. A non-combustible wall at least 5 feet high should be used to separate cylinders.

Applications

- Oxygen cutting would be useful only for those materials which readily get oxidized and the oxides have lower melting points than the metals. So it is most widely used for ferrous materials.
- Oxygen cutting is NOT used for materials like aluminum, bronze, stainless steel which resist oxidation.
- Cutting of high carbon steels and cast irons require special attention due to formation of heat affected zone (HAZ) where structural transformation occurs.

Typical Facts about Gas Cutting:

- 1) The flame is not intended to melt the metal, but to bring it to its ignition temperature. The oxygen flow rate is critical — too little will make a slow ragged cut; too much will produce a wide concave cut. Oxygen lances and other custom made torches do not have a separate pressure control for the cutting oxygen, so the cutting oxygen pressure must be controlled using the oxygen regulator. The oxygen cutting pressure should match the cutting tip oxygen orifice. Consult the tip manufacturer's equipment data for the proper cutting oxygen pressures for the specific cutting tip. (Oxy-acetylene torches can easily cut through ferrous materials in excess of 2 inches and oxygen lances are used in scrapping operations and cut sections thicker than 8 inches. A thermic lancer is a tool which uses rapid oxidation of iron to cut through almost any material);
- 2) The oxidation of iron by gas cutting is highly exothermic. Once started, steel can be cut at a surprising rate, far faster than if it was merely melted through. At this point, the pre-heat jets are there purely for assistance. The rise in temperature will be obvious by the intense glare from the ejected material, even through proper goggles;
- 3) Since the melted metal flows out of the work piece, there must be room on the opposite side of the work piece for the spray to exit. When possible, pieces of metal are cut on a grate that lets the melted metal fall freely to the ground;

- 4) Oxy-acetylene cutting speed is usually twice as fast as a cut-off grinder. Besides, an oxy-fuel torch is light, small and quiet and needs very little effort to use, compared to a cut-off grinder, which is heavy, noisy and needs considerable operator exertion and may vibrate severely. Cut-off grinders are useless for thick sections;
- 5) Gas cutting can be done manually or by a machine. The manual cutting is used for general purpose work and for straight line cutting. In machine cutting the torch is mounted on a rail and both rail and the torch can move simultaneously along the two mutually perpendicular axes in the horizontal plane with the help of servo motors. Robotic oxy-fuel cutters provide flexibility to produce almost any shape from large steel plates. There is provision to hold more than one torch so that large number of identical pieces can be cut at the same time;
- 6) Hydrocarbon gases, such as propane, butane and LPG are also used for cutting up scrap to save money as these gases are far cheaper than acetylene on BTU-for-BTU basis. With a right torch (injector style), propane can make a faster and cleaner cutting and is much more useful for heating and bending applications than acetylene.

Note that hydrocarbon gases, such as propane, butane and natural gas, are NOT suitable for welding ferrous materials due to their oxidizing characteristics.

SECTION – 4

SAFE WORKING PRACTICES

This section describes safe practices developed from experience in using welding and cutting equipment. Continuous research, development, and field experience result in reliable equipment and safe installation, operation, and servicing practices. Accidents occur because of improper equipment use or maintenance. Some safe practices are based on common sense; others may require technical volumes to explain. In any event, rules should be followed.

Work Area

- The work area must have a fireproof floor. Concrete is best;
- Use heat resistant shields to protect walls and unprotected flooring from sparks and hot metal;
- Oxygen itself will not burn; however, the presence of pure oxygen will accelerate combustion and cause materials to burn with great intensity;
- Use tables with fireproof tops. Firebricks work well to protect table and bench surfaces;
- Chain or otherwise secure cylinders to a wall, bench or cart;
- Keep the area between you and the cylinder valves unobstructed;
- Keep cylinders clear of areas where they may be struck or knocked over.
- Post “No Smoking” warning sign in area.

Hazardous Fume Accumulation & Ventilation

- Maintain adequate ventilation to prevent the accumulation of toxic fumes and gases; (Refer to ANSI Standard Z49-1);
- Work in a confined space only while it’s being ventilated, or when wearing an air-supplied respirator. Do NOT use oxygen for ventilation.

