Section 3

Cutting and Gouging

Chapter 7
Flame Cutting

See Oxyacetglene Welding Series.

Chapter 8
Plasma Arc Cutting

Chapter 9
Related Cutting Processes

Success STORY

What do welding, sculpting, and showing high school students a better way to make a life have in common? Everything, at least in Franklin, Virginia.

Caroline Gatten has had a wide and varied career path. When the fifty-year-old decided to move back to her hometown, she found an interesting hobby that turned into a new career.

She has always been an artist. Caroline boned up on her welding skills at Franklin's Paul D. Camp Community College to help her create works of art.

Her new job for the local school district is to connect with the at-risk and troubled kids in the community from the elementary to the secondary levels. "We have some serious problems with drugs here," she said, "specifically with pot and crack cocaine."

Caroline teaches a noncredit course to the teens, mostly boys but also a few girls, as an activity to get them off the street and to teach them something constructive. "It is really to get them some self-esteem," she said.

Caroline has a small workshop at home with a wood lathe and uses the welding equipment at the community college. She likes to make art that has different feels and textures, usually hard, heavy metals on the outside with different substances such as glass, on the inside. She has taken MIG welding courses and is learning TIG welding so she can work with copper.

In the classes with the students in her school, she likes to show them that welding and art are not just a way to pass time but something they can do with their own hands and make a living at.

Hunting is a popular sport in her area and she noted that one of her students was taking scrap metal and turning it into tree stands for hunters, selling them for a $150 profit. "We have kids that come in and make things, and they sell them in the community," she said.

She shows that welding technology is very practical in real life. Caroline said one time she looked in a catalog and saw that a small greenhouse she wanted cost about $500. Rather than paying out-of-pocket for a premade item, she made the same thing herself. "I got $30 worth of lights and some scrap metal," she recalled. "It didn't cost me any more than about ten more dollars."

She noted that after she introduces the students to welding and art, she gets newfound respect from the high schoolers, "They can see I am there to help them."

Artwork by Caroline Gatten.
Photo courtesy of Donald Bridgers.

Chapter 7

Flame Cutting

OBJECTIVES

After completing this chapter, the student should be able to

- ☑ explain how the flame-cutting process works.
- ☑ demonstrate how to properly set up and use an oxyfuel gas cutting torch.
- ☑ safely use an oxyfuel gas cutting torch to make a variety of cuts.

KEY TERMS

blowpipe
coupling distance
cutting lever
cutting tips
drag
drag lines
equal-pressure torches
hard slag
high-speed cutting tip
kindling point
machine cutting torch
MPS gases
orifice
oxyacetylene hand torch
oxyfuel gas cutting (OFC)
preheat flame
preheat holes
slag
soapstone
soft slag
tip cleaners
venturi

INTRODUCTION

Oxyfuel gas cutting (OFC) is a group of oxygen cutting processes that uses heat from an oxyfuel gas flame to raise the temperature of the metal to its kindling temperature before a high-pressure stream of oxygen is directed onto the metal, causing it to be cut. The kindling temperature of a material is the temperature at which rapid oxidation (combustion) can begin. The kindling temperature of steel in pure oxygen is 1600° to 1800°F (870°C to 900°C). The processes in this group are identified by the type of fuel gas used with oxygen to produce the preheat flame. Oxyfuel gas cutting is most commonly performed with oxyacetylene cutting (OFC-A). **Table 7-1** lists a number of other fuel gases used for OFC. MIPS (MAPP®) gas is increasingly being used today for cutting and rivals acetylene's popularity in some areas of the country.

Fuel Gas	Flame (Fahrenheit)	Temperature* (Celsius)
Acetylene	5589°	3087°
MAPP®	5301°	2927°
Natural gas	4600°	2538°
Propane	4579°	2526°
Propylene	5193°	2867°
Hydrogen	4820°	2660°

*Approximate neutral oxyfuel flame temperature.

TABLE 7-1 Fuel Gases Used for Flame Cutting.

More people use the oxyfuel cutting torch than any other welding process. The cutting torch is used by workers in virtually all areas, including manufacturing, maintenance, automotive repair, railroad, farming, and more. It is unfortunately one of the most commonly misused processes. Most workers know how to light the torch and make a cut, but their cuts are very poor quality. Often, in addition to making bad cuts, they use unsafe torch techniques. A good oxyfuel cut should not only be straight and square, but it also should require little or no postcut cleanup. Excessive postcut cleanup results in extra cost, which is an expense that cannot be justified.

Manual, mechanized, and automatic OFC processes are used in industry. Hand-controlled, manual cutting is done in short-run production and one-of-a-kind fabrication, as well as in demolition and scrapping operations. Manual cutting is also used in the field for steel construction. Mechanized or automatic cutting is widely used in production work where a large number of identical cuts are made over and over or where very precise cuts are required. In mechanized or automatic cutting more than one cutting head may be mounted so several cuts can be made at the same time.

Various oxyfuel cutting specialties are found on the job, including flame cutting, gouging, beveling, scarfing, and the operation of an automated cutting machine. In addition to these cutting jobs, some welders work dismantling scrap metal, such as scrap autos or construction demolition.

Metals Cut by the Oxyfuel Process

Oxyfuel gas cutting is used to cut iron base alloys. Low carbon steels (up to 0.3% carbon) are easy to cut. Any metal that requires preheating for welding, such as high alloy and high alloy carbon steels should also be preheated before cutting. High nickel steels, cast iron, and stainless steel are difficult to cut. Most nonferrous metals—such as brass, copper, and aluminum—cannot be cut by oxyfuel cutting. A few reactive nonferrous metals, such as titanium and magnesium, can be cut. These metals seldom are cut with the OFC process because of the extensive postcut cleanup required.

Type of Cutting Operation	Hazard	Suggested Shade Number
Light cutting, up to 1 in.	Sparks, harmful	3 or 4
Medium cutting, 1–6 in.	rays, molten metal,	4 or 5
Heavy cutting, over 6 in.	flying particles	5 or 6

TABLE 7-2 A General Guide for the Selection of Eye and Face Protection Equipment.

Eye Protection for Flame Cutting

The National Bureau of Standards has identified proper filter plates and uses. The recommended filter plates are identified by shade number and are related to the type of cutting operation being performed.

Goggles or other suitable eye protection must be used for flame cutting. Goggles should have vents near the lenses to prevent fogging. Cover lenses or plates should be provided to protect the filter lens. All lens glass should be ground properly so that the front and rear surfaces are smooth. Filter lenses must be marked so that the shade number can be readily identified, **Table 7-2.**

Cutting Torches

The oxyacetylene hand torch is the most common type of oxyfuel gas cutting torch used in industry. The hand torch, as it is often called, may be either a part of a combination welding and cutting torch set or a cutting torch only, **Figure 7-1.** The combination welding-cutting torch offers more flexibility because a cutting head, welding tip, or heating tip can be attached quickly to the same torch body, **Figure 7-2.** Combination torch sets are often used in schools, automotive repair shops, auto body shops, and small welding shops or with any job where flexibility in equipment is needed. A cut made with either type of torch has the same quality; however, the dedicated cutting torches are usually longer and have larger gas flow passages than the combination torches. The added length of the dedicated cutting torch helps keep the operator farther away from the heat and sparks and allows thicker material to be cut.

Oxygen is mixed with the fuel gas to form a high-temperature preheating flame. The two gases must be completely mixed before they leave the tip and create the flame.

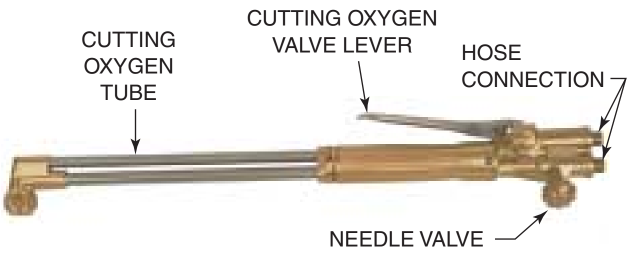


FIGURE 7-1 Oxyfuel cutting torch. Courtesy of Victor Equipment, a Thermadyne Company.

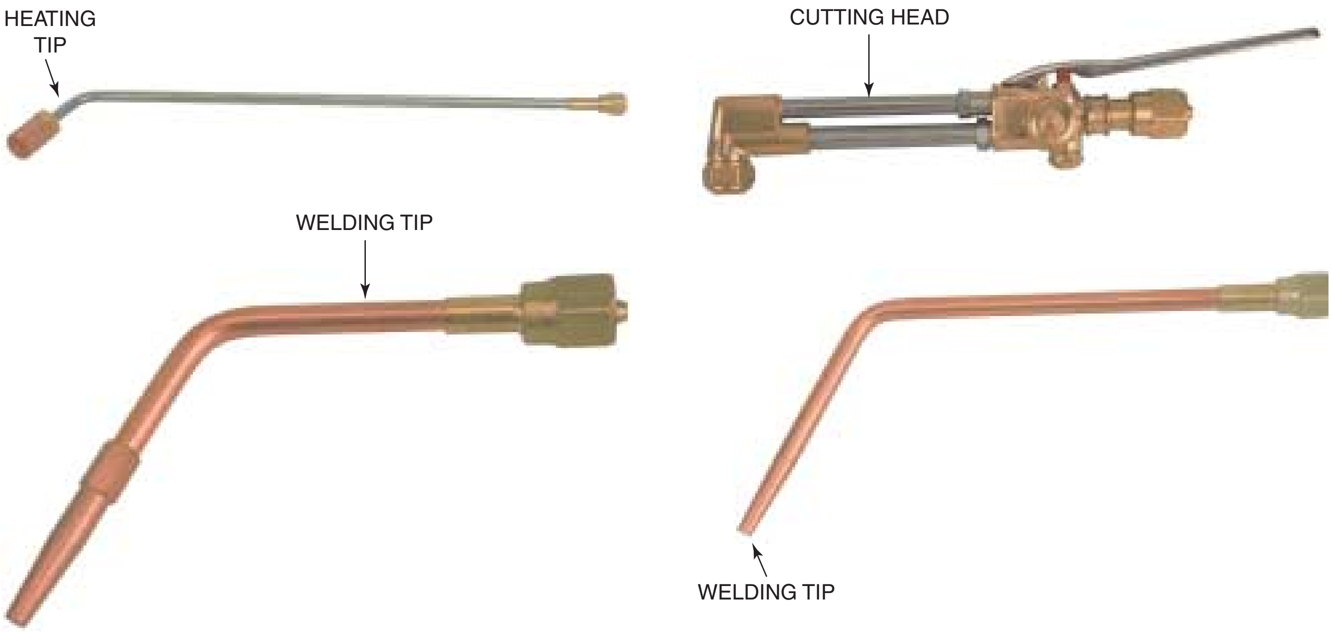


FIGURE 7-2 The attachments that are used for heating, cutting, welding, or brazing make the combination torch set flexible. Courtesy of Victor Equipment, a Thermadyne Company.

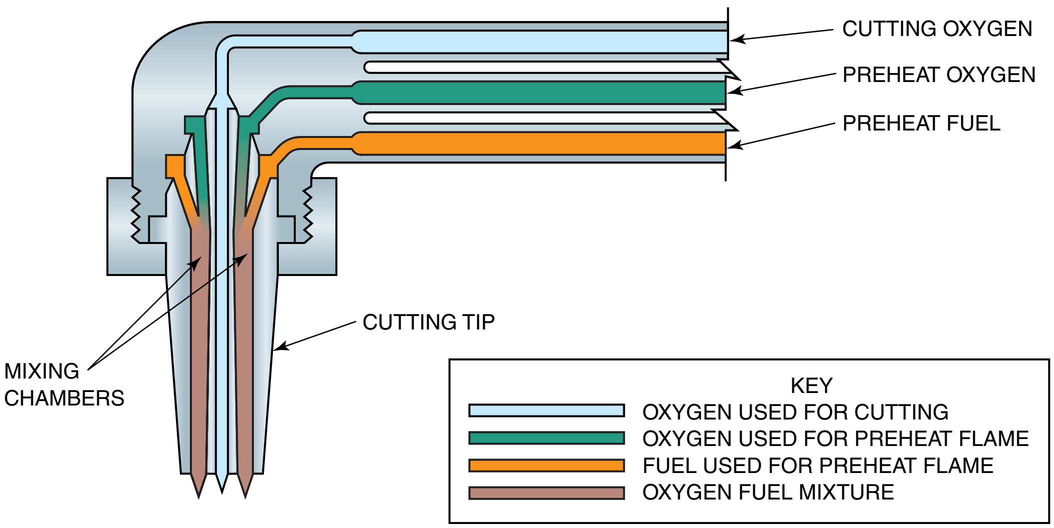


FIGURE 7-3 A mixing chamber located in the tip.

Two methods are used to mix the gases. One method uses a mixing chamber, and the other method uses an injector chamber.

The mixing chamber may be located in the torch body or in the tip, **Figure 7-3**. Torches that use a mixing chamber are known as **equal-pressure torches** because the gases must enter the mixing chamber under the same pressure. The mixing chamber is larger than both the gas inlet and the gas outlet. This larger size causes turbulence in the gases, resulting in the gases mixing thoroughly.

Injector torches will work with both equal gas pressures and low fuel-gas pressures, **Figure 7-4**. The injector allows the oxygen to draw the fuel gas into the chamber even if the fuel gas pressure is as low as 6 oz/in.^{2} (26 g/cm^2). The injector works by passing the oxygen through a **venturi,** which creates a low-pressure area that pulls the fuel gases in and mixes them together. An injector-type torch must be used if a low-pressure acetylene generator or low-pressure residential natural gas is used as the fuel gas supply.

The cutting head may hold the cutting tip at a right angle to the torch body or it may be held at a slight angle. Torches with the tip slightly angled are easier for the welder to use when cutting flat plate. Torches with a right-angle tip are easier for the welder to use when cutting pipe, angle iron, I-beams, or other uneven material shapes. Both types of torches can be used for any type of material being cut, but practice is needed to keep the cut square and accurate.

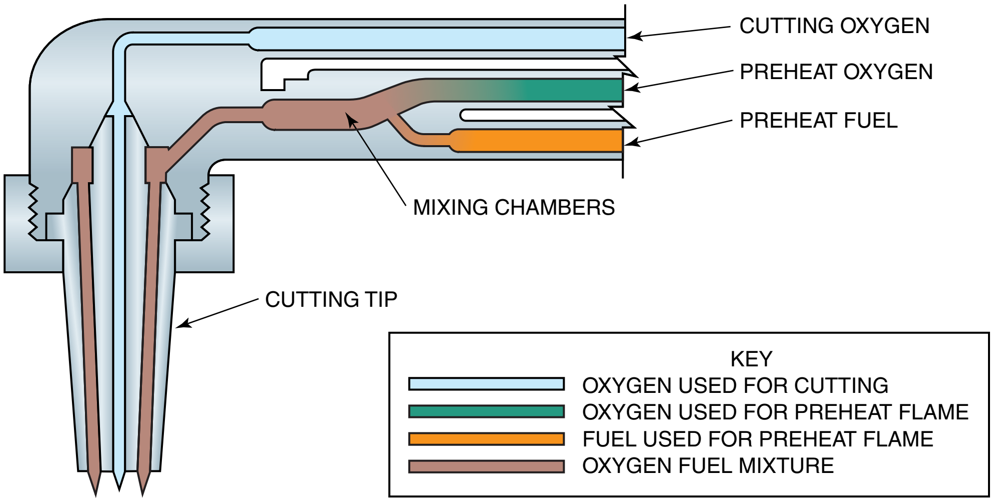


FIGURE 7-4 Injector mixing torch.

