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An American National Standard

Operator's Manual for Oxyfuel Gas Cutting



American Welding Society

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Operator's Manual for Oxyfuel Gas Cutting

Prepared by
AWS Committee on Oxyfuel Gas Welding
and Cutting

Superseding
AWS C4.2-78

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

The new revised manual for oxyfuel gas cutting includes the latest procedures to be used in conjunction with oxyfuel gas cutting equipment. The manual also includes the latest safety requirements. Complete lists of equipment are available from individual manufacturers.



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Foreword

(This Foreword is not a part of ANSI/AWS C4.2-90, *Operator's Manual for Oxyfuel Gas Cutting*, but is included for information purposes only.)

This manual is intended for use by the oxyfuel gas cutter (operator). It describes the oxyfuel gas cutting process, including information relating to equipment, safety, and operating procedures.

Although many references are made to safe practice throughout this manual, it is strongly recommended that all operators become thoroughly familiar with all aspects of safe operation. A suggested standard is ANSI Z49.1, *Safety in Welding and Cutting*, available from the American Welding Society.

Much of the information in this manual is necessarily general in nature due to the large number of variations in equipment produced by various manufacturers. The manufacturer's manual should be consulted for details on safe installation and use of all equipment.

When equipment, or parts of equipment, need repair, the work shall be performed by skilled mechanics who have been properly instructed.

Table of Contents

	Page No.
<i>Personnel</i>	iii
<i>Foreword</i>	iv
<i>List of Figures</i>	vii
 1. <i>Scope</i>	 1
2. <i>Introduction</i>	1
3. <i>Equipment and Supplies</i>	1
3.1 Oxygen Supply	1
3.2 Fuel Supply	2
3.3 Pressure Regulators	2
3.4 Hoses and Fittings	3
3.5 Torches	3
3.6 Cutting Tips	4
3.7 Protective Clothing and Equipment	9
3.8 Cutting Machines	9
3.9 Use, Handling and Storage of Gas Cylinders	9
3.10 Working Environment	10
4. <i>Start Up and Shut Down Procedure</i>	10
4.1 Setting up Equipment	10
4.2 Lighting the Torch	12
4.3 Extinguishing the Torch	12
4.4 Shutting Down	12
4.5 Equipment not in Use	12
4.6 Re-Use of Equipment Already Connected for Use	12
5. <i>Flame Adjustment</i>	12
5.1 Types of Flames	12
5.2 Flashback and Backfire Safety Note	13
6. <i>Cutting Procedures—Hand Torches</i>	13
6.1 Starting Methods	13
6.2 Torch Position and Motion	13
6.3 Piercing	14
6.4 Oxygen Lancing	15
6.5 Gouging, Washing, and Special Applications	15
7. <i>Machine Oxygen Cutting</i>	17
7.1 Cutting Charts	17

7.2	Operating Techniques	17
7.3	Bevel Cutting	17
8.	<i>Hints for Best Selection of Tips, Speeds, and Pressures</i>	18
8.1	Correct Cutting Techniques	18
8.2	Common Cutting Faults	18
8.3	Tip Distance	19
8.4	Gas Adjustment	19
8.5	Bevel Cutting	20

List of Figures

Figure	Page No.
1 — Description of Oxyfuel Gas Cutting	2
2 — Oxygen Cylinder	3
3 — Fuel Gas Cylinders	4
4 — Pressure Regulators	5
5 — Hoses and Fittings	6
6 — Manual Oxygen Cutting Torch	6
7 — Combination Torch	7
8 — Three Hose Machine Torch	7
9 — Torches Classified According to Methods of Mixing	8
10 — Oxyfuel Gas Cutting Tips	9
11 — Oxyfuel Gas Cutting Tips—One and Two-Piece Designs	9
12 — Cutting Torch Starting a Cut and in Action	14
13 — Lead Torch Angle for Straight Line Cutting	14
14 — Oxygen Lance	15
15 — Special Application Tips	16
16 — Oxygen Orifice Design for Washing Tips	16
17 — Bevel Cutting	17

Operator's Manual for Oxyfuel Gas Cutting

1. Scope

This manual describes the equipment, procedures and safe practices for the oxyfuel cutting of steel. It is for the operators of both hand and machine torches and is recommended for management personnel associated with the oxyfuel cutting process.

2. Introduction

Oxyfuel gas cutting is a process whereby a metal (usually an iron base alloy) is heated to its kindling temperature (well below the melting point) by an oxyfuel gas flame and then burned rapidly by a regulated jet of oxygen. A cutting torch is used for this operation.

The process is a chemical reaction between iron and oxygen (Figure 1). When iron is heated to a temperature in excess of 1600°F (870°C) and then exposed to a stream of high purity oxygen, the iron oxidizes (burns) rapidly and produces a mixture of molten oxides and iron called *slag*. When cutting, a narrow slot called a *kerf* is formed as a result of removal of some of the metal by the cutting oxygen jet.

Oxyfuel gas cutting of steel has been used on material ranging in thickness from 1/32 in. (0.8 mm) to thicknesses in excess of 100 in. (2.5 m). The majority of cutting is done on steel from 1/4 in. (6 mm) to 2 in. (50.8 mm) in thickness. A skilled oxyfuel gas cutting operator using a mechanically guided torch can easily maintain tolerances as close as 1/32 in. (0.8 mm) on materials up to 2 in. (50.8 mm) thick.

Oxyfuel cutting offers advantages over machining methods in terms of speed, versatility, and cost. Cutting speeds of 20 in./min. (508 mm/min.) on 1 in.

(25.4 mm) steel are not uncommon. Almost any two-dimensional shape can be produced by oxyfuel gas cutting. Much of the versatility is due to the nature of the oxygen cutting jet, as it will operate in any axis with equal facility.

3. Equipment and Supplies

In order to perform oxyfuel gas cutting, the following are required as a minimum:

- (1) Oxygen
- (2) Fuel gas
- (3) Pressure regulators
- (4) Hoses
- (5) Torch
- (6) Cutting tips
- (7) Spark lighter
- (8) Tip cleaners
- (9) Protective clothing and safety equipment
(See ANSI-Z49.1, *Safety in Welding and Cutting*)

3.1 Oxygen Supply. Oxygen of high purity (99.5 percent minimum) is supplied in individual cylinders of various sizes (Figure 2) or may be distributed by pipeline from manifold cylinders or bulk liquid tanks. Oxygen from on-site oxygen generators, while of a lesser purity, may be used for flame cutting in some applications. Always call oxygen by its proper name, "OXYGEN". It should never be called "AIR". Regardless of the source, be sure that sufficient pressure and volume are available for the work to be done. Consult cutting apparatus manufacturer's literature for pressure and volume requirements. **CAUTION:** Oxygen supports combustion! Improper use

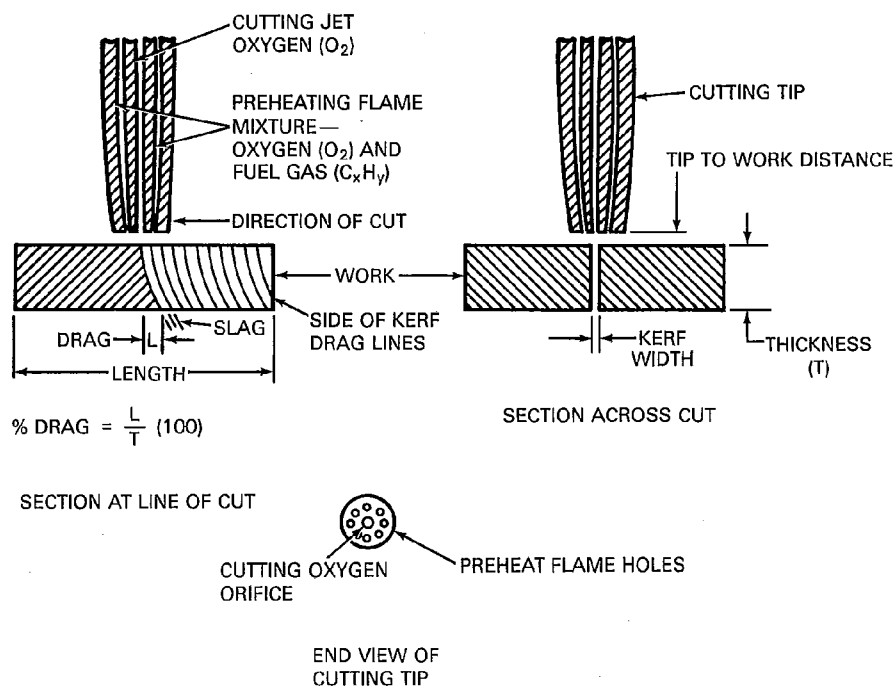


Figure 1—Description of Oxyfuel Gas Cutting

may result in fire or explosion. Never use oxygen in pneumatic tools, to clean equipment, or to dust off clothing.

3.2 Fuel Supply. Many different fuel gases are utilized in oxyfuel gas cutting. They include acetylene, propane, natural gas, methylacetylene-propadiene stabilized (MPS), propylene, hydrogen, and several propane or propylene base mixtures. The different fuel gases vary in flame characteristics. The oxyfuel gas cutter should become familiar with the proper flame adjustments for the fuel being used. A sufficient supply of fuel should always be available. Fuel gases are supplied in individual cylinders (Figure 3) or distributed by pipeline from manifolded cylinders or bulk sources. Never completely drain any cylinder or leave the valve open on "empty" cylinders. This could result in contamination of the cylinder.