Protective Clothing

- Wear protective clothing – gauntlet gloves, hat, and high safety toe shoes. Keep shirt collar and pocket flaps buttoned and wear cuffless trousers to prevent entry

of sparks and slag. Hot metal such as welding rod, electrode stubs and work pieces should never be handled without gloves;

-
- Wear safety goggles or glasses with side shields, appropriate filter lenses or plates (protected by clear cover glass). This is a MUST for welding or cutting (and chipping), to protect the eyes from radiant energy and flying metal. Replace cover glass when broken, pitted, or spattered. For eye protection refer ANSI Z 87.1;
- Do not wear oily or greasy clothing while welding or cutting. They are readily ignited by sparks;
- Wear ear protection when working overhead or in a confined space. A hard hat should be worn when others work overhead.

Fires and Explosions

- Fire or explosion can occur if the equipment is improperly installed, repaired or used. Be aware that: flying sparks or falling slag can pass through cracks, along pipes, through windows or doors, and through wall or floor openings, out of sight of the goggled operator. Sparks and slag can fly 35 feet;
- Inspect oxy-fuel apparatus for oil, grease, or damaged parts;
- Do not use the oxy-acetylene apparatus if oil or grease is present or if damage is evident;
- Never use oil or grease on or around any oxy-acetylene apparatus;
- Keep flames, heat and sparks away from cylinders and hoses;
- Have a fire extinguisher of proper type and size on hand in the work area, know where they are located in the shop;
- Open the oxygen valve all the way to seal the cylinder back seal packing;
- Never test for leaks with a flame. Use soapy water;
- After work is complete, inspect the area for any possible fires or smoldering materials.

Fuel Leakage and Detection

- Joints and hoses should be checked for leaks before any welding is attempted. Whilst acetylene may be detected by its distinctive smell (usually at levels of less than 2%) oxygen is odorless;
- Leak detection is best carried out applying a weak (typically 0.5%) solution of a detergent in water or a leak detecting solution from one of the gas supply companies. It is applied to the joints using a brush and the escaping gas will form bubbles. On curing the leak, the area should be cleaned to remove the residue from the leak detecting solution.

Use of Oxygen

- Always refer to oxygen by correct name; Say “oxygen”, never “air”. It is very important that oxygen not be confused with compressed air, or used as a substitute for compressed air;
- Oxygen is not flammable but even materials that do not burn in air usually burn in oxygen. Those that burn slowly in air can ignite easily and burn violently in an oxygen enriched atmosphere;
- Never use oxygen to ventilate confined spaces. Use air to replace atmospheric oxygen consumed by welding or cutting. Oxygen-enriched (> 23%) or oxygen-depleted (<19%) atmospheres should be avoided;
- Never saturate clothes with oxygen. Clothing saturated with oxygen will burn intensely when ignited;
- Grease, oil, oil-bearing materials, greasy gloves and rags, and other combustibles that can readily ignite in the presence of oxygen must be kept from any oxygen equipment;
- Keep oxygen cylinders at least 20 feet from fuel gas cylinders or other readily combustible materials particularly grease or oil OR separated by a five foot non-combustible barrier having a fire resistance rating of at least ½ hour);
- If liquid oxygen is used, cylinders must be transported, stored and used in upright position to maintain gaseous state for safety devices, and to prevent liquid from reaching regulator.

Use of Acetylene Gas

- Refer to fuel gas by its correct name. Say “acetylene”, not “gas”. The other gases – natural gas, methane, or the liquefied petroleum (LP) gases, propane and butane – differ from acetylene, and from each other, in heat content, flammability limits, and safe handling requirements. Therefore, be specific when you refer to any gas;
- Acetylene cylinders must be transported, stored, and used in upright position to avoid discharge of acetone with the gas during use;
- CGA 5.3.3.13 or G-1 calls for a withdrawal rate “not to exceed 1/10(one-tenth) of the capacity of the cylinder per hour during intermittent use. For full withdrawal of the contents of the cylinder on a continuous basis, the flow rate should be no more than 1/15 (one-fifteenth) of the capacity of the cylinder per hour”;
- If cylinder valves leaks, immediately close valve on fuel gas cylinder. If valve still leaks immediately, remove cylinder outdoors, away from possible source of ignition and notify cylinder supplier at once;
- Acetylene cylinder wrench should be left on an open cylinder valve and removed after closing valve. Use only approved wrench, available from cylinder supplier.

