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Structural Journeyman

Volume 3. Oxyacetylene Applications

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IN THIS VOLUME you will study oxyacetylene application information that you will use in your future work on the job.

Unit 1 addresses oxyacetylene welding equipment. It covers equipment procedures that include assembly, leak testing, troubleshooting, shutdown, and disassembly. Unit 2 covers oxyacetylene welding. Unit 3 focuses on oxyacetylene cutting and hard surfacing.

A glossary is included for your use.

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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Student Notes

Unit 1. Oxyacetylene Welding Equipment

OXYACETYLENE welding is a gas flame process that controls heat to join (weld) metal parts together. A torch is used to control the amount of acetylene and oxygen needed to produce the right flame needed for the particular welding job. In this unit, we explain equipment procedures that include assembly, leak testing, troubleshooting, shut down and disassembly. To add to your understanding, we recommend that you familiarize yourself with the oxyacetylene equipment that your shop uses while studying this unit.

1–1. Oxyacetylene Welding Equipment Assembly and Repair

Air Force structural shops make extensive use of oxyacetylene welding equipment. This section shows you the parts and assembly procedures used for portable oxyacetylene equipment.

401. Oxyacetylene welding assembly

The oxyacetylene welding components that we use are designed to be portable and are often referred to as a portable-welding outfit. These outfits (fig. 1–1) have a cart, oxygen and acetylene cylinders, two-stage oxygen and acetylene pressure regulators complete with gauges and connections, two lengths of hose with adapter connections for the regulators and torch, torch with tip and wrenches, and safety equipment such as flashback arrestors, safety flint igniter, gloves, welding goggles, and fire extinguisher. If any part is damaged or missing, the whole outfit is out of commission until corrections are made (e.g., the part is repaired or replaced).

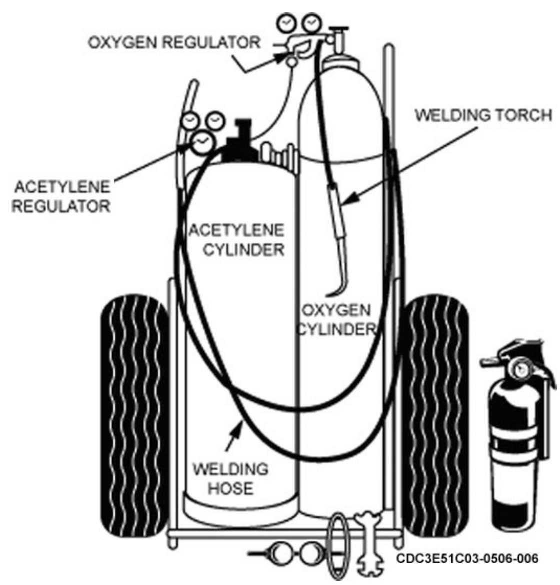


Figure 1–1. Portable welding outfit.

Cylinders

Steel cylinders are designed to store gas under pressure, this pressure changes based on temperature and altitude. Since the work we do is usually done on the base at about the same altitude, the altitude is not as great a factor as the temperature. Therefore, we'll focus on temperature. A cylinder is charged (filled) with gas at a set temperature and pressure. If that cylinder was stored at a colder temperature, the pressure inside the cylinder would drop. If the cylinder was stored at a higher temperature, the pressure would increase. The reason for this is that when the cylinder gets warmer, the gas expands and the pressure increases, by contrast when the cylinder gets cooler, the gas contracts and the pressure decreases. All cylinders have information that is usually marked on its shoulder to identify the gas type, cylinder composition code, pressure ratings, and inspection dates. The information can be stenciled or stamped on the cylinder, or it can be printed on a label and attached to the cylinder. A typical cylinder that is stamped reads DOT3AA2400. The DOT is Department of Transportation, the 3AA is the cylinder composition code, and the 2400 is the pressure rating. (**NOTE**: Some gasses are allowed to exceed this pressure by a certain percentage. If allowed, the percentage amount is identified on the cylinder.)

Cylinders also have features that are designed to store a particular gas and control over-pressurization. All cylinders used by the Air Force must be maintained according to Air Force regulations. One such regulation is the US Department of Transportation, 49 Code of Federal Regulations (CFR), *Transportation*, parts 171–179. Here are some common rules to follow for maintaining cylinders:

1. Keep oxygen cylinders away from oil and grease.

   CAUTION: Oil or grease mixed under pressure with oxygen may explode.

2. Do *not* drop cylinders or handle them roughly.
3. Store cylinders in a cool, dry, well-ventilated area that is protected from direct sunlight.
4. Store oxygen and acetylene cylinders in an upright, secured position. Separate full and empty cylinders.
5. When a cylinder is empty, re-install the safety cap and write “EMPTY” or “MT” on the cylinder in chalk.

Acetylene cylinders

Acetylene cylinders are painted yellow, and most are rated to store acetylene at up to 250 pounds per square inch (psi). To be sure, check the pressure rating stamped into the cylinder shoulder. All cylinders that store acetylene gas have certain features built into them. For example, they are packed with a porous material that is saturated with acetone. The acetone stabilizes the pressurized acetylene without changing the acetylene’s nature. To keep the acetone from escaping, store the cylinders in an upright position. There is a protective cap that screws onto the cylinder valve to prevent damage when you move the cylinder. Another feature is the left-handed threads that are found on the valves. These left-handed threads assure the connections from the cylinder to the hose can only carry acetylene. The last feature is the safety plug. It releases gas pressure if the cylinder is overheated. These plugs melt between 212°F and 220°F and are small enough to keep the gas from burning back into the cylinder.

Oxygen cylinders

Oxygen cylinders are painted green and typically have a high-pressure rating. The amount of pressure varies among different cylinder sizes. For example, some cylinders have a pressure rating of 2400 psi but will allow that to be exceeded 10 percent. In this case, the maximum pressure would be 2600 psi. If pressure inside the cylinder exceeds a set amount, a safety nut allows oxygen to escape to keep the pressure at a safe level. Another pressure releasing device is the bursting disc. It is found on the cylinder valve and bursts when the cylinder is overheated and the pressure increases. The release of pressure prevents the cylinder from exploding. The valve also has right-hand threads to assure the connection from the cylinder to the hose is only carrying oxygen.

CAUTION: Always handle oxygen cylinders carefully. If you break off the valve or pierce the cylinder, the cylinder has the potential to become a missile.

Regulators

The regulators, or reducing valves, are mechanical devices that reduce the high pressure of the gases as they flow from the cylinders. There are two types of regulators: the single-stage and the two-stage. The single-stage regulator reduces the pressure of the gases from cylinder pressure to working pressure in one step (stage). As cylinder pressure decreases, a single-stage regulator must be continually adjusted to maintain correct working pressure. Two-stage regulators (fig. 1–2) reduce the high pressure of the gases as they flow from the cylinders in two steps. With a two-stage regulator, once the working pressure is set with the adjusting screw, no adjustments are necessary as the cylinder pressure decreases.

NOTE: *Never* lubricate the adjusting screw on a regulator with oil. Use soap or glycerin.

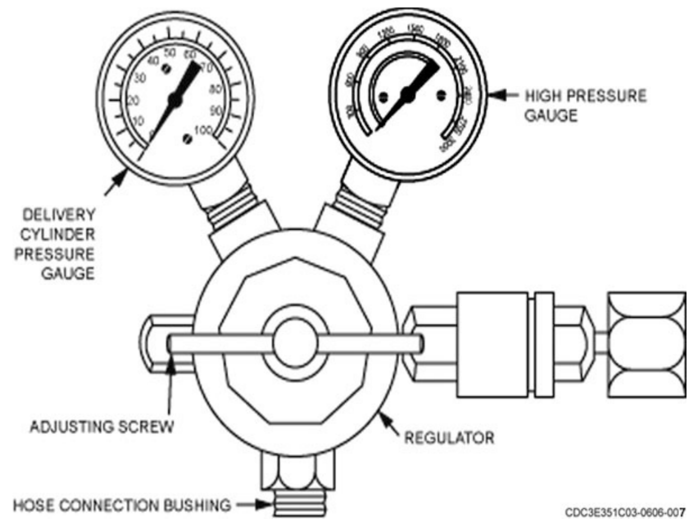


Figure 1–2. Regulator.

Hoses

Hoses take gases at working pressure from regulators to torch needle valves. The oxygen hose is *always* green or black; the acetylene hose is *always* red or maroon.

Torch

Figure 1–3 is a cutaway view of an oxyacetylene torch. The gases flow from the hoses through tubes to the mixing head. The gases combine in the mixing head and flow forward through the tip to produce a flame.

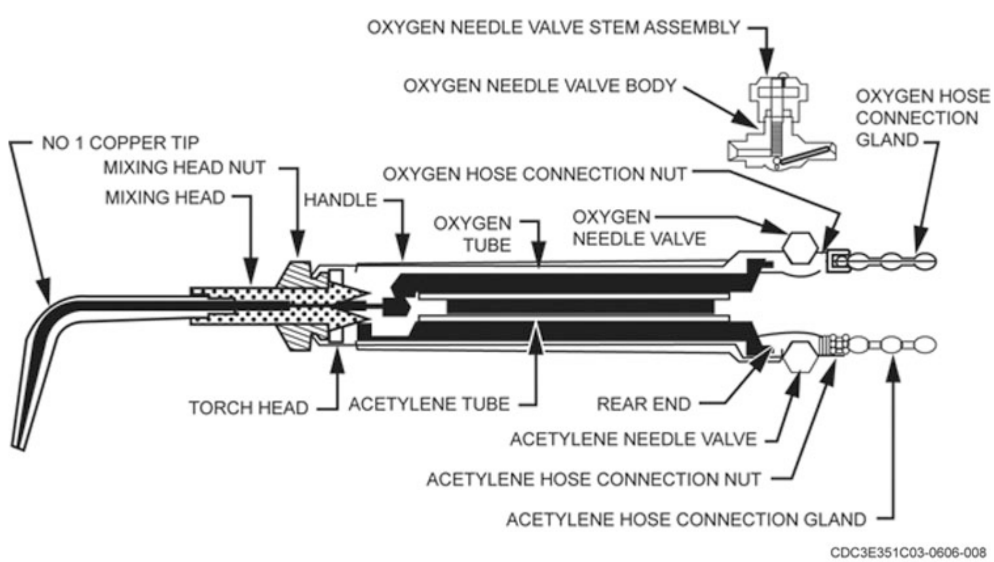


Figure 1–3. Oxyacetylene torch.

The torch tip directs the flow of the oxyacetylene mixture to control the flame. Torch wrenches are designed for oxyacetylene outfits. A torch wrench has slots or patterns made into it to tighten or loosen all connections.

Safety equipment

Welding goggles, gloves, flashback arrestor, flint igniter, and fire extinguisher are all items of safety equipment used with the outfit. This equipment is designed to protect the operator from injury and to prevent damage to property.

Assembling oxyacetylene welding equipment

Assembling the oxyacetylene welding equipment properly is critical to eliminate a possible explosion. Let's look at the steps you must follow to safely assemble oxyacetylene equipment for welding.

1. Put the acetylene and oxygen cylinders on the cart and secure them. You'll need to remove the cylinder valve protective caps and note their location for re-installation after use.
2. Open (crack) each cylinder outlet valve slightly for an instant to blow out any dirt lodged in the outlet nipple (fig. 1–4).
3. Attach the two-stage regulators to their respective cylinders and tighten the union nut with the torch wrench (fig. 1–5).

NOTE: *Do not* attempt to interchange the oxygen and acetylene regulators.

Figure 1–4. Cracking a valve.

Figure 1–5. Tightening the union nut.

4. Attach the red acetylene hose to the acetylene regulator outlet (left-hand threads). Attach the green oxygen hose to the oxygen regulator outlet (right-hand threads).
5. Secure the nuts tightly with the torch wrench (fig. 1–6). Be sure the adjusting screws on the regulators are fully released before opening the cylinder valve (fig. 1–7).

NOTE: To make sure the regulator adjusting screws are backed out, turn them counterclockwise until they're loose.

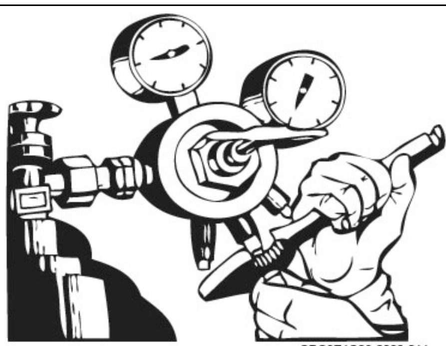


Figure 1–6. Attaching the hose.

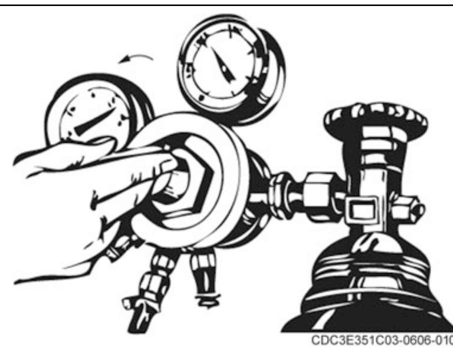


Figure 1–7. Releasing regulator pressure on the diaphragm.

6. Open the acetylene cylinder valve a recommended ¾ turn. The maximum amount is 1½ turns. The less that you open the cylinder valve, the faster you can close it in an emergency.
7. Next, open the oxygen valve slowly at first, then fully open. Read the high-pressure gauges to check the pressure of each cylinder.
8. Open each regulator by turning the adjusting screw clockwise. Blow out the hoses one at a time, as shown in figure 1–8. (**NOTE:** If a regulator does not function properly, shut **OFF** the gas supply and see your supervisor about getting it repaired or replaced.)
9. After blowing out the hoses, release the adjusting screws. Between the hoses and the torch, install flashback arrestors. These are normally installed on the oxygen and acetylene torch gland nuts. They keep a flashback from burning back into the oxygen or acetylene hoses.

Figure 1–8. Blowing out the hoses.

10. After installing the flashback arrestors, connect the hoses to them. The red hose connects to the acetylene flashback arrestor with the left-hand threads, and the green hose connects to the oxygen flashback arrestor with the right-hand threads (fig. 1–9).

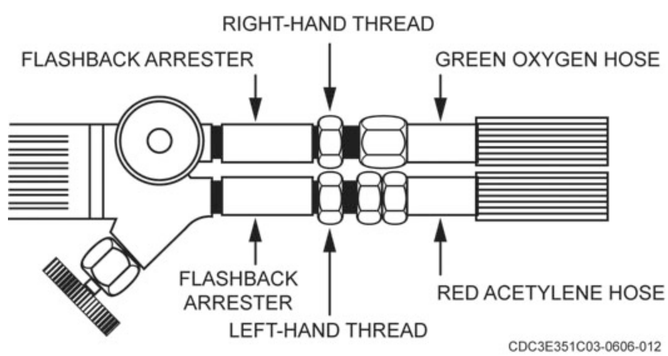


Figure 1–9. Connecting the hoses.

11. Select a torch tip and attach it to the torch. Tighten the tip moderately.

Now, the outfit is assembled and ready for you to operate. (**NOTE:** All acetylene connections are left-handed threads, and all oxygen connections are right-handed threads. This assures proper connections.)

402. Equipment maintenance and repair

You are required to maintain the oxyacetylene welding equipment that you use. In this lesson you'll learn how to test and do operator maintenance on your equipment. Of course, the manufacturer must do some repairs, but if you can do operator maintenance successfully, your equipment will be more productive.