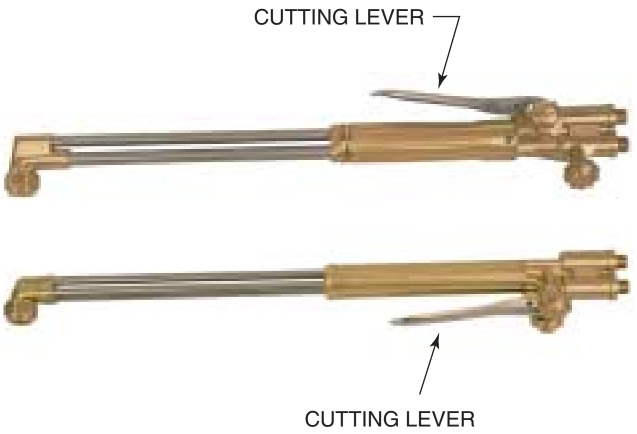


FIGURE 7-5 The cutting lever may be located on the front or back of the torch body. Courtesy of Victor Equipment, a Thermadyne Company.

FIGURE 7-7 Multiple head cutting machine. Courtesy of ESAB Welding & Cutting Products.

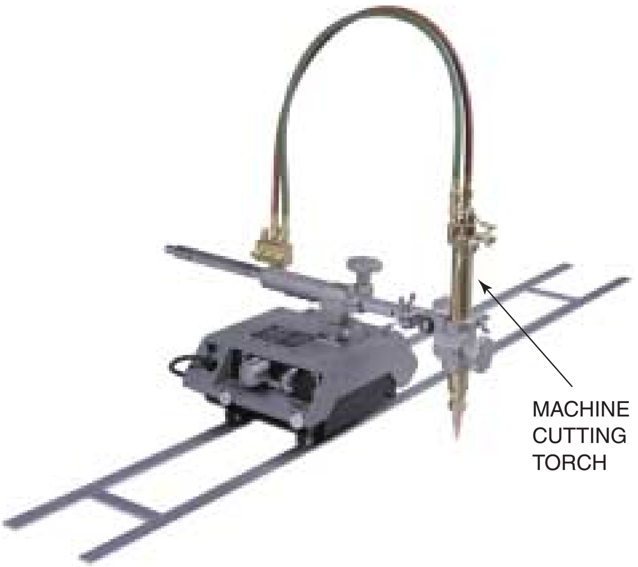


FIGURE 7-6 Portable flame-cutting machine. Courtesy of Victor Equipment, a Thermadyne Company.

The location of the cutting lever may vary from one torch to another, **Figure 7-5.** Most cutting levers pivot from the front or back end of the torch body. Personal preference will determine which one the welder uses.

A machine cutting torch, sometimes referred to as a blowpipe, operates in a similar manner to a hand cutting torch. The machine cutting torch may require two oxygen regulators, one for the preheat oxygen and the other for the cutting oxygen stream. The addition of a separate cutting oxygen supply allows the flame to be more accurately adjusted. It also allows the pressures to be adjusted during a cut without disturbing the other parts of the flame. Various machine cutting torches are shown in **Figure 7-6**, **Figure 7-7**, and **Figure 7-8.**

Cutting Tips

Most cutting tips are made of copper alloy, but some tips are chrome. Chrome plating prevents spatter from sticking to the tip, thus prolonging its usefulness. Tip designs change for the different types of uses and gases, and from one torch manufacturer to another, **Figure 7-9.**

Tips for straight cutting are either standard or high-speed, **Figure 7-10.** The high-speed cutting tip is designed

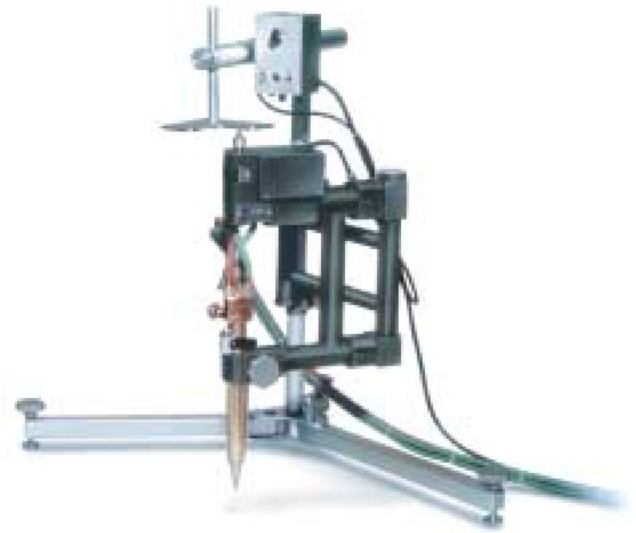


FIGURE 7-8 Portable cutting machine for highly complex shapes. Courtesy of ESAB Welding & Cutting Products.

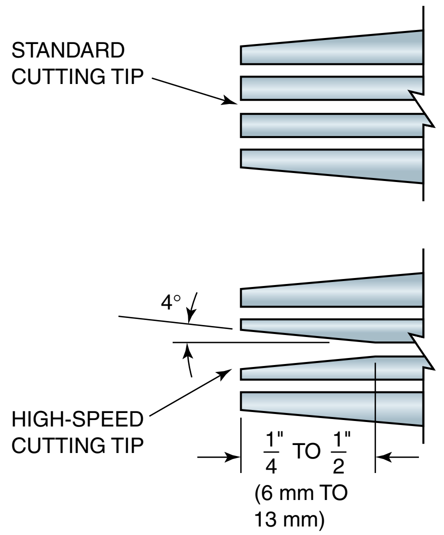


FIGURE 7-10 Comparison of standard and high-speed cutting tips.

FIGURE 7-9 Different cutting torch seals for different manufacturers' torches. Courtesy of American Torch Tip.

to allow a higher cutting oxygen pressure, which allows the torch to travel faster. High-speed tips are also available for different types of fuel gases.

The diameter, or size of the center cutting orifice, determines the thickness of the metal that can be cut. A larger diameter oxygen orifice is required for cutting thick metal. There is no standard numbering system for sizing cutting tips. Each manufacturer uses its own system. Some systems are similar, some are not. **Table 7-3** lists several manufacturers' tip numbering systems. As a way of comparing the size of one manufacturer's tip size to another, the center hole diameter in inches is given below the tip number. For example, on Table 7-3 you can see that Airco's tip number 00 has a center orifice size equal to a number 70 drill size. On Table 7-3 you can see that this cutting tip is designed for cutting metal approximately 1/8″ (3 mm) thick. Other manufacturer tip numbers designed for this thickness have the following numbers: 000, 00, 1/4, 2, and 3.

Finding the correctly sized tip for a job can be confusing, especially if you are using the cutting unit for the first time. To make it easier to select a tip, you can use a standard set of tip cleaners to find the size of the center cutting orifice. **Table 7-4** lists the material thickness being cut with the tip cleaner size.

If the manufacturers' recommendations for gas pressure are not available, you can use Table 7-4 to find the approximate pressures to be used with the tip. Actual gas pressures vary, depending on a number of factors, such as the equipment manufacturer, the condition of the equipment, hose length, hose diameter, regulator size, and operator skill. In all cases start out with the pressure recommended by the particular manufacturer of the equipment being used. Adjust the pressure to fit the job being cut.

A wide variety of tip shapes are also available for specialized cutting jobs. Each tip, of course, also comes in several sizes. Some tips are specialized for the kind of fuel gas being used. Different means are used to attach the cutting tip to the torch head. Some tips screw in; others have a push fitting.

In addition to those tips for torch hand cutting, different designs are used for mechanized and automated cutting tips. Mechanized and automated cutting tips are designed for high-speed cutting with high-speed oxygen flow.

Always choose the correct type and size of tip for the specific cutting job. Check the manufacturer's literature

Manufacturer	Metal Thickness, Inches (mm)										
	1/8 (3)	1/4 (6)	1/2 (13)	3/4 (19)	1 (24)	1 1/2 (37)	2 (49)	2 1/2 (61)	3 (74)	4 (98)	5 (123)
Cutting orifice drill number	70	68	60	56	54	53	50	47	45	39	31
Airco	00	0	1	1	2	2	3	4	4	5	6
ESAB	1/4	1/4	1/2	1 1/2	1 1/2	1 1/2	4	4	4	4	8
Harris	000	00	0	1	1	2	2	3	3	3	4
Oxweld	2	3	4	6	6	6	8	8	8	8	8
Purox	3	3	4	4	5	5	7	7	7	7	9
Smith	00	0	1	2	2	3	3	4	4	4	5
Victor	000	00	0	1	2	2	3	4	4	5	6

Table 7-3 Comparison of Some Manufacturers' Oxyacetylene Cutting Tip Identifications.

Tip Size	Metal Thickness, Inches (mm)										
	1/8 (3)	1/4 (6)	1/2 (13)	3/4 (19)	1 (24)	1 1/2 (37)	2 (49)	2 1/2 (61)	3 (74)	4 (98)	5 (123)
Cutting orifice drill number	70	68	60	56	54	53	50	47	45	39	31
WYPO tip cleaner number*	10	10	15	18	22	24	26				
Campbell Hausfeld tip cleaner number*	3	3	6	9	10	11	12				
Oxygen pressure, psi**	20 25	20 25	25 30	30 35	35 40	35 40	40 45	40 45	40 45	45 55	45 55
Oxygen pressure, kPa**	140 170	140 170	170 200	200 240	240 275	240 275	275 310	275 310	275 310	310 380	310 380
Acetylene pressure, psi**	3 5	3 5	3 5	3 5	3 5	3 5	4 8	4 8	5 11	6 13	8 14
Acetylene pressure, kPa**	20 35	20 35	20 35	20 35	20 35	20 35	30 55	30 55	35 75	40 90	55 95

*There is no standard numbering system for tip cleaners, so numbers can differ from one manufacturer to another.
** Tip size and pressures are approximate. Use the manufacturer's specification for equipment being used when available.

Table 7-4 Center Cutting Orifice Size, Metal Thickness, and Gas Pressures for Oxyacetylene Cutting.

for tip size and type recommendations. Make sure the tip is designed for the type of fuel gas being used. Inspect the tip before using it. If the tip is clogged or dirty, clean the tip and clean out the orifices with the proper size drill. Check to make sure there is no damage to the threads. If the threads or the tapered seat is damaged, do not use the tip.

The amount of preheat flame required to make a perfect cut is determined by the type of fuel gas used and by the material thickness, shape, and surface condition. Materials that are thick, are round, or have surfaces covered with rust, paint, oil, and so on require more preheat flame, **Figure 7-11**.

Different cutting tips are available for each of the major types of fuel gases. The differences in the type or number of preheat holes determine the type of fuel gas to be used in the tip. **Table 7-5** lists the fuel gas and range of preheat holes or tip designs used with each gas. Acetylene is used in tips having from one to six preheat holes. Some large acetylene cutting tips may have eight or more preheat holes.

CAUTION

If acetylene is used in a tip that was designed to be used with one of the other fuel gases, the tip may overheat, causing a backfire or the tip to explode.

Fuel Gas	Number of Preheat Holes
Acetylene	One to Six
MPS (MAPP ®)	Eight to two-piece tip
Propane and natural gas	Two-piece tip

Table 7-5 Fuel Gas and Number of Preheat Holes Needed in the Cutting Tip.

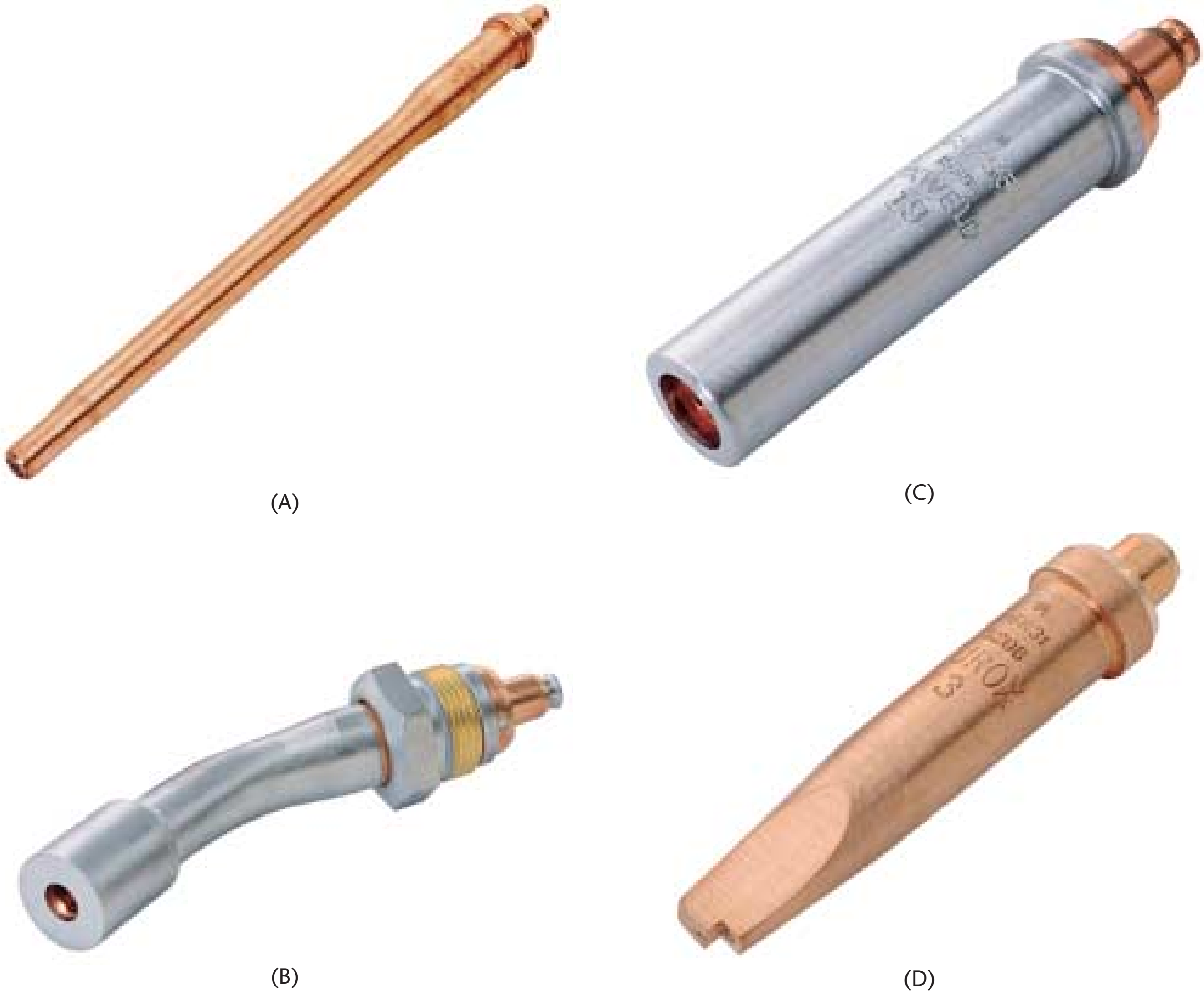


FIGURE 7-11 Special cutting tips come in a variety of shapes, for many purposes. They can have different sizes and numbers of preheat holes. (A) 10-in-long cutting tip, (B) water cooled cutting tip, (C) two piece cutting tip, and (D) sheet metal cutting tip. Courtesy of ESAB Welding & Cutting Products.

MPS gases are used in tips having eight preheat holes or in a two-piece tip that is not recessed, **Figure 7-12.** These gases have a slower flame combustion rate (see Chapter 26) than acetylene. For tips with less than eight preheat holes, there may not be enough heat to start a cut, or the flame may pop out when the cutting lever is pressed.

CAUTION

If MPS gases are used in a deeply recessed, two-piece tip, the tip will overheat, causing a backfire or the tip to explode.

Propane and natural gas should be used in a two-piece tip that is deeply recessed, **Figure 7-12.** The flame burns at such a slow rate that it may not stay lit on any other tip.