Pressure regulators

- NEVER withdraw gas from a cylinder or pipeline except through an approved pressure reducing regulator;
- Regulator relief valve is designed to protect only the regulator from overpressure; it is not intended to protect any downstream equipment. Provide such protection with one or more relief devices;
- Never connect a regulator to a cylinder containing gas other than that for which the regulator was designed;
- Remove regulator from cylinder when transporting unsecured on a cart not designed for such purpose;
- The following symptoms indicate a faulty regulator:
 - Leaks - if gas leaks externally.
 - Excessive creep - if the regulator delivery pressure continues to rise with downstream valve closed.

- Faulty gauge - if gauge pointer does not move off “stop” pin when pressurized, nor return to “stop” pin after pressure release.

Cylinders

- Cylinders must be handled carefully to prevent leaks and damages to their walls, valves, or safety devices: a. Avoid electrical circuit contact with cylinders including third rails, electrical wires, or welding circuits. They can produce arcs that may damage the cylinder wall, causing a possibly serious accident. Never strike an arc on a cylinder;
- Identifying gas content; Use only cylinders with name of gas marked on them; do not rely on color of cylinder to identify contents. Notify supplier if content of cylinder is not clearly identifiable. Never deface or alter name, number, or other markings on a cylinder. It is illegal and hazardous;
- Never use a cylinder or its contents for other than its intended use. Never use as a support, roller, or clothes rack;
- Secure from falling. Always chain or secure cylinders upright when a regulator (and hose) is connected to it;
- Transporting cylinders. With a crane, use a secure support such as a platform or cradle designed for the purpose. Do NOT lift cylinders off the ground by their valves or caps, or by chains, slings, or magnets;
- Do NOT expose cylinders to excessive heat, sparks, slag, and flame, etc. that may cause rupture;
- Do not allow contents to exceed 130°F;
- Protect cylinders, particularly valves from bumps, falls, falling objects, and weather. Keep caps securely tightened on cylinders not in use or being moved.
- Stuck valve. Do NOT use a hammer or metal wrench (except special key for acetylene) to open a cylinder valve that cannot be opened by hand. Notify your supplier;
- Cylinder fittings should never be modified or used for other than their intended purpose.

Torch

- Examine seating surface of torch and connections before use for wear and damage. Worn or damaged parts should be replaced;
- Do not attempt repair of torches (or regulators). If faulty, send them for repair to manufacturer's designated repair center where special techniques, tools and tests are used by trained personnel;
- Torch is not a hammer. Never use it to chip slag. Such misuse can distort torch or tip to create hazards. Use appropriate tool for the job;
- Torch tip cleaning should be done only with specifically-designed cleaning tip orifices to avoid enlarging or damaging the exit holes.

Hoses

- NEVER use hose other than that designed for the specified gas. A general hose identification rule is: **red** for fuel gas, **green** for oxygen, and **black** for inert gases;
- Use RMA-CGA Grade T hose for fuel gas (including acetylene) to prevent hose failures. Grades R and RM are for use with acetylene only;
- Use ferrules or clamps designed for the hose (not ordinary wire or other substitute) to connect hoses to fittings;
- Use only standard brass fittings to splice hose. No copper tubing splices;
- Avoid long runs to prevent kinks and abuse. Suspend hose off ground or protect it from damage by vehicles, sparks, slag or open flames;
- Examine hose regularly for leaks, wear, and loose connections. Immerse pressured hose in water; bubbles indicate leaks;
- Repair leaky or worn hose by cutting out damaged area and splicing. Do NOT use tape.

Proper Connections

- Clean cylinder valve outlet of impurities that may clog orifices and damage seats before connecting regulator;
- Match regulator to cylinder. Before connecting, be sure the regulator label and cylinder marking agree, and the regulator inlet and cylinder outlet connections are proper for the intended service;

- Do not use pipe compound or lubricant. Tighten but do not force connection. If connection leaks, close cylinder valve, depressurize line. Disassemble, clean, and retighten the valve. For metal-to-metal seating, use correct wrenches, available from your supplier. For O-ring connections, hand-tighten;
- Avoid using adapters between cylinder and regulator, but if unavoidable, use a CGA adapter (available from your supplier). Use two wrenches to tighten adapter with both right and left hand threads;
- Regulator outlet (or hose) connections may be identified by **right** hand threads for oxygen and **left** hand threads (with grooved hex on nut or shank) for fuel gas.