Disassembling welding equipment

Disassembling a welding outfit is the opposite of assembly. You can use a checklist that includes these items in this order:

1. Be sure the gas supply is off.
2. Bleed the regulators (allow gas to escape).
3. Remove the torch tip.

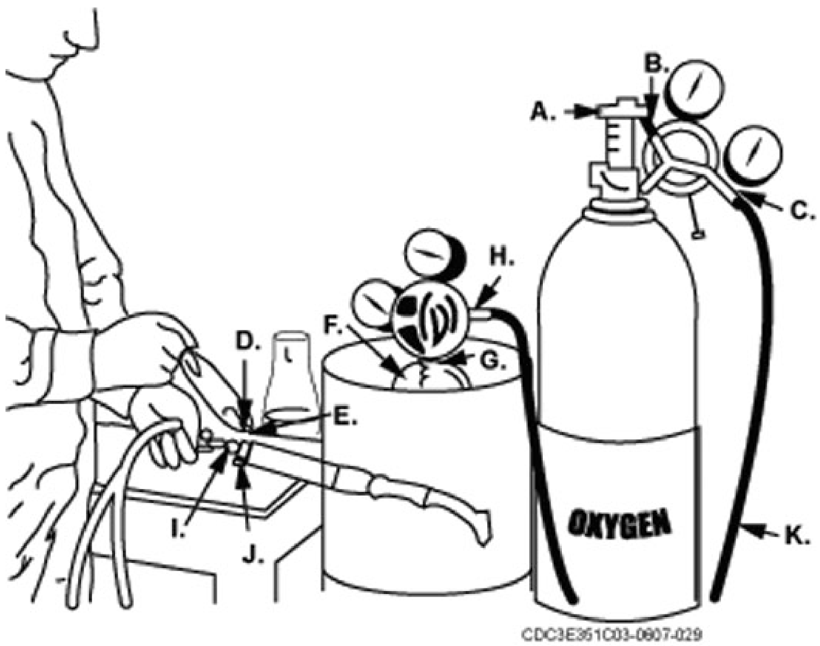
4. Disconnect the hoses from the torch.
5. Disconnect the hoses from the regulators.
6. Disconnect the regulators from the cylinder or manifold line.
7. Reinstall the cylinder valve safety cap or line protective nuts.

In disassembling an oxyacetylene outfit, use the torch wrench to keep from rounding the corners on the connecting nuts. Also, handle the tips, torches, and regulators carefully to keep from damaging them.

Testing welding equipment for gas leaks

Before any welding outfit torch is lit, the entire outfit must be checked thoroughly for gas leaks. Testing the outfit is a very simple, but critical, task for you to do. It can be done with a container of soapy water, a small paintbrush or acid brush, and a bucket of clear water or commercially available leak detection liquid.

After the apparatus has been assembled and adjusted to a working pressure, test all connections by brushing soapy water onto them. Wherever bubbles form, there is a leak. The connections to check are shown in figure 1–10 (callouts, A–K).



A. Oxygen cylinder valve packing nut.
B. Oxygen cylinder regulator connection.
C. Oxygen regulator hose connection.
D. Oxygen hose torch connection and flashback arrester.
E. Torch oxygen needle valve nut.
F. Acetylene cylinde valve packing nut.
G. Acetylene cylinder regulator connection.
H. Acetylene regulator hose connection.
I. Acetylene hose torch connection and flashback arrester.
J. Torch acetylene needle valve nut.
K. Hoses.

Figure 1–10. Checkpoints for leaks.

There are various ways to test hoses for leaks. We recommend that you simply submerge the hoses in a bucket of clear water. A leak is indicated by a string of bubbles. This method is inexpensive and it instantly identifies all leaks.

Stopping leaks in welding equipment

Stopping gas leaks in your welding equipment is an obvious task that you will do before you attempt to light the torch. Let's take a look at areas that are prone to leaks, possible causes, and methods that you can use to stop leaks.

Regulators

The primary problem with regulators is gas leakage between the regulator seat and the nozzle (fig. 1–11). You can detect leakage by observing a gradual pressure rise on the working pressure gauge after the cylinder or manifold valve is opened. This is known as a *creeping* regulator and is caused by worn or cracked seats or by dirt particles lodged between the seat and the nozzle. In this case, see your supervisor about getting it repaired or replaced. Always keep a tight connection between the regulator and the cylinder. If the connection leaks after tightening, close the cylinder valve and remove the regulator. Clean both the inside of the cylinder valve seat and the regulator inlet-nipple seat. If the leak persists, the seat and threads are probably damaged, and the regulator must be repaired or replaced.

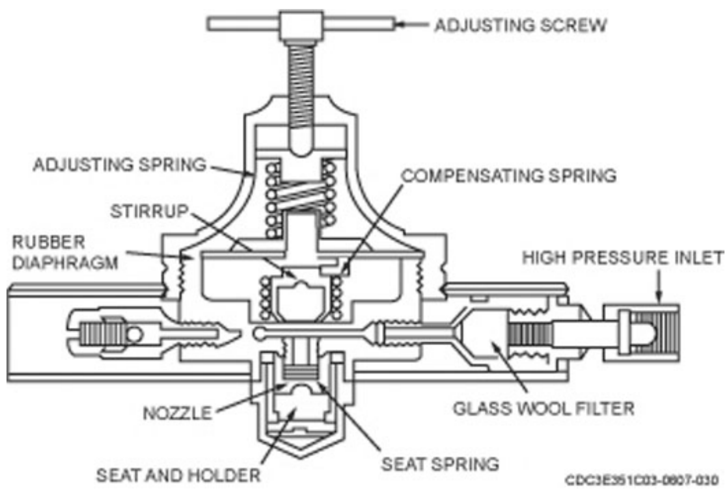


Figure 1–11. Pressure regulator, cutaway view.

Gauges

A gas leak in a gauge is usually caused by a cracked bourdon tube. A fluctuating gauge pressure or gas leaking from the gauge case is an indication that the bourdon tube is cracked and allowing gas to escape. Figure 1–12 shows a bourdon tube in a pressure gauge. Look at it as we discuss how a bourdon tube works.

The bourdon tube is a steel tube attached to the needle through a linkage. When gas pressure fills the bourdon tube, the tube begins to straighten out. As the tube straightens, it moves the linkage and the needle pointer. A bourdon tube is a precision instrument that can be damaged easily. If the cylinder valve is opened quickly, and the regulator adjusting screw is not released, the sudden pressure increase can crack the bourdon tube and cause it to leak. If the leak is minor, you can repair it with silver brazing, but the manufacturer must make major repairs.

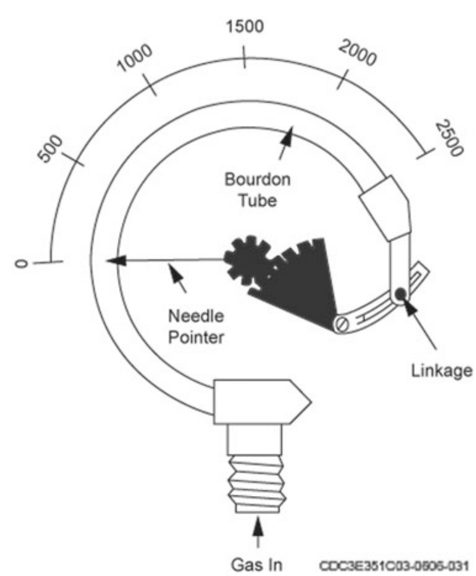


Figure 1–12. Bourdon tube gauge.

Torches

Leaks in torches are common in the mixing head seat, leaking needle valves, and clogged torch tubes. When gas continues to flow after the valve is closed, you'll know the needle valve is leaking. This condition can be caused by a worn or bent valve stem, a damaged valve seat, or loose packing around the needle valve. A leak in the mixing head seat allows the gases to escape, and unless you correct the trouble immediately, a dangerous flashback is the result.

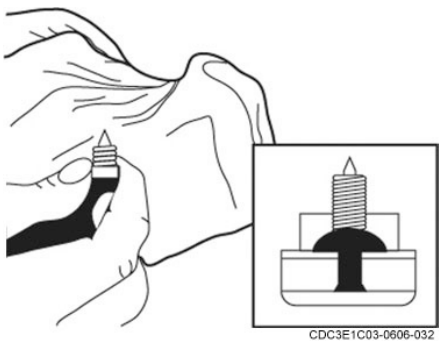


Figure 1–13. Cleaning a needle valve.

Repair needle valve leaks around the seat by tightening the packing gland nut. If the leak is in the seat, remove the needle valve with a wrench and clean it (fig. 1–13). If it is worn or pitted, replace the needle valve with a new one. If the valve seat is scored, pitted, or otherwise damaged, return the torch to the manufacturer for repair.

Remove and clean leaking mixing head seats. If the seats are damaged, return the torch to the manufacturer for repair. Clean clogged torch tubes by removing the hoses and mixing head and then blowing out each tube with 20 to 30 pounds of oxygen pressure.

Hoses

Check welding hoses at regular intervals for leaks, worn spots, and loose connections. To find leaks in the hoses, immerse them in clean water while they're pressurized. Since worn or leaking hoses are dangerous and wasteful, repair or replace them immediately. Repair leaks in the hose by removing the damaged section and inserting a hose splice. In figure 1–14, the hose splice and sleeves shown are parts of a hose repair kit. To make this repair, cut and remove the damaged section of hose. Then place the sleeves over the ends of the hose. After the sleeves are in place, slide both hose ends over the splice. The final step of the repair is to crimp the sleeves with the crimping tool included in the hose repair kit.

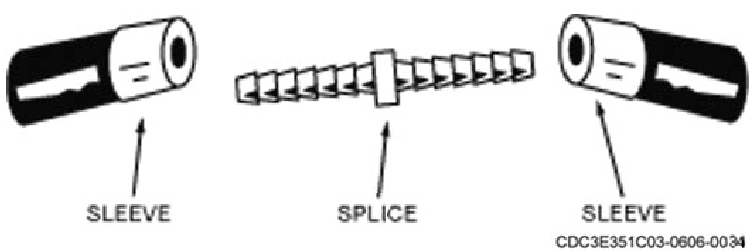


Figure 1–14. Hose splice and sleeves.

Before placing the hose back in service, test it for leaks using the procedures described earlier.

WARNING: Do not (by way of a shortcut or for other reasons) use a piece of copper tubing in place of a brass hose splice. Why? When copper and acetylene are placed together, they form copper acetylide, an unstable compound that will explode violently at the slightest shock. In short, DO NOT USE COPPER WITH ACETYLENE.**/** Repair hoses that are leaking at the regulator or torch connection by cutting off 1 or 2 inches of hose and replacing the connections.

Repairing welding and cutting torch tips

Welding and cutting torch tips can't function properly if they're dirty or improperly cared for. There are two major malfunctions of both welding and cutting tips: accumulating dirt and leaking gas.

Dirty torch tips

Torches require frequent cleaning because small particles of metal and oxide collect on the torch tip surface and inside of the tip orifice. Use a soft wire or drill-type tip cleaner to clean the tip. The tip cleaner should be approximately one size smaller than the tip orifice to prevent enlarging the orifice during cleaning. There are two correct ways of using a tip cleaner. One method is to remove the tip from the torch and insert the cleaner from the threaded end, as shown in figure 1–15. The other method is to open the oxygen valve and insert the tip cleaner, as shown in figure 1–16. Whichever method you use, always use a straight back-and-forth motion to prevent enlarging the orifice. If a tip orifice becomes scored, out of round, or enlarged, replace the tip. Remember—improper cleaning will enlarge the orifice.

Figure 1–15. Cleaning a disassembled torch tip.

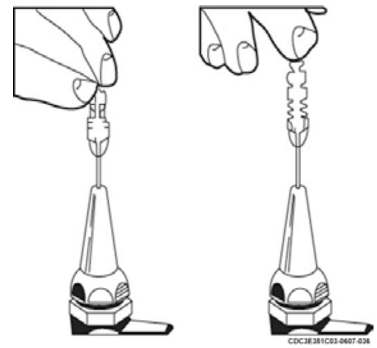


Figure 1–16. Cleaning an assembled torch tip.

Slag accumulation (fig. 1–17) is a bigger problem on cutting tips than on welding tips. To remove slag from the tip, use a cloth placed on a file, as shown in figure 1–18. Open the oxygen valve to blow out the slag and dirt after you've loosened it. When you use this method, be very careful not to remove too much of the tip. If too much of the tip is removed, the orifices will be enlarged because of their original taper. In addition to cleaning the slag from the tip face, remove the slag from the tip sides.

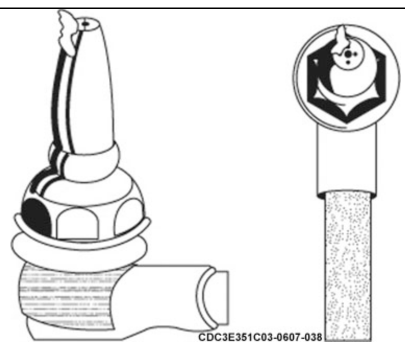


Figure 1-17. Slag on tip.

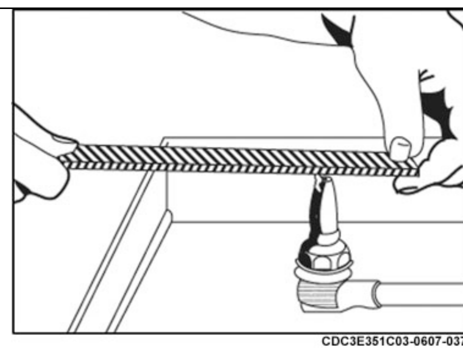


Figure 1-18. Cleaning the tip face.

You must maintain a sharp edge at the meeting of the face and sides of the tip to prevent distorting the flame. This is known as dressing the tip. Distorted welding and cutting tips cause uneven preheating and create problems when making a weld or cut.

Gas leakage

Gas leakage around a tip usually indicates that the tip is damaged. You should stop using the damaged tip and do an inspection. An inspection usually reveals a nick or flat spot in the tip seat. If this is the case, discard the tip. Always check for bad torch seats as well. Gas leakage around the tip can cause a flashback. (**NOTE:** *Never* use welding equipment that has a gas leak.)

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

401. Oxyacetylene welding assembly

1. How long must an entire welding outfit be out of commission if you damage just one component?

2. What could occur if you mix pressurized oxygen with oil or grease?

3. What must you do to a cylinder after it has been emptied?

4. Why is acetone put into acetylene cylinders?

5. Why should you store acetylene cylinders vertically?

6. What color are oxygen cylinders?

7. Why must you handle oxygen cylinders carefully?

8. Which type of regulator reduces cylinder pressure directly to working pressure?

9. What do you use “red” hoses for in oxyacetylene welding?

10. Where do the gases combine in the oxyacetylene outfit?

11. What tool is designed for you to use to tighten or loosen connections on oxyacetylene outfits?

12. List the safety equipment that you use with an oxyacetylene outfit.

13. Why should cylinder valves be opened (cracked) before regulators are connected?

14. How far do you open each cylinder valve to blow out the hoses?

15. What safety feature is installed to keep the flames from entering the oxygen or acetylene hoses?

16. What is the difference between oxygen and acetylene threaded connections?

402. Equipment maintenance and repair

1. What is the *first* thing to do in disassembling a welding outfit?

2. When disassembling a welding outfit, what must you do after disconnecting the regulator from the cylinder or manifold line?

3. Why should you use a torch wrench to disassemble oxyacetylene welding equipment?

4. What equipment do you use to test a welding outfit for leaks?

5. How can you find leaks in the connections of welding equipment?

6. How do you test the welding outfit hoses for leaks?

7. What can you observe to detect a *creeping* regulator?

8. How do you know when a bourdon tube is defective?

9. Who should repair a torch with a pitted valve seat?

10. You should not use what type of tubing as a hose splice for an acetylene hose?

11. What can you use to clean a torch tip orifice, and what must you avoid while cleaning the orifice

12. Why should you use a straight back-and-forth movement when cleaning a dirty torch tip?

13. Improperly cleaning a torch tip can cause what type of damage?

14. When you are dressing the torch tip, why must you maintain a sharp edge where the face and sides of the tip meet?

15. What must you do if you notice gas leakage around a torch tip? Why?

1–2. Using the Oxyacetylene Welding Torch

A key part of your welding skill is your ability to use a welding torch. This section shows you how to adjust the torch for different flames, how to shut it down, and how to disassemble it. Your ability to perform these procedures properly could prevent you or someone working with you from being injured by an explosion or fire.

403. Lighting and adjusting the torch

Before you light the torch, you must adjust the working pressure of the oxygen and acetylene gases. To do this, first open the acetylene torch valve, adjust the regulator and then close the valve. Adjust the oxygen working pressure in the same way. Figure 1–19 shows suggested working pressures for acetylene and oxygen regulators. Now you are ready to light the torch.

Tip Number	Metal Thickness (inches)	Oxygen Pressure (PSI)	Acetylene Pressure (PSI)
0	1/32	3	3
1	1/16	3	3
2	3/32	3	3
3	1/8	3	3
4	3/16	4	4
5	1/4	5	5

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Figure 1–19. Recommended working pressures.

To light the torch, first open the acetylene torch valve. Strike the flint igniter in front of the tip, keeping your hand at one side as shown in figure 1–20. (**NOTE:** *Always* use a flint igniter. Other methods are not recommended.)

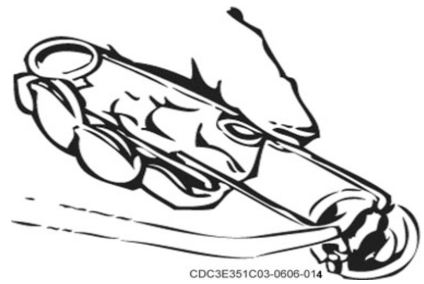

Figure 1–20. Lighting the torch.

Hold the torch so the flame is directed away from the cylinders or manifold, the hose, any flammable material, and you. The pure acetylene flame is long and bushy and has a yellowish color. Since you have the oxygen valve closed at this point, the acetylene burns in combination with the air. Because there is not enough oxygen in the air to burn the acetylene completely, the flame is smoky. It produces soot of fine, unburned carbon. The pure acetylene flame is unsuitable for welding.

When the oxygen valve is opened, the flame shortens and the gases burn in contact with the tip face. The flame changes to a bluish white and forms a bright inner cone surrounded by an outer envelope. The inner cone develops the high temperature needed for welding. The outer envelope contains varying amounts of incandescent carbon soot, depending on the proportion of oxygen to acetylene.

Oxyacetylene welding flames

You can adjust the oxyacetylene welding outfit to produce three distinct flames for specific welding needs. The three flames are neutral, reducing or carburizing, and oxidizing.

Neutral flame

To adjust the torch for a neutral flame, open the torch oxygen valve slowly until the feather flame design at the end of the central cone disappears. There are two clearly defined cones in a neutral flame. The inner cone is luminous and bluish white. Around this cone is a colorless area surrounded by a large flame envelope or sheath (fig. 1–21) that's faintly luminous and has a light bluish tint. The neutral flame is produced by a mixture of approximately one part of oxygen and one part of acetylene supplied from the torch. The temperature at the tip of the inner cone is approximately 5,850°F.

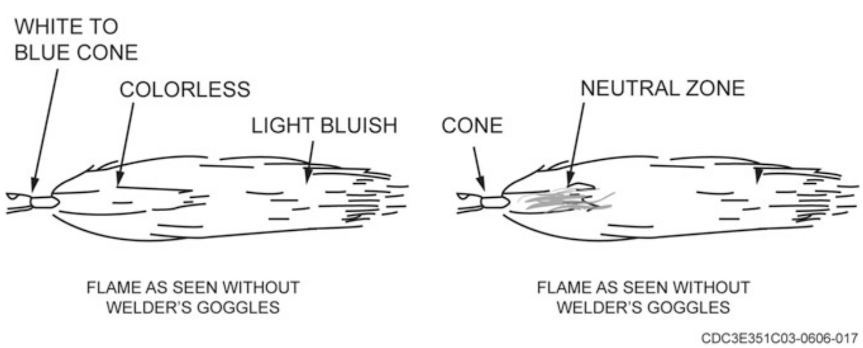

Figure 1–21. Neutral flame.

Reducing or carburizing flame

To adjust the torch for a reducing or carburizing flame, you must start with a neutral flame. Next, open the acetylene torch valve slightly to produce a white streamer or feather of acetylene at the end of the inner cone. The reducing or carburizing flame (fig. 1–22) is produced by slightly more than one part acetylene to one part oxygen. You can recognize the reducing or carburizing flame by the presence of three distinct flame cones: 1) the clearly defined, intense white, central cone; 2) a white feather or intermediate reducing cone indicating the amount of excess acetylene; and 3) the light-orange to bluish outer flame envelope. The flame has a temperature of approximately 5,700°F at the tip of the central cone.

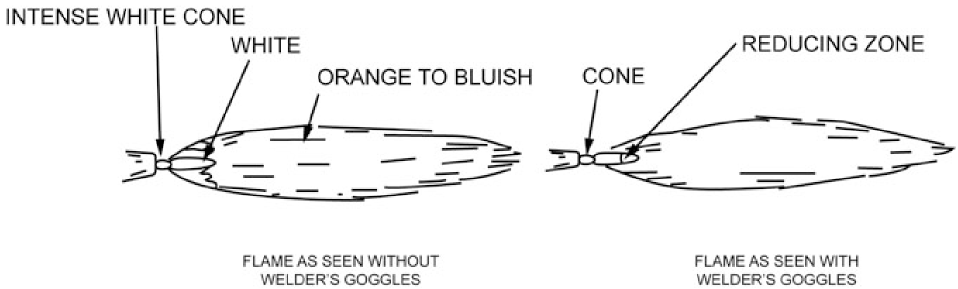

Figure 1–22. Carburizing flame.

To adjust the torch for an oxidizing flame, you must start with a neutral flame. Next, increase the flow of oxygen by opening the oxygen torch valve. The oxidizing flame (fig. 1–23) is produced by slightly more than one part oxygen mixed with one part acetylene. You'll know this flame by the short, pointed central cone; a white or colorless middle cone; and somewhat shorter outer envelope. There is a distinct hissing sound. This flame has a temperature of 6,300°F.

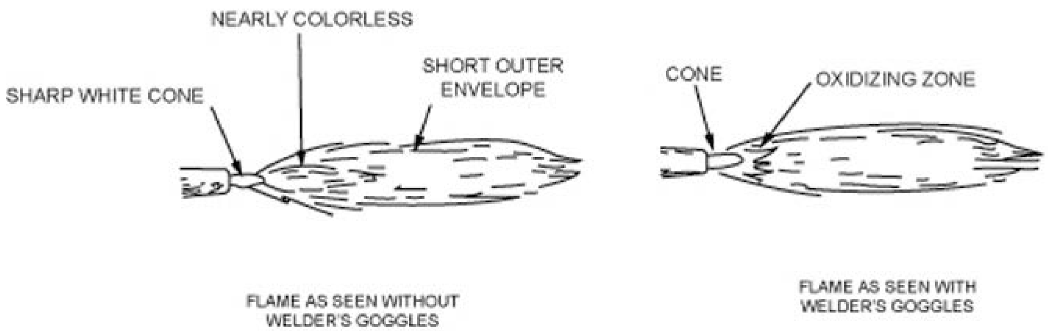

Figure 1–23. Oxidizing flame.

Closing down welding equipment

The next paragraphs cover the procedures for the routine and emergency close down of welding equipment. By following these procedures carefully, you can prevent an accident.

Portable outfit

In closing down a portable welding outfit, turn off the oxygen torch valve FIRST and then close the acetylene torch valve quickly to avoid smoke. Close both cylinder valves. Open the torch valves one at a time to bleed the regulators. Close the torch valves. Turn the regulator adjusting screw counterclockwise to relieve the pressure on the diaphragm and prevent damage to it. Hang the torch and hose properly to prevent kinking the hose or damaging the torch. Be careful not to damage the tip by letting it hit the cylinder or cart.

Emergency closing down

If you have to close down because of an emergency, ALWAYS shut down the oxygen torch valve FIRST, then the oxygen cylinder valve. A flame can't burn back inside the torch without oxygen. The emergency shutdown of equipment may be necessary because of a flashback or other reason. A flashback is an occurrence initiated by a backfire where the flame continues to burn inside the equipment instead of out the tip. A flashback is usually recognized by a high-pitch whistling or squealing sound. Flashback arrestors are installed between the torch and hoses. However, arrestors are not foolproof—you should still shut down the equipment if a flashback occurs. If the flashback reaches the cylinder, the cylinder could explode.

Don't confuse a flashback with a backfire. Backfires can be caused by shutting off the fuel gas first, letting the flame burn back in the oxygen-rich mixture. The flame can't burn without oxygen, so oxygen should always be shut off first to keep the soot from collecting within the internal working parts of the equipment. A backfire is merely the popping of the torch caused by a dirty tip, a tip size too small, a tip being held too close to the work, or too little gas pressure.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

403. Lighting and adjusting the torch

1. When you light the torch, which valve do you open first?

2. When you light the torch, how should you hold the igniter?

3. How should you hold the torch when you are lighting it?

4. Compare the gas volume of a neutral flame to that of an oxidizing flame.

5. How can you recognize the reducing flame?

6. What does the central white feather of a carburizing flame indicate?

7. Give the type and temperature of the *hottest* welding flame.

8. When closing down the portable welding outfit, which valve *must* you turn off *first*?

9. Why do you release the regulator adjusting screws when you close down the portable welding outfit?

10. Why should the oxygen torch valve be shut off *immediately* when a flashback occurs?

11. What is a flashback? What noise characterizes a flashback?

Answers to Self-Test Questions

401

1. Until that one part is repaired or replaced.
2. An explosion.
3. Replace the safety cap, mark the cylinder “EMPTY” or “MT”, secure it in an upright position, and place it in the empty cylinder area away t from the full cylinders.
4. So it can absorb the acetylene to stabilize it under pressure.
5. To keep acetone from escaping.
6. Green.
7. Oxygen is under great pressure and a broken valve or pierced cylinder could make a missile out of the cylinder and cause injury and damage.
8. Single-stage regulator.
9. Acetylene gas.
10. In the mixing head.
11. Torch wrench.
12. Welding goggles, gloves, flashback arrestors, flint igniter, and fire extinguisher.
13. To blow out any dirt that may be lodged in the outlet nipple.
14. Acetylene valves are opened no more than 1½ turns. Oxygen valves are opened fully.
15. Flashback arrestors.
16. Oxygen connections have right-hand threads, and acetylene connections have left-hand threads.

402

1. Be sure the gas supply is shut off.
2. Reinstall the cylinder valve safety cap or line protective nuts.
3. To keep from rounding the corners on the connecting nuts.
4. A container of soapy water, brush, and bucket of clear water or leak detection liquid.
5. By brushing the soapy water on the connection. If it bubbles, it leaks.
6. Submerge them in a bucket of clear water and watch for bubbles.
7. The gradual pressure rise on the working pressure gauge after the cylinder valve is opened.
8. Fluctuating gauge pressure; gas leaking from the gauge case.
9. The manufacturer.
10. Copper.
11. A soft wire or drill bit type cleaner; enlarging the orifice.
12. To keep from enlarging the orifice.
13. An enlarged orifice.
14. To prevent flame distortion.
15. Stop using the tip and check the tip seats for nicks or flat spots; and if you find any, replace the tip. Also, check the torch seats; leaking gas can produce flashback.

403

1. The acetylene valve.
2. Keep your hand at one side of the tip.
3. With the flame directed away from you and anything else in the area that is flammable.
4. The gas part is one-to-one in a neutral flame. There is slightly more than one part of oxygen to one part of acetylene in an oxidizing flame.
5. By the presence of three distinct flame cones.
6. An excessive amount of acetylene in the flame.

7. Oxidizing flame with a temperature of 6,300°F.
8. The oxygen valve.
9. To relieve the pressure on the regulator diaphragm and prevent damage to it.
10. To keep the fire from moving through the hose and regulator into the supply line or cylinder and causing an explosion.
11. The burning of gas inside the torch; a high-pitched whistle.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (401) When a gas storage cylinder is cooled, what happens to the gas and pressure?
   a. Gas expands and pressure increases.
   b. Gas expands and pressure decreases.
   c. Gas contracts and pressure increases.
   d. Gas contracts and pressure decreases.

2. (401) The *greatest* concern of mixing oil or grease with oxygen under pressure is that it can
   a. cause a fire.
   b. cause an explosion.
   c. cause a tripping hazard.
   d. create poisonous fumes.

3. (401) On the oxyacetylene welding assembly, what colors are the oxygen and acetylene hoses?
   a. Oxygen is red or maroon and acetylene is green or black.
   b. Oxygen is green or black and acetylene is red or maroon.
   c. Oxygen is black or red and acetylene is green or maroon.
   d. Oxygen is green or red and acetylene is black or maroon.

4. (401) What does the tip of an oxyacetylene torch do?
   a. Cuts the metal.
   b. Mixes the gas.
   c. Directs gas flow.
   d. Maintains temperature.

5. (401) When assembling oxyacetylene welding equipment, open the acetylene cylinder valve a *maximum* of
   a. one-turn.
   b. one-half turn.
   c. one and one-half turns.
   d. one and three-quarter turns.

6. (401) How are oxygen and acetylene connections made on oxyacetylene welding equipment?
   a. Both are left-handed threads.
   b. Both use right-handed threads.
   c. Acetylene uses right-handed threads and oxygen uses left-handed threads.
   d. Acetylene uses left-handed threads and oxygen uses right-handed threads.

7. (402) Ease=0.750 DI=0.300 Related= Endid
   When disassembling oxyacetylene welding equipment, which tool should you use to keep from rounding corners on connecting nuts?
   a. Torch wrench.
   b. Box end wrench.
   c. Socket and ratchet.
   d. Adjustable open end wrench.

8. (402) You test welding equipment connectors for gas leaks with which substance?
   a. Soapy water.
   b. Caustic soda.
   c. Distilled water.
   d. Fluorescent dye.

9. (402) To repair a leak around the needle valves of welding equipment, tighten the
   a. valve.
   b. valve seat.
   c. hose connection.
   d. packing gland nut.

10. (402) When cleaning a welding or cutting torch tip, you *must* use straight back-and-forth motion to keep from
    a. scoring the tip face.
    b. enlarging the orifice.
    c. clogging the tip with filings.
    d. distorting the preheating flame.

11. (402) Gas leakage around a torch tip is usually caused by
    a. a damaged tip seat.
    b. using the wrong tip size.
    c. excessive torch pressure.
    d. a cross-threaded tip connection.

12. (403) The *safest* way for you to light a welding torch is to use
    a. matches.
    b. a flint igniter.
    c. an electric spark.
    d. a butane lighter.

13. (403) A pure acetylene flame is smoky because there is
    a. a low percentage of acetone in it.
    b. a high percentage of acetone in it.
    c. not enough oxygen in the air to burn the acetylene completely.
    d. not enough pressure in the mixture to burn the acetylene completely.

14. (403) Which part of an oxyacetylene torch flame produces the high temperature needed for welding?
    a. Inner cone.
    b. Outer cone.
    c. Oxygen feather.
    d. Acetylene feather.

15. (403) A neutral flame is produced by mixing approximately
    a. one part acetylene to one part oxygen.
    b. one and one-half parts acetylene to one part oxygen.
    c. one part acetylene to one and one-half parts oxygen.
    d. one and one-half parts acetylene to two parts oxygen.

16. (403) The reason that regulators are bled during oxyacetylene close down is to
    a. clean out the hoses.
    b. prevent relighting of the torch.
    c. relieve pressure on the diaphragm.
    d. relieve pressure on the torch valves.

17. (403) To relieve the pressure on the diaphragm of a regulator, you
    a. turn the adjusting screw clockwise.
    b. open the torch valves one at a time.
    c. open both torch valves at the same time.
    d. turn the adjusting screw counterclockwise.

18. (403) If a flashback occurs in oxyacetylene welding equipment, what type of sound does it make?
    a. A loud popping or pinging.
    b. A muffled roaring or groaning.
    c. A low-pitched whistling or hissing.
    d. A high-pitched whistling or squealing.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Oxyacetylene Welding

WELDING procedures and qualifications in today's nuclear and space age involve more than just meeting ductility and strength requirements and passing tensile tests prescribed by existing manuals and codes. Other factors that you must consider are operating temperatures and pressure ranges.

To meet the more critical service requirements and conditions today, new metals and alloys are being produced. To join these metals and alloys properly, new welding methods are being developed while present methods are being improved. Although there are new methods of welding, such as ultrasonic welding, electron beam welding, laser welding, and inert gas welding, you'll find that oxyacetylene welding still has many applications.

2–1. Metals

The ability of carbon steel to be welded depends to a great extent on its carbon content, which varies from 0.04 to 1.70 percent. Weldability becomes poorer as the carbon content increases because of the hardening effect of carbon. In high carbon steels, a hard, brittle zone forms in the fusion area, caused by the rapid cooling of the molten metal.

404. Metal identification

In this lesson, you will learn the many methods used to identify a piece of metal. Identification is necessary when selecting a metal for use in fabrication or in determining its weldability. Some common methods used for field identification are surface appearance, spark test, chip test, and magnetic test using a magnet.

Surface appearance

Sometimes it is possible to identify metals by their surface appearance. The table below describes the surface colors of some of the more common metals. Referring to the table, you can see that the outside appearance of a metal helps to identify and classify metal. Newly fractured or freshly filed surfaces offer additional clues.

A surface examination does not always provide enough information for identification but should give us enough information to place the metal into a class. The color of the metal and the distinctive marks left from manufacturing help in determining the identity of the metal. Cast iron and malleable iron usually show evidence of the sand mold. Low-carbon steel often shows forging marks, and high-carbon steel shows either forging or rolling marks. Feeling the surface may provide another clue.

Stainless steel is slightly rough in the unfinished state, and the surfaces of wrought iron, copper, brass, bronze, nickel, and Monel are smooth. Lead also is smooth but has a velvety appearance.

COMMON METALS SURFACE COLORS			
Metals	**Color of unfinished, unbroken surface**	**Color and structure of newly fractured surface**	**Color of freshly filed surface**
White cast iron	Dull gray	Silvery white, crystalline	Silvery white
Gray cast iron	Dull gray	Dark gray; crystalline	Light silvery gray
Malleable iron	Dull gray	Dark gray; finely crystalline	Light silvery gray
Wrought iron	Light gray	Bright gray	Light silvery gray
Low-carbon and cast steel	Dark gray	Bright gray	Bright silvery gray
High-carbon steel	Dark gray	Light gray	Bright silvery gray
Stainless steel	Dark gray	Medium gray	Bright silvery gray
Copper	Reddish brown to green	Bright red	Bright copper color
Brass and bronze	Reddish yellow, yellow-green, or brown	Red to yellow	Reddish yellow to yellowish white
Aluminum	Light gray	White; finely crystalline	White
Monel metal	Dark gray	Light gray	Light gray
Nickel	Dark gray	Off-white	Bright silvery white
Lead	White to gray	Light gray; crystalline	White

There may be times when you cannot make positive identification from the metal's surface appearance. When this is the case, you'll need to use other identification methods. The three simplest and most reliable tests (when done by a skilled person) are the spark test, the chip test, and the magnetic tests.

Spark test

To use the spark test, hold a sample of metal against an abrasive wheel and visually inspect the spark stream. An experienced metalworker can identify the metals with considerable accuracy. This test is fast, economical, convenient, and easily accomplished, and there is no requirement for special equipment. We can use this test for identifying metal salvaged from scrap. Identification of scrap is particularly important when selecting material for cast iron or cast steel heat treatment.

When you hold a piece of iron or steel in contact with a high-speed abrasive wheel, small particles of the metal are torn loose so rapidly that they become red-hot. As these glowing bits of metal leave the wheel, they follow a path (trajectory) called the carrier line. This carrier line is easily followed with the eye, especially when observed against a dark background. The sparks given off, or the lack of sparks, aid in the identification of the metal. The length of the spark stream, the color, and the form of the sparks are features you should look for. Figure 2–1 illustrates the various basic spark forms produced in spark testing.

Steels having the same carbon content but differing alloying elements are difficult to identify because the alloying elements affect the carrier lines, the bursts, or the forms of characteristic bursts in the spark picture. The effect of the alloying element may slow or accelerate the carbon spark or make the carrier line lighter or darker in color. Molybdenum, for example, appears as a detached, orange-colored spearhead on the end of the carrier line. Nickel appears to suppress the effect of the carbon burst; however, tiny blocks of brilliant white light are identified with the nickel spark. Silicon suppresses the carbon burst even more than nickel. When silicon is present, the carrier line usually ends abruptly in a white flash of light.

Spark testing may be done with either a portable or stationary grinder. In either case, the speed on the wheel should rotate at a high speed—at least 15,000 feet per minute or more. The abrasive wheel should be rather coarse, very hard, and kept clean to produce a true spark.

To conduct a spark test on an abrasive wheel, hold the piece of metal on the wheel in a position that allows the spark stream to cross your line of vision. Vary the amount of pressure to get a stream of the proper length without reducing the speed of the grinder. (**NOTE:** Excessive pressure increases the temperature of the spark stream. This, in turn, increases the temperature of the burst and gives the appearance of higher carbon content than is actually present.)

When making the test, watch a point about one-third of the distance from the tail end of the spark stream. Watch only those sparks that cross your line of vision and try to form a mental image of the individual spark. Fix this spark image in your mind and then examine the whole spark picture.

Spark test safety

Be sure to adhere to all applicable safety precautions when using a grinder. We discussed portable and stationary grinders in the *Structural Journeyman*, 3E351A, Volume 1, *Project planning, Tools and Equipment*, CDCs.

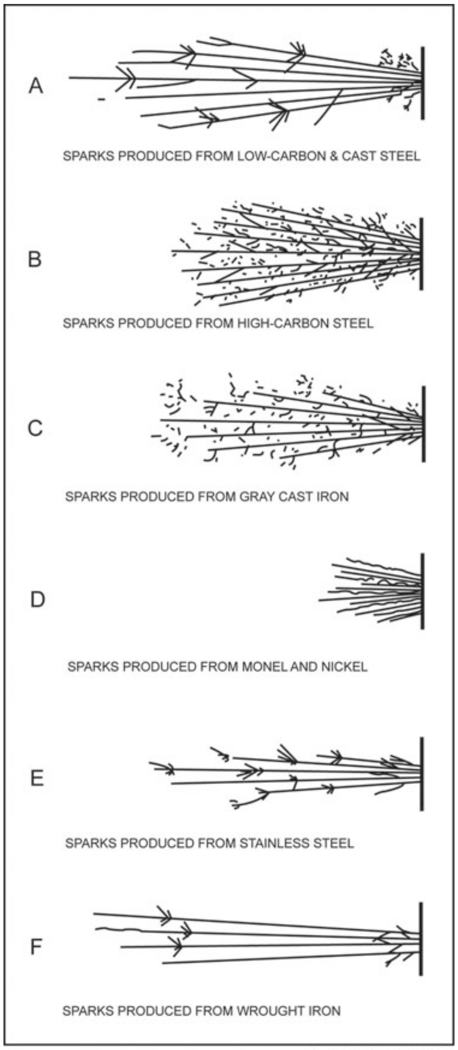

Figure 2–1. Spark forms produced in spark testing.

Spark streams

In low-carbon steel (fig. 2–1, view A), the spark stream is about 70- inches long and the volume is moderately large. In high-carbon steel (fig. 2–1, view B), the stream is shorter (about 55- inches) and the volume larger. The few sparklers that may occur at any place in low-carbon steel are forked, and in high-carbon steel, they are small and repeating. Both metals produce a spark stream white in color.

Gray cast iron (fig. 2–1, view C) produces a stream of sparks about 25 inches in length. The sparklers are small and repeating, and their volume is rather small. Part of the stream near the wheel is red, and the outer portion is straw-colored.

Monel and nickel (fig. 2–1, view D) form almost identical spark streams. The sparks are small in volume and orange in color. The sparks form wavy streaks with no sparklers. Because of the similarity of the spark picture, these metals must be distinguished from each other by some other method.

Stainless steel (fig. 2–1, view E) produces a spark stream about 50 inches in length, moderate volume, and with few sparklers. The sparklers are forked. The stream next to the wheel is straw-colored, and at the end, it is white.

The wrought-iron spark test (fig. 21, view F) produces a spark stream about 65 inches in length. The stream has a large volume with few sparklers. The sparks appear near the end of the stream and are forked. The stream next to the wheel is straw-colored, and the outer end of the stream is a brighter red.

One way to become proficient in spark testing ferrous metals is to gather an assortment of samples of known metals and test them. Make all of the samples about the same size and shape so their identities are not revealed simply by the size or shape. Number each sample and prepare a list of names and corresponding numbers. Then, without looking at the number of the sample, spark test one sample at a time, calling out its name to someone assigned to check it against the names and numbers on the list. Repeating this process gives you some of the experience you need to become proficient in identifying individual samples.

Chip test

Another simple test used to identify an unknown piece of metal is the chip test. The chip test is made by removing a small amount of material from the test piece with a sharp, cold chisel. The material removed varies from small, broken fragments to a continuous strip. The chip may have smooth, sharp edges; it maybe coarse-grained or fine-grained; or it may have saw-like edges. The size of the chip is important in identifying the metal. You should also take into consideration the ease in which the chipping is done. The table below describes the chip characteristics of different metals.

METAL CHIP CHARACTERISTICS

Metals	**Chip characteristics**
White cast iron	Chips are small, brittle fragments. Chipped surfaces are not smooth.
Gray cast iron	Chips are about ⅛ inch in length. This metal is not easily chipped causing chips to break off, preventing a smooth cut.
Malleable cast iron	Chips vary from ¼ to ⅜ inch in length. The chips are larger than cast iron chips. This metal is hard and tough to chip.
Wrought iron	Chips have smooth edges. This metal is easily cut or chipped. Chips can form as continuous strips.
Low-carbon and cast steel	Chips have smooth edges. This metal is easily cut or chipped. Chips can form as continuous strips.
High-carbon steel	Chips show a fine grain structure. The chip’s edges are light in color than chips from low-carbon steel. This metal is hard, but it can be chipped in a continuous strip.
Copper	Chips are smooth, with saw tooth edges. This metal is easily cut as a continuous strip.
Brass and bronze	Chips are smooth, with saw tooth edges. These metals are easily cut, but the chips are more brittle than copper chips. A continuous strip is not easily cut.
Aluminum and aluminum alloys	Chips are smooth, with saw tooth edges. A chip can be cut as a continuous strip.
Monel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
Nickel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
Lead	Chips of any shape may be obtained. This metal is very soft. It can even be cut with a knife.

Magnetic test

The use of a magnet is another method used to aid in the general identification of metals. Remember that ferrous metals, being iron-based alloys, normally are magnetic, and nonferrous metals are nonmagnetic. This test is not 100-percent accurate because some stainless steels are nonmagnetic. In this instance, there is no substitute for experience.

This test places the unknown metal into a specific identification grouping based on the magnetic force. There are three categories of magnetic force—strong attraction, weak attraction and no attraction.

The table below shows some of the metals and the group (magnetic force category) into which they fall.

METALS GROUP	
Magnetic Force Category	**Metals**
Strong Attraction	Carbon steels Cast irons Cobalt Nickel Stainless steels (400 series) Tool steels
Weak Attraction	Stainless steels (300 series) Monel 400
No Attraction	Alloy 20 types Nonferrous metals Copper-nickels Stainless steels (Austenitic) Aluminum

405. Carbon steel types and uses

In this lesson, you will learn the terminology and definition of various metal characteristics. Strength, hardness, toughness, elasticity, plasticity, brittleness, and ductility and malleability are mechanical properties used as measurements of how metals behave under a load. These properties are described in terms of the types of force or stress that the metal must withstand and how these are resisted.

Types of stress

Common types of stress are compression, tension, and shear or a combination of these, such as fatigue.

Compression

Compression stresses develop within a material when forces compress or crush the material. A column that supports an overhead beam is in compression, and the internal stresses that develop within the column are compression.

Tension

Tension (or tensile) stresses develop when a material is subject to a pulling load (e.g., when using a wire rope to lift a load or when using it as a guy to anchor an antenna). “Tensile strength” is defined as resistance to longitudinal stress or pull and can be measured in pounds per square inch of cross section.

Shearing

Shearing stresses occur within a material when external forces are applied along parallel lines in opposite directions. Shearing forces can separate material by sliding part of it in one direction and the rest in the opposite direction.

Mechanical properties

As mentioned previously, strength, hardness, toughness, elasticity, plasticity, brittleness, ductility, and malleability are the eight mechanical properties of metal.

Strength and hardness

Strength is the property that enables a metal to resist deformation under load from mechanical forces placed on it. The ultimate strength is the maximum strain a material can withstand. *Tensile strength* is a measurement of the resistance to being pulled apart when placed in a tension load. *Fatigue strength* is the ability of material to resist various kinds of rapidly changing stresses. *Impact strength* is the ability of a metal to resist suddenly applied loads.

Hardness is the property of a material to resist permanent indentation, deformation, or scratching. Because there are several methods of measuring hardness, the hardness of a material is always specified in terms of the particular test that was used to measure this property.

Toughness and elasticity

Toughness is the property that enables a material to withstand shock and to be deformed without rupturing. Toughness may be considered as a combination of strength and plasticity. When a material has a load applied to it, the load causes the material to deform. *Elasticity* is the ability of material to return to its original shape after the load is removed.

Plasticity and brittleness

Plasticity is the ability of a material to deform permanently without breaking or rupturing. This property is the opposite of strength. *Brittleness* is the opposite of plasticity. A brittle metal is one that breaks or shatters before it deforms. White cast iron and glass are good examples of brittle material. Generally, brittle metals are high compressive strength but low in tensile strength. As an example, you would not choose cast iron for fabricating support beams in a bridge.

Ductility and malleability

Ductility is the property that enables a material to stretch, bend, or twist without cracking or breaking. In comparison, *malleability* enables a material to deform by compressive forces without developing defects. A malleable material is one that can be stamped, hammered, forged, pressed, or rolled into thin sheets.

Corrosion resistance

Corrosion resistance, although not a mechanical property, is important in the discussion of metals. Corrosion resistance is the property of a metal that gives the ability to withstand attacks from atmospheric, chemical, or electrochemical conditions. Corrosion, sometimes called oxidation, is illustrated by the rusting of iron.

The following table lists four mechanical properties and corrosion resistance of various metals or alloys. The metal or alloy in each column exhibits the best characteristics of that property. The last metal or alloy in a column exhibits the least. In the column labeled “Toughness,” note that iron is not as tough as copper or nickel; however, it is tougher than magnesium, zinc, and aluminum. In the column labeled “Ductility,” iron exhibits a reasonable amount of ductility; however, in the columns labeled “Malleability” and “Brittleness,” it is last.

TOUGHNESS	BRITTLENESS	DUCTILITY	MALLEABILITY	CORROSION RESISTANCE
Copper	White cast iron	Gold	Gold	Gold
Nickel	Gray cast iron	Silver	Silver	Platinum
Iron	Hardened steel	Platinum	Aluminum	Silver
Magnesium	Bismuth	Iron	Copper	Mercury
Zinc	Manganese	Nickel	Tin	Copper
Aluminum	Bronzes	Copper	Lead	Lead
Lead	Aluminum	Aluminum	Zinc	Tin
Tin	Brass	Tungsten	Iron	Nickel
Cobalt	Structured steels	Zinc		Iron
Bismuth	Zinc	Tin		Zinc
	Monel	Lead		Magnesium
	Copper			Aluminum
	Iron			

NOTE: Metals/alloys are ranked in descending order of having the property named in the column heading.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

404. Metal identification

1. What is the surface appearance of cast iron, malleable iron, low-carbon steel, and high-carbon steels?

2. How do you perform the spark test?

3. What features do you look for when performing the spark test?

4. How long are the spark streams for stainless steel and wrought iron?

5. How can the chip test identify the type of metal?

6. Which metals are normally magnetic, and which are normally nonmagnetic?

405. Carbon steel types and uses

1. List the common types of stresses that carbon steel metal must withstand.

2. What is the definition for “tension” strength, and how can it be measured?

3. List the eight mechanical properties of metal.

4. What is the definition for tensile strength?

5. The ability of material to return to its original shape *after* the load is removed is known as what?

6. Which metal has the *highest* resistance to corrosion?

2–2. Welding Fundamentals

You must have a clear understanding of oxyacetylene welding fundamentals to produce adequate welds. Also, you must be able to select the correct torch tip, welding or filler rod type, and welding method to use—forehand and backhand—to use. You also must be familiar with welding positions. Most welding jobs are classified according to position. The position of a weld is based on the placement of the metal or its joint edges.

To complete a weld within required guidelines, you must understand welding symbols (road signs to good welds) used on blueprints. Welding symbols show the types of weld joints that must be made in fabrication and repair. When you finish this section, you should have a fundamental knowledge of oxyacetylene welding principles and welding symbols.

406. Oxyacetylene welding principles and weld symbols

In this lesson you will learn basic principles involved with oxyacetylene welding and understand the most commonly used welding symbols.

Principles

Oxyacetylene welding is a fusion welding process. When steel is heated, it goes through a soft or plastic range between the solid and liquid states. The metals to be joined actually flow together to form a complete bond. Steel does not become fluid until it reaches a temperature between 2,450°F and 2,750°F. The metal composition determines the temperature at which its fluidity occurs. The temperature range is important when you weld various metals. Knowing the range allows you to control the weld. When you perform a weld correctly, the section where the weld is made will be as strong as the base metal itself.

Weld symbol and welding symbol

There is an important distinction between the terms *weld* symbol and *welding* symbol. A weld symbol provides only information on the weld type to use, while a welding symbol gives that information plus much more. We will discuss the other information a welding symbol provides under the paragraph on welding symbol.

Weld symbol

A weld symbol indicates the desired weld type. It tells the welding process to be used in a metal-joining operation such as the weld is to be localized, or all around, or whether it must be a shop or field weld. It also specifies the contour of the weld.

Refer to figure 2–2 as you study the summary of basic weld symbols.

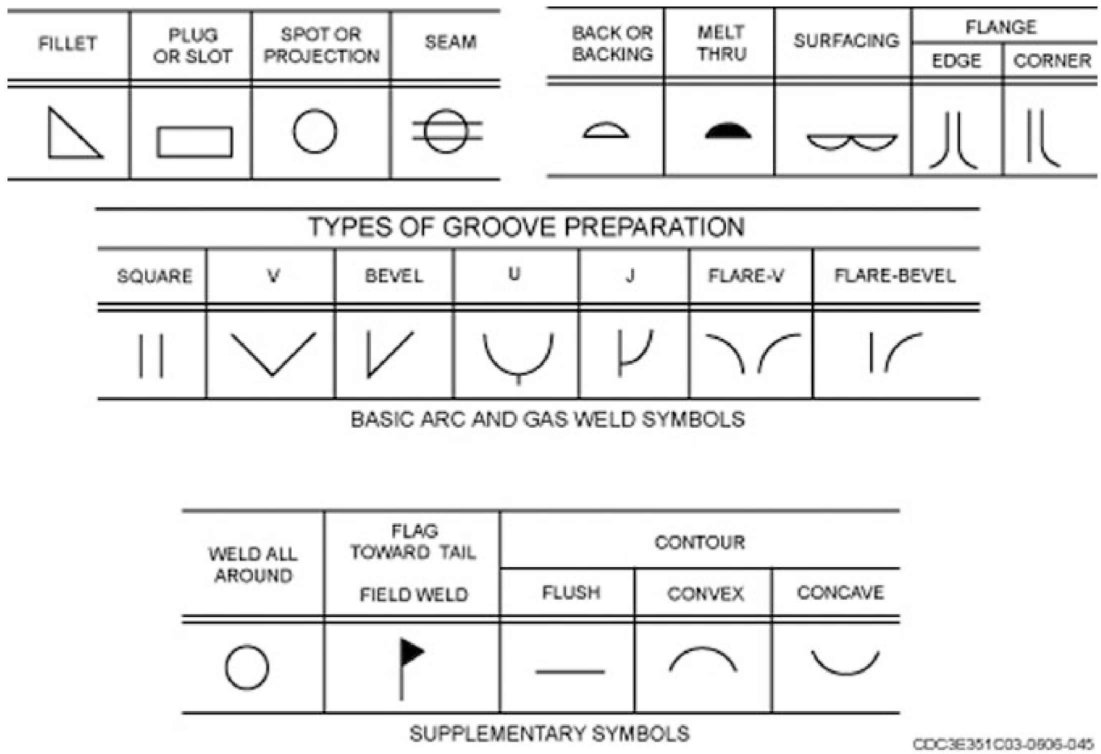

Figure 2–2. Weld symbols.

WELD SYMBOLS	
Symbol	**Explanation**
Arc and gas weld	Represents bead, fillet, plug or slot, square, V, bevel, U, and J welds.
Resistance weld	Represents spot, projection, and seam welds.
Braze, forge, and induction	Don't have specific weld symbols, the tail of the welding symbol designates which of these welding processes is used, together with the specifications, procedures, and other supplementary information needed for making the weld. The codes for these notations in the welding symbol are usually established according to their uses.
Supplementary	Represent common requirements in many welding processes. Some symbols include a circle to indicate weld all around, flag for a field weld, or curved lines to show flush and convex contour welds.

Welds on the arrow side of the joint are indicated by the weld symbol being placed below the reference line, as in figure 2–3, view "A". Welds on the other side of the joint are indicated by the weld symbol being placed above the reference line, as in figure 2–3, view "B." Welds on both sides of the joint are indicated by the weld symbols on both sides of the reference line, as in figure 2–3, view "C."

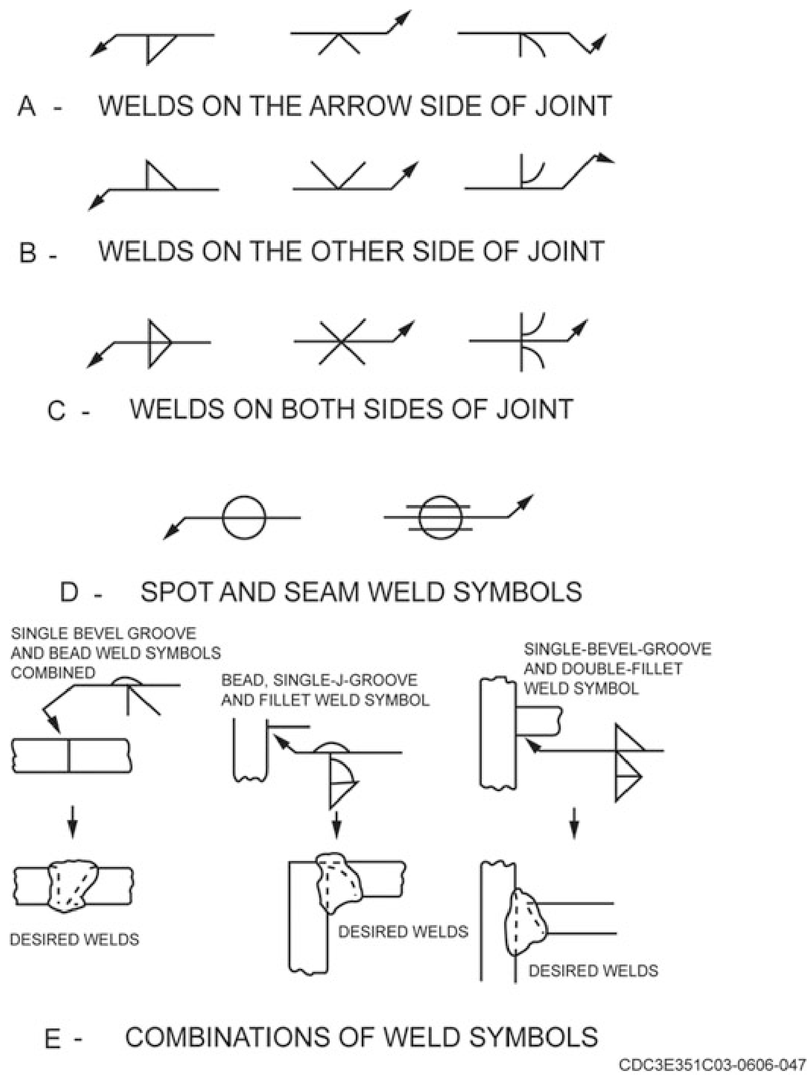

Figure 2–3. Weld type and location symbols.

The symbols for spot, seam, flash, and upset welds have no arrow side or "side" significance in themselves, although supplementary symbols used with these symbols may have, for example, the flush-contour symbol shown in figure 2–2. This symbol is used with the spot and seam weld symbols in figure 2–3 to show that the exposed surface of one member of the joint is to be flush. Spot, seam, flash, or upset weld symbols are centered on the reference line, as in figure 2–3, view "D." If more than one type of weld is to be used on a joint, the symbol for each weld is like the ones shown in figure 2–3, view "E."

Welding symbol

A welding symbol contains the following elements: reference line, arrow, basic weld symbol, dimensions and other data, supplementary symbols, tail, and the specifications, process, or other reference. If necessary, a tail is attached to the reference line and is used to provide specific notations. If such notations are not required, the tail welding symbol and the standard location of the elements is omitted. Welding symbols on blueprints provide complete welding information and concise information to guide you.

Figure 2–4 shows a welding symbol and the standard location of the welding information elements.

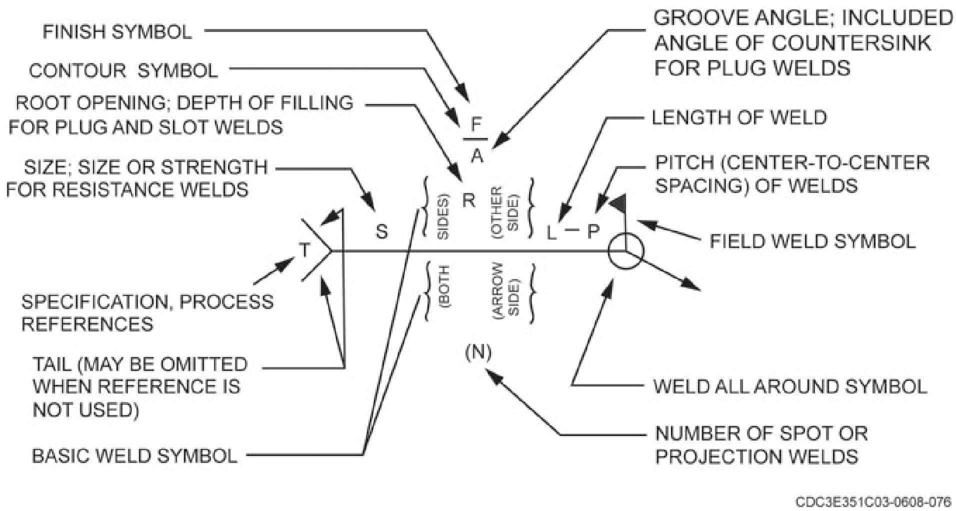

Figure 2–4. Welding symbol nomenclature.

407. Selecting torch tips, filler rods and welding methods/positions

In this lesson, you will learn how to select the correct torch tip, filler rod, welding method, and position for various welding requirements. Correct torch tip selection is vital to produce the correct heat and flame that you want for welding different metal types and joints.

Torch tips

Selecting the proper tip size depends on the thickness of the metal and rate at which the heat is conducted and radiated in it. If you select a tip that is too large, the metal will overheat and excessive scaling and loss of elements from the metal will occur, producing a weak weld. In light metals, overheating often results in the burning of holes, excessive penetration, and large globules of metal protruding on the opposite side of the weld. If the tip is too small, the flame volume is too small to get proper fusion. Adhesion occurs between the base metal and the filler rod and produces only a physical bond (a bond made at the surface level of an object or between two or more objects). Another bond type is called *fusion*. In a fusion bond, a chemical bond is made by the actual mixing of the materials to form a solid mass. We use the fusion bond in a process called *fusion welding*. In fusion welding, the tip size selection is critical to the mixing of the metals to produce a sound weld joint. If you don't have the torch manufacturer's table giving the tip sizes for welding different thickness of material, you can select the tip size by gauging the tip orifice and referring to a table, such as the one shown in figure 2–5.

METAL THICKNESS	TIP SIZE NO.
1/64" to 1/32"	0
1/32" to 1/16"	1
1/16" to 1/8"	2
1/8" to 3/16"	3
3/16" to 1/4"	4
1/4" to 3/8"	5

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Figure 2–5. Recommended tip sizes.

Filler rod

In most instances, some extra metal in the form of a wire rod (filler rod) is added to the molten metal to build up the joint slightly for greater strength. The type of filler for the job depends on the type of metal you are welding. In fusion welding, the filler rod is usually of the same composition as the base metal. For welding low carbon steels, use a copper-coated, low carbon rod. The size of the filler rod depends on the thickness of the metal you are welding. Welding rods are available in diameters of $^{1}/_{16}$- inch and larger. Figure 2–6 recommends the proper filler rod diameter to use on metals with different thickness.

METAL THICKNESS	FILLER ROD
1/16" to 1/8"	1/16" to 3/32"
1/8" to 1/4"	1/8"
3/8" to 1/2"	3/16"
1/2" AND UP	1/4"

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Figure 2–6. Filler rod sizes.

Oxyacetylene welding methods

The two basic methods for oxyacetylene welding are forehand and backhand. Either method can be used to produce a high quality weld. The method you choose depends on the material, thickness, location, or joint that you need to weld.

Welding forehand

To make satisfactory bead welds on the surface of a plate in flat-position welding, the flame motion, tip angle, and position of the welding flame above the molten puddle should be carefully maintained. Adjust the welding torch to give the proper type of flame for the metal you are welding. Make narrow bead welds by raising and lowering the welding flame with a slight circular motion while progressing in a forward direction. Hold the tip of the torch at an angle of 45 to 60° to the plate surface, and point the flame in the direction of welding at all times, as shown in figure 2–7. To increase the depth of fusion, either increase the angle between the tip and the plate surface or decrease the welding speed. The size of the puddle should not be too large or it will cause the flame to burn through the plate. A properly made bead weld, without filler rod, should be slightly depressed below the upper surface of the plate, and a ridge should form on the underside to indicate full penetration.

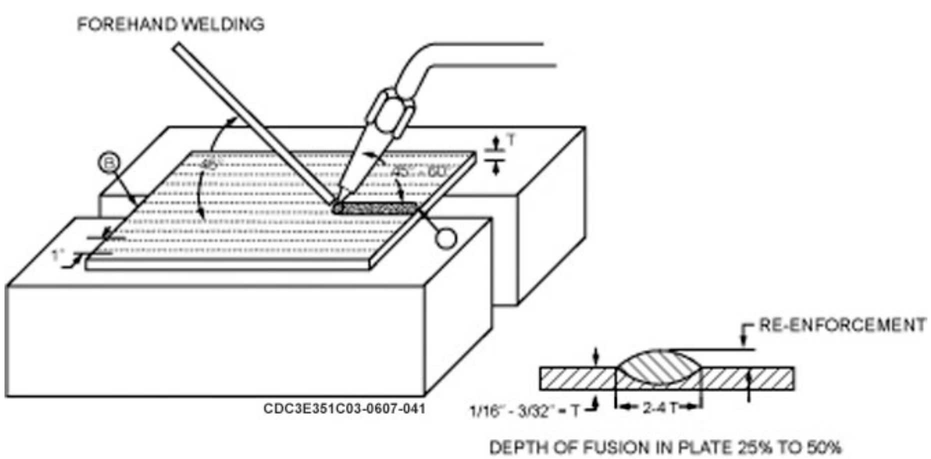


Figure 2–7. Welding flame direction.

A butt weld made with a welding rod is shown in figure 2–8. In making this weld, heat the surfaces of the two pieces to bring a small portion of the metal on each side of the joint up to the melting temperature. Then insert the welding rod into the puddle and melt both the base metal and rod together. Move the torch from side to side slightly to get good fusion. By varying the welding speed and the amount of metal deposited from the welding rod, you can control the size of the welding bead.

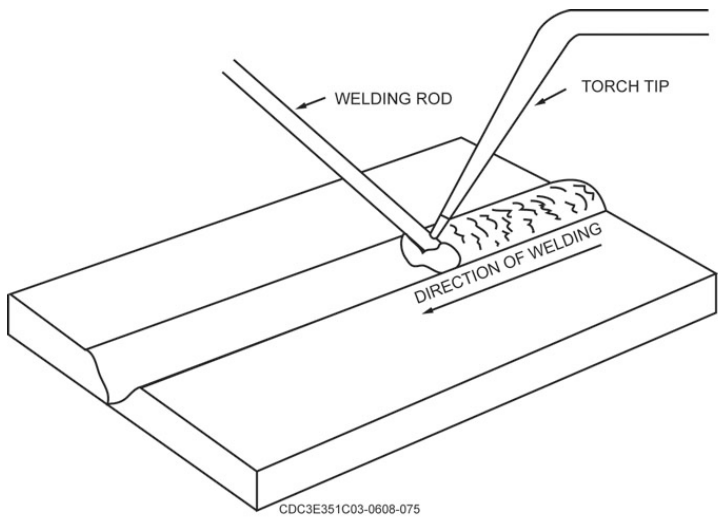


Figure 2–8. Forehand welding a butt joint.

Welding backhand

In this method of welding, the welding tip precedes the rod in the direction of travel, and the flame is pointed back at the molten puddle and the completed weld. Hold the end of the rod between the flame and the molten puddle, and keep the welding tip at an angle of approximately 60° to the plates, figure 2–9 shows an example of welding heavy plate. Positioning the welding rod and tip requires less transverse motion, making it slightly easier than forehand welding.

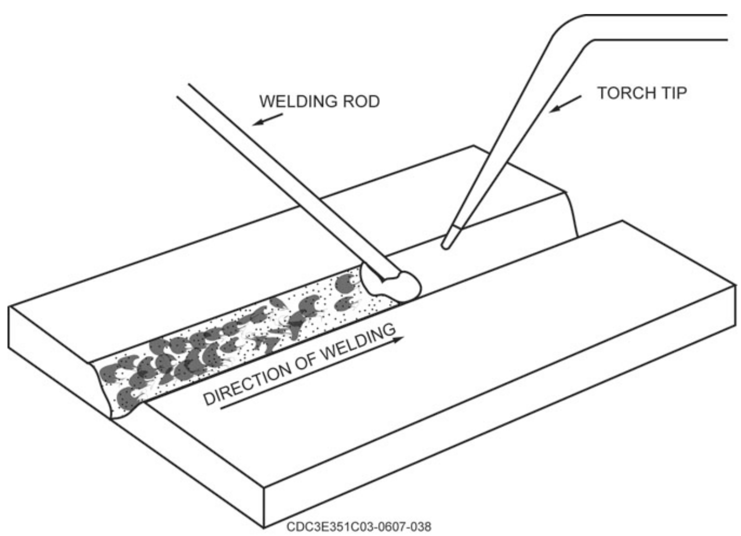


Figure 2–9. Backhand welding a heavy section.

If you use a straight welding rod, rotate the rod so the end rolls from side to side in the puddle and melts off evenly. If you use a bent rod, move the rod and the tip toward and away from each other to simulate a rapid bellows action. In a welding operation in which you are making a large weld deposit, move the end of the rod in full circles in the molten puddle. Move the torch back and forth across the weld while you advance slowly and uniformly in the direction of the welding.

Use backhand welding mainly for welding heavy sections because it permits forming narrower “V”s at the joint. A 60° included angle of bevel is sufficient for a good joint weld. Less weld rod is used in welding by this method than by forehand welding. You can compare the forehand and backhand methods by referring to figures 2–8 and 2–9.

Welding positions

There are four general welding positions: flat, horizontal, vertical, and overhead. To make satisfactory welds, you must know the factors that you can control in the various positions.

Controlling the weld in any position

Gravity causes the molten weld metal in a puddle to seek a lower level. There are five forces that resist this lower leveling:

1. Molten pool cohesion.
2. Support provided by the base metal and solidified weld metal.
3. Flame pressure on the molten metal.
4. Filler rod manipulation and the chilling effect of the filler rod upon the molten pool.
5. Surface tension.

The most important force that counteracts the force of gravity is the molten metal pool cohesion. The cohesion force permits a certain amount of molten metal to remain in the molten pool without running or falling. Cohesion is directly affected by the heat applied. When more heat is applied than necessary, it increases the fluidity of the molten metal giving it a greater tendency to run or fall.

Flat position

Flat-position welding is done when a weld is made with the parts flat on the table or inclined at an angle less than 45°. The filler metal is deposited from the upper side of the joint and the face of the weld is approximately horizontal.

Horizontal position

When you weld joints with the joint edges horizontal, as illustrated in figure 2–10, you hold the tip at an angle of 45° to the plate surface, and incline it slightly in the vertical plane to direct the flame upward. Inclining the tip slightly keeps the molten metal from sagging to the lower edge of the weld. Move the tip slightly from side to side to deposit the metal uniformly along the joint. Add the filler rod to the upper edge of the molten pool to permit an even distribution of weld metal.

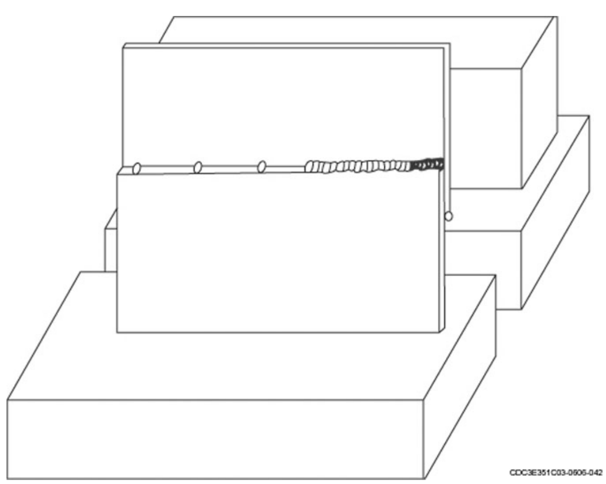


Figure 2–10. Horizontal lap joint

Vertical position

When you're welding with the parts inclined at an angle greater than 45° and the seam is running vertically (figs. 2–11 and 2–12), you produce a vertical weld. During vertical welding, gravity causes the molten metal to run down and produce a highly crowned bead. To control the flow of the molten metal, hold the flame below the welding rod and point it upward at an angle of 45° to the plate. Removing the flame momentarily when the molten metal tends to sag will aid in producing a weld of proper contour. The solidified weld metal just below the molten pool acts as a ledge that provides support.

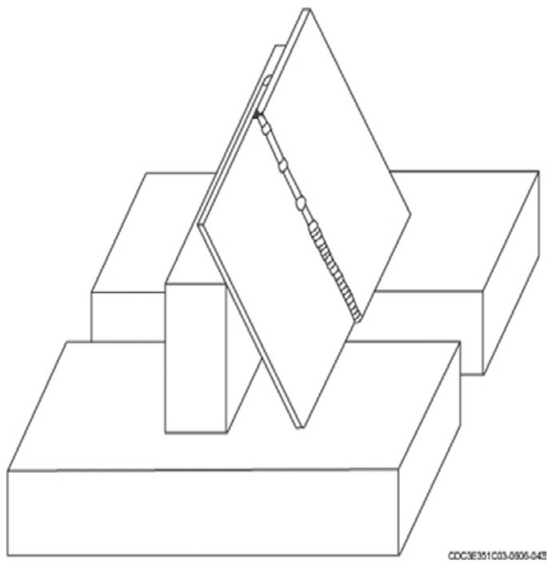


Figure 2–11. Vertical lap joint.

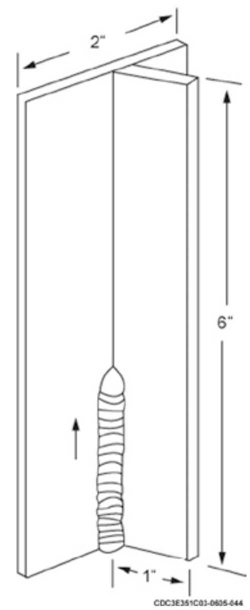


Figure 2–12. Vertical tee joint.

Overhead position

The overhead position is probably the most difficult of all welding positions. Metal deposited in the overhead position tends to drop or build up in the center of the molten pool, causing the bead to have a high crown. In this case, where there is no supporting ledge of solidified weld metal to provide partial support, the pool carried must be relatively small so gravity does not exceed the forces of cohesion and flame pressure. Manipulate the filler rod and let its chilling effect keep the pool of metal small. Form the bead by moving the rod slowly from side to side so the molten metal can't collect at one spot and run off. The filler rod metal chills the pool of molten metal to a plastic state, and it solidifies quickly to form the weld bead. If the molten pool becomes too large, remove the flame from the pool for an instant to allow the weld metal to solidify before resuming.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

406. Oxyacetylene welding principles and weld symbols

1. What is an important distinction between the terms weld symbol and welding symbol?

2. What does weld symbols on both sides of the reference line indicate?

3. What type of symbol represents a field weld?

4. List the elements that a welding symbol contains.

407. Selecting torch tips, filler rods and welding methods/positions

1. What are the factors that govern tip size selection?

2. Describe what happens if you use a tip that is too large.

3. What determines filler rod *type* and *size*?

4. Describe the movements in forehand welding.

5. In forehand welding, how do you hold the torch tip?

6. How do you control weld bead size?

7. Why is the backhand oxyacetylene welding method considered *slightly easier* than the forehand method?

8. Name the four welding positions.

9. Describe the vertical position.

10. What effect must you overcome when you are welding a vertical joint?

11. What does metal deposited in the overhead position tend to do, and what does this cause?

2–3. Welded Joints

Top quality welded joint properties depend partly on the correct preparation of its edges. You must remove all mill scale, rust, oxides, and other impurities from the joint edges and surfaces. If you don't, these impurities will lower the quality of your weld. A properly prepared joint produces a weld that fuses completely without excessive melting and minimizes radiated heat loss into the base metal from the weld. It also helps maintain a good balance between expansion and contraction.

The preparation of the edges and the joints needed are determined by the form, thickness, and metal type; load carrying capacity; and available means for preparation. In the following lesson, we'll discuss edge preparation, welding techniques, and weld specifications including the five basic types of welded joints: lap, butt, tee, and edge.

408. Welding lap joints

In order to make quality lap joints, you must understand lap joint terms, specifications, and techniques. We will begin this lesson by discussing the edge preparation, definition, layout, and uses for the single-fillet, double-fillet, and joggled types of lap joints. Some common edge preparations are shown in figure 2–13. We will then explain lap joint terms, specifications, and techniques.

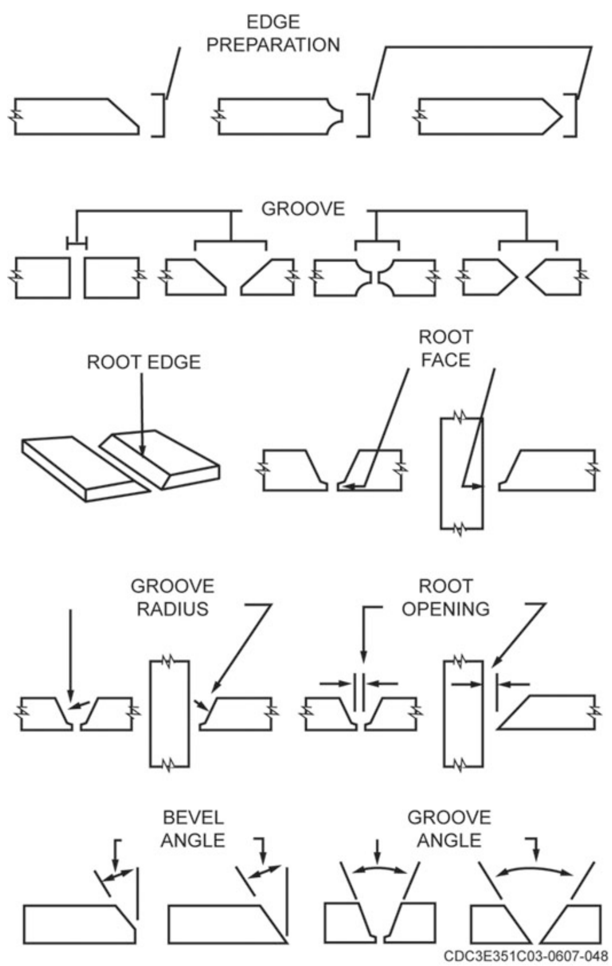


Figure 2–13. Edge preparation.

Lap joint types

A lap joint is made from two metal sheets. You place the edge of the first metal sheet over the edge of the second metal sheet, and weld the edge of the first sheet to the surface of the second sheet. Lap joints are used extensively in constructing equipment made from plate and sheet metal. The lap joint is not the strongest joint, but certain types develop the full base metal strength under tensile pull. The fillet weld is used when making lap joints. You can see the different lap joint types—single-fillet, double-fillet, and joggled—in figure 2–14.

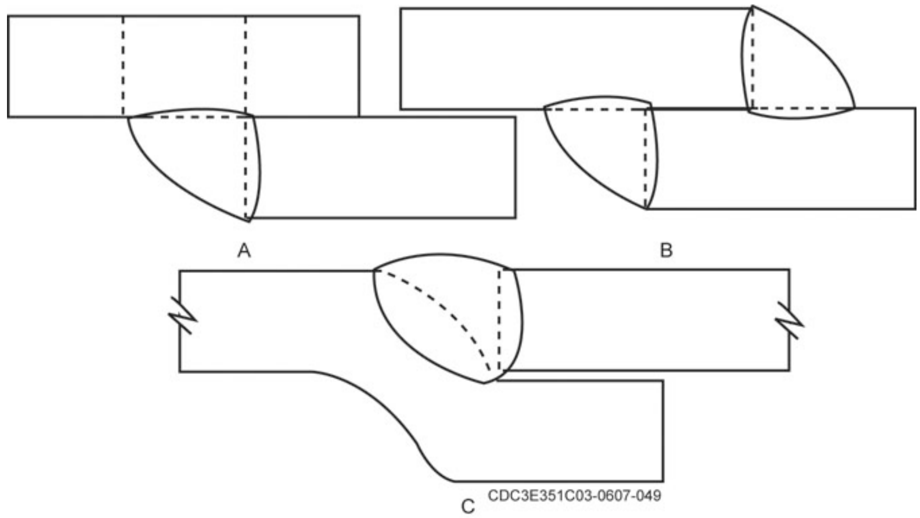


Figure 2–14. Sample lap joints.

An explanation of each type of joint is given in the table below.

TYPES OF LAP JOINTS	
Joint	**Explanation/Illustration**
Single-fillet lap (fig. 2–14, A)	Requires no machining of the joint edges. This joint is used when the design of the part does not permit welding from both sides. The single-fillet lap joint does not develop full base metal strength. It is stronger than a butt weld in some applications, such as when tubing or frames overlap or telescope together. If loading is not severe, this joint is suitable for welding metals of all thickness. However, with fatigue or impact loads, stress concentrates at the edge of the weld, and, under tension, the plates will pull out of line causing the root to bend.
Double-fillet lap (fig. 2–14, B)	Can withstand much more severe load conditions than the single-fillet lap joint. When properly made, this joint develops the full strength of the base metal..
Joggled lap (fig. 2–14, C)	Gives a more uniform distribution of load stresses than the single- or double-fillet lap joint. When you want to use a lap joint and the metal surfaces must be kept on the same plane, use the joggled lap joint.

Lap joint specifications

Before you make lap joints, you must understand what the lap joint specifications are. Let’s look at the nomenclature, specifications, and techniques that are used for lap joints.

Weld nomenclature

You need to be familiar with the nomenclature (terms given to parts of a lap weld) to identify their location in a welded lap joint.

Figure 2–15 shows the nomenclature and location of a typical welded lap joint.

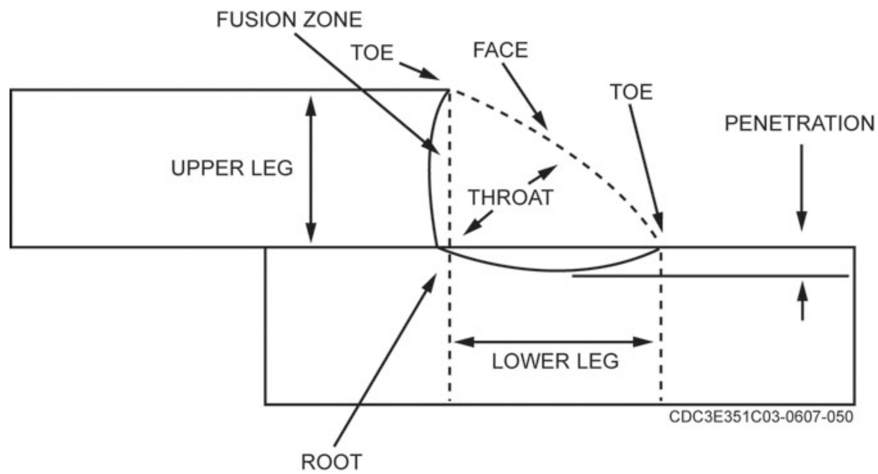


Figure 2–15. Welded lap joint nomenclature

The terms that define the meaning and location of a welded joint are shown in the following table:

WELDED JOINT TERMS	
Term	**Definition**
Fusion zone	Area of weld metal that has penetrated beyond the surface of the base metal.
Root	Portion of the weld metal deposited at the bottom of the joint.
Leg	Dimension of the weld extending on each side of the root of the joint.
Face	Outer surface of the weld reinforcement.
Toes of the weld	Outer edges of the weld face.
Penetration	Distance from the original surface of the base metal to the point at which fusion ceases.
Throat	Distance through the center of the weld from the root to the face.

Weld specifications

The basic weld specifications for lap joints start with you knowing the welding terms and definitions first. Next, remember that all welding specifications are based on the base metal thickness (T). When you must make welds on metals of unequal thickness, the specifications are based on the lighter gauge metal. The specifications for a lap joint are detailed here:

- The upper leg should equal T.
- The lower leg should equal 1½ times the thickness.
- The face of a lap weld should be slightly convex in shape.
- Penetration for metal $^1/_8$- inch or less in thickness should be 30 to 50 percent of the metal thickness. For metal over $^1/_8$-inch thick, the minimum penetration should be $^1/_{16}$ inch.
- The throat thickness should equal T.

Welding techniques

When you join metal thickness of $^1/_8$ inch or less, overlap the sheets from four to six times the metal thickness. Tack weld the joint at intervals of approximately 1½ inches, as shown in figure 2–16.

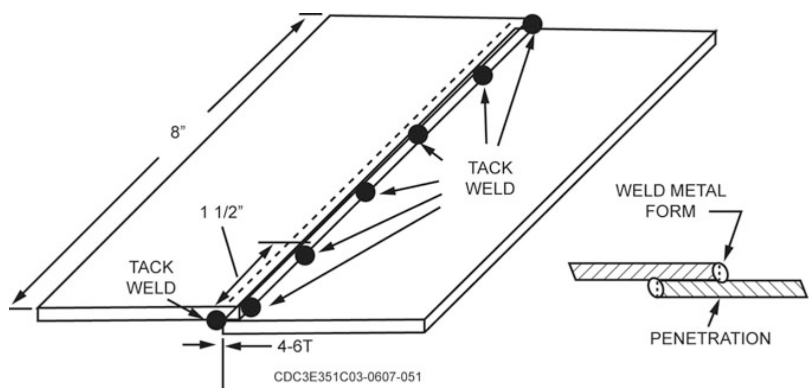


Figure 2–16. Lap joint setup.

Before welding, preheat both sheet edges by directing the flame above and below the joint edges. This raises the metals temperature so fusion into the joint root can be easily obtained. Hold the torch approximately 60° from horizontal to direct the heat on the bottom sheet, and point the flame in the direction of travel. When the edges are heated to a molten state, the center of the molten pool should be in line with the un-melted upper sheet edge. This procedure permits more base metal to be melted into the molten pool. As more base metal is melted into the pool, less filler rod is used and better fusion into the upper sheet is obtained.

To prevent possible undercutting at the upper edge of the joint and overlapping on the lower plate, add the filler rod to the upper edge of the molten pool. You can determine the speed of travel by the size of the molten pool at the joint edges. Figure 2–16 shows dimensions, weld metal form, and penetration. The following if/then chart shows some common lap welding errors and their possible causes:

Lap Welding Errors and Causes	
If	**Then**
The weld face is concave	Too large a welding tip was used and not enough filler rod was added to the weld. Excess penetration and undercutting at the toes of the weld are the results.
The weld face is excessively convex	The weld was made with insufficient welding heat and the addition of too much filler rod. Overlap and lack of penetration result.
Undercutting and overlapping occur when the flame is directed improperly	Undercutting occurs on the overheated edge, and overlapping occurs on the insufficiently heated edge. This same condition can result from the improper addition of filler rod into the molten pool.
Improper welding travel speed along the joint	Narrow and wide welds are caused. When the welding speed is too fast, the weld will be narrow. When the welding speed is too slow, the molten pool will increase in size and the weld will be wide. Slow travel usually causes excessive penetration, and rapid travel causes inadequate penetration.

409. Welding butt joints

There are two basic methods that are used to set up and weld butt joints. These methods are often referred to as *rigid* or *evenly spaced* and *open* or *progressively spaced*. For simplicity, we'll refer to them as evenly spaced and progressively spaced. This lesson covers these methods along with butt joint identification, set-up, and common welding techniques.

Butt joint identification

A welded butt joint is formed from two edge surfaces that are fused together You can use a butt joints to join the edges of two pieces of metal when their surfaces are in approximately the same plane. A proper butt joint develops the full strength of the base metal, and it is satisfactory for all types of loads. Regardless of the metal thickness, penetration through the base metal must be 100 percent, and fusion into the side walls must be at least $^{1}/_{16}$ inch. To weld butt joints, you must know the parts of a butt joint, as shown in figure 2–17. For maximum strength, definite specifications for reinforcement, penetration, and face shape have been established. Proper fusion and a uniform bead are necessary, as shown in figure 2–18.

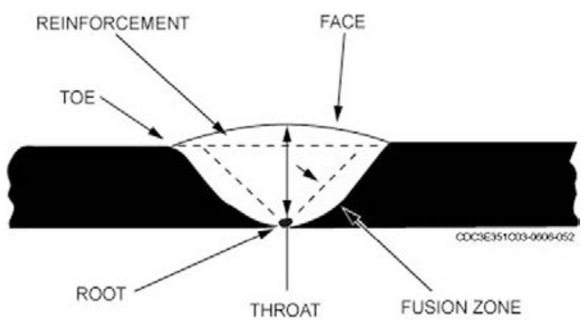


Figure 2–17. Butt joint nomenclature.

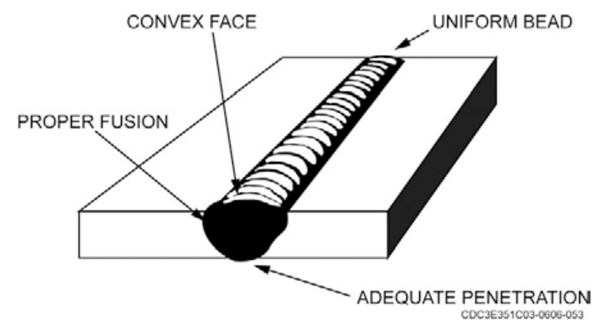


Figure 2–18. Proper butt joint welding characteristics.

Joint preparation

You can weld butt joints on metal up to 1/8-inch thick without any special edge preparation. Butt joints over $^{1}/_{8}$-inch thick require their edges to be prepared a certain way to produce a satisfactory weld. An example of a butt joint edge preparation technique is shown in figure 2–19, views “A-D.” You can prepare these edges by flame cutting, shearing, machining, chipping, or grinding. Plate thickness of $^{3}/_{8}$- to ½ inch can be welded, using the single V-joint or single U-joint type, as shown in views “A” and “C” of figure 2–19. For welding heavy sections, the single U-groove is more satisfactory and requires less filler metal than the single V-groove. The double V-groove joint requires approximately one-half the amount of filler metal used to produce the single V-groove joints for the same plate thickness. Butt joints prepared on both sides of heavy sections permit easier welding, produce less distortion, and ensure better weld metal qualities than joints prepared on one side only.

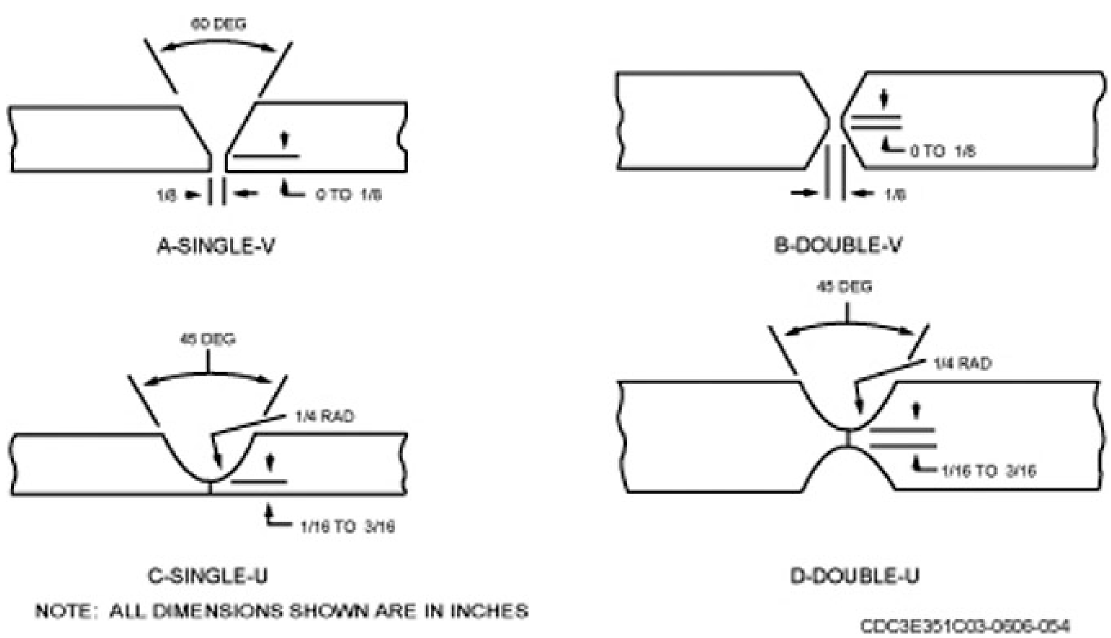


Figure 2–19. Preparing a heavy section for a butt joint.

Evenly spaced butt joint setup

Figure 2–20 shows the proper setup for welding an evenly spaced butt joint in the flat position. Place the joint edges in the same plane and support them with a material, like firebrick, that will not radiate the heat away from the plate you are welding. Tack weld evenly spaced butt joints to prevent the edges from being drawn together. If the edges draw together, it is impossible to get the necessary penetration. The importance of making good tack welds is crucial to producing a good welded butt joint. The proper spacing, size, and penetration of tack welds combine to make satisfactory welds. Figure 2–20 shows the desired dimensions 2–21. The torch should be approximately perpendicular to the joint edges. Ensure you melt the base metal before adding filler rod. Unless penetration is 100 percent on the tack welds, it is impossible to get the required penetration when you weld along the seam over the tack welds. Make the tack welds every 1½ inches along the entire weld seam. After tack welding, the edge joint spacing is approximately equal to the thickness of the metal being welded.

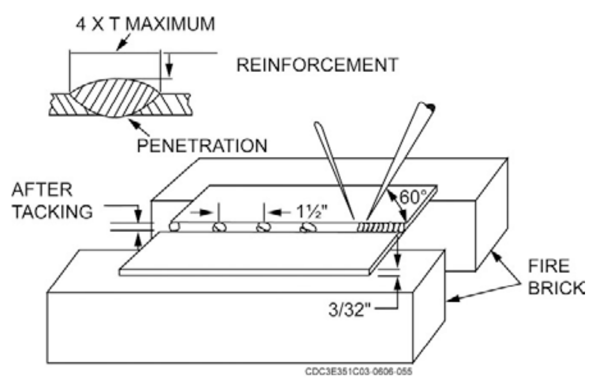


Figure 2–20. Setup for an evenly spaced butt joint.

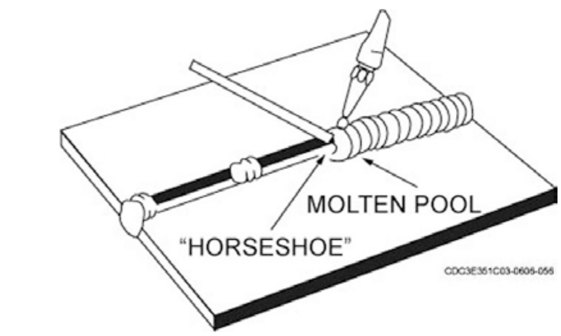


Figure 2–21. Technique to weld an evenly spaced butt joint.

Progressively spaced butt joint setup

This joint type requires you to space the joint edges so that they draw together as the weld progresses along the joint. You start by placing two metal pieces side by side to form a joint that is close together at one end but progressively widens at the other. Next, place a tack weld at the close together end as shown in figure 2–22. Next, look at figure 2–23 to see a detailed setup for a progressively spaced butt joint.

Figure 2–22. Tack weld for a progressively spaced butt joint.

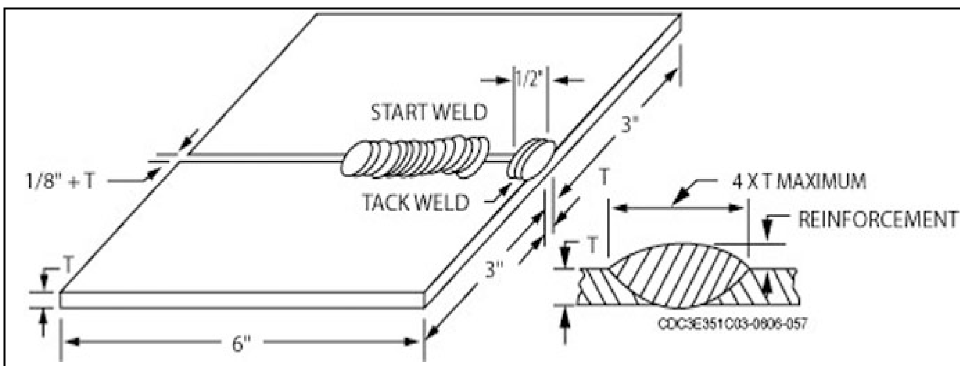


Figure 2–23. Setup for a progressively spaced butt joint.

A recommended technique to set the tack weld at the close end of the weld is to use the thickness of your welding rod as a guide. Next, add a ¼-inch space for every 12 inches of joint length. Now you are ready to make your tack weld. Don't worry about the wide space at the end of the joint. The heat generated as you weld will pull the space together to form a quality weld as shown in the nearly completed weld in figure 2–24.

NOTE: For carbon steels, the joint space is ¼ inch per foot of joint length plus the base metal thickness.

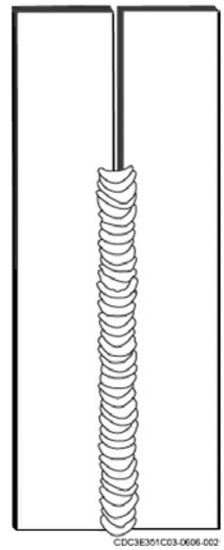


Figure 2–24. Nearly completed weld.

Common welding techniques

To make a good weld, use the following four common welding techniques:

1. Use the correct torch tip size.
2. Use the correct welding rod.
3. Adjust the flame properly.
4. Manipulate the torch and welding rod properly.

Adjust the torch to produce a neutral flame. Correct torch tip size and correct oxygen and acetylene regulator pressures are necessary to get the proper volume of heat for a given metal thickness. The welding tip should form an angle approximately 60° with the plate surface. Always point the flame in the direction of the welding. Add the filler rod to the molten pool at an angle of about 45°. Control the motion of the flame to melt or break down the sidewalls of the sheets at the joint, as well as to melt enough of the welding rod to produce a pool of molten metal of the desired size.

Evenly spaced butt joint welding technique

Figure 2–21 shows the technique for welding evenly spaced butt joints. Melt the edges of the metal to the bottom of the joint, which causes the molten metal to form in the shape of a horseshoe. Add the filler rod to the molten pool just behind the horseshoe opening. As you do this, molten metal bridges form across the edges. Use the force of the flame to reestablish the horseshoe opening. Repeat this procedure each time a filler (welding) rod is added. By maintaining the horseshoe opening, you assure penetration to the bottom edges of the joint.

Progressively spaced butt joint welding technique

Figure 2–23 shows the setup and technique for welding a progressively spaced butt joint. You start by tack welding the joint edges approximately ½ inch from the plate edges. Start the weld without delay about ½ inch from the tack weld. As the weld progresses along the joint edges, the spacing will gradually close to a space equal to the base metal thickness. This spacing is necessary for penetration to be easily achieved. Next, return to the other end and finish the weld using the backhand method.

Weld specifications

All welds have specifications that show what you must do to produce a weld for specific applications. The following chart shows jobs and specifications for the butt joints:

Job	Specs
Penetration	100 percent
Bead	Slightly convex and uniform
Toes	Properly fused
Bead width	2 to 4 T (base metal thickness)
Reinforcement	25 percent of T

410. Welding tee and edge joints

Tee joints and edge joints require that you do some setup work before any welding can be done. In this lesson, we explain what these joints are along with the procedures that allow you to produce high quality welds.

Tee joint

A tee joint is welded when the edge of one plate is approximately perpendicular to the surface of another. The weld, which has a triangular cross section, is called a *fillet* weld. You should recall you also studied fillet welds in the lesson on lap joints. The parts of a tee joint are named in figure 2–25. The terms used to identify the sections of this weld are the same as for other types of welds.

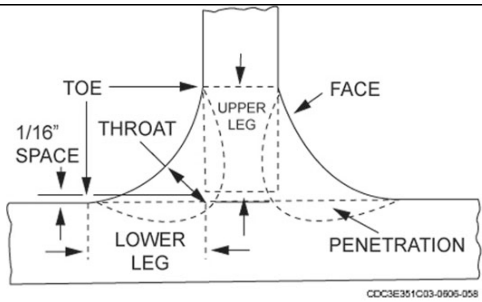


Figure 2–25. Tee joint nomenclature.

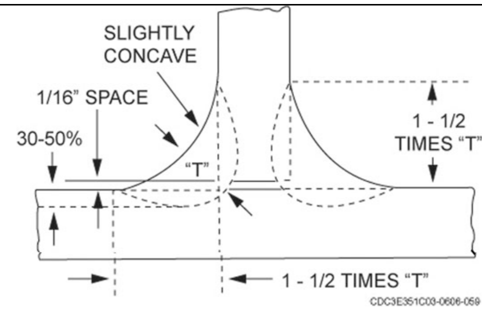


Figure 2–26. Tee joint specifications.

Weld specifications

Figure 2–26 shows the specifications for welding the tee joint. When welds are made on metals of equal thickness, the upper leg and lower leg should be 1½ times the thickness. The specifications for metals of unequal thickness are based on the thickness of the lighter gauge sheet. Penetration of metals ⅛ inch or less should be 30 to 50 percent of the metal thickness. For heavier gauge, the minimum penetration is $^{1}/_{16}$ inch. The throat thickness should equal the thickness of the base metal.

Joint preparation and setup

The tee joint (fig. 2–27) used on metal $^{1}/_{8}$-inch thick or less requires no special preparation other than cleaning the edge of the vertical sheet and the surface of the horizontal sheet. Welds on metals $^{1}/_{8}$ inch up to ½ inch in thickness requires beveling when the joint can be welded from one side only. Use the 45° double bevel on heavy plate when the joint can be welded from both sides.

Space the vertical sheet approximately $^{1}/_{32}$ to $^{1}/_{16}$ inch above the horizontal sheet. You cannot use the welding heat to the greatest advantage unless the edges and the surface are spaced to permit easy fusion without excessive heating. The spacing should be uniform along the joint to get uniform penetration and fusion. When you need to weld the joint from both sides of the vertical sheet, tack weld alternately from one side to the other to maintain alignment of the vertical sheet.

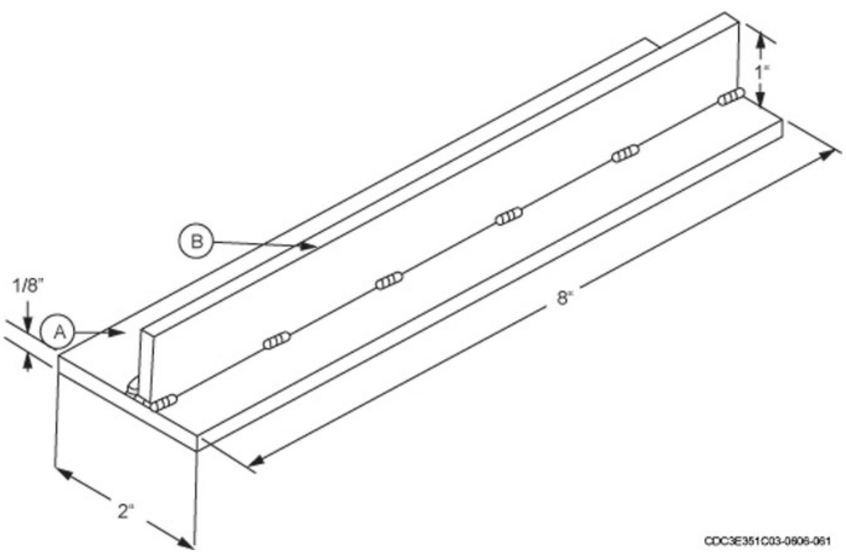


Figure 2–27. Setup for tee joints.

Welding techniques

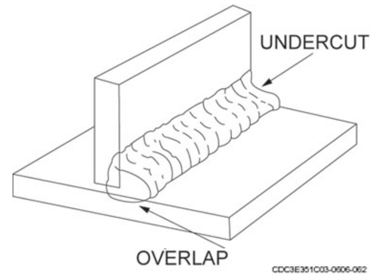


Figure 2–28. Overlapped and undercut welding bead

Before welding, preheat the joint to raise the temperature of the metal to a point that will permit fusion into the root of the joint. Hold the torch 60° from horizontal, thus directing most of the heat on the horizontal sheet of the tee joint. Adjust the torch to a neutral flame and point it in the direction of travel. When the base metal is heated to the molten state, the molten pool should extend equally on the vertical and horizontal sheets. This technique will produce a weld with equal length upper and lower legs. To prevent undercutting at the upper edge of the weld and overlapping on the lower plate, as shown in figure 2–28, the angle of the torch must be correct and the filler rod should be added to the upper edge of the molten pool.

Edge joint

The edge joint is not very strong and is used mainly to join sheet metal edges and to weld reinforcing plates to I-beam flanges or the angles' edges. The following chart shows the three types of edge joints:

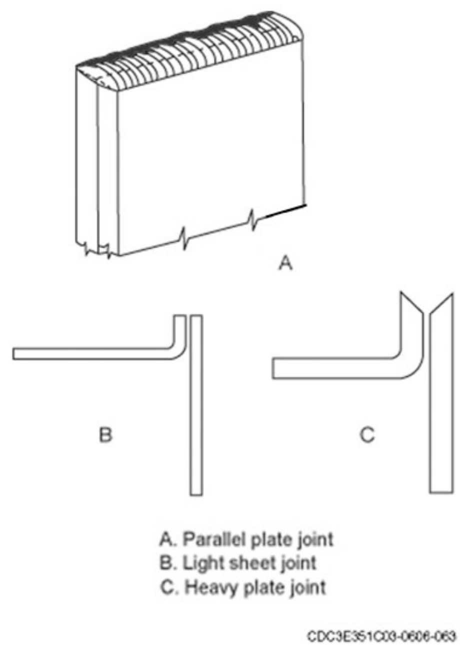
<table>
<tr><td>A parallel plate edge joint has two parallel edges that are welded as shown in figure 2–29 "A." On heavy plate, sufficient filler metal is added to fuse or melt each plate edge completely and to reinforce the joint.</td><td rowspan="3">

Figure 2–29. Edge joint, parallel plate type.</td></tr>
<tr><td>A light sheet edge joint has two parallel edges that are welded as shown in figure 2–29 "B." No special preparation is necessary other than to clean the edges and tack weld them in position, and no filler metal is required.</td></tr>
<tr><td>A heavy plate edge joint must be beveled to ensure good penetration and fusion of the side walls as shown in figure 2–29 "C", Filler metal is used on this joint to add strength to the joint.</td></tr>
</table>

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

408. Welding lap joints

1. What weld do you use to make a lap joint?

2. List the three lap joints types.

3. Which lap joint, when properly made, develops the full strength of the base metal?

4. Which lap joint is used to keep the metal surfaces on one side of the joint on the same plane?

5. What is the weld fusion zone?

6. What are the specifications for the legs of a single-fillet lap joint?

7. What face shape should a lap weld have?

8. When you are welding lap joints of ½-inch-thick metal, what is the penetration range in inches?

9. How far apart should the tack welds be spaced on a lap joint?

10. Where should the center of the molten pool be aligned?

11. What problem is indicated if the weld face is excessively convex?

12. What problem is indicated if the weld is too wide or narrow?

409. Welding butt joints

1. How much penetration is needed when welding butt joints?

2. How are the edges prepared for a butt joint on $^{1}/_{8}$-inch metal?

3. What preparation is done on heavy sections to produce less distortion and ensure better weld metal qualities?

4. What two types of spaced methods are used to weld butt joints?

5. Give the four common welding techniques for producing a sound weld.

6. When welding evenly spaced butt joints, in what shape do you want the molten metal to form?

7. What is the proper bead width for a butt joint?

410. Welding tee and edge joints

1. What type of weld, having a triangular cross section, is formed when a tee joint is welded?

2. What should the legs measure on a tee joint of ½-inch-thick metal?

3. When welding a tee joint, why is the vertical sheet spaced above the horizontal sheet?

4. When you weld a tee joint from both sides of the vertical sheet, why should you tack weld alternately on one side then the other?

5. What is the torch angle when welding tee joints?

6. When you are welding tee joints, where do you add the filler rod?

7. What are edge joints used for?

2–4. Braze Welding and Silver Brazing

The braze welding and silver brazing processes require lower temperatures when compared to other types of welding. These types of welding are very similar to fusion welding, except the base metal is not melted. This section covers the principles and procedures that are used in braze welding.

411. Braze welding principles

We will begin this lesson with Braze welding principles. Braze welding, also called *bronze welding*, is a method of joining metals together without fusion. In braze welding, you use an oxyacetylene welding outfit with a welding filler rod that has a melting point above 840°F but below the melting point of the metals you're joining. The filler metal is distributed onto the metal surfaces by tinning. The lower temperature makes braze welding relatively quick and easy to make sound joints, even in intricate castings.

NOTE: Braze welding does not distribute the filler metal in the joint through capillary action.

An essential element in braze welding is to have a clean metal surface. This allows the filler metal to flow smoothly and evenly over the weld area. For adhesion to take place between the molten filler metal and the base metal, the surface of the base metal must be chemically clean. Oxides may be present on some metals after they are mechanically cleaned. That is why you must use the correct flux to compensate for those oxides.

Bronze filler metals, used to braze weld carbon steels and ferrous castings, yield readily as they cool until the temperature is below 500°F. This yielding allows for contraction, as the braze-welded parts cool. They also yield slowly under reasonably low stresses, even at room temperatures. This yielding does not weaken the deposited bronze filler metal but acts to reduce the locked-up stresses in a braze-welded casting or carbon steel part. The ductility of the bronze filler metal also takes up minor stresses later when the part is used. Most braze-welded joints are almost as strong as fusion-welded joints. They're even preferred for many joints of cast iron. The heat required for a braze-welded joint won't alter the properties of the metals being joined. This is an advantage when you're working with metals that have been heat-treated.

Braze welding is a practical method of repairing malleable iron castings. Other repair methods such as fusion welding require higher temperatures. These higher temperatures destroy the malleability in the iron castings. The relatively low temperature used in braze welding has little effect on malleability. You can use braze welding to repair broken and cracked cylinder blocks, cylinder heads, and machine castings.

Another advantage of braze welding is that it allows you to join dissimilar metals. Unfortunately, there are a few disadvantages of braze welding. There is a loss of strength when the metal is subjected to high temperatures and braze welded joints have an inability to withstand high stresses. The last disadvantage, although minor, is its color. The yellow colored bronze filler metal contrasts with the colors of steel and cast iron.

Equipment

The equipment needed for braze welding is basically the same equipment you will use when silver brazing. Braze welding requires more heat than silver brazing. For this reason, you should use an oxyacetylene torch. Select a torch tip that will allow for proper temperature without overheating the base metal. The torch tip should be about the same size as that used for fusion welding steel of the same thickness.

Joint preparation

Before braze welding cast iron or steel, you must clean the metal in the weld to remove all scale, rust, grease, and oil. Bevel the parts and grind off all sharp corners to produce round edges and a smooth, rounded surface. The rounded V-groove joint (fig. 2–30, shows the weld formation and base metal) develops the highest strength. This is because the bond area between the filler metal and the base metal is greater with the base metal rounded, than with an ordinary 90° V-groove. You can make the rounded V-groove, shown in figure 2–30, view A, by grinding. It will develop almost the full strength of the metal and should be used when high strength is required. You can grind the rounded V-groove, shown in figure 2–30, view B, but in large castings it's quicker to make the groove with a pneumatic chipping hammer. Use a portable grinder with a wheel shaped to produce the desired groove. Use this joint to braze weld cracks in the water jackets of cylinder heads and blocks.

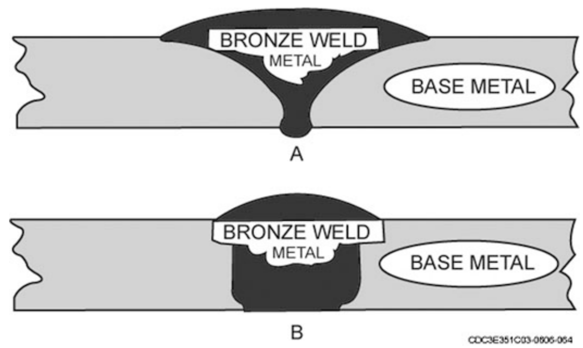


Figure 2–30. Braze-welded cast iron joints.

After cleaning and rounding the edges, sandblast or sear the surfaces to remove the free carbon. To sear the edges, move an oxidizing flame along the surface of the joint with the central cone touching the metal. The free carbon combines with the excess oxygen in the flame, and a better bond results.

Flux

Flux is essential in braze welding. You can apply flux in powder, paste or liquid form. You can apply the flux by either by dipping the hot end of the filler rod in the powder or brushing the paste on the rod. Flux should be used liberally in the tinning (coating) operation. In filling the vee, use the flux sparingly to avoid too much reduction of the oxide film covering the molten pool. There are different fluxes for braze welding different metals. To get the best results, make sure the flux you're using is compatible with the base metal. A braze-welding flux with an American Welding Society (AWS) number of 3A or 3B is compatible with the ferrous metals you'll be joining.

Filler metal

The primary filler metals used for braze welding are brasses. They are usually around 60 percent copper and 40 percent zinc. This type of filler metal allows sufficient tensile strength and ductility. There are trace amounts of other metals to include tin, iron, manganese, aluminum, lead, nickel, chromium and silicon. The purpose of the other metals is to aid in deoxidizing the weld, reduce fumes and enhance the filler metal's ability to flow.

Braze welding procedures

After the joint edges have been prepared, lay the material flat. Adjust the flame to neutral to prevent oxidation of the material. Run the torch flame over the weld area to heat the surface to a dull red—that is a tinning temperature. Figure 2–31 shows the beveling, work setup, and the finished braze-welded butt joint.

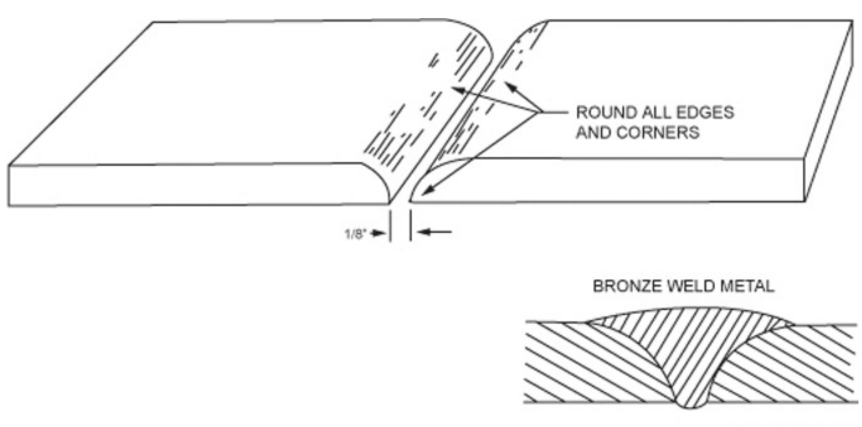


Figure 2–31. Braze welding cast iron.

Apply the flame slightly behind the filler rod application point until the weld area attains a dull red heat. When the filler metal is applied, it should spread quickly and tin (thinly coat) the heated area. Make a small molten pool at the vee bottom. Be sure the tinning action takes place continuously just ahead of the molten pool. Proper braze-welding technique combines into one continuous operation the tinning action and the building up of the filler metal to the desired size.

Braze welding heavy material

To braze weld heavy material, it's often necessary to deposit the bronze in layers. In such cases, be sure the base metal is well tinned as you put on the first layer. This ensures strong filler metal deposit and a good bond with the succeeding layers.

To apply the filler metal, move the torch in a slight circular motion. Deposit the filler metal in the same way you would when fusion welding. The filler metal application to cast iron requires careful attention to ensure a good bond between the two metals. If the base metal gets too hot, the filler metal will bubble and run off like water. If the base metal is not hot enough, the filler metal balls up and rolls off the base metal. You will know the temperature is correct when the filler metal spreads out evenly on the weld area.

Braze welding cast iron

The primary method used to repair broken cast iron is to braze weld it. When braze welding cast iron, you do not need to use high preheat temperatures. 400-600°F is the ideal temperature range required to preheat cast iron.

When you're braze welding a crack or break that terminates in a hole or an opening in the casting, the braze weld should progress toward the hole or opening. In long breaks on flat surfaces, the braze weld should progress from the ends of the break toward the middle. To repair cracks that