Some cutting tips have metal-to-metal seals. When they are installed in the torch head, a wrench must be used to tighten the nut. Other cutting tips have fiber packing seats to seal the tip to the torch. If a wrench is used to tighten the nut for this type of tip, the tip seat may be damaged, **Figure 7-13.** A torch owner's manual should be checked or a welding supplier should be asked about the best way to tighten various torch tips.

When removing a cutting tip, if the tip is stuck in the torch head, tap the back of the head with a plastic hammer, **Figure 7-14.** Any tapping on the side of the tip may damage the seat.

To check the assembled torch tip for a good seal, turn on the oxygen valve and spray the tip with a leak-detecting solution, **Figure 7-15.**

CAUTION

Carefully handle and store the tips to prevent damage to the tip seats and to keep dirt from becoming stuck in the small holes.

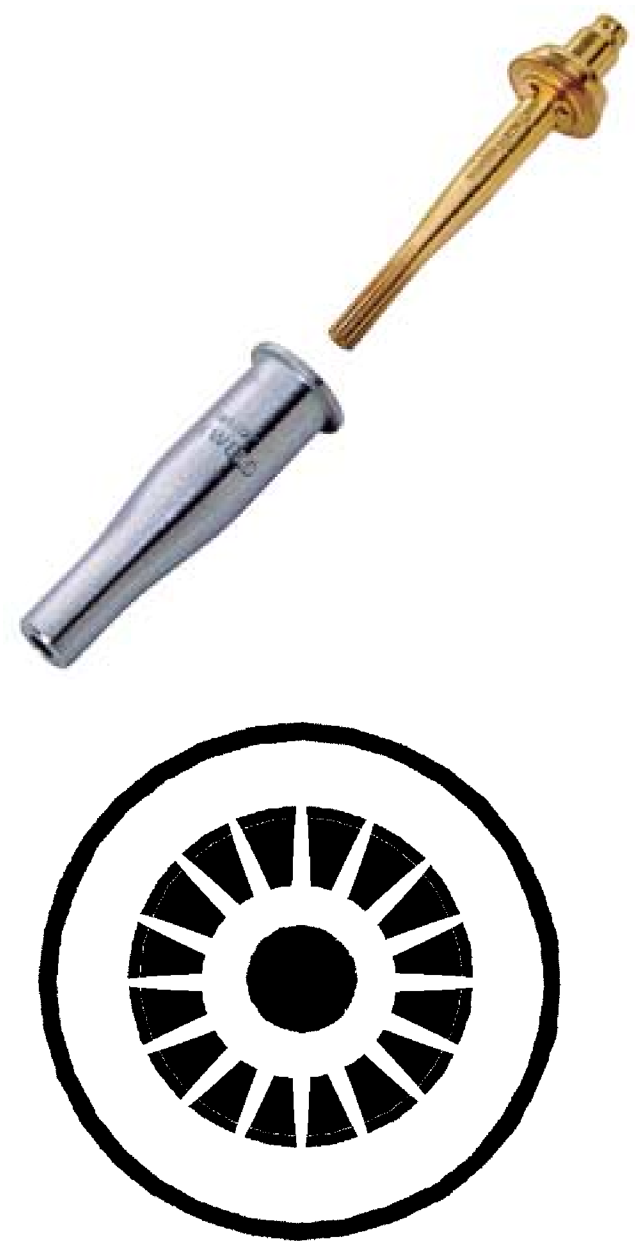


FIGURE 7-12 Parts of a two-piece cutting tip. Courtesy of ESAB Welding & Cutting Products.

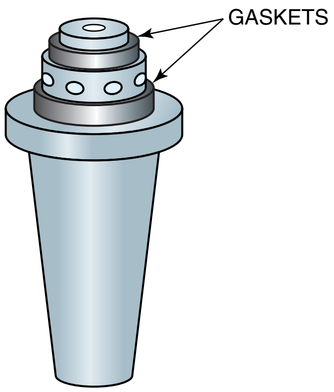


FIGURE 7-13 Some cutting tips use gaskets to make a tight seal.

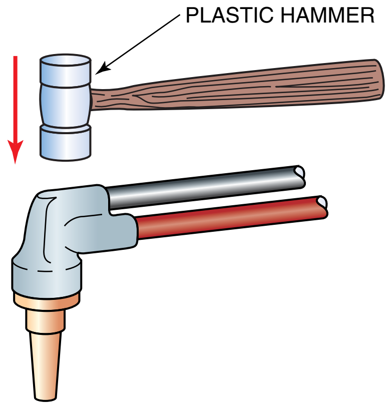


FIGURE 7-14 Tap the back of the torch head to remove a tip that is stuck. The tip itself should never be tapped.

FIGURE 7-15 Checking a cutting tip for leaks.
Courtesy of Larry Jeffus.

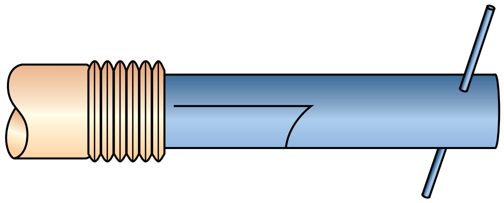


FIGURE 7-16 Damaged torch seats can be repaired by using a reamer.

If the cutting tip seat or the torch head seat is damaged, it can be repaired by using a reamer designed for the specific torch tip and head, **Figure** 7-16, or it can be sent out for repair. New fiber packings are available for tips with packings. The original leak-checking test should be repeated to be sure the new seal is good.

Oxyfuel Cutting, Setup, and Operation

The setting up of a cutting torch system is exactly like setting up oxyfuel welding equipment except for the adjustment of gas pressures. This chapter covers gas pressure adjustments and cutting equipment operations.

Chapter 28, Oxyfuel Welding and Cutting, Equipment, Setup and Operation, gives detailed technical information and instructions for oxyfuel systems. The chapter covers the following topics:

- Safety
- Pressure regulator setup and operation
- Welding and cutting torch design and service
- Reverse flow and flashback valves
- Hoses and fittings
- Types of flames
- Leak detection

FIGURE 7-17 Leak-check all gas fittings. Courtesy of Larry Jeffus. See OFW video series.

PRACTICE 7-1

Setting Up a Cutting Torch

Demonstrate to other students and your instructor the proper method of setting up cylinders, regulators, hoses, and the cutting torch.

1. The oxygen and acetylene cylinders must be securely chained to a cart or wall before the safety caps are removed.
2. After removing the safety caps, stand to one side and crack (open and quickly close) the cylinder valves, being sure there are no sources of possible ignition that may start a fire. Cracking the cylinder valves is done to blow out any dirt that may be in the valves.
3. Visually inspect all of the parts for any damage, needed repair, or cleaning.
4. Attach the regulators to the cylinder valves and tighten them securely with a wrench.
5. Attach a reverse flow valve or flashback arrestor, if the torch does not have them built in, to the hose connection on the regulator or to the hose connection on the torch body, depending on the type of reverse flow valve in the set. Occasionally, test each reverse flow valve by blowing through it to make sure it works properly.
6. If the torch you will be using is a combination-type torch, attach the cutting head at this time.
7. Last, install a cutting tip on the torch.
8. Before the cylinder valves are opened, back out the pressure regulating screws so that when the valves are opened the gauges will show zero pounds working pressure.
9. Stand to one side of the regulators' face as the cylinder valves are opened slowly.
10. The oxygen valve is opened all the way until it becomes tight, but do not overtighten, and the acetylene valve is opened no more than one-half turn.
11. Open one torch valve and then turn the regulating screw in slowly until 2 psig to 4 psig (14 kPag to 30 kPag) shows on the working pressure gauge. Allow the gas to escape so that the line is completely purged.
12. If you are using a combination welding and cutting torch, the oxygen valve nearest the hose connection must be opened before the flame adjusting valve or cutting lever will work.
13. Close the torch valve and repeat the purging process with the other gas.
14. Be sure there are no sources of possible ignition that may result in a fire.
15. With both torch valves closed, spray a leak-detecting solution on all connections, including the cylinder valves. Tighten any connection that shows bubbles, **Figure 7-17.**

Complete a copy of the "Student Welding Report" listed in Appendix I or provided by your instructor. ◆

PRACTICE 7-2

Cleaning a Cutting Tip

Using a cutting torch set that is assembled and adjusted as described in Practice 7-1, and a set of tip cleaners, you will clean the cutting tip.

1. Turn on a small amount of oxygen, **Figure 7-18.** This procedure is done to blow out any dirt loosened during the cleaning.
2. The end of the tip is first filed flat, using the file provided in the tip cleaning set, **Figure 7-19.**
3. Try several sizes of tip cleaners in a preheat hole until the correct size cleaner is determined. It should easily go all the way into the tip, **Figure 7-20.**
4. Push the cleaner in and out of each preheat hole several times. Tip cleaners are small, round files. Excessive use of them will greatly increase the orifice (hole) size.

FIGURE 7-18 Turn on the oxygen valve. Courtesy of Larry Jeffus.

FIGURE 7-19 File the end of the tip flat. Courtesy of Larry Jeffus.

FIGURE 7-20 A tip cleaner should be used to clean the flame and center cutting holes. Courtesy of Larry Jeffus.

5. Next, depress the cutting lever and, by trial and error, select the correct size tip cleaner for the center cutting orifice.

A tip cleaner should never be forced. If the tip needs additional care, refer to the section on tip care in Chapter 25.

Complete a copy of the "Student Welding Report" listed in Appendix I or provided by your instructor. ◆

PRACTICE 7-3

Lighting the Torch

Wearing welding goggles, gloves, and any other required personal protective clothing, and with a cutting torch set that is safely assembled, you will light the torch.

1. Set the regulator working pressure for the tip size. If you do not know the correct pressure for the tip, start with the fuel set at 5 psig (35 kPag) and the oxygen set at 25 psig (170 kPag).
2. Point the torch tip upward and away from any equipment or other students.
3. Turn on just the acetylene valve and use only a sparklighter to ignite the acetylene. The torch may not stay lit. If this happens, close the valve slightly and try to relight the torch.
4. If the flame is small, it will produce heavy black soot and smoke. In this case, turn the flame up to stop the soot and smoke. The welder need not be concerned if the flame jumps slightly away from the torch tip.
5. With the acetylene flame burning smoke free, slowly open the oxygen valve and by using only the oxygen valve adjust the flame to a neutral setting, **Figure 7-21**.
6. When the cutting oxygen lever is depressed, the flame may become slightly carbonizing. This may occur because of a drop in line pressure due to the high flow of oxygen through the cutting orifice.
7. With the cutting lever depressed, readjust the preheat flame to a neutral setting.

The flame will become slightly oxidizing when the cutting lever is released. Since an oxidizing flame is hotter than a neutral flame, the metal being cut will be preheated faster. When the cut is started by depressing the lever, the flame automatically returns to the neutral setting and does not oxidize the top of the plate. Extinguish the flame by first turning off the oxygen and then the acetylene.

Complete a copy of the "Student Welding Report" listed in Appendix I or provided by your instructor. ◆

CAUTION

Sometimes with large cutting tips the tip will pop when the acetylene is turned off first. If that happens, turn the oxygen off first.

Hand Cutting

When making a cut with a hand torch, it is important for the welder to be steady in order to make the cut as smooth as possible. A welder must also be comfortable and free to move the torch along the line to be cut. It is a good idea for a welder to get into position and practice the cutting movement a few times before lighting the torch.

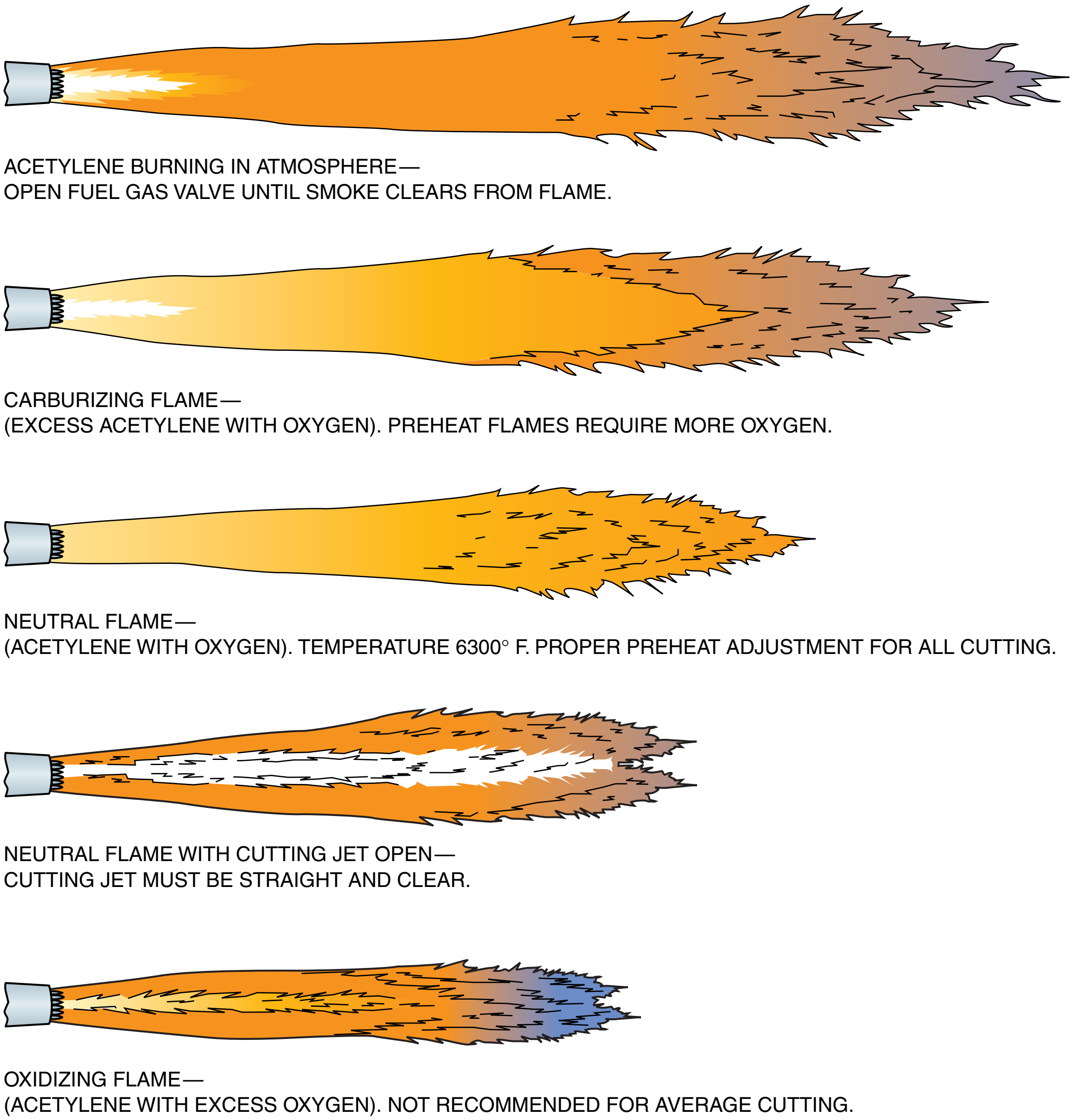


FIGURE 7-21 Oxyacetylene flame adjustments for the cutting torch.

Even when the welder and the torch are braced properly, a tiny movement such as a heartbeat will cause a slight ripple in the cut. Attempting a cut without leaning on the work, to brace oneself, is tiring and causes inaccuracies.

The torch should be braced with the left hand if the welder is right-handed or with the right hand if the welder is left-handed. The torch may be moved by sliding it toward you over your supporting hand, **Figures** 7-22 and **Figure** 7-23. The torch can also be pivoted on the supporting hand. If the pivoting method is used, care must be taken to prevent the cut from becoming a series of arcs.