Safety in Operation & Use

- Acetylene is unstable at pressures above 15 PSI;
- NEVER release acetylene, or any other fuel gas in confined spaces, where it might cause a fire or explosion;
- DO NOT open an acetylene cylinder valve more than one turn. This permits adequate flow of acetylene from the cylinder and allows for quick closing of the valve in an emergency situation;
- To open and close acetylene cylinder valves not provided with hand-wheels, always use the special wrench or key provided by the supplier. Leave the wrench or key in position, ready for immediate use should it be necessary to close the valve promptly. (When several cylinders are manifold together, a wrench on every cylinder is not required.)
- More than 1/10 the capacity of the cylinder should not be used per hour. This causes the acetylene to rapidly come out of solution, like carbon dioxide bubbles violently fizzing from a fizzy soft drink that has just been shaken;
- Oxygen cylinder contains pressures over 2000 PSI and must be handled carefully;
- Pure oxygen will accelerate combustion to the point that it can cause an explosion;
- Do not use oxygen to dust off clothing or the work area;

- Use the correct size wrench when tightening or loosening fittings. They are made of brass and can be damaged easily;
- When not in use, cylinder must have a protective cap installed;
- NEVER use a cylinder that is leaking. If leakage around the cylinder valve stem is detected after the valve has been opened (one and one-half turns for an acetylene cylinder, as far as possible for an oxygen cylinder) close the valve tight and return it to your supplier after tagging the cylinder to tell him that the valve is unserviceable;
- Stand to the side of the equipment when opening the cylinder valves, and open them slowly. This will limit the risk of injury due to exploding regulators;
- Only use a friction lighter to light your torch;
- Hot metal left out should be marked “HOT” so the others will not be burned by it;
- Use pliers or tongs to grab hot metal;
- Do not weld or cut on a closed container;
- Inspect the hoses frequently and when necessary replace them;
- ALWAYS keep oxygen and acetylene cylinders vertical upright at all times. Do not store them in the horizontal position; if an acetylene cylinder is used in the horizontal position, solvent may be lost and flame quality may be affected;
- Store oxygen cylinders separately from fuel gas cylinders. Unless a fire-resistant noncombustible partition, at least 5 feet high, is used to separate the two types of cylinders or a minimum 20-foot separation should be maintained;
- Oil, grease, coal dust, and similar organic materials are easily ignited and burn violently in the presence of high oxygen concentrations. Never allow such materials to come in contact with oxygen or oxy-acetylene equipment, including hose. Oxy-acetylene apparatus does not require lubrication;
- DO NOT use pipe-fitting compounds or thread lubricants for making connections. Connections for oxy- acetylene and oxygen-fuel gas equipment are designed so that they can be made up tight without the need for lubricants or sealants. Of special importance is the need to keep all materials containing oil and grease away from equipment that uses oxygen.

Lighting Torch

- Purge lines daily before lighting to remove air and other contaminants from hoses. Open each torch valve in turn long enough for the pure gas to purge out any gas mixtures. Shut one valve before opening the other. Do NOT purge in a confined space, in the presence of flame or other source of ignition, or toward people;
- Point tip away from yourself and others when lighting and using torch;
- Use spark lighter or pilot light to light torch. Do NOT use matches or cigarette lighter, hand burns may result;
- Light as follows: Open fuel valve and ignite gases flowing from tip. Adjust fuel valve for full flow without blowing off. Adjust oxygen valve to desired flame.

Extinguishing Flame:

- Close oxygen and (without delay) fuel torch valves tightly;
- Check for gas leak from tip or valves;
- Leave torch in safe position to prevent accidental dislodging that may open valves or cause damage;
- Leaving Equipment unattended (lunch or overnight):
 - Extinguish flame by closing torch valves;
 - Close cylinder valves.
- Leaving equipment unattended (over weekend or longer):
 - Extinguish flame by closing torch valves and close cylinder valve;
 - Drain gas from regulators by opening torch valves, venting gases in safe direction, then closing valves one at a time. If in public area, disconnect and store equipment to prevent unauthorized or accidental use, which may create a hazard;
 - Purge lines before lighting or reuse.