Acetylene shall not be generated, piped (except in approved cylinder manifolds), or utilized at a pressure in excess of 15 psi (103 kPa) gauge pressure, or 30 psi (206 kPa) absolute pressure. Use at higher pressures is hazardous, because it creates the possibility of acetylene decomposition (explosion) from shock or heat. NOTE: The 30 psi (206 kPa) absolute pressure limit is intended to prevent unsafe use of

acetylene in pressurized chambers such as caissons, underground excavations, or tunnel construction. [Absolute pressure is equal to gauge pressure plus atmospheric pressure, which at sea level is about 15 psi (103 kPa). Thus, at sea level, a gauge reading of 15 psi (103 kPa) is equal to an absolute pressure of 30 psi (206 kPa).]

3.3 Pressure Regulators. Regulators are pressure control devices used to reduce high source pressures to desired working pressures. Regulators are adjusted by means of a pressure adjusting screw. Regulators may be single or two stage.

Two different types of regulators for use in oxyfuel gas cutting are available. One is for use on cylinders and the other is for attachment to valved outlets (stations) on gas piping systems (see Figure 4).

Cylinder regulators usually have two gauges; one to indicate cylinder pressure, the other to indicate working pressure. Station regulators have usually one gauge that indicates working pressures. Regulators designed for station use should *never* be attached to high pressure cylinders because cylinder pressure may exceed the design rating and result in damage to the equipment and injury to personnel. Use of cylinder regulators on pipelines is not recommended.

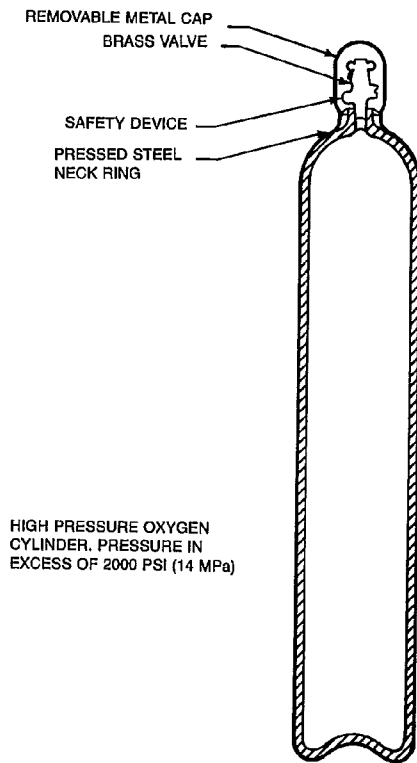


Figure 2—Oxygen Cylinder

because this may result in restricted gas flow. Regulators shall be used only with the gases for which they are designed. Never force a regulator connection.

Special precautions shall be observed in the use of oxygen regulators to reduce hazards of fire and explosion. Oxygen does not burn, but it vigorously supports combustion of other material. It is imperative to avoid any contact of oxygen regulators with oil, grease, dust, dirt, or any other foreign material that might contaminate them.

Before attaching an oxygen regulator to a valve, check that the regulator meets the pressure requirements of the oxygen supply. The regulator inlet connection, the valve outlet, and all other connections should be clean and free of oil, grease, or other contaminants. Oxygen regulators should not be handled with oily hands or gloves, and oil should never be applied to the threads of any nuts or screws on the regulators. Oxygen regulators should always be bled to zero pressure, and have the pressure adjusting screw backed out before opening the cylinder or sta-

tion valve. This is done to close the regulator valve seat and protect the regulator parts from damage due to high pressure surges.

3.4 Hoses and Fittings (see Figure 5). Only hoses and fittings specifically designed for oxyfuel gas cutting and welding should be used. Oxygen hoses used in the U.S.A. always are green in color. The fittings have right hand threads and a smooth outside surface. Fuel gas hoses are usually red in color. The fittings have left hand threads. The hex nuts are notched for easy identification.

All fittings are designed to form gas-tight seals with the application of very little mechanical force. Overtightening can damage them and cause a gas leak. A fuel gas hose or regulator should never be used for oxygen or vice versa.

Hoses should always be checked for kinks, burns, cuts, and other signs of damage before use. Tape or other temporary means should never be used to stop a leak. This creates a safety hazard that could result in a fire or a serious injury to personnel. A flame should not be used to test for a leak. An approved leak detector solution can be used, or the hoses can be submerged into clean water and observed for bubbles. Hoses should never be crimped to stop flow of gases.

Hoses and fittings used with any cutting apparatus should be of sufficient size to provide the required flow rate. The use of undersized hose or fittings or excessive hose length can cause pressure drops that may result in a low flow rate. Low flow rates can result in overheating of torches and possibly cause backfire (see 5.2).

3.5 Torches. The following are three basic types of cutting torches which are available in many styles and sizes:

(1) *Hand Torch* (see Figure 6). A torch consisting of a rear body and handle equipped with valves to control the preheat oxygen and fuel gas, a spring-loaded valve for the cutting oxygen, tubes to carry the gases, and a head to accept the cutting tip.

(2) *Combination Hand Torch* (see Figure 7). A torch consisting of a gas welding torch handle to which a cutting attachment is fastened. The valve to control the preheat oxygen is usually located on the cutting attachment. Other features are basically the same as the standard cutting torch.

(3) *Machine Torch* (see Figure 8). A torch consisting of a rear body usually equipped with valves to control the oxygen and fuel gas, tubes to carry the gases, and a head to accept the cutting tips—all

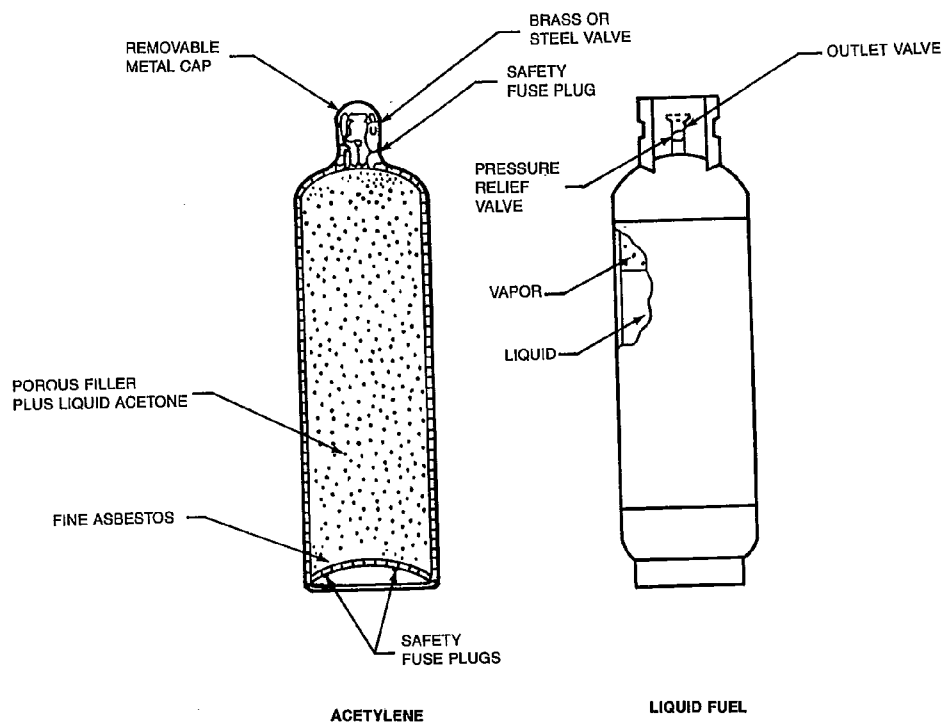


Figure 3—Fuel Gas Cylinders

encased in a larger tube or barrel for mounting on a cutting machine. They are usually in a straight configuration and may be equipped with a rack for positioning.

A hand or machine torch may have either two or three gas inlet hose connections. A two-hose torch has one inlet connection for fuel gas and one inlet for the combined preheat and cutting oxygen. A three-hose torch has separate inlet connections for fuel gas, preheat oxygen, and cutting oxygen. Three-hose torches are recommended when (1) precise preheat flame adjustment and cutting oxygen control are desired, (2) when large cutting oxygen volume is required, or (3) when remote control is desired.

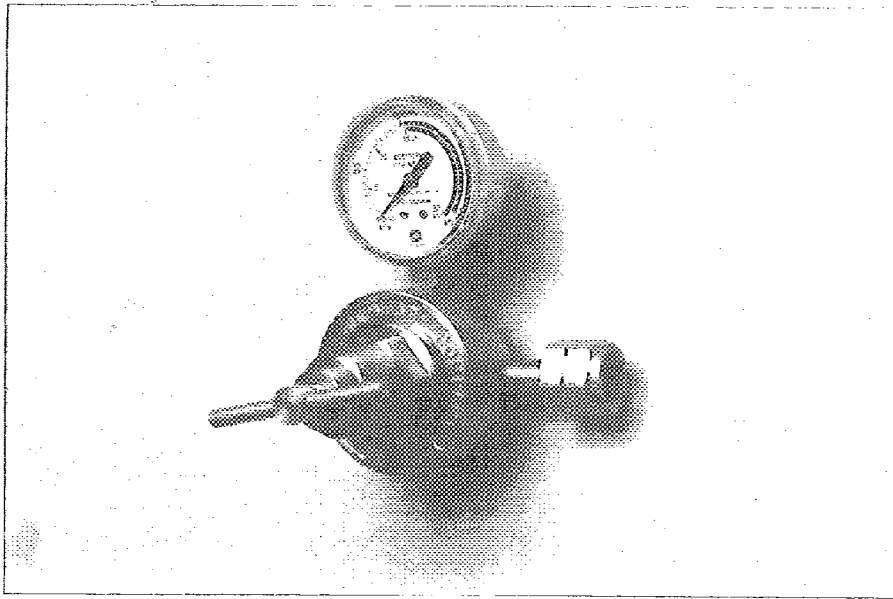
Torches are classified by the manner in which fuel and oxygen are mixed (see Figure 9). In the tip mix type, fuel gas and oxygen for the preheat flames are mixed in the tip. In the torch mix type, mixing takes place in the torch head or at some location back of the head.