A slight forward torch angle helps the flame preheat the metal, keeps some of the reflected flame heat off the tip, aids in blowing dirt and oxides away from the cut, and keeps the tip clean for a longer period of time because slag is less likely to be blown back on it, **Figure** 7-24. The forward angle can

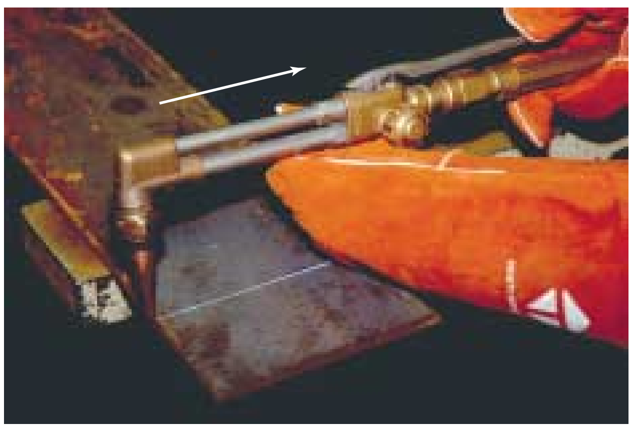
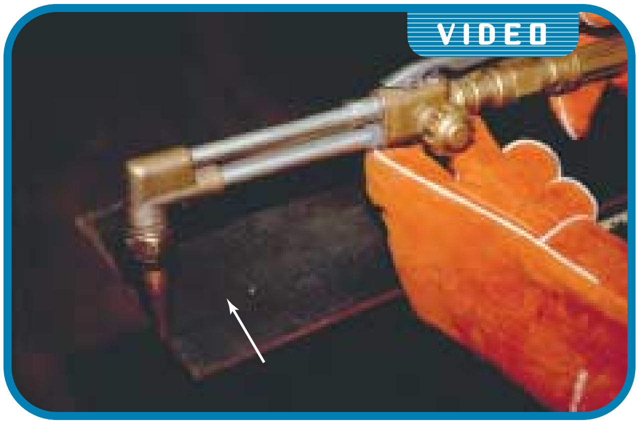


FIGURE 7-22 For short cuts, the torch can be drawn over the gloved hand. Courtesy of Larry Jeffus.



(A)

(B)

FIGURE 7-23 For longer cuts, the torch can be moved by sliding your gloved hand along the plate parallel to the cut: (A) start and (B) finish. Always check for free and easy movement before lighting the torch. Courtesy of Larry Jeffus. **See DFW video series.**

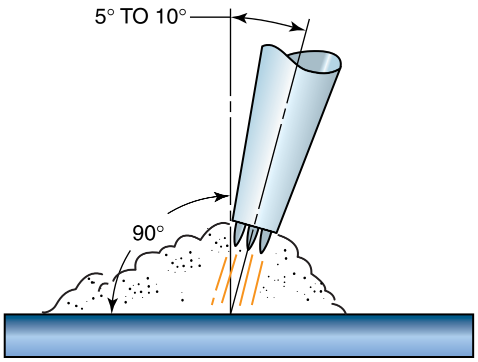


FIGURE 7-24 A slight forward angle helps when cutting thin material.

be used only for a straight line square cut. If shapes are cut using a slight angle, the part will have beveled sides.

When making a cut, the inner cones of the flame should be kept 1/8 in. (3 mm) to 3/8 in. (10 mm) from the

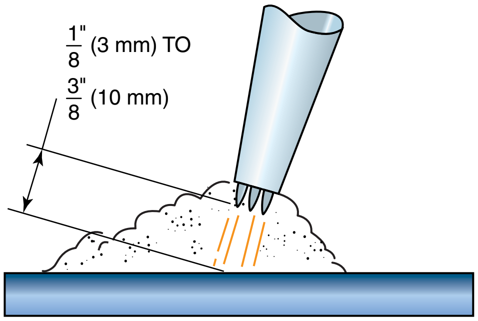


FIGURE 7-25 Inner cone to work distance.

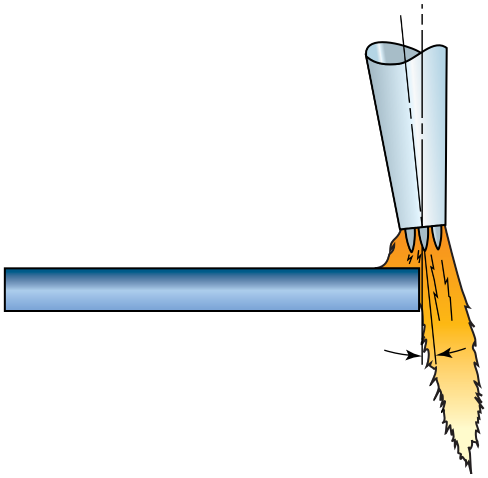


FIGURE 7-26 Starting a cut on the edge of a plate. Notice how the torch is pointed at a slight angle away from the edge.

surface of the plate, **Figure 7-25**. This distance is known as the coupling distance.

To start a cut on the edge of a plate, hold the torch at a right angle to the surface or pointed slightly away from the edge, **Figure 7-26**. The torch must also be pointed so that the cut is started at the very edge. The edge of the plate heats up more quickly and allows the cut to be started sooner. Also, fewer sparks will be blown around the shop. Once the cut is started, the torch should be rotated back to a right angle to the surface or to a slight leading angle.

CAUTION

NEVER USE A CUTTING TORCH TO CUT OPEN A USED CAN, DRUM, TANK, OR OTHER SEALED CONTAINERS. The sparks and oxygen cutting stream may cause even nonflammable residue inside to burn or explode. If a used container must be cut it must first have one end removed and all residue cleaned out. In addition to the possibility of a fire or an explosion you might be exposing yourself to hazardous fumes. Before making a cut check the material specification data sheet (MSDS) for safety concerns.

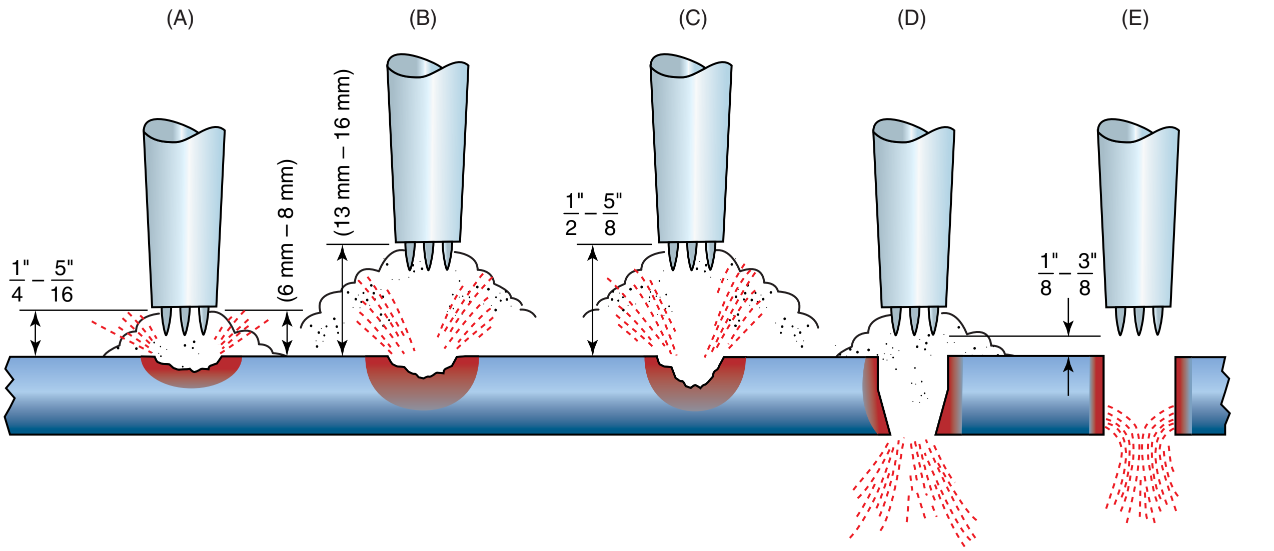


FIGURE 7-27 Sequence for piercing plate.

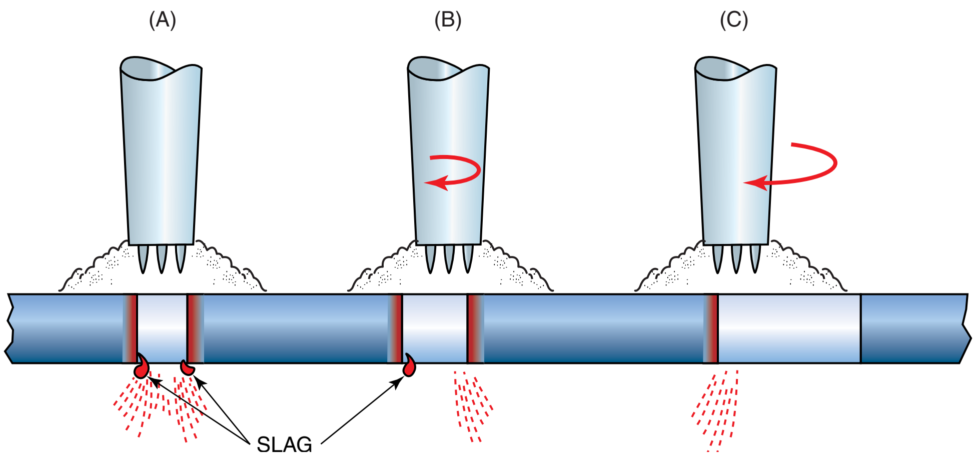


FIGURE 7-28 A short, backward movement (A) before the cut is carried forward (B) clears the slag from the kerf (C) slag left in the kerf may cause the cutting stream to gouge into the base metal, resulting in a poor cut.

If a cut is to be started in a place other than the edge of the plate, the inner cones should be held as close as possible to the metal. Having the inner cones touch the metal will speed up the preheat time. When the metal is hot enough to allow the cut to start, the torch should be raised as the cutting lever is slowly depressed. When the metal is pierced, the torch should be lowered again, **Figure 7-27.** By raising the torch tip away from the metal, the amount of sparks blown into the air is reduced, and the tip is kept cleaner. If the metal being cut is thick, it may be necessary to move the torch tip in a small circle as the hole goes through the metal. If the metal is to be cut in both directions from the spot where it was pierced, the torch should be moved backward a short distance and then forward, **Figure 7-28.** This prevents slag from refilling the kerf at the starting point, thus making it difficult to cut in the other direction. The kerf is the space produced during any cutting process.

Starts and stops can be made more easily and better if one side of the metal being cut is scrap. When it is necessary to stop and reposition oneself before continuing the cut, the cut should be turned out, a short distance, into the scrap side of the metal, **Figure 7-29.** The extra space that this procedure provides will allow a smoother and more even start with less chance that slag will block the cut. If neither side of the cut is to be scrap, the forward movement should be stopped for a moment before releasing the cutting lever. This action will allow the **drag,** or the distance that the bottom of the cut is behind the top, to catch up before stopping, **Figure 7-30.** To restart, use the same procedure that was given for starting a cut at the edge of the plate.

The proper alignment of the preheat holes will speed up and improve the cut. The holes should be aligned so that one is directly on the line ahead of the cut and another is aimed down into the cut when making a straight line square cut, **Figure 7-31.** The flame is directed toward the smaller piece and the sharpest edge when cutting a bevel. For this reason, the tip should be changed so that at least two of the flames are on the larger plate and

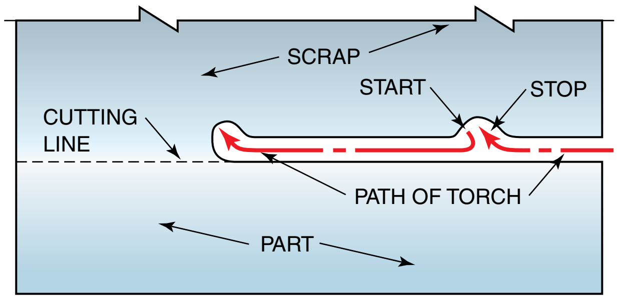


FIGURE 7-29 Turning out into scrap to make stopping and starting points smoother.

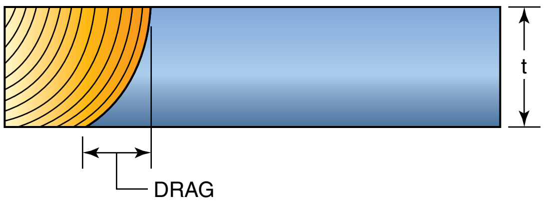


FIGURE 7-30 Drag is the distance by which the bottom of a cut lags behind the top.

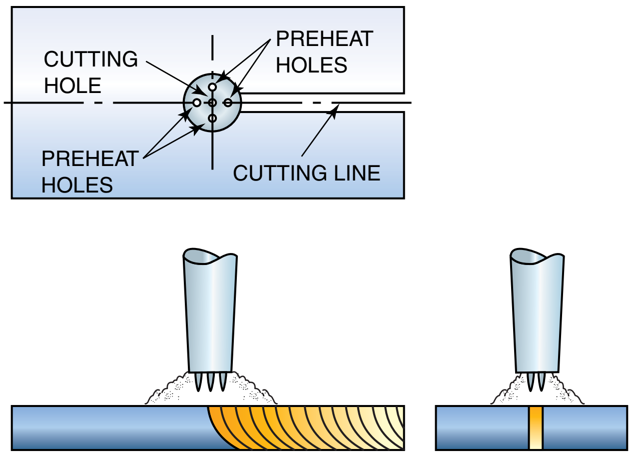


FIGURE 7-31 Tip alignment for a square cut.

none of the flames are directed on the sharp edge, **Figure 7-32.** If the preheat flame is directed at the edge, it will be rounded off as it is melted off.

Layout

Laying out a line to be cut can be done with a piece of soapstone or a chalk line. To obtain an accurate line, a scribe or a punch can be used. If a piece of soapstone is used, it should be sharpened properly to increase accuracy, **Figure 7-33.** A chalk line will make a long, straight line on metal and is best used on large jobs. The scribe and punch can both be used to lay out an accurate line, but the punched line is easier to see when cutting. A punch can be held as shown in **Figure 7-34,** with the tip just above the surface of the metal. When the punch is struck with a lightweight hammer, it will make a mark. If you move your hand along the line and rapidly strike the punch, it will leave a series of punch marks for the cut to follow.

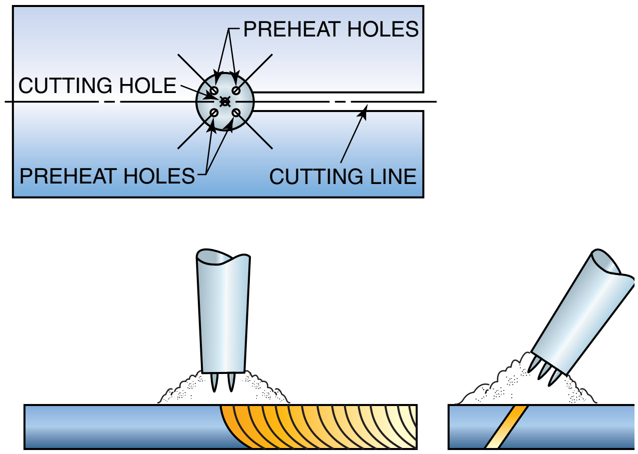


FIGURE 7-32 Tip alignment for a bevel cut.