Backfires and Flashbacks

A backfire is a loud noise produced by the explosion of gases at the cutting or welding tip usually following a minor flashback of the flame, extinguishment, and re-ignition at the tip. Repeated backfire can cause tip to overheat and eventually cause a sustained flashback. Causes are:

- Bringing tip too close to work or touching it;
- Foreign particles entering tip and impeding gas flow;
- Overheated tip, such as caused by working in corners;
- Trying to operate with incorrect or too low a gas flow.

Backfire remedy

If torch does not stay lit, close oxygen gas and fuel gas valves - in that order. Re-light fuel gas with spark lighter only. If stable flame is not obtained by adding oxygen, close torch valves, check tip cleanliness and regulator settings, purge, and relight.

Flashback and its causes

A flashback is a burning back of the flame into the tip, or into or through the torch. It is also called a sustained burning in tip or torch. A flashback can be caused by faulty or misused equipment. If it doesn't cause fire or hose rupture, then it may produce a hissing or squealing due to burning inside torch or tip (usually at the mixer). Examples of faulty or misused equipment are:

- Failure to purge.
- Incorrect pressures.
- Distorted or loose tips or adapter seats.
- Kinked hoses.
- Clogged tip or torch orifices.
- Overheated tip or torch.

To stop a flashback:

- Do NOT touch any parts of the tip, mixer, or extension that may be hot;
- When squealing sound is heard: the internal combustion must be extinguished immediately by shutting off torch fuel gas and oxygen valves in that order;

- Wait a MOMENT, OR UNTIL NO SQUEALING is heard on reopening fuel gas valve, then relight;
- When squealing is not heard (and flashback is indicated by flow of hot gases from tip): flame is inside the torch. Immediately shut off cylinder valves and wait. After five minutes, if torch, regulator, and cylinder are cool, disconnect equipment and inspect torch and regulator for inner damage.

Chemical exposure

A less obvious hazard of welding is exposure to harmful chemicals. Exposure to certain metals, metal oxides, or carbon monoxide can often lead to severe medical conditions. Damaging chemicals can be produced from the fuel, from the work-piece, or from a protective coating on the work-piece.

- Lead-, Cadmium-, Zinc-, Mercury-, and Beryllium-bearing and similar materials, when welded (or cut) may produce harmful concentrations of toxic fumes. Long-term exposure to beryllium may result in shortness of breath, chronic cough, and significant weight loss, accompanied by fatigue and general weakness. Adequate local exhaust ventilation must be used, or each person in the area as well as the operator must wear an air-supplied respirator. For beryllium, both must be used;
- Other alloying elements such as arsenic, manganese, silver, and aluminum can cause sickness to those who are exposed. Metals coated with or containing materials that emit toxic fumes should not be heated unless coating is removed from the work surface, the work area is well ventilated, or the operator wears an air-supplied respirator;
- More common are the anti-rust coatings on many manufactured metal components. Zinc, cadmium, and fluorides are often used to protect irons and steels from oxidizing. Galvanized metals have a very heavy zinc coating. Exposure to zinc oxide fumes can lead to a sickness named "metal fume fever". This condition rarely lasts longer than 24 hours, but is still unpleasant.
- Vapors from chlorinated solvents can be decomposed by the flame heat to form PHOSGENE, a highly toxic gas, and other lung and eye-irritating products. The ultraviolet (radiant) energy of the arc can also decompose trichloroethylene, perchlorethylene and other chlorinated solvent vapors to form phosgene. DO NOT WELD or cut where solvent vapors can be drawn into the welding or cutting

atmosphere or where radiant energy can penetrate to atmospheres containing even minute amounts of the solvent vapors;

(Data from Occupational Safety and Health Administration)

Additional information regarding welding and cutting safe practices can be found in Standards and Pamphlets published by ANSI, NFPA (standard 51), AWS, and CGA. The National Electrical Code, Occupational Safety and Health Administration and local industrial codes also provide mandatory requirements for equipment installation, use, and service.

CASE STUDY

This case study is presented for people who use acetylene for welding, cutting and similar processes. It provides information on the fire and explosion hazards of acetylene.

Acetylene cylinder explosion

An operator was lighting an oxy/acetylene cutting torch. There was a flashback to the acetylene cylinder, which started to vibrate. Three minutes later the cylinder exploded. The cylinder split into two parts. The largest part shot through a window and travelled 23 meters before embedding itself in an embankment at the factory boundary.