Torches are also classified as either positive pressure or injector type. In the positive pressure type (sometimes called equal pressure), both the oxygen and fuel gas are supplied at pressures high enough to

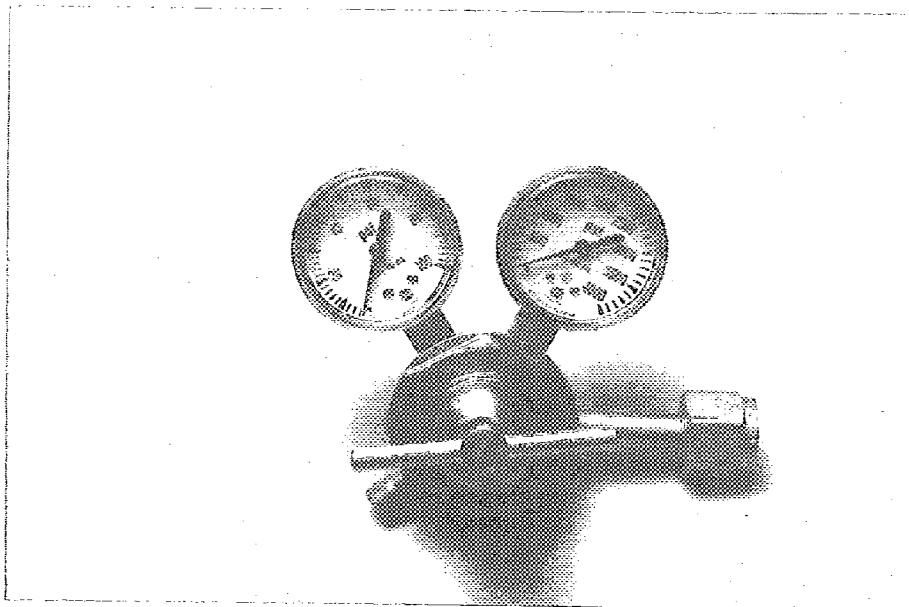
obtain sufficient flow of both gases. In the injector type torch (sometimes called universal or low pressure), the fuel gas is supplied at relatively low pressure, often less than 1 or 2 psig (7 to 14 kPa). The injector is designed to cause high pressure oxygen to aspirate, or pull, large volumes of low pressure fuel gas (that could not be obtained if only fuel gas pressure was used) to obtain the desired flow.

3.6 Cutting Tips. Cutting tips are precision tools (see Figures 10, 11, 15 and 16) that should not be subjected to excessive physical or thermal abuse. Tips and torches should obviously not be used as hammers because such use could result in damage to the tip that could cause inefficient and hazardous operating conditions. Exposure to excessive heat, by burying the tip in flame or slag, can result in overheating, melting of the tip, or a flashback (see 5.2). Cutting tips not in use should be stored in their original containers or in a special storage rack to avoid damage to the seating surfaces. Damage to the seat can result in gas leaks that have an adverse effect on adjustment, operation, and safety.

All oxygen cutting tips have preheat flame ports,



(A) Station



(B) Cylinder

Figure 4 — Pressure Regulators

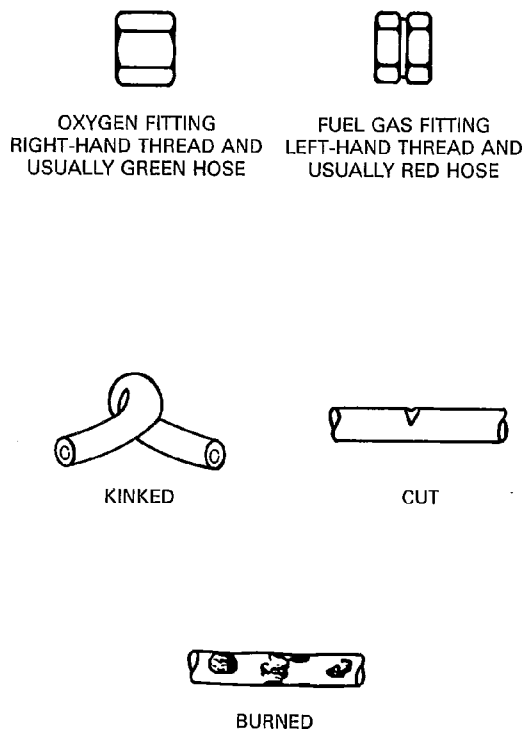


Figure 5—Hoses and Fittings

usually arranged in a circle, and a central cutting oxygen orifice. The size of the flame ports and of the oxygen orifice increases as the thickness of metal to be cut increases. Cutting tips are designated as standard or high speed according to the oxygen orifice design.

Standard tips have a straight-bore centerhole and are usually used with oxygen pressures from 30 to 60 psig (207 to 414 kPa) (see Figure 11). High speed tips differ from standard tips in that the exit end of the oxygen orifice is diverged. The divergence allows the use of higher pressures, typically 60 to 100 psig (414 to 690 kPa), while maintaining a uniform oxygen jet at supersonic velocities. High speed tips are ordinarily used only for machine cutting and usually provide speed increases of approximately twenty percent compared with the use of standard tips.

Cutting oxygen orifice size and design are not affected by the type of fuel used. However, flame port design is different for the various fuel gases. Different fuel gases require different volumes of oxygen and fuel and burn at different velocities. Therefore, the flame port size and number are varied to provide a stable flame that will produce enough heat to obtain the desired performance with the fuel gas being used.

Tips for use with acetylene are usually one piece with drilled or swaged flame ports and flat on the flame end. Tips for use with other fuel gases can be one piece with drilled or swaged flame ports or two pieces with milled splines on the tip inserts (see Figure 11).

Tips for use with methylacetylene-propadiene stabilized (MPS), and propylene base fuels are usually flat or slightly recessed on the flame end. Tips for use with natural gas and propane-base fuels usually have a deeper recess. **USE TIPS DESIGNED FOR THE FUEL GAS BEING USED.** Tips used for fuels other than those for which they are designed can result in inefficient and hazardous operation.

3.6.1 Maintenance of Cutting Tips. Cutting tips, although considered consumable items, are nonethe-

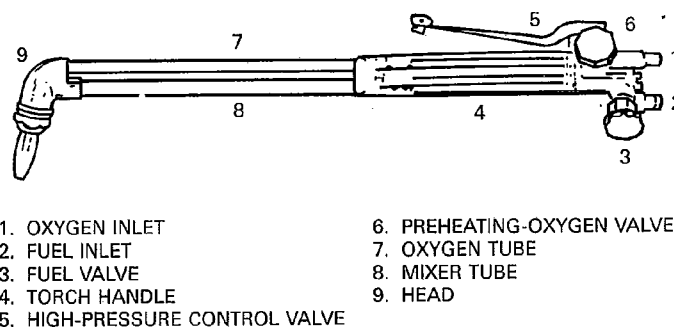


Figure 6—Manual Oxygen Cutting Torch

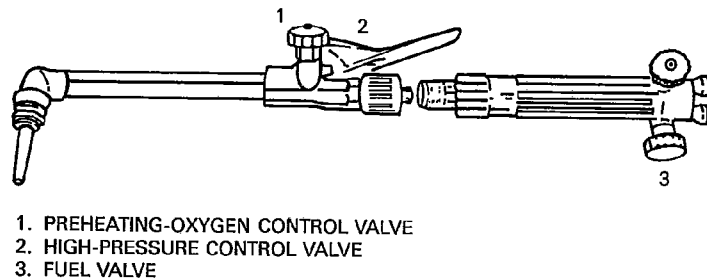


Figure 7—Combination Torch

less precision tools. In the list of apparatus needed for cutting, the tip has the greatest influence on cutting performance. Proper maintenance of tips can greatly extend their useful life and provide months of additional high quality performance.

The accumulation of slag in and around the preheat gas and cutting oxygen passages disturbs the flame and oxygen stream characteristics, resulting in an obvious reduction in performance and quality of cut. When this happens, the tips should be taken out of service and restored to good working condition or replaced.

There are two recommended cleaning procedures for cutting tips—chemical and mechanical.

3.6.2 Chemical Cleaning. Chemical cleaning involves the use of a commercial tip cleaning compound. The compound solution is prepared according to the manufacturer's specified procedure. The solution removes the slag from the tip. The tips are soaked in the solution, then rinsed and blown clean.

3.6.3 Mechanical Cleaning. Mechanical cleaning is done with special cleaning tools. It is important to remember that cleaning tools are only intended to remove slag and foreign matter from the tip.