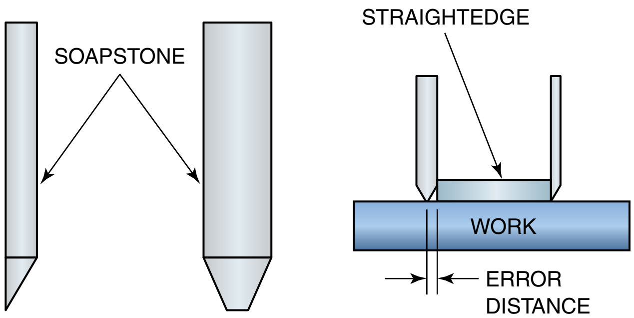


FIGURE 7-33 Proper method of sharpening a soapstone.

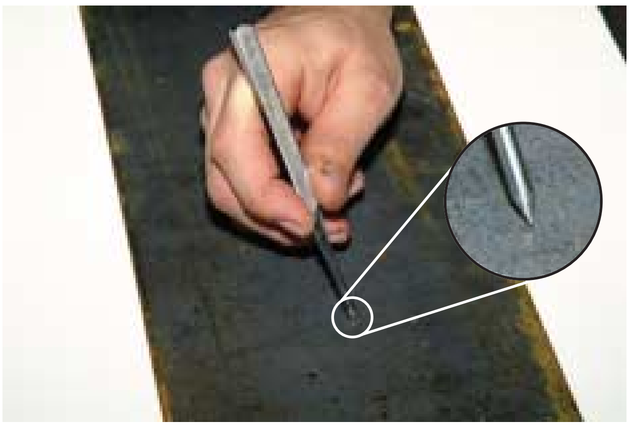


FIGURE 7-34 Holding the punch slightly above the surface allows the punch to be struck rapidly and moved along a line to mark it for cutting. Courtesy of Larry Jeffus.

Selecting the Correct Tip and Setting the Pressure

Each welding equipment manufacturer uses its own numbering system to designate the tip size. It would be impossible to remember each of the systems. Each

Metal Thickness in (mm)	Center Orifice Size No. Drill Size	Tip Cleaner No.*	Oxygen Pressure lb/in² (kPa)	Acetylene lb/in² (kPa)
1/8 (3)	60	7	10 (70)	3 (20)
1/4 (6)	60	7	15 (100)	3 (20)
3/8 (10)	55	11	20 (140)	3 (20)
1/2 (13)	55	11	25 (170)	4 (30)
3/4 (19)	55	11	30 (200)	4 (30)
1 (25)	53	12	35 (240)	4 (30)
2 (51)	49	13	45 (310)	5 (35)
3 (76)	49	13	50 (340)	5 (35)
4 (102)	49	13	55 (380)	5 (35)
5 (127)	45	**	60 (410)	5 (35)

*The tip cleaner number when counted from the small end toward the large end in a standard tip cleaner set
**Larger than normally included in a standard tip cleaner set

TABLE 7-6 Cutting Pressure and Tip Size.

manufacturer, however, does relate the tip number to the numbered drill size used to make the holes. On the back of most tip cleaning sets, the manufacturer lists the equivalent drill size of each tip cleaner. By remembering approximately which tip cleaner was used on a particular tip for a metal thickness range, a welder can easily select the correct tip when using a new torch set. Using the tip cleaner that you are familiar with, try it in the various torch tips until you find the correct tip that the tip cleaner fits. **Table 7-6** lists the tip drill size, pressure range, and metal thickness range for which the tip can be used.

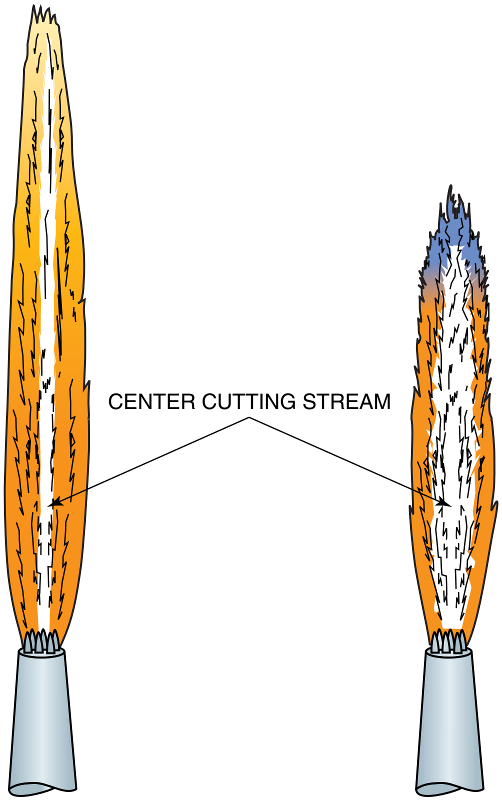


FIGURE 7-35 A clean cutting tip will have a long, well-defined oxygen stream.

PRACTICE 7-4

Setting the Gas Pressures

Setting the working pressure of the regulators can be done by following a table, or it can be set by watching the flame.

1. To set the regulator by watching the flame, first set the acetylene pressure at 2 psig to 4 psig (14 kPag to 30 kPag) and then light the acetylene flame.
2. Open the acetylene torch valve one to two turns and reduce the regulator pressure by backing out the setscrew until the flame starts to smoke.
3. Increase the pressure until the smoke stops and then increase it just a little more.

This is the maximum fuel gas pressure the tip needs. With a larger tip and a longer hose, the pressure must be set higher. This is the best setting, and it is the safest one to use. With this lowest possible setting, there is less chance of a leak. If the hoses are damaged, the resulting fire will be much smaller than a fire burning from a hose with a higher pressure. There is also less chance of a leak with the lower pressure.

4. With the acetylene adjusted so that the flame just stops smoking, slowly open the torch oxygen valve.
5. Adjust the torch to a neutral flame. When the cutting lever is depressed, the flame will become carbonizing, not having enough oxygen pressure.
6. While holding the cutting lever down, increase the oxygen regulator pressure slightly. Readjust the flame, as needed, to a neutral setting by using the oxygen valve on the torch.
7. Increase the pressure slowly and readjust the flame as you watch the length of the clear cutting stream in the center of the flame, **Figure 7-35.** The center stream will stay fairly long until a pressure is reached that causes turbulence disrupting the cutting stream. This turbulence will cause the flame to shorten in length considerably, **Figure 7-35.**
8. With the cutting lever still depressed, reduce the oxygen pressure until the flame lengthens once again. This is the maximum oxygen pressure that this tip can use without disrupting turbulence in the cutting stream. This turbulence will cause a very poor cut. The lower pressure also will keep the sparks from being blown a longer distance from the work, **Figure 7-36.**

Complete a copy of the "Student Welding Report" listed in Appendix I or provided by your instructor. ◆

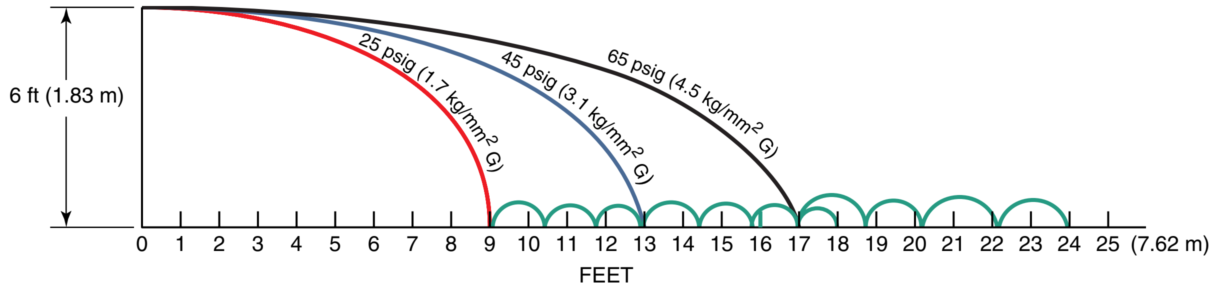


FIGURE 7-36 The sparks from cutting a mild steel plate, 3/8 in. (10 mm) thick, 6 ft (1.8 m) from the floor, will be thrown much farther if the cutting pressure is too high for the plate thickness. These cuts were made with a Victor cutting tip no. 0–1–101 using 25 psig (1.7 kg/mm^2) as recommended by the manufacturer and by excessive pressures of 45 psig (3.1 kg/mm^2) and 65 psig (4.5 kg/mm^2).

The Chemistry of a Cut

The oxyfuel gas cutting torch works when the metal being cut rapidly oxidizes or burns. This rapid oxidization or burning occurs when a high-pressure stream of pure oxygen is directed on the metal after it has been preheated to a temperature above its kindling point. Kindling point is the lowest temperature at which a material will burn. The kindling temperature of iron is 1600°F (870°C), which is a dull red color. Note that iron is the pure element and cast iron is a alloy primarily of iron and carbon. The process will work easily on any metal that will rapidly oxidize, such as iron, low carbon steel, magnesium, titanium, and zinc.

CAUTION

Some metals release harmful oxides when they are cut. Extreme caution must be taken when cutting used, oily, dirty, or painted metals. They often produce very dangerous fumes when they are cut. You may need extra ventilation and a respirator to be safe.

The process is most often used to cut iron and low carbon steels, because unlike most of the metals, little or no oxides are left on the metal, and it can easily be welded.

The burning away of the metal is a chemical reaction with iron (Fe) and oxygen (O). The oxygen forms an iron oxide, primarily Fe_3O_4, that is light gray in color. Heat is produced by the metal as it burns. This heat helps carry the cut along. On thick pieces of metal, once a small spot starts burning (being cut), the heat generated helps the cut continue quickly through the metal. With some cuts the heat produced may overheat small strips of metal being cut from a larger piece. As an example, the center piece of a hole being cut will quickly become red hot and will start to oxidize with the surrounding air, **Figure 7-37**. This heat produced by the cut makes it difficult to cut out small or internal parts.

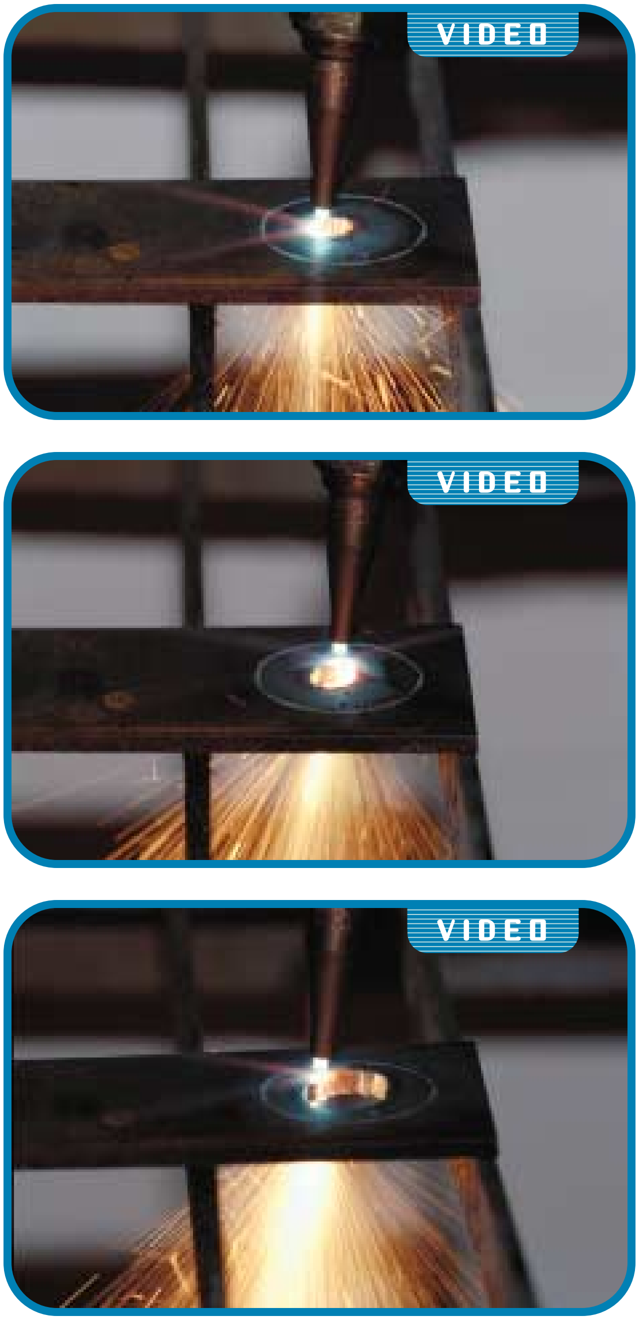


FIGURE 7-37 As a hole is cut, the center may be overheated. Courtesy of Larry Jeffus. See OFW video series.

EXPERIMENT 7-1

Observing Heat Produced during a Cut

This experiment may require more skill than you have developed by this time. You may wish to observe your instructor performing the experiment or try it at a later time.

Using a properly lit and adjusted cutting torch, welding gloves, appropriate eye protection and clothing, and one piece of clean mild steel plate 6 in. (152 mm) long × 1/4 in. (6 mm) to 1/2 in. (13 mm) thick, you will make an oxyfuel gas cut without the preheat flame.

Place the piece of metal so that the cutting sparks fall safely away from you. With the torch lit, pass the flame over the length of the plate until it is warm, but not hot. Brace yourself and start a cut near the edge of the plate. When the cut has been established, have another student turn off the acetylene regulator. The cut should continue if you remain steady and the plate is warm enough. *Hint: Using a slightly larger tip size will make this easier*.

Complete a copy of the "Student Welding Report" listed in Appendix I or provided by your instructor. ◆

The Physics of a Cut

As a cut progresses along a plate, a record of what happened during the cut is preserved along both sides of the kerf. This record indicates to the welder what was correct or incorrect with the preheat flame, cutting speed, and oxygen pressure.

Preheat The size and number of preheat holes in a tip has an effect on both the top and bottom edges of the metal. An excessive amount of preheat flame results in the top edge of the plate being melted or rounded off. In addition, an excessive amount of hard-to-remove slag is deposited along the bottom edge. If the flame is too small, the travel speed must be slower. A reduction in speed may result in the cutting stream wandering from side to side. The torch tip can be raised slightly to eliminate some of the damage caused by too much preheat. However, raising the torch tip causes the cutting stream of oxygen to be less forceful and less accurate.

Speed The cutting speed should be fast enough so that the drag lines have a slight slant backward if the tip is held at a 90° angle to the plate, **Figure 7-38.** If the cutting speed is too fast, the oxygen stream may not have time to go completely through the metal, resulting in an incomplete cut, **Figure 7-39.** Too slow a cutting speed results in the cutting stream wandering, thus causing gouges in the side of the cut, **Figure 7-40** and **Figure 7-41.**

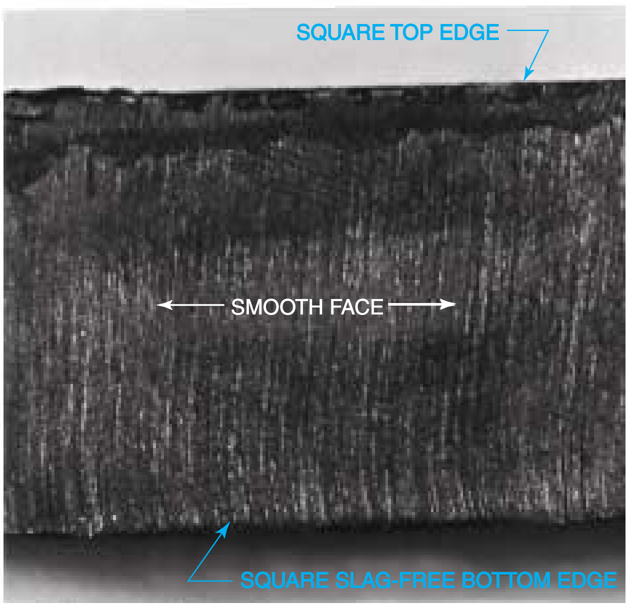


FIGURE 7-38 Correct cut. Courtesy of Larry Jeffus.