The workshop was badly damaged. The windows were blown out and the roof collapsed. The explosion also lifted the roof of the main factory building, which had to be replaced. The cost of the damage was over £1 million.

Fortunately, no-one was injured, because the operator realized that the cylinder was in a dangerous condition. He raised the alarm and the factory was immediately evacuated.

What went wrong?

The operator did not fully appreciate the hazards of acetylene. He did not follow the recommended procedures or take adequate precautions. In particular:

1. The correct lighting up procedure was not followed. The gas hoses were not purged.
2. The acetylene gas was not at the correct pressure.
3. The gas cylinders were not protected with flashback arresters.

A flashback can occur...if there is a flammable mixture of fuel gas and oxygen in the hoses when the torch is lit. If it is not stopped, the flame will ignite the mixture and will

travel backwards from the torch, along the hoses, through the regulator and into the cylinder. A flashback can trigger decomposition of the acetylene in the fuel hose, in the regulator and in the cylinder itself.

Hazards of acetylene cylinders

There are a number of incidents each year where a flashback into an acetylene cylinder triggers decomposition, leaving the cylinder in a dangerous, unstable condition. An explosion of the cylinder only three minutes after a flashback is extremely rare. In most cases, if the decomposition is identified at an early stage, there is time for the building to be evacuated, the fire brigade to be called and for emergency action to be taken.

To make an unstable cylinder safe, the fire brigade may have to apply cooling water for many hours. It could be several days before the cylinder can be moved, because moving the cylinder could restart or accelerate the decomposition.

These incidents put at risk anyone in the vicinity of the cylinder and anyone who tries to make the cylinder safe, such as the emergency services.

Acetylene cylinders can be used safely

An acetylene cylinder has a different design from most other gas cylinders. It consists of a steel shell containing a porous mass. The porous mass is a cellular structure which completely fills the cylinder. The acetylene gas in the cylinder is dissolved in acetone which is absorbed by the porous mass. Decomposition of the acetylene is usually triggered by heat. For example, if the cylinder is:

1. Involved in a fire;
2. Scorched by flames from a blowtorch; or
3. Involved in a flashback.

The porous mass is designed to slow down or stifle any decomposition of the gas. From the start of decomposition to the cylinder exploding should take several hours. This will usually (but not always) provide time for emergency action.

Decomposition can be triggered more easily and can proceed more rapidly if:

1. The porous mass has been damaged by repeated flashbacks or by mishandling or dropping the cylinder;

2. The cylinder valve is leaking gas (an open or leaking valve increases the rate of decomposition within the cylinder); or
3. The acetylene in the hoses is above the pressure recommended by the supplier. For most welding and cutting processes, the acetylene pressure should not exceed 9 psi.

What can you do to prevent flashback?

Training

Do not use oxy/acetylene equipment unless you have been trained.

Use the correct lighting-up procedures

Before lighting the blowpipe, purge the hoses by opening the gas supply to each hose for a few seconds. This will flush out any flammable mixtures of gases in the hose. Purge one hose at a time and close the blowpipe valve after purging. Use a well-ventilated area.

Maintain non-return valves

- Fit non-return valves (often called check valves) on the torch, to prevent back-feeding of gas into the hoses.
- Inspect regularly and replace damaged non-return valves. Note: non-return valves will not stop a flashback once it has occurred.

Keep nozzles in good condition

Poorly maintained nozzles cause turbulent gas flow, which increases the risk of flashback.

- Inspect nozzles regularly. Make sure they are not blocked by dirt or spatter. Replace damaged nozzles.
- Do not hold the nozzle too close to the workpiece. The nozzle can overheat and cause a flashback.

If a flashback does occur:

- Immediately close the cylinder valves, both acetylene and oxygen, if it is safe to do so. The flame should go out when the fuel gas (acetylene) is shut off. If the

flame cannot be put out at once, evacuate the area and call the emergency fire services and the gas supplier.

- Check any acetylene cylinder which has been involved in a flashback or which may have been affected by fire or flames. If it becomes warm or starts to vibrate, evacuate the building immediately and call the emergency fire services. Also call the gas supplier.
- Do not attempt to move an unstable cylinder. Direct water spray at the cylinder body, if it is safe to do so.
- Before using again, check flashback arresters and other components which may have been damaged by the flashback. Replace if necessary. If in doubt, consult the supplier.