3.6.3.1 Preheat Gas Passages. One-piece copper tips have either swaged or drilled round preheat gas

passages. The tool commonly used for cleaning has round wires of various diameters with ridges around the circumference. Cutting tips should be removed from the torch before cleaning to avoid pushing solid particles into the torch. To clean the preheat gas passages, the wire size which fits snugly (it should not be forced) into the passages from the exit end of the tip should be selected. The passages should be cleaned one at a time by sliding the wire in and out several times. The wire should not be forced sideways or the ridges will remove metal from the tip and eventually change the shape of the flame ports.

Two-piece tips contain splined preheat gas passages around the outside of the tip insert. After disassembly, these are cleaned using a soft wire brush. The brush is stroked lengthwise along the slots toward the flame end.

3.6.3.2 Cutting Oxygen Orifice. The cutting oxygen orifice is always round. However, the inside shape and cleaning procedure will vary, depending upon whether the tip is a standard or high speed tip.

Standard tip cutting oxygen orifices have straight cylindrical passages and, therefore, cleaning procedures are identical to those described in 3.6.3.1 above. Extreme care shall be taken not to distort the passage.

High speed cutting orifices contain a straight cylindrical passage followed by an enlarged taper at the

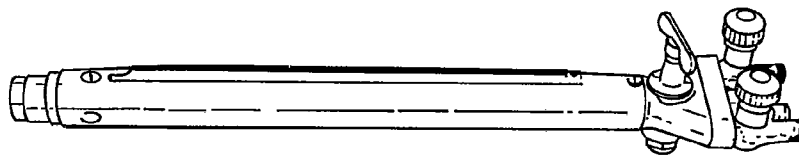


Figure 8—Three Hose Machine Torch

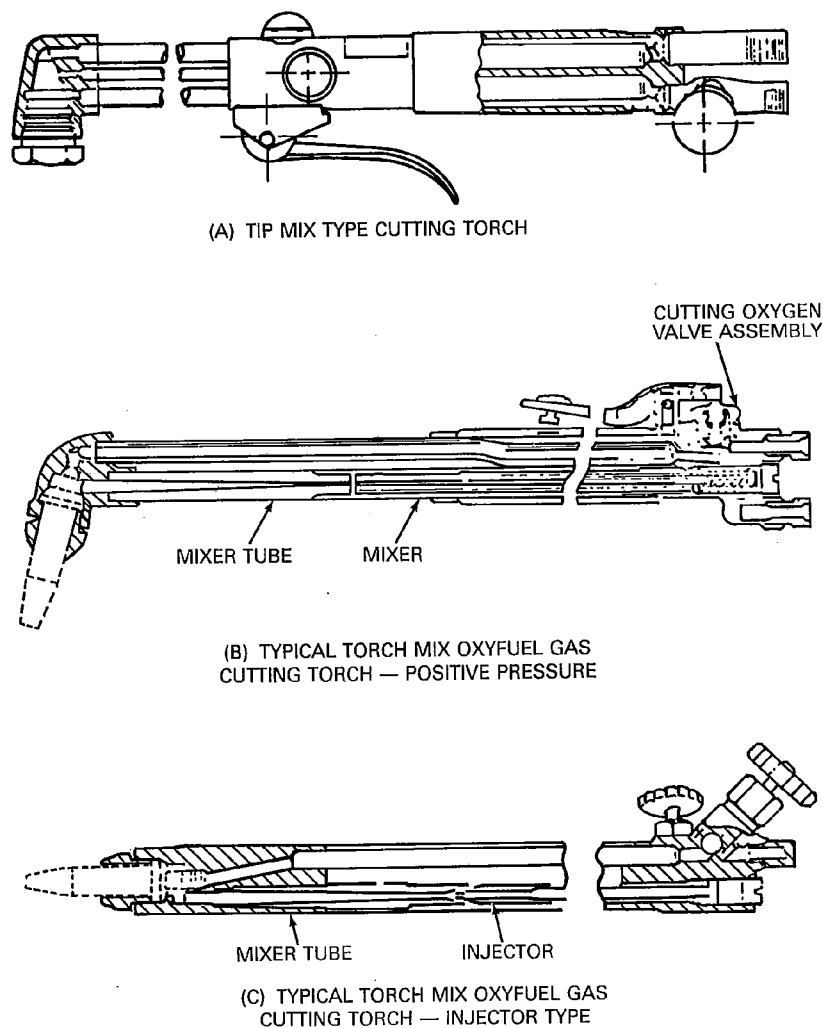


Figure 9—Torches Classified According to Method of Mixing

exit end of the tip. The shapes are extremely critical and any change in shape can render the tip useless. Manufacturers of these tips recommend special cleaning tools to prevent damage to the tip by the operator. The special tools are generally tapered in shape to permit careful cleaning of the taper without removing metal. Tapered reamers, drills without cutting edges, and fiber materials are most commonly used. The straight cylindrical passages are cleaned with the procedure in 3.6.3.1 above, followed by cleaning of the taper according to the manufacturer's recommendations.

3.6.3.3 Flame End of Tip. Should cleaning of the front (flat) face of the tips be required, a light sanding with fine abrasive paper is usually satisfactory. Care should be exercised to remove only the smallest amount of material to clean out the face. Heavy repeated sanding will eventually destroy the performance of the tip. This operation should always be followed by cleaning of both preheat and cutting oxygen orifices.

3.6.3.4 Reseating Tips or Torches. Operators should never attempt to reseat torches or tips. Specialized tools and knowledge are required for these operations.

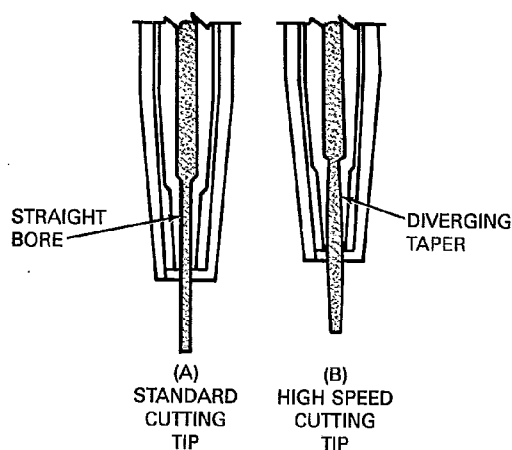


Figure 10—Oxyfuel Gas Cutting Tips

3.7 Protective Clothing and Equipment. Appropriate protective clothing and equipment for oxyfuel gas cutting operations will vary with the size, nature and location of the work to be performed. Some or all of the following may be required:

- (1) Tinted goggles or face shields
 - (a) Light cutting, up to 1 in. (25.4 mm) shade 3 or 4
 - (b) Medium cutting, 1 to 6 in. (25.4 to 152.4 mm) shade 4 or 5
 - (c) Heavy cutting over 6 in. (152.4 mm) shade 5 or 6
- (2) Hard hats (At times, a close fitting hat may be needed underneath)
- (3) Safety glasses
- (4) Protective clothing
Flame resistant jackets, coats, hoods, aprons, leggings, spats, gloves, etc. Leather or woolen clothing

is preferable to cotton. Synthetic material should not be worn during cutting or welding operations. Sleeves and collars should be kept buttoned. Cuffs should be eliminated. Pockets should be kept buttoned.

(5) Respiratory protection may be needed for cutting plated or coated material.

All clothing should be free of grease or oil and ragged edges. Liquified fuel gases should not be allowed to come in contact with the skin.

3.8 Cutting Machines. Cutting machines are mechanical devices used to carry one or more machine torches for the purpose of improving the efficiency and precision of the oxygen cutting process. They vary in complexity from a simple hand-guided machine to very sophisticated computer controlled units. Many machines are designed for special purposes such as those for making vertical cuts, edge preparation for welding, pipe cutting, and beveling, mirror image cutting, etc. The varieties of machines and guidance systems are too numerous and complex to be described in this manual.

3.9 Use, Handling and Storage of Gas Cylinders. Gas cylinders are manufactured to U.S. Department of Transportation (DOT) specifications. Formerly, gas cylinders were manufactured to Interstate Commerce Commission (ICC) specifications. When maintained and used properly, they do not ordinarily present undue hazards. However, improper treatment can result in extremely hazardous consequences. Accordingly, the following should be kept in mind when working with gas cylinders.

3.9.1 Use. All gas cylinders shall be secured or located where they are not likely to be knocked over

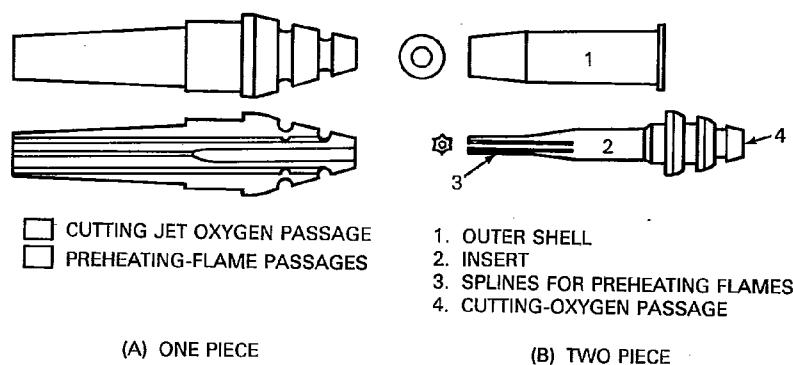


Figure 11—Oxyfuel Gas Cutting Tips—One- and Two-Piece Designs

or struck by falling objects. Fuel gas cylinders shall always be upright, with valve end up, to avoid the hazard of liquid withdrawal from the cylinder.