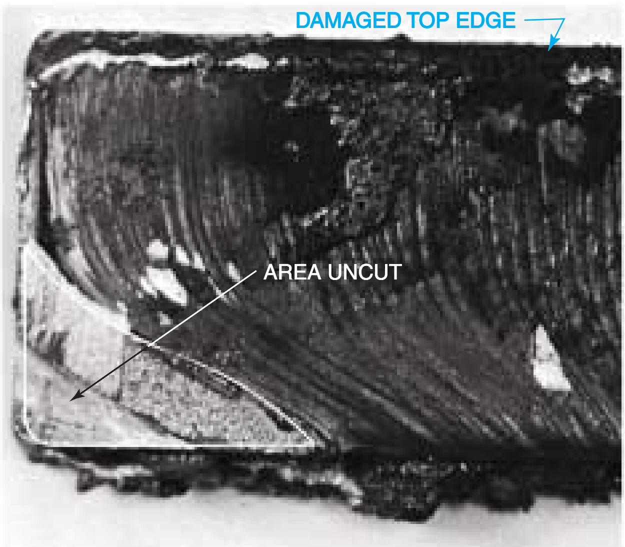


FIGURE 7-39 Too fast a travel speed resulting in an incomplete cut; too much preheat and the tip is too close, causing the top edge to be melted and removed.
Courtesy of Larry Jeffus.

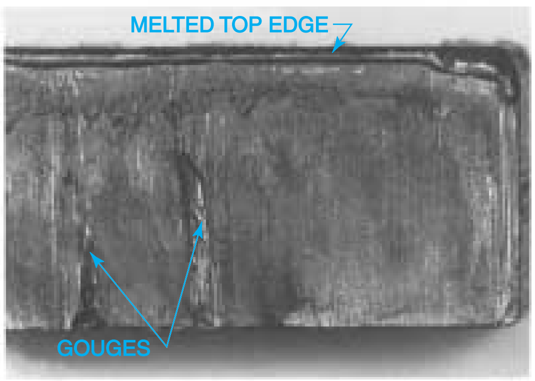


FIGURE 7-40 Too slow a travel speed results in the cutting stream wandering, thus causing gouges in the surface; preheat flame is too close, melting the top edge.
Courtesy of Larry Jeffus.

Pressure A correct pressure setting results in the sides of the cut being flat and smooth. A pressure setting that is too high causes the cutting stream to expand as it leaves the tip, resulting in the sides of the kerf being slightly dished, **Figure** 7-42. When the pressure setting is too low, the cut may not go completely through the metal.

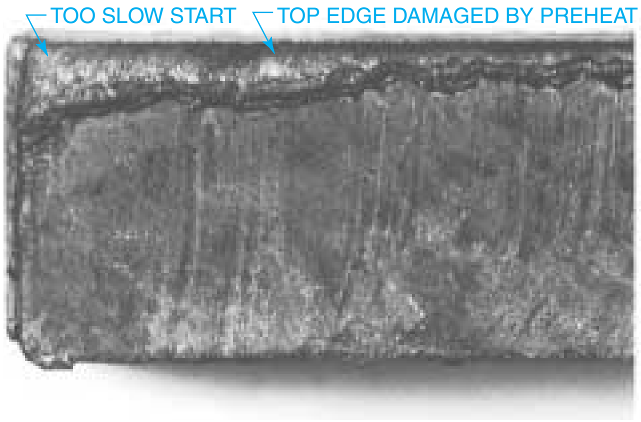


FIGURE 7-41 Too slow a travel speed at the start; too much preheat. Courtesy of Larry Jeffus.

EXPERIMENT 7-2

Effect of Flame, Speed, and Pressure on a Machine Cut

Using a properly lit and adjusted automatic cutting machine, welding gloves, appropriate eye protection and clothing, a variety of tip sizes, and one piece of mild steel plate 6 in. (152 mm) long × 1/2 in. (13 mm) to 1 in. (25 mm) thick, you will observe the effect of the preheat flame, travel speed, and pressure on the metal being cut.

Using the variety of tips, speeds, and oxygen pressures, make a series of cuts on the plate. As the cut is being made, listen to the sound it makes. Also look at the stream of sparks coming off the bottom. A good cut should have a smooth, even sound, and the sparks should come off the bottom of the metal more like a stream than a spray, **Figure** 7-43. When the cut is complete, look at the drag lines to determine what was correct or incorrect with the cut, **Figure** 7-44.

Repeat this experiment until you know a good cut by the sound it makes and the stream of sparks. A good cut has little or no slag left on the bottom of the plate.

Complete a copy of the "Student Welding Report" listed in Appendix I or provided by your instructor. ◆

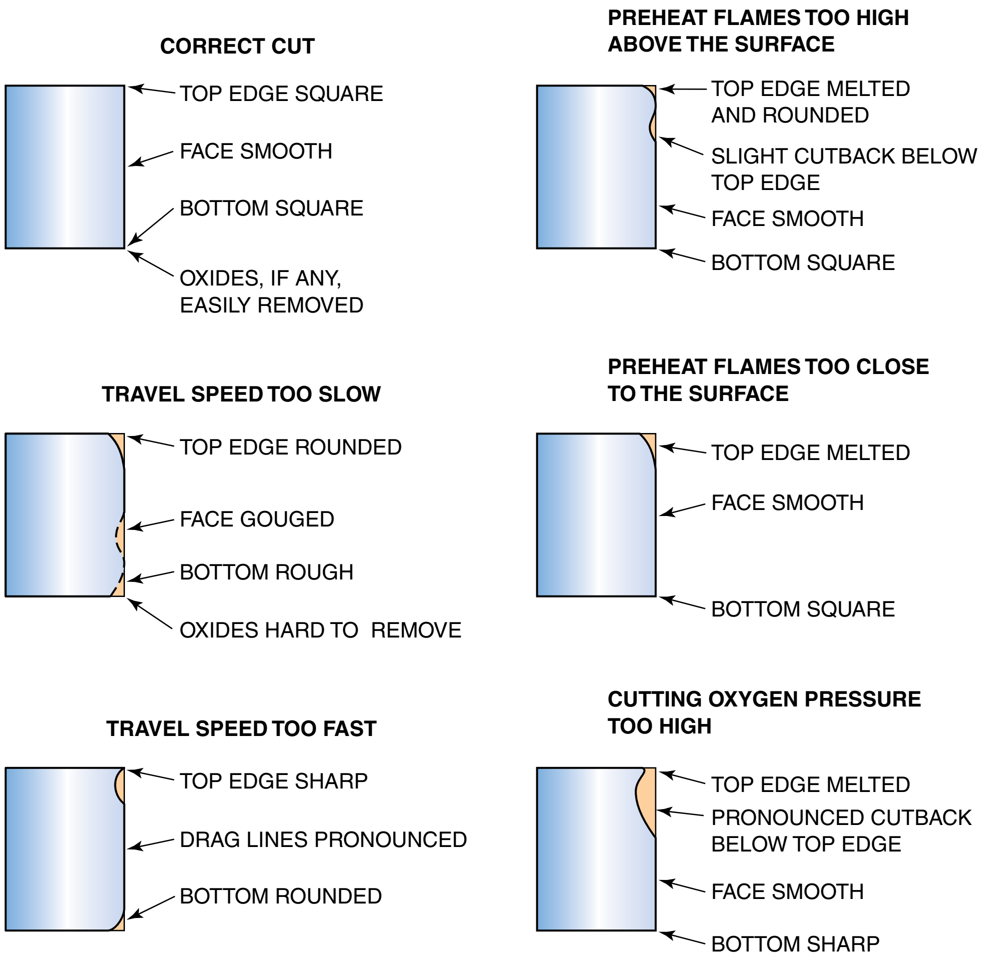


FIGURE 7-42 Profile of flame-cut plates.

FIGURE 7-43 A good cut showing a steady stream of sparks flying out from the bottom of the cut.
Courtesy of Larry Jeffus. See DFW video series.

FIGURE 7-44 Poor cut. The slag is backing up because the cut is not going through the plate. Courtesy of Larry Jeffus.

EXPERIMENT 7-3

Effect of Flame, Speed, and Pressure on a Hand Cut

Using a properly lit and adjusted hand torch, welding gloves, appropriate eye protection and clothing, and the same tip sizes and mild steel plate, repeat Experiment 7-2 to note the effects of the preheat flame, travel speed, and pressure on hand cutting. Complete a copy of the "Student Welding Report" listed in Appendix I or provided by your instructor.

Slag The two types of slag produced during a cut are soft slag and hard slag. Soft slag is very porous, brittle, and easily removed from a cut. There is little or no unoxidized iron in it. It may be found on some good cuts. Hard slag may be mixed with soft slag. Hard slag is attached solidly to the bottom edge of a cut, and it requires a lot of chipping and grinding to be removed. There is 30% to 40% or more unoxidized iron in hard slag. The higher the unoxidized iron content, the more difficult the slag is to remove. Slag is found on bad cuts,

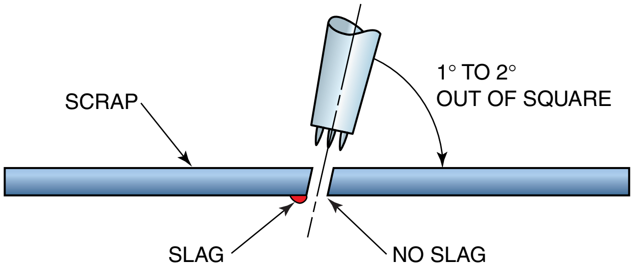


FIGURE 7-45 A slight angle on the torch will put the slag on the scrap side of the cut.

due to dirty tips, too much preheat, too slow a travel speed, too short a coupling distance, or incorrect oxygen pressure.

The slag from a cut may be kept off one side of the plate being cut by slightly angling the cut toward the scrap side of the cut, **Figure 7-45**. The angle needed to force the slag away from the good side of the plate may be as small as 2° or 3°. This technique works best on thin sections; on thicker sections the bevel may show. ◆

Plate Cutting

Low carbon steel plate can be cut quickly and accurately, whether thin-gauge sheet metal or sections more than 4 feet (1.2 m) thick are used. It is possible to achieve cutting speeds as fast as 32 inches per minute (13.5 mm/s), in 1/8-in. (3-mm) plate, and accuracy on machine cuts of ±3/64 in. Some very large hand-cutting torches with an oxygen cutting volume of 600 cfh (2830 L/min) can cut metal that is 4 ft (1.2 m) thick, **Figure 7-46**. Most hand torches will not easily cut metal that is more than 7 in. (178 mm) to 10 in. (254 mm) thick.

The thicker the plate, the more difficult the cut is to make. Thin plate, 1/4 in. (6 mm) or less, can be cut and the pieces separated even if poor techniques and incorrect pressure settings are used. Thick plate, 1/2 in. (13 mm) or thicker, often cannot be separated if the cut is not correct. For very heavy cuts, on plate 12 in. (305 mm) or thicker, the equipment and operator technique must be near perfection or the cut will be faulty.

Plate that is properly cut can be assembled and welded with little or no postcut cleanup. Poor-quality cuts require more time to clean up than is needed to make the required adjustments to make a good weld.

Cutting Table

Because of the nature of the torch cutting process, special consideration is given to the flame cutting support. Any piece being cut should be supported so the torch flame will not cut though the piece and into the table. Special cutting tables are used that expose only a small metal area to the torch flame. Some tables use parallel steel bars of metal and others use cast iron pyramids. All cutting should be set up so the flame and oxygen stream runs between the support bars or over the edge of the table.

FIGURE 7-46 Hand torches for thick sections. Courtesy of Victor Equipment, a Thermadyne Company.

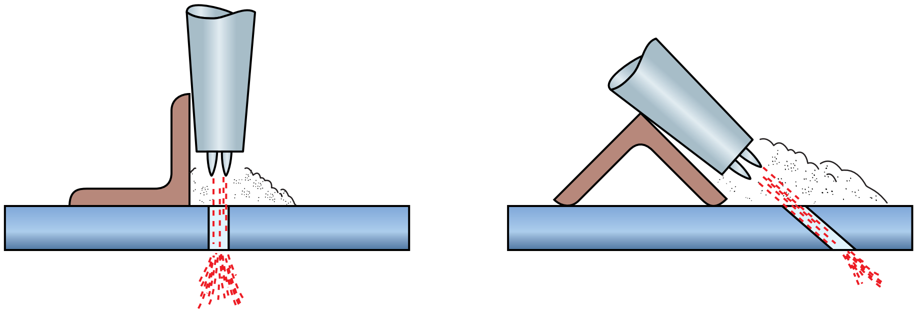


FIGURE 7-47 Using angle irons to aid in making cuts.

If an ordinary welding table or another steel table is used, special care must be taken to avoid cutting through the table top. The piece being cut may be supported above the support table by firebrick. Another method is to cut the metal over the edge of the table.

Torch Guides

In manual torch cutting a guide or support is frequently used to allow for better control and more even cutting. It takes a very skilled welder to make a straight, clean cut even when following a marked line. It is even more difficult to make a radius cut to any accuracy. Guides and supports allow the height and angle of the torch head to remain constant. The speed of the cut, which is very important to making a clean, even kerf, must be controlled by the welder.

Since the torch must be held in an exact position while making any accurate cut, the welder normally supports the torch weight with the hand. Supporting the torch weight this way not only allows for more accurate work but also cuts down on fatigue. A rest, such as a firebrick, is also used to support the torch.

Various types of guides can be used to guide the torch in a straight line. **Figure** 7-47 shows one type of guide using angle iron. The edge of the angle is followed to give the straight cut. Bevel cuts can be made freehand with the torch, but it is very difficult to keep them uniform. More accurate bevel cuts are made by resting the torch against the angle side of an angle iron.

Special roller guides, **Figure** 7-48, can also be attached to the torch head. The attachment holds the torch cutting tip at an exact height.

When cutting circles, a circle cutting attachment is used. **Figure** 7-48 shows how the attachment fits on the torch head. The radius can be preset to any required distance. The cutter revolves around the center point when making the cut. The roller controls the torch tip height above the plate surface.

FIGURE 7-48 Devices that are used to improve hand cutting. Courtesy of Victor Equipment, a Thermadyne Company.

PRACTICE 7-5

Flat, Straight Cut in Thin Plate

Using a properly lit and adjusted cutting torch and one piece of mild steel plate 6 in. (152 mm) long × 1/4 in. (6 mm) thick, you will cut off 1/2-in. (13-mm) strips.

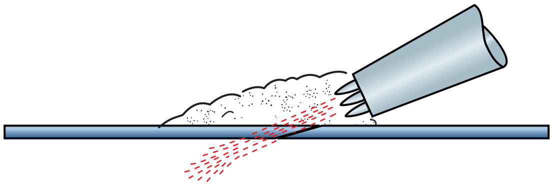


FIGURE 7-49 Cut the sheet metal at a very sharp angle.