Backfire or flashback procedure

After an un-sustained backfire in which the flame is extinguished:

- Close the blowpipe control valves (fuel gas first);
- Check the nozzle is tight;
- Check the pressures on regulators;
- Re-light the torch using the recommended procedure;

If the flame continues to burn:

- Close the oxygen valve at the torch (to prevent internal burning);
- Close the acetylene valve at the torch;
- Close cylinder valves or gas supply point isolation valves for both oxygen and acetylene;
- Close outlets of adjustable pressure regulators by winding out the pressure-adjusting screws;
- Open both torch valves to vent the pressure in the equipment;
- Close torch valves;
- Check nozzle tightness and pressures on regulators;
- Re-light the torch using the recommended procedure

If a flashback occurs in the hose and equipment, or fire in the hose, regulator connections or gas supply outlet points:

- Isolate oxygen and fuel gas supplies at the cylinder valves or gas supply outlet points (only if this can be done safely);
- If no risk of personal injury, control fire using first aid fire-fighting equipment;
- If the fire cannot be put out at once, call emergency fire services after the equipment has cooled, examine the equipment and replace defective components.

When a backfire has been investigated and the fault rectified, the torch may be re-lit. After a flashback, because the flame has extended to the regulator it is essential not only to examine the torch, but the hoses and components must be checked and, if necessary, replaced. The flashback arrestor should also be checked according to manufacturer's instructions and, with some designs, it may be necessary to replace it.

Note: The fitting of flashback arresters is not a substitute for safe working practices.

Always read and understand these safe practices before attempting to install, operate or service the equipment. Comply, as applicable, with the practices for particular equipment used, and their instruction manuals for personal safety and the safety of others. Failure to observe these safe practices may cause serious injury or death. Habitual safety promotes confident equipment use.

Annexure - 1

Terminology

- 1) **Acetone:** A flammable liquid used in acetylene cylinders to dissolve and store acetylene.
- 2) **Acetylene:** A colorless, flammable gas that is used in oxyfuel welding. Acetylene is the most commonly used gas for mixing with oxygen to fuel oxyfuel torches.
- 3) **Airtight:** Not allowing any gases or air to penetrate. An airtight joint will not leak any gas.
- 4) **Aluminum:** A silvery white metal that is soft, light, and has a high strength-to-weight ratio. Aluminum is one of the most difficult metals to weld.
- 5) **Arc welding:** A joining process that uses electricity to generate the heat needed to melt the base metals.
- 6) **Braze pool:** The pool formed by the melted filler metal during braze welding. The temperature to melt the filler metal is low enough that the pieces being joined do not melt.
- 7) **Braze welding:** A process in which a filler metal is melted at a temperature above 840° F (450° C), but below the melting point of the base metals to fill in a gap between two base metals. Braze welding differs from brazing because the filler metal is used to fill a gap.
- 8) **Brazing:** A joining process that is used to combine dissimilar metals at temperatures lower than welding.
- 9) **Butt joint:** A joint formed by joining two pieces of metal edge to edge.
- 10) **Capillary action:** The ability of a substance to draw a liquid upwards against the force of gravity. In brazing, capillary action causes a filler metal to be drawn into the space between work pieces.
- 11) **Copper:** A reddish metal that is very ductile, thermally and electrically conductive, and corrosion resistant. Copper can be welded using limited methods.
- 12) **Cutting:** The use of an oxyfuel torch to separate metal from a workpiece. Oxyfuel cutting uses an additional high-pressure stream of oxygen to cut metal.