Compressed gas cylinders supplied with protective caps shall have the cap in place at all times except when in use or connected ready for use. When connected for use, cylinders shall be secured.

Cylinders shall never be placed in locations that are exposed to excess heat or open flames. A cylinder should never be heated by applying flame on the cylinder walls. It could cause the cylinder to explode.

Gas cylinders should not be placed where they might become part of an electrical circuit. For example, cylinders should not be secured to welding tables. Poor grounding during arc welding could result in arcing the cylinder, which could cause weakening of the cylinder wall and possible rupture. An arc should never be struck on a gas cylinder.

3.9.2 Handling. Any action that may cause cylinders to be damaged by impact should be avoided. Regulators should be removed from cylinders before moving them. Slings or magnets should never be used to move cylinders. Cylinders should never be used as a support or roller of any kind.

If any cylinder is damaged or defective in any way, it should be removed from service immediately and returned to the supplier with a tag stating the problem. If a cylinder is leaking, it should immediately be removed to a safe outside location, the supplier notified, and instructions followed.

Under no circumstances should anyone try to fill one cylinder from another. This operation is extremely dangerous and can result in an explosion of gases or cylinders or both.

3.9.3 Storage. Valves should be closed and caps replaced on all cylinders that are empty or not in use. All empty cylinders should be marked accordingly and never mixed with full ones. Unused oxygen or fuel gas should not be drained from cylinders. Oxygen and fuel gas cylinders should be separated during storage.

3.10 Working Environment. The operation of oxygen cutting equipment should be done only in areas free of conditions or materials that could result in situations hazardous to the operator or others. The following is a summary of some important considerations.

(1) Torches should not be used where chlorinated solvent vapors are present. Exposure of such vapors to heat can result in the formation of phosgene (an

extremely poisonous gas) and other corrosive or toxic products.

(2) Adequate ventilation should always be present, especially when cutting materials containing lead, cadmium, zinc, mercury, beryllium, or other toxic materials. An air supply mask should be worn if necessary.

(3) A flame should not be used in a closed vessel or pipeline that has contained gasoline or other flammable or explosive materials without first making sure it has been properly purged and vented. AWS F4.1, *Safe Practices for Welding and Cutting Containers That Have Held Combustibles*, should be consulted for details.

(4) Adequate and proper ventilation should be available when working in confined areas.

(5) A torch should not be used in a confined area without having an assistant on hand outside the confined area. A safety line may be required.

(6) Always know what is on the other side of the workpiece that you are cutting.

(7) Always know the location of the nearest fire extinguishers and how to use them properly.

(8) Do not cut over concrete or asphalt without protecting it with metal or other suitable material. Concrete can spall with explosive violence from the heat of the torch or slag.

(9) The hose should be protected from sparks, hot slag, hot objects, sharp edges, and open flames.

4. Start Up and Shut Down Procedure

The correct methods of using oxyfuel gas cutting equipment have resulted from many years of experience. It is imperative that all oxyfuel gas cutting operators become thoroughly familiar with safe procedures and conscientiously follow them at all times. Any attempt to bypass even one little detail could result in fire or explosion and possible injury to the operator or others. The following steps should be followed in the sequence given as a guide for safe operation.

4.1 Setting Up Equipment

4.1.1 Secure the cylinders to a substantial support or to a cylinder cart.

4.1.2 Before attaching any regulator to a cylinder or pipeline valve, remove any foreign matter that may be present. Be especially sure that no oil or

grease is present. As an additional precaution, while standing with the valve opening pointing away, the valve should be quickly opened and closed (called *cracking*) to blow out any foreign matter that may be deep in the valve orifice. Make certain that there are no combustible materials, open flames, or other sources of ignition before cracking oxygen or fuel gas valves. Do not use a hammer or wrench (except those supplied for some acetylene valves) on valves that will not open by hand.

4.1.3 Inspect regulator inlet connections to ensure that they are clean and oil-free. Attach regulators to the valves, and tighten the inlet connection nuts firmly with a closefitting wrench. Do not wear oily gloves or allow oil or grease to come in contact with oxygen regulators or fittings. Inspect hoses for cuts or other damage. Have them repaired or replaced, if damaged.

4.1.4 Connect the proper hoses to the oxygen and fuel gas regulators. Do not force connections on any equipment. The oxygen hose is usually green and has fittings with right hand threads. The fuel gas hose is usually red and has left hand threaded fittings which are notched on the outside for easy identification.

4.1.5 Attach hoses to torch inlet connections after inspecting fittings for cleanliness. Close torch valves. Install desired tip in accordance with torch manufacturer's instructions and size recommendations.

4.1.6 WARNING: BEFORE OPENING either cylinder valve, check the regulators to ensure that both adjusting screws or knobs are turned out counterclockwise until no pressure is being exerted on the adjusting spring. This is done to close the regulator valve seat and protect the regulator parts from damage due to high pressure surges.

4.1.7 Opening the Oxygen Valve. Open the oxygen cylinder or pipeline station valve *very slowly* to allow pressure to increase slowly in the regulator. This procedure shall be followed to reduce the possibility of fire or explosion in oxygen regulators. **WARNING:** Do not stand directly in front of or behind the regulator when opening the valve. After pressure in the regulator is equalized, open the oxygen cylinder valve fully. Oxygen cylinder valves can leak if not seated in the fully open or fully closed position.

4.1.8 Opening the Fuel Gas Valve. Fuel gas cylinder valves should not be opened completely so that

they can be turned off quickly in the event of a fire. Open fuel gas cylinder valves no more than 1 1/2 turns.

Acetylene cylinder valves that are opened with a wrench are preferably opened no more than 3/4 of a turn, and the wrench should be left in place while in use. *Pipeline station* fuel gas valves should be opened all the way. This is necessary to ensure adequate volume at lower source pressures.

4.1.9 Purging Hoses Before Attaching to Torch. New hoses or hoses that have been in storage should be purged before connecting to the torch inlets to limit the possibility of propelling dirt or other foreign matter into the torch. New hoses may contain residue from the manufacturing process which should be blown out (purged) before use. One method is as follows:

Holding the outlet end of each hose to prevent whipping, adjust the oxygen regulator to deliver 5 psig (35 kPa) outlet pressure and allow the oxygen to flow for about 5 seconds for each 50 ft. (15 m) of hose, in an area away from open flames or combustible material. Do not direct oxygen at clothing. Then back out the adjusting screw (turn counterclockwise) to shut off the flow of oxygen. On *three* hose machine torch installations, make sure that both oxygen hoses are purged before attaching to the torch. Repeat the procedure with the fuel gas regulator and hose, again ensuring that the gas is vented away from open flames or other sources of ignition. Back out the fuel gas regulator adjusting screw to shut off flow of fuel gas.

4.1.10 Pressure Adjustments and Purging Hoses. With the torch and tip properly attached and valves closed, open the torch oxygen valve or cutting oxygen valve, or both. Turn the adjusting screw(s) on the oxygen regulator(s) clockwise until the recommended oxygen pressure for the tip being used is obtained. Allow oxygen to flow for 5 seconds for each 50 ft. (15 m) of hose in an area away from open flames or combustible material. Do not direct cutting oxygen stream at any part of the body. The high velocity oxygen stream can penetrate the skin or saturate clothing, which can be a fire hazard. *Close* the torch oxygen valve.

Next, open the torch fuel gas valve, and then turn the adjusting screw on the fuel gas regulator clockwise until the recommended pressure is obtained. Allow fuel to flow about 5 seconds for each 50 ft. (15 m) of hose in an area away from open flames or combustible material. *Close* the torch fuel gas valve.

Note: With certain types of equipment, fuel gas regulator adjustments may not be possible or required. Follow the equipment manufacturer's recommendations in all cases. Have the regulator repaired if any malfunction is noticed.

4.2 Lighting the Torch

4.2.1 The recommended lighting procedure depends on the type of equipment and fuel gas being used. In all cases, use only a spark lighter or other appropriate device. Do not use matches or cigarette lighters. Put on approved shaded or tinted eye protection. If the torch is found to be faulty in any manner, do not use it. Never leave a lighted torch unattended.

4.2.2 "Positive" or equal pressure torches using an appropriate fuel gas may be lighted in either of the following ways:

(1) The preferred method for lighting acetylene is to open the fuel gas valve slightly and light with a spark lighter. Adjust acetylene until a smokeless flame is obtained. Open the oxygen valve slowly and increase the volume until the desired flame is attained. Intensity of the flame may be adjusted by slightly increasing or decreasing the flow rate of both gases slightly.

(2) Certain other fuel gases may be more easily lighted by opening the fuel gas valve slightly to make sure fuel gas is flowing from the tip. Then open the oxygen valve slightly. Light the gases with a spark lighter. Adjust the oxygen and fuel gas in successive steps to obtain the desired flame.

4.2.3 "Universal" or low pressure torches use an injector or venturi mixing method with relatively low fuel pressures. To light the torch, open the fuel gas valve about 3/4 turn. Then open the oxygen valve slightly, and light with a spark lighter. Adjust the preheat oxygen valve to obtain the desired flame.

4.3 Extinguishing the Torch

Rapidly close the torch valves in the sequence recommended by the manufacturer.

4.4 Shutting Down

4.4.1 After extinguishing the torch, close both oxygen and fuel gas cylinders or pipeline valves.

4.4.2 Open the torch fuel gas valve and bleed off fuel gas from regulator, hose, and torch. Back out regulator adjusting screw and then close the torch fuel gas valve.

4.4.3 Open the torch oxygen valve and bleed off oxygen from regulator, hose, and torch. Back out the regulator adjusting screw and then close the torch oxygen valve.

4.5 Equipment Not In Use. Equipment, when not in use, should be secured in a manner to prevent accidental dropping, damage or tampering. All cylinder or pipeline valves should be closed when equipment is not in use. Regulator pressure adjustments should never be changed on equipment that you are not using yourself. If storage is anticipated, dismantle all equipment and store in a clean, protected area. Hoses should not be stored in unventilated cabinets, nor should hoses or torches be left in confined work areas.

4.6 Re-Use of Equipment Already Connected For Use. Equipment should be examined for any signs of damage before reusing. If cylinder or station valves are closed, regulator pressure adjusting screws should be backed out and all components drained of gas. Then proceed as in 3.1.9 and 3.2. If valves are open, check pressure adjustments and purge hoses before lighting.

5. Flame Adjustment

Flame adjustment is a critical factor in attaining satisfactory torch operation. The amount of heat produced by the flame depends on the intensity and type of flame used.

5.1 Types of Flames. Three types of flames—carburizing, neutral, and oxidizing—can be set by properly adjusting the torch valves.

5.1.1 A *carburizing* flame with acetylene or methylacetylene-propadiene stabilized (MPS) is indicated by feathers on the primary flame cone or by long yellow-orange streamers in the secondary flame envelope.

Propane base fuels or natural gas have a long rounded primary flame cone. The carburizing flame (reducing flame) is often used for best finish and stack cutting of thin material.

5.1.2 A *neutral* flame with acetylene or MPS is indicated by sharply defined dark incandescent flame

cones and pale blue secondary flame envelope. Propane base fuels or natural gas have a short and sharply defined cone. This balanced flame is obtained by adding oxygen to the carburizing flame. This type of flame is most frequently used for cutting.

5.1.3 An *oxidizing* flame for acetylene or MPS has lighter color primary cones, a smaller secondary flame envelope and generally a harsh whistling sound. With propane base fuels and natural gas, the primary flame cones are larger, less sharply defined, and have a lighter color.

This flame is obtained by adding slightly more oxygen to the neutral flame. This type of flame is frequently used for a fast, nonquality cut or used selectively in piercing and quality beveling.

5.2 Flashback and Backfire Safety Note. Every oxy-fuel gas cutting torch operator should be aware of the severe burn hazard which exists if a flashback occurs. A flashback is a recession of the flame into or back of the mixing chamber of the torch. A flashback that stops at the mixer is usually characterized by a high pitched whistling or shrill humming sound.

The torch will usually get hot and may burn through and direct flames at the operator or others. If a flashback occurs, most manufacturers recommend that it should be extinguished immediately by closing the oxygen valve on the torch. Then turn off the fuel valve. If flashbacks re-occur, the torch should be removed from service.

A backfire is the momentary recession of the flame into the torch tip followed by immediate reappearance or complete extinguishing of the flame. After this condition, the torch is still workable. If backfiring continues, the torch or tips, or both, should be removed from service for cleaning and possible repair.

6. Cutting Procedures—Hand Torches

6.1 Starting Methods. Two methods can be used to start on an edge of the workpiece.

6.1.1 The most common method is to place the tip halfway over the edge, holding the end of the preheat cones 1/16 in. to 1/8 in. (1.6 mm to 3.2 mm), above the surface of the material to be cut (see Figure 12).

When the top corner reaches a reddish yellow color, slowly squeeze the cutting oxygen lever and the cutting process starts.

6.1.2 Another method is to put the tip entirely over the material to be cut, and then move back and forth a short distance along the line of cut. Move the tip back off the edge, squeeze the oxygen lever, and slowly move the torch toward the material to begin cutting. This method has the advantage of producing sharper corners at the beginning of the cut.

6.2 Torch Position and Motion. Once the cut has been started, the torch is moved along the line of a cut with a smooth, steady motion. Maintain as constant a tip-to-work distance as possible. Move the torch at a speed that produces a light ripping sound and a smooth spark stream. Be sure that hoses are not in a position where sparks or slag will hit them. Do not use your body to support hoses.

Hold the torch with both hands and make sure your arms are free to move the torch along the intended line of cut with no hinderance. The arm controlling the cutting valve should be held close at the side, with the forearm and torch extending straight out. The other hand should hold the torch further towards the tip, with the back of the wrist resting on the workpiece for stability. It is this arm and hand that act as a pivot point and guide the torch.

The cutting line should be suitably marked. When making very long cuts, it may be necessary to stop cutting and reposition yourself several times. If the cut is stopped and then picked up again to continue, a blow hole may occur at each restarting point. This can be avoided by moving the torch a short distance into the scrap area perpendicular to the line of cut. The cut can then be restarted at the corner, thus formed without forming a blow hole. If a long cut is being made for severance where both pieces will be used, blowholes can also be avoided by stopping torch travel before releasing the cutting oxygen lever.

For plate thicknesses of 1/2 in. (12.7 mm) or more, the cutting tip should be held perpendicular to the plate. For thin plate, the tip can be angled in the direction of cut (see Figure 13). This increases the cutting speed and helps prevent slag welding back across the kerf. If very straight cuts are desired, a metal straight edge can be placed next to the line of cut, and the edge of the tip can be guided along it. When cutting material in the vertical position, start

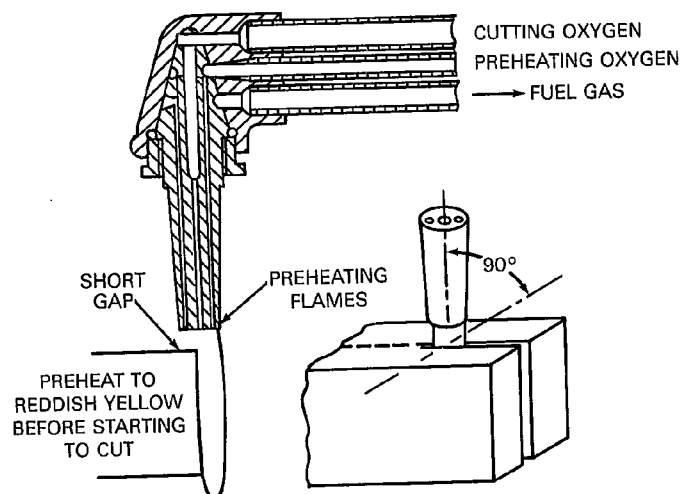


Figure 12—Cutting Torch Starting a Cut and In Action

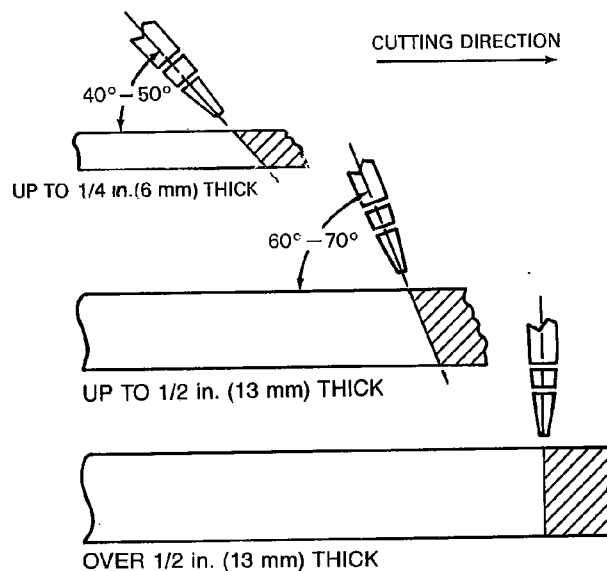


Figure 13—Lead Torch Angle for Straight Line Cutting

on the lower edge of the material and cut upwards to avoid cutting on the slag.

6.3 Piercing. It is often necessary to start a cut at some point other than on the edge of a piece of metal. This can be accomplished by drilling a hole with a power drill at the desired starting point and then starting a cut in the same manner as at the edge

of the material. However, it is much faster to use the cutting torch to produce this starting hole. This technique is known as *piercing*.

Piercing anything except very light plate will usually require a somewhat larger flame than is used for an edge start. A method used to shorten preheat time is to upset the plate surface with a center punch or make a burr with a chisel. In addition, the flame

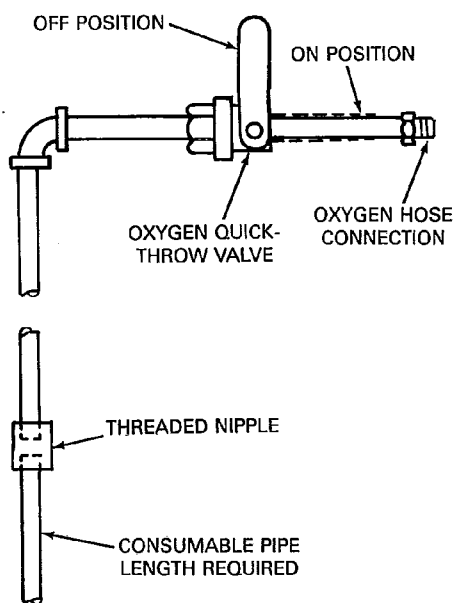


Figure 14—Oxygen Lance

should be adjusted to be slightly oxidizing in order to help concentrate the heat. The spot to be pierced should be located in the scrap area if possible, and can be brought to the starting temperature very rapidly if the ends of the primary flame cones are allowed to just touch the surface. A few up and down movements of the tip will soon indicate the proper distance. When a few sparks are observed, the material is hot enough. A slight rotary motion of the tip will ensure that the center of the spot is also hot.

Simultaneously, slowly squeeze the cutting oxygen lever, momentarily lift the tip away from the plate, and start moving slowly along the cut line, not directly away from you. If the cutting oxygen is turned on abruptly and the torch is not lifted, slag may be blown onto the tip and result in plugged holes. Avoid cutting across slag after piercing, as the slag may fly in all directions.

6.4 Oxygen Lancing. Lancing is a special piercing technique used to produce a hole through very thick plate or billets. The oxygen lance is made from a length of small diameter black iron pipe, which is connected with fittings and nipples to a quick throw valve (see Figure 14). Oxygen is fed through the oxygen hose with a regulated pressure of 80 to 90 psig (552 to 621 kPa).

A good rule to follow for the required length of the consumable pipe is to use 2.5 in. (63.5 mm) of pipe

for every 1 in. (25.4 mm) of material thickness to be pierced. Example: 8 in. (203 mm) plate thickness will require 20 in. (504 mm) of pipe ($8 \times 2.5 = 20$). Then, add another 6 to 8 in. (152 to 203 mm) so that the threaded female nipple will not get damaged.

A spatter protection shield is required to protect the oxygen cutter from molten metal and slag. An empty metal bucket can be used. Put a 1/2 in. (12.7 mm) hole in the center of the bottom, and cut a half circle with 3 in. (76.2 mm) radius on the lip of the bucket. The bucket is turned upside down and the pipe is inserted through the 1.2 in. (12.7 mm) hole and held firmly on the surface to be lanced. A hand-held cutting torch can then be inserted through the big opening at the bottom for preheating. This usually requires the assistance of a helper.

Use a hand-held cutting or heating torch with a high preheat flame to quickly heat the bottom of the pipe to near melting. As soon as the pipe is red hot and the hand torch is clear of the opening, open the oxygen quick-throw valve, and push the pipe through the plate firmly and smoothly. A slight twist or rotary motion applied to the lance will produce a hole larger than the pipe to permit slag to blow out. As soon as the hole is completely through the plate, close the oxygen valve, remove the pipe, remove the shield, and clean slag off the top surface. The plate is now prepared and ready to set up burning equipment and make the required cut.

6.5 Gouging, Washing, and Special Applications. Many special tips for specific applications are available (see Figure 15). Tips used in applications where gouging and washing actions are desired usually utilize a low-velocity oxygen stream. This can be achieved by a centerhole design that incorporates a small metering hole opening into a larger diameter exit hole (see Figure 16). Gouging and washing operations require a degree of skill that can be obtained only through experience.

6.5.1 Gouging. Gouging is ordinarily used for removing metal or defects. It is also used for J or U grooves in edge preparation. Flame adjustment may vary, depending on the speed and amount of metal removal desired.

Gouging is accomplished by first preheating the area by directing the flames perpendicular to the work. When the material is preheated, the tip is angled 10 to 20 degrees with respect to the top and pulled back 1/4 to 1/2 in. (6.4 to 12.7 mm). The cutting oxygen lever is then depressed, and the torch is moved forward along the desired path. Speeds will

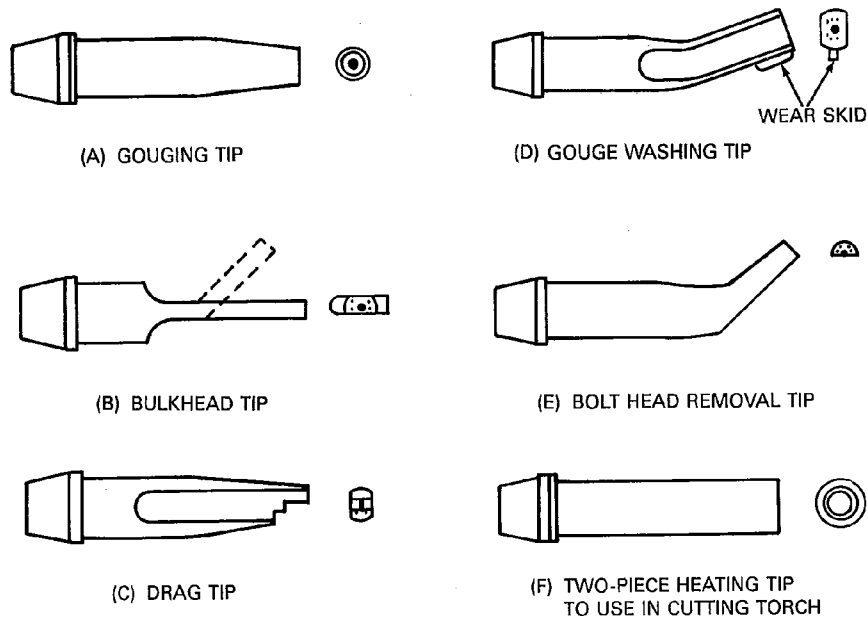


Figure 15—Special Application Tips

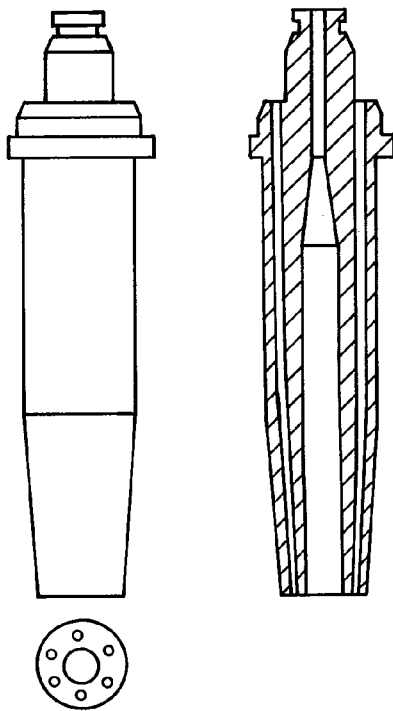


Figure 16—Oxygen Orifice Design for Washing Tips

vary from 2 to 7 ft/min. (0.6 to 2.1 m/min.), depending on the oxygen pressure and the depth of gouge. A variation of the angle of impingement will result in a change in the depth of the gouge.

When removing a short section of defective weld, a lower oxygen pressure and a different technique is used. After ignition temperature is reached, the oxygen valve is opened and the torch is pulled back to start. The torch is alternately moved forward about 1 1/4 in. (32 mm) and pulled backward about 3/4 in. (19 mm). The oxygen valve is usually closed during the forward motion. The motion can be repeated until no more defects, which are seen as dark spots or lines, are observed in the reaction zone.

6.5.2 Washing. Washing is used for such purposes as removing riser pads from castings and for shaping surfaces. Washing tips can be straight or bent, and the speed of reaction can be controlled by regulating the oxygen pressure or throttling with the cutting oxygen valve. The torch can be moved either in successive parallel lines or oscillated sideways while slowly being moved forward. For curved surfaces, the angle of impingement can be varied to obtain the desired curvature.

Rivet washing is a technique for removing rivets by consuming the head with a washing action. The rivet head is first preheated, the oxygen valve is opened,

and the torch is manipulated in a circular motion until the entire rivet head has been removed. The shank of the rivet can then be punched out or the washing action can be continued until the entire shank of the rivet is removed. The use of a proper technique will not destroy the original hole in the plate.

Other applications that utilize specially designed tips (see Figure 15) are trimming and cutting light sheet metal, stiffener removal, etc. Drag tips are guided by pulling the tip along the edge of a guide. Bulkhead and bolt head tips permit cutting off of right angle projections flush with the base metal without damage to the parent metal. The equipment manufacturer should be contacted for information regarding specialty applications and procedures.

7. Machine Oxygen Cutting

7.1 Cutting Charts. Operating parameters for machine oxygen cutting will vary, depending on the fuel gas and the brand and style of cutting tip being used. Tip size designations, tip design, and operating pressure differ among manufacturers. Operating data cards can be obtained from suppliers of the different fuel gases and tips, and they should be used.

7.2 Operating Techniques. Start-up and shut-down procedures for machine oxygen cutting are essentially the same as those previously given for hand torch operation. However, proper adjustment of operation parameters is more critical if high speed quality cuts are to be obtained. Use a manufacturer's or supplier's cutting chart to find the proper tip size for the thickness to be cut. In addition to tip size, the fuel and oxygen pressure settings and travel speeds will also be listed. Frequently, gas flow rates, drill size of the oxygen orifice, preheat cone lengths, and kerf width are also included.

Of greatest importance are proper tip size and cutting oxygen pressure. If the proper tip size is not used, the maximum speed and quality of the cut will not be achieved. Likewise, the cutting oxygen pressure setting is fairly critical and large deviations from the recommended setting will affect performance. For these reasons, some manufacturers specify the pressure setting for use with a certain length of hose, and suggest that regulator settings be increased as hose length increases. Still others suggest that a pressure gauge be attached at the torch inlet and cutting oxygen pressure settings be adjusted at that point to compensate accurately for variations due to the hose

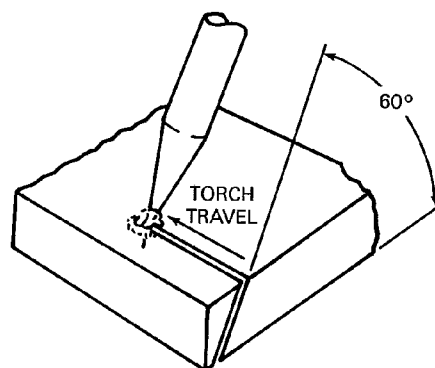


Figure 17—Bevel Cutting

length involved. Once the regulators have been adjusted, oxygen cutters generally use the torch valves to throttle the gas flows to the desired preheat level.

If sufficient flow rates are not obtained, pressure settings at the regulator can be increased to compensate. Manufacturers differ in their listing of travel speeds. Some give a range of speeds for differing cut quality, while others list a single speed. In either case, the settings are intended only as a guide. No two manufacturers agree completely on what is considered a "quality cut" or "slag free cut".

Furthermore, cleanliness of the nozzle, type of base metal, purity of cutting oxygen, and other factors have a direct effect on performance. In determining the proper speed for a particular application, begin the cut at a slower rate than recommended and gradually increase the speed until quality falls below the required level. Then, reduce the speed below that which was producing the desired quality and increase to desired speed and continue to operate at that rate.

7.3 Bevel Cutting (see Figure 17). When plate is being cut for use in welded assemblies, the edges are often cut at an angle rather than perpendicular to the plate surface. Bevel cuts can be obtained by tilting the entire torch or by use of a bevel adaptor. A larger size tip is often required because the length of a bevel cut face is greater than that of a square cut.

Adequate preheat is essential for bevel cutting. More heat is needed than for square cutting. The angle of the tip to the plate surface causes much of the heat to bounce off. Some fuel gases will perform more satisfactorily for beveling if a preheat torch is positioned a short distance 1 to 2 in. (25.4 mm to 50.8 mm) ahead of the cutting torch. High beveling speeds

can often be best attained if a large, slightly oxidizing flame is used and the preheat cones almost touch the plate surface.

8. Hints for Best Selection of Tips, Speeds, and Pressures

Select the correct tip size for the thickness of steel that you are cutting. Set the oxygen pressure listed for that tip, and start cutting with a conservative speed. Increase the speed to the best combination of quality and speed for the job.

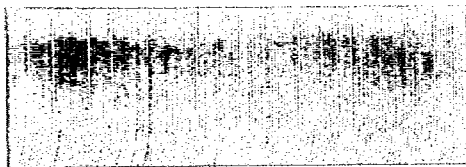
You can recognize good quality cuts at efficient speeds by a popping or tearing noise and slag free cuts. Sparks will break slightly forward as they emerge from the kerf.

A higher pressure or larger tip than recommended should not be used. You will only increase costs, not speeds. A lower pressure than recommended will give you a slower speed.

Efficient production cutting is based on using the correct pressures and tip sizes, and a cutting speed 1 to 3 in. (25.4 to 76.2 mm) per minute less than the absolute maximum. This provides an adequate safety margin in case of a slight fall in pressure, a variation in machine speed, or a change in tip height and to compensate for changes in surface conditions.

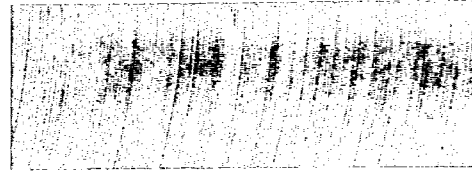
8.1 Correct Cutting Techniques

8.1.1 Precision Cut



A regular surface with slightly sloping drag lines denotes a precision cut. A slight amount of scale at the top of the cut is caused by preheat flames and is easily removed. This surface can be used for many purposes without machining.

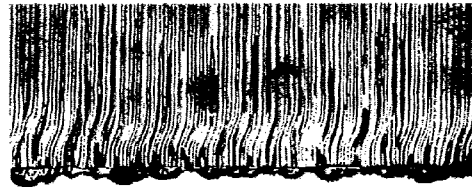
8.1.2 Production Cut



Moderately sloping drag lines and a reasonably smooth surface characterize a production cut. For production operations, a cut of this type represents the best combination of quality and economy.

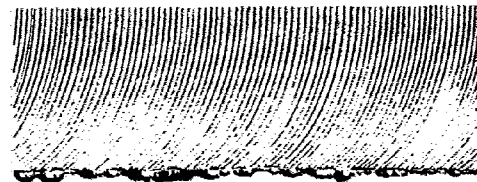
8.2 Common Cutting Faults

8.2.1 Dirty Tip

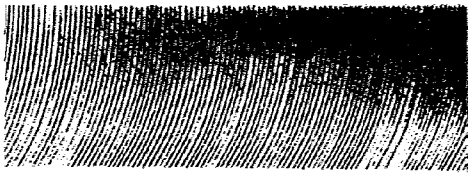


Dirt or scale in the tip will deflect the oxygen stream and cause one of the following problems: excess slag on the steel, an irregular cut surface, pitting, or undercutting.

8.2.2 Cutting Speed



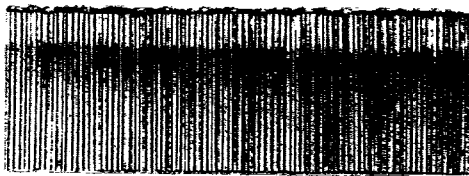
Extremely Fast: A rake angle of drag lines indicates extremely fast cutting speed. The top edge is good, and the cut face is smooth. However, slag adheres to the bottom side, and there is danger of losing the cut. Not enough time is allowed for the slag to blow out of the kerf. The cut face is often slightly concave.



Slightly Too Fast: Drag lines still incline backwards, but a "drop cut" is still attained. The top edge is good, and the cut face is smooth and slag free. Quality is satisfactory for much production work.

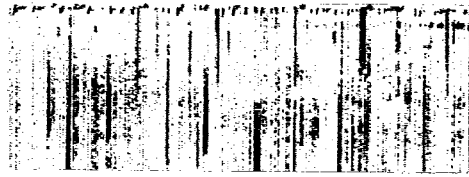


Extremely Slow: Pressure marks indicate too much oxygen for cutting conditions. Either the tip is too big, cutting oxygen pressure too high, or speed is too slow as shown by a rounded or beaded top edge as in this case. As oxygen volume nears correct proportions, pressure marks appear closer to the bottom edge until they finally disappear.

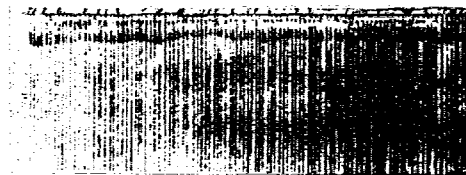


Slightly Too Slow: The cut is high quality, although there is some surface roughness caused by vertical drag lines. The top edge is unusually slightly beaded. Quality is generally acceptable, but faster speeds are more desirable.

8.3 Tip Distance

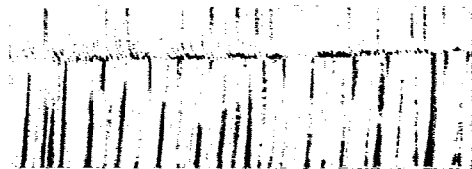


Too Close: Grooves and deep drag lines are caused by unstable cutting action. Part of the preheat cone burns inside the kerf where normal gas expansion deflects oxygen cutting stream.



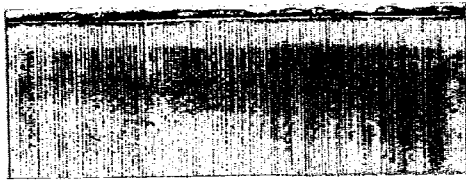
Too High: The top edge is beaded or rounded; the cut face is not smooth and often is slightly beveled when preheat effectiveness is partially lost due to the tip being held too high. The cutting speed is reduced because of the danger of losing the cut.

8.4 Gas Adjustment



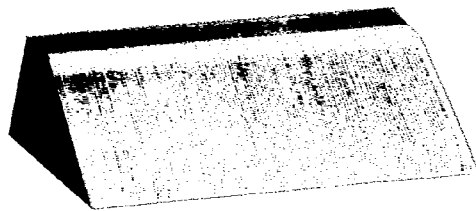
Excessive Cutting Oxygen: Pressure marks are caused by too much cutting oxygen. When more oxygen is supplied than can be consumed in oxidation, the remainder goes around the slag, creating gouges, or pressure marks. This fault can be corrected by lowering cutting oxygen pressure, increasing speed, or using a smaller tip. As oxygen volume nears the

correct proportion, pressure marks appear closer to the bottom edge until they finally disappear.

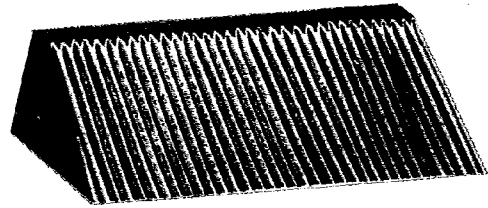


Excessive Preheat: The rounded top edge is caused by too much preheat. Excess preheat does not increase cutting speed; it only wastes gases.

8.5 Bevel Cutting



Good Quality: The top edge is excellent, and the cut face is extremely smooth. Slag should be easy to remove and the cut part dimensionally accurate. Cutting speed is slower than square cutting because preheat effect is partially deflected from plate.



Poor Quality: Gouging is the most common fault, and is caused by either incorrect speed or inadequate preheat. Another fault is rounded top edge caused by too much preheat.