Using a straightedge and soapstone, make several straight lines 1/2 in. (13 mm) apart. Starting at one end, make a cut along the entire length of plate. The strip must fall free, be slag free, and be within ±3/32 in. (2 mm) of a straight line and ±5° of being square. Repeat this procedure until the cut can be made straight and slag free. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

Complete a copy of the "Student Welding Report" listed in Appendix I or provided by your instructor. ◆

PRACTICE 7-6

Flat, Straight Cut in Thick Plate

Using a properly lit and adjusted cutting torch and one piece of mild steel plate 6 in. (152 mm) long × 1/2 in. (13 mm) thick or thicker, you will cut off 1/2-in. (13-mm) strips. *Note: Remember that starting a cut in thick plate will take longer, and the cutting speed will be slower.* Lay out, cut, and evaluate the cut as was done in Practice 7-5. Repeat this procedure until the cut can be made straight and slag free. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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PRACTICE 7-7

Flat, Straight Cut in Sheet Metal

Use a properly lit and adjusted cutting torch and a piece of mild steel sheet that is 10 in. (254 mm) long and 18 gauge to 11 gauge thick. Holding the torch at a very sharp leading angle, **Figure 7-49**, cut the sheet along the line. The cut must be smooth and straight with as little slag as possible. Repeat this procedure until the cut can be made flat, straight, and slag free. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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PRACTICE 7-8

Flame Cutting Holes

Using a properly lit and adjusted cutting torch, welding gloves, appropriate eye protection and clothing, and one piece of mild steel plate 1/4 in. (6 mm) thick, you will cut holes with diameters of 1/2 in. (13 mm) and 1 in. (25 mm). Using the technique described for piercing a hole, start in the center and make an outward spiral until the hole is the desired size, **Figure 7-50.** The hole must be within ±3/32 in. (2 mm) of being round and ±5° of being square. The hole may have slag on the bottom. Repeat this procedure until both small and large sizes of holes can be made within tolerance. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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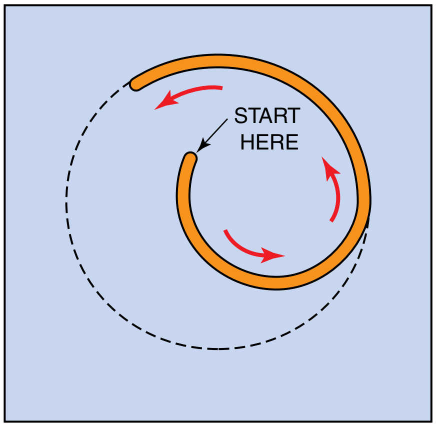

FIGURE 7-50 Start a cut for a hole near the middle.

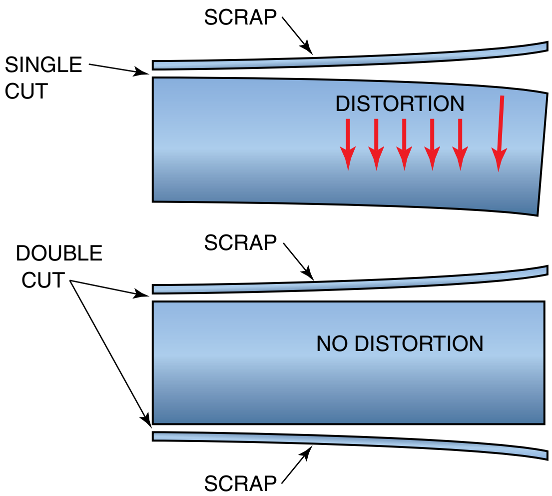

FIGURE 7-51 Making two parallel cuts at the same time will control distortion.

Distortion

Distortion is when the metal bends or twists out of shape as a result of being heated during the cutting process. This is a major problem when cutting a plate. If the distortion is not controlled, the end product might be worthless. There are two major methods of controlling distortion. One method involves making two parallel cuts on the same plate at the same speed and time, **Figure 7-51.**

FIGURE 7-52 Slitting adaptor for cutting machine. It can be used for parallel cuts from 1" (38 mm) to 12" (500 mm). Ideal for cutting test coupons. Courtesy of Victor Equipment, a Thermadyne Company.

Because the plate is heated evenly, distortion is kept to a minimum, **Figure 7-52.**

The second method involves starting the cut a short distance from the edge of the plate, skipping other short tabs every 2 ft (0.6 m) to 3 ft (0.9 m) to keep the cut from separating. Once the plate cools, the remaining tabs are cut, **Figure 7-53.**

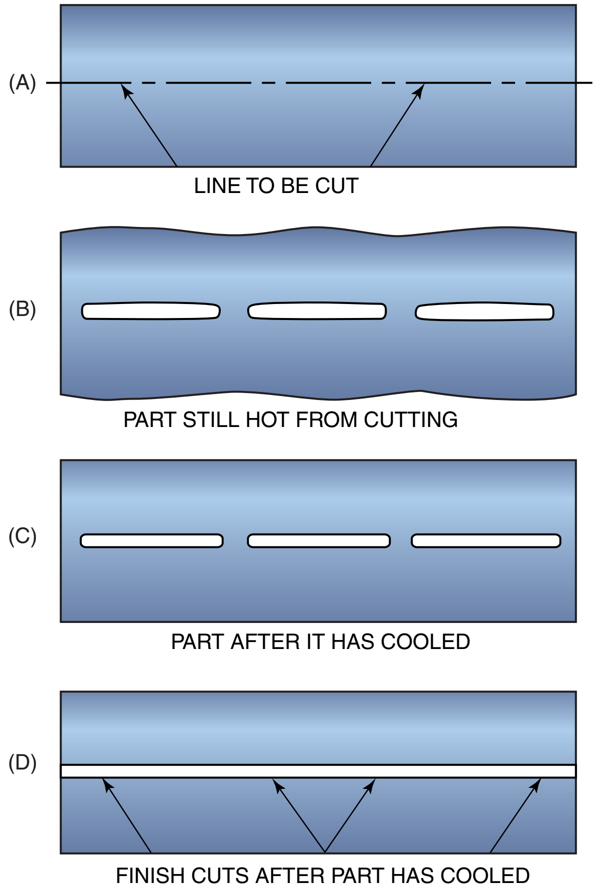

FIGURE 7-53 Steps used during cutting to minimize distortion.

EXPERIMENT 7-4

Minimizing Distortion

Using a properly lit and adjusted cutting torch, welding gloves, appropriate eye protection and clothing, and two pieces of mild steel 10 in. (254 mm) long × 1/4 in. (6 mm) thick, you will make two cuts and then compare the distortion. Lay out and cut out both pieces of metal as shown in **Figure 7-54.** Allow the metal to cool, and then cut the remaining tabs. Compare the four pieces of metal for distortion.

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PRACTICE 7-9

Beveling a Plate

Use a properly lit and adjusted cutting torch, welding gloves, appropriate eye protection and clothing, and one piece of mild steel plate 6 in. (152 mm) long × 3/8 in. (10 mm) thick. You will make a 45° bevel down the length of the plate.

Mark the plate in strips 1/2 in. (13 mm) wide. Set the tip for beveling and cut a bevel. The bevel should be within ±3/32 in. (2 mm) of a straight line and ±5° of a 45° angle. There may be some soft slag, but no hard slag, on the beveled plate. Repeat this Practice until the cut can be made within tolerance. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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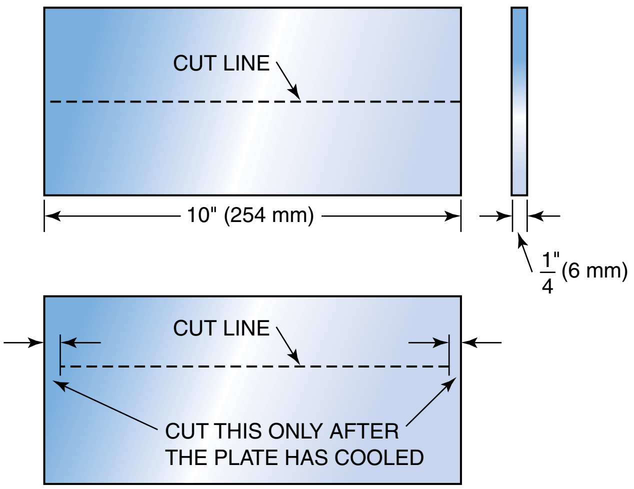

FIGURE 7-54 Making two cuts with minimum distortion. *Note:* Sizes of these and other cutting projects can be changed to fit available stock.

PRACTICE 7-10

Vertical Straight Cut

For this Practice, you will need a properly lit and adjusted cutting torch, welding gloves, appropriate eye protection and clothing, and one piece of mild steel plate

6 in. (152 mm) long × 1/4 in. (6 mm) to 3/8 in. (10 mm) thick, marked in strips 1/2 in. (13 mm) wide and held in the vertical position. You will make a straight line cut. Make sure that the sparks do not cause a safety hazard and that the metal being cut off will not fall on any person or object.

Starting at the top, make one cut downward. Then, starting at the bottom, make the next cut upward. The cut must be free of hard slag and within ±3/32 in. (2 mm) of a straight line and ±5° of being square. Repeat these cuts until they can be made within tolerance. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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PRACTICE 7-11

Overhead Straight Cut

Using a properly lit and adjusted cutting torch, welding gloves, appropriate eye protection and clothing, and one piece of mild steel plate 6 in. (152 mm) long × 1/4 in. (6 mm) to 3/8 in. (10 mm) thick, marked in strips 1/2 in. (13 mm) wide, you will make a cut in the overhead position. When making overhead cuts, it is important to be completely protected from the hot sparks. In addition to the standard safety clothing, you should wear a leather jacket, leather apron, cap, ear protection, and a full face shield.

The torch can be angled so that most of the sparks will be blown away. The metal should fall free when the cut is completed. The cut must be within 1/8 in. (3 mm) of a straight line and ±5° of being square. Repeat this practice until the cut can be made within tolerance. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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Cutting Applications

Making practice cuts on a piece of metal that will only become scrap is a good way to learn the proper torch techniques. If a bad cut is made, there is no loss. In a production shop, where each piece of metal is important, however, scrapped metal due to bad cuts decreases the shop's profits.

A number of factors can affect your ability to make a quality cut on a part that do not exist during practice cuts. The following are some of the things that can become problems when cutting:

- *Changing positions:* Often, parts are larger than can be cut from one position, so you may have to move to complete the cut. Stopping and restarting a cut can result in a small flaw in the cut surface. If this flaw exceeds the acceptable limits, the cut surface must be repaired before the part can be used. To avoid this problem, always try to stop at corners if the cut cannot be completed without moving.
- *Sparks:* You will often be making cuts in large plates. Even an ideal cut can create sparks that bounce around the plate surface. These sparks often find their way into your glove, under your arm, or to any other place that will become uncomfortable. Experienced welders will usually keep working if the sparks are not too large or too uncomfortable. With experience you will learn how to angle the torch, direct the cut, and position your body to minimize this problem.
- *Hot surfaces:* As you continue making cuts to complete the part, it will begin to heat up. Depending on the size of the part, the number of cuts per part, and the number of parts being cut, this heat can become uncomfortable. You may find it necessary to hold the torch farther back from the tip, but this will affect the quality of your cuts, **Figure 7-55**. Sometimes you might be able to rest your hand on a block to keep it off of the plate. Another problem with heat buildup is that it may become high enough to affect the cut quality. Heat becomes a problem when it causes the top edge of the plate to melt during a cut, as if the torch tip were too large. This is more of a problem when several cuts are being made in close proximity. Planning your cutting sequence and allowing cooling time will help control this potential problem.
- *Tip cleaning:* As with any cutting, the tip will catch small sparks and become dirty or clogged. You must decide how dirty or clogged you will let the tip get before you stop to clean it. Time spent cleaning the tip reduces productivity, unfortunately. On the other hand, if you do not stop occasionally to clean up, the quality of the cut will become so bad that

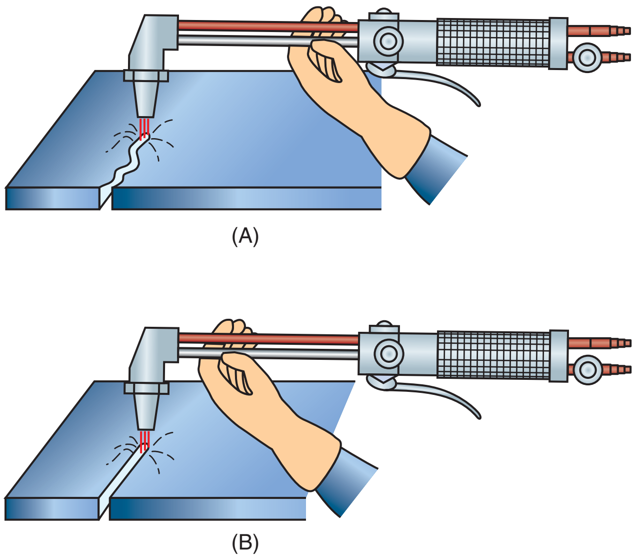
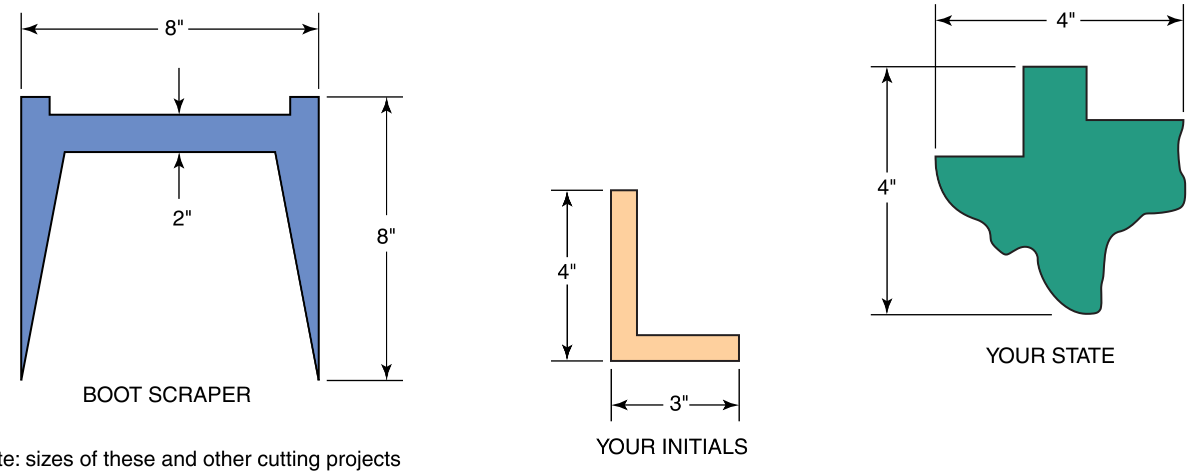


FIGURE 7-55 It is easier to make straight, smooth cuts if you can brace the torch closer to the tip, as in cut B.



Note: sizes of these and other cutting projects can be changed to fit available stock.

FIGURE 7-56 Suggested patterns for practice.

postcut cleanup will become excessive. It is your responsibility to decide when and how often to clean the tip.

- *Blow back:* As a cut progresses across the surface of a large plate, it may cross supports underneath the plate. During practice cuts this seldom if ever happens, but, depending on the design of the cutting table, it will occur even under the best of conditions. If the support is small, the blowback may not cover you with sparks, plug the cutting tip, or cause a major flaw in the cut surface. If the support is large, then one or all of these events can occur. If you see that the blow back is not clearing quickly, it may be necessary to stop the cut. Stopping the cut halts the shower of sparks but leaves you with a problem restart.

FIGURE 7-57 Beginning a cut with the torch concentrating the flame on the thin edge to speed starting.
Courtesy of Larry Jeffus.

PRACTICE 7-12

Cutting Out Internal and External Shapes

Using a properly lit and adjusted cutting torch, welding gloves, appropriate eye protection and clothing, and one piece of plate 1/4 in. (6 mm) to 3/8 in. (10 mm) thick, you may lay out and cut out one of the sample patterns shown in **Figure 7-56**, one of the projects in Chapter 18, or any other design available.

Choose the pattern that best fits the piece of metal you have and mark it using a center punch. The exact size and shape of the layout are not as important as the accuracy of the cut. The cut must be made so that the center-punched line is left on the part and so that there is no more than 1/8 in. (3 mm) between the cut edge and the line, **Figures 7-57** and **Figure 7-58**. Repeat this practice until the cut can be made within tolerance. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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FIGURE 7-58 The torch is rotated to allow the preheating of the plate ahead of the cut. This speeds the cutting and provides better visibility of the line being cut. Courtesy of Larry Jeffus.

Pipe Cutting

Freehand pipe cutting may be done in one of two ways. On small diameter pipe, usually under 3 in. (76 mm), the torch tip is held straight up and down and moved from the

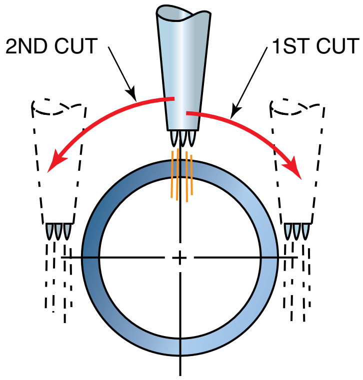

FIGURE 7-59 Small diameter pipe can be cut without changing the angle of the torch. After the top is cut, roll the pipe to cut the bottom.

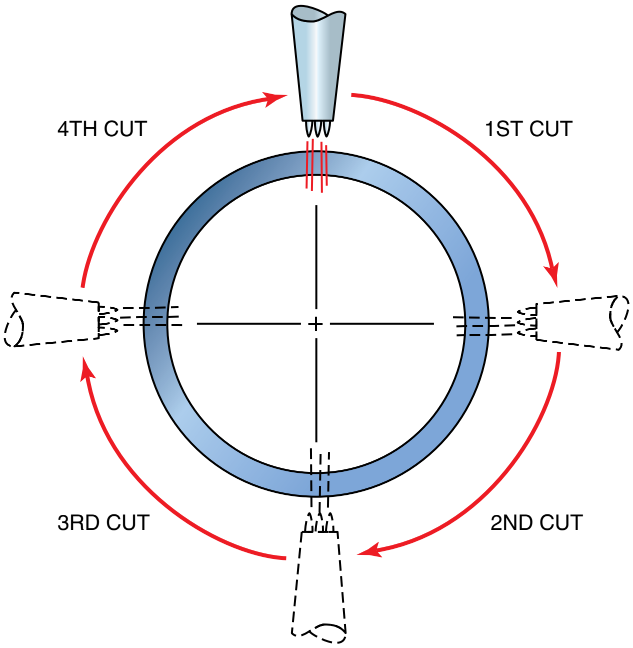

FIGURE 7-60 On large diameter pipe, the torch is turned to keep it at a right angle to the pipe. The pipe should be cut as far as possible before stopping and turning it.

center to each side, **Figure 7-59**. This technique can also be used successfully on larger pipe.

For large diameter pipe, 3 in. (76 mm) and larger, the torch tip is always pointed toward the center of the pipe, **Figure 7-60**. This technique is also used on all sizes of heavy-walled pipe and can be used on some smaller pipe sizes.

The torch body should be held so that it is parallel to the centerline of the pipe. Holding the torch parallel helps to keep the cut square.

CAUTION

When cutting pipe, hot sparks can come out of the end of the pipe nearest you, causing severe burns. For protection from hot sparks, plug up the open end of the pipe nearest you, put up a barrier to the sparks, or stand to one side of the material being cut.

PRACTICE 7-13

Square Cut on Pipe, 1G (Horizontal Rolled) Position

Using a properly lit and adjusted cutting torch, welding gloves, appropriate eye protection and clothing, and one piece of schedule 40 steel pipe with a diameter of 3 in. (76 mm), you will cut off 1/2-in. (13-mm)-long rings.

Using a template and a piece of soapstone, mark several rings, each 1/2 in. (13 mm) wide, around the pipe. Place the pipe horizontally on the cutting table. Start the cut at the top of the pipe using the proper piercing technique. Move the torch backward along the line and then forward; this will keep slag out of the cut. If the end of the cut closes in with slag, this will cause the oxygen to gouge the edge of the pipe when the cut is continued. Keep the tip pointed straight down. When you have gone as far with the cut as you can comfortably, quickly flip the flame away from the pipe. Restart the cut at the top of the pipe and cut as far as possible in the other direction. Stop and turn the pipe so that the end of the cut is on top and the cut can be continued around the pipe. When the cut is completed, the ring must fall free. When the pipe is placed upright on a flat plate, the pipe must stand within 5° of vertical and have no gaps higher then 1/8 in. (3 mm) under the cut. Repeat this procedure until the cut can be made within tolerance. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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PRACTICE 7-14

Square Cut on Pipe, 1G (Horizontal Rolled) Position

Using the same equipment, materials, and markings as described in Practice 7-13, you will cut off the 1/2 in. (13-mm)-long rings while keeping the tip pointed toward the center of the pipe.

Starting at the top, pierce the pipe. Move the torch backward to keep the slag out of the cut and then forward around the pipe, stopping when you have gone as far as you can comfortably. Restart the cut at the top and proceed with the cut in the other direction. Roll the pipe and continue the cut until the ring falls off freely. Stand the cut end of the pipe on a flat plate. The pipe must stand within 5° of vertical and have no gaps higher than 1/8 in.

(3 mm). Repeat this practice until the cut can be made within tolerance. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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PRACTICE 7-15

Square Cut on Pipe, 5G (Horizontal Fixed) Position

With the same equipment, materials, and markings as described in Practice 7-13, you will cut off 1/2-in. (13-mm) rings, using either technique, without rolling the pipe.

Start at the top and cut down both sides as far as you can comfortably. Reposition yourself and continue the cut under the pipe until the ring falls off freely. Stand the cut end of the pipe on a flat plate. The pipe must stand within 5° of vertical and have no gaps higher than 1/8 in. (3 mm). Repeat this practice until the cut can be made within tolerance. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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PRACTICE 7-16

Square Cut on Pipe, 2G (Vertical) Position

With the same equipment, materials, and markings as listed in Practice 7-13, you will cut off 1/2-in. (13-mm) rings, using either technique, from a pipe in the vertical position.

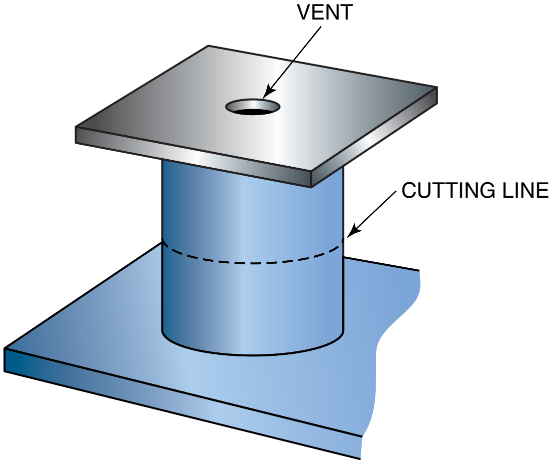

FIGURE 7-61 Place a plate on top of a short piece of pipe to keep the sparks from flying around the shop.

Place a flat piece of plate over the open top end of the pipe to keep the sparks contained, **Figure 7-61.** Start on one side and proceed around the pipe until the cut is completed. Because of slag, the ring may have to be tapped free. Stand the cut end of the pipe on a flat plate. The pipe must stand within 5° of vertical and have no gaps higher than 1/8 in. (3 mm). Repeat this practice until the cut can be made within tolerance. Turn off the cylinder valves, bleed the hoses, back out the pressure regulators, and clean up your work area when you are finished cutting.

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Summary

The oxyfuel cutting torch is one of the most commonly used (and misused) tools in the welding industry. When used properly it can produce almost machine-cut quality requiring no post-cut cleanup. However, when misused the oxyfuel torch can produce some of the most difficult problems for the welding fabricator to overcome. As you learn to use the cutting torch efficiently, you can dramatically reduce postcut cleanup time and increase productivity.

Equipment setup and torch tip cleaning are essential elements required for the welder to produce quality oxyfuel cuts. Take your time each time you are setting up and preparing to make a cut; this is not wasted time. A good setup will ensure that that cut's quality will meet the fabricator's quality needs.

The travel speed for cutting will vary, depending on a number of factors, such as plate thickness or the surface condition of the metal being cut. A good, clean, quality cut will progress at its own rate. Do not try to rush through too quickly. Learn to develop a sense for the cutting rate that produces the best-quality cut.

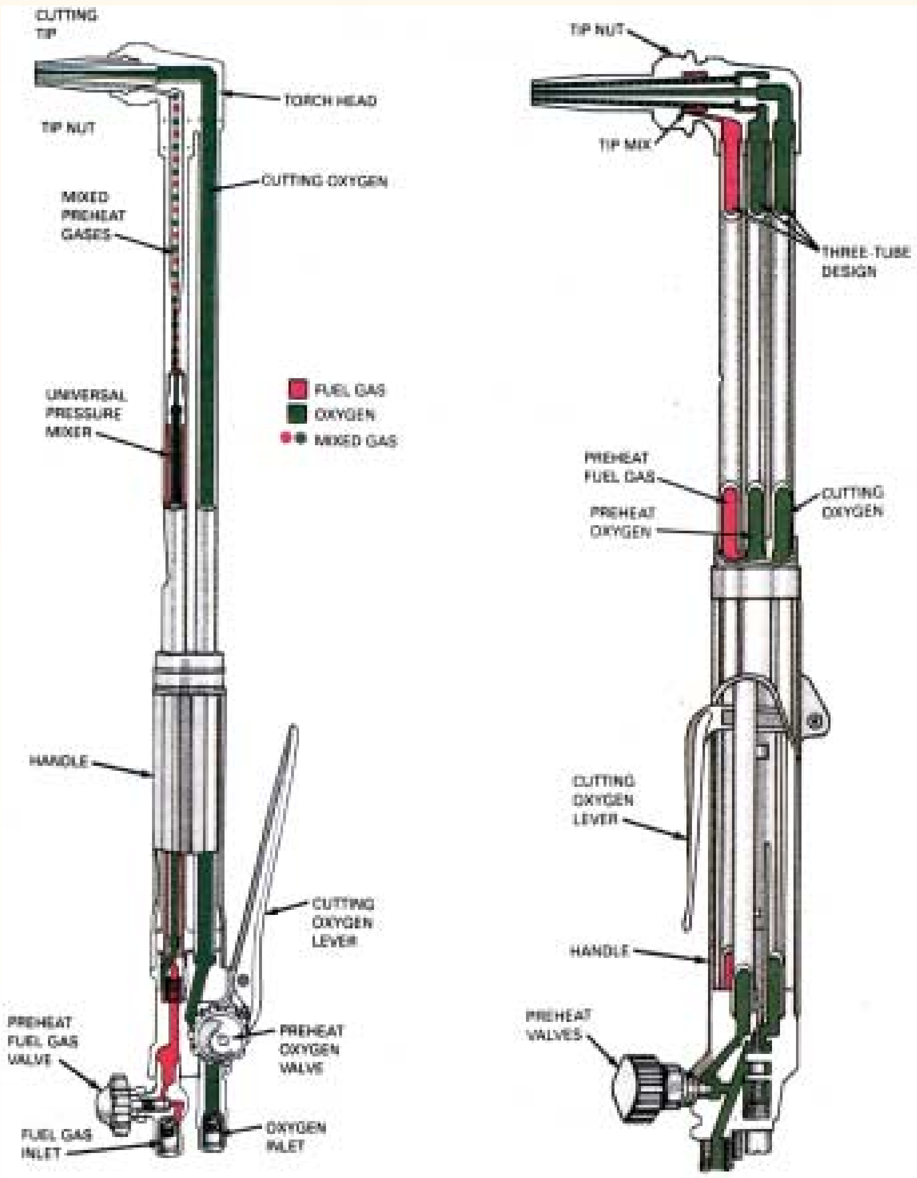
Oxygen Cutting

The chemical reaction between oxygen and an oxidizing metal heated to a high temperature begins the cutting action of the oxygen cutting (OC) process. The temperature of the metal is maintained with a flame from the combustion of an oxygen-fuel gas mixture. A separate stream of oxygen does the cutting.

The cutting torch has internal chambers for mixing the fuel gas and oxygen, as well as a separate chamber for delivering high-purity oxygen to the cutting area. The torch nozzle or tip has numerous ports machined into it for regulating and concentrating the flame and the stream of cutting oxygen.

When iron is brought to a temperature above 1600°F (870°C) and combined with oxygen of 99.5% or greater purity, rapid oxidation occurs. This chemical reaction releases a tremendous amount of heat, which supports the cutting process by preheating the metal at the cutting point to its ignition temperature. Some of the iron adjacent to the cutting point also is melted and blown away by the oxygen stream. Oxygen with purity levels below 99.5% significantly decreases the cutting efficiency.

Since oxidation of iron is at the heart of the cutting process, metals with high levels of nickel or chromium and nonferrous metals cannot be cut effectively with this process.



Schematics of two types of oxygen cutting torches. (Art courtesy of the Welding Handbook, Vol. 2, 8th Edition)

A variety of fuel gases can be used in oxygen cutting. Acetylene, with its widespread availability and high flame temperature, is the common choice. Depending on the shape and color of the flame, the correct ratio of oxygen to acetylene for efficient cutting can be determined. Acetylene must not be used at pressures higher than 15 lb/in^2 gauge pressure or 30 lb/in^2 absolute pressure. When used at higher pressures, it can become explosive under heat or shock conditions.

Hoses with specially designed fittings are used in oxygen cutting. The hose for oxygen, which in the United States is green, has a right-hand-threaded fitting with a smooth surface. The fuel gas hose, which is normally red, has left-hand threads, and the nut is notched.

Art and article courtesy of the American Welding Society.

Review

1. Using **Table 7-1**, list the six different fuel gases in rank order according to their temperature.
2. What is a combination welding-cutting torch?
3. State one advantage of owning a combination welding-cutting torch as opposed to just having a cutting torch.
4. State one advantage of owning a dedicated cutting torch as compared to having a combination welding-cutting torch.
5. What is a mixing chamber? Where is it located?
6. Define the term *equal-pressure torch*. How does it work?
7. How does an injector-type mixing chamber work?
8. State the advantages of having two oxygen regulators on a machine-cutting torch.
9. Why are some copper alloy cutting tips chrome plated?
10. What determines the amount of preheat flame requirements of a torch?
11. What can happen if acetylene is used on a tip designed to be used with propane or other such gas?
12. Why are some propane and natural gas tips made with a deep, recessed center?
13. What types of tip seals are used with cutting torch tips?
14. If a cutting tip should stick in the cutting head, how should it be removed?
15. How can cutting torch tip seals be repaired?
16. Why is the oxygen valve turned on before starting to clean a cutting tip?
17. Why does the preheat flame become slightly oxidizing when the cutting lever is released?
18. What causes the tiny ripples in a hand cut?
19. Why is a slight forward torch angle helpful for cutting?
20. Why should cans, drums, tanks, or other sealed containers be opened with a cutting torch?
21. Why is the torch tip raised as the cutting lever is depressed when cutting a hole?
22. Why are the preheat holes not aligned in the kerf when making a bevel cut?
23. Sketch the proper end shape of a soapstone that is to be used for marking metal.
24. Using **Table 7-4**, answer the following:
    - **a.** Oxygen pressure for cutting 1/4-in. (6-mm) -thick metal
    - **b.** Acetylene pressure for cutting 1-in. (25-mm) -thick metal
    - **c.** Tip cleaner size for a tip for 2-in. (51-mm) -thick metal
    - **d.** Drill size for a tip for 1/2-in. (13-mm) -thick metal
25. What is the best way to set the oxygen pressure for cutting?
26. What metals can be cut with the oxyfuel gas process?
27. Why is it important to have extra ventilation and/or a respirator when cutting some used metal?
28. What factors regarding a cut can be read from the sides of the kerf after a cut?
29. What is hard slag?
30. Why is it important to make good-quality cuts?
31. Describe the methods of controlling distortion when making cuts.
32. How does cutting small diameter pipe differ from cutting large diameter pipe?