- 13) **Cylinder:** A container for compressed gases. Each gas is stored in a unique type of cylinder.
- 14) **Die:** A reusable mold that holds heated liquid metal and imparts its shape as the metal cools. Oxygen cylinders are shaped in dies.
- 15) **Distillation:** The process by which oxygen is extracted from the air to be stored in a cylinder.
- 16) **Ductility:** The ability of a metal to be drawn, stretched, or formed without breaking.
- 17) **Edge joint:** A joint formed by joining the edges of two pieces of metal that are parallel to each other.
- 18) **Ferrous metal:** A metal that contains iron. Ferrous metals are the most common type of welded metal.
- 19) **Filler metal:** A type of metal sometimes added to the joint in fusion welding. Filler metal adds to the strength and mass of the welded joint.
- 20) **Flashback:** A torch malfunction in which the flame briefly or continually moves up into the torch and hoses. If a flame reaches the hoses, an explosion can occur.
- 21) **Flashback arrestor:** A part of an oxyfuel outfit that is installed between the hoses and the torch. A flashback arrestor reduces the chances of flashback occurring while a torch is used.
- 22) **Flux:** A non-metallic material used to protect the weld puddle and solid metal from atmospheric contamination.
- 23) **Hose connector:** The part of an oxyfuel torch where the flashback arrestor is attached to the torch.
- 24) **Impurities:** Any elements contained in an oxyfuel weld that are not the metal being joined or the filler metal.
- 25) **Injector:** The part of an injector torch that pulls low-pressure acetylene into the torch and mixes it with oxygen.
- 26) **Injector torch:** A type of torch that uses lower-pressure acetylene and features an internal injector that pulls the acetylene into the torch.
- 27) **In-tip mixer:** A welding tip that contains a mixing chamber as part of the tip.

- 28) **Joining:** Bringing two separate materials together through some type of forming. Joining is one of the main ways metals can be formed.
- 29) **Lap joint:** A joint formed by two overlapping pieces of metal.
- 30) **Low-carbon steel:** Carbon steels that contain less than 0.3% carbon. Also referred to as mild steel, low-carbon steel is the most commonly welded metal.
- 31) **MAPP gas:** Also called methylacetylene-propadiene gas. A liquefied petroleum gas that can be used in oxyfuel processes. The main disadvantage of MAPP gas is that it costs much more than acetylene.
- 32) **Metal:** A hard, crystalline solid that conducts electricity and heat. It is shiny when polished, and it can be hammered, bent, formed, and machined.
- 33) **Mixing chamber:** A part of an oxyfuel outfit that is connected to the tip of the torch, or is part of the tip. The mixing chamber is where the two gases are combined before being burned by the flame.
- 34) **Non-ferrous metal:** A metal that does not contain iron. Nonferrous metals are more difficult to weld than ferrous metals.
- 35) **Orifice:** The hole or holes at the end of a torch tip. The shape and number of holes determine the use of the tip.
- 36) **Outside corner joint:** A joint formed by the edges of two metal pieces being welded together at an angle of around 90 degrees. The weld is done on the outside of the corner.
- 37) **Oxide:** A chemical compound containing oxygen and one other element. Oxides form during oxyfuel welding is harmful to the weld.
- 38) **Oxy-fuel welding:** A joining process that uses a mix of gases to fuel a torch to join two metal parts.
- 39) **Oxygen:** A nonmetallic element that is colorless, odorless, and tasteless. Oxygen is one of the two gases used in oxyfuel welding.
- 40) **Porous:** Full of holes that allow the material to absorb liquids. The material inside an acetylene cylinder is porous, enabling it to hold acetone.
- 41) **Positive pressure torch:** A torch that uses equal pressures of oxygen and acetylene and does not have an injector.

- 42) **Propylene:** Also known as propane. A flammable gas that can be used in oxyfuel welding instead of acetylene.
- 43) **Soldering:** A joining process in which a filler metal is melted at temperatures below 840° (450° C) to form a joint between two base metals. Soldering is often used for delicate projects such as jewelry and electronics.
- 44) **Stainless steel:** A type of steel that contains more than 15% chromium and exhibits excellent corrosion resistance. Stainless steel can be welded using many methods.
- 45) **T-joint:** A joint formed when the edge of one piece is welded to the surface of another piece at a 90° angle.
- 46) **Torch:** A tool used to generate the flame for oxyfuel welding by mixing oxygen and a fuel gas, usually acetylene.
- 47) **Torch body:** Also called the handle. The part of the torch held by the welder. Inside the torch body are hoses which direct the flow of gases to the mixing chamber.
- 48) **Unstable:** Highly reactive and dangerous, possibly explosive. Unstable chemicals require careful handling to ensure safety.
- 49) **Valve:** The part of the torch used to regulate the amount of oxygen and fuel gas flowing into the torch.
- 50) **Watertight:** Not allowing any liquids to penetrate. A watertight joint will not leak any liquids at all.
- 51) **Welding rod:** Also know as a filler metal. Filler metals come in rods that are used during the welding process.
- 52) **Welding tip:** The end of the torch where the flame is ignited. Tips are usually interchangeable, and are made of solid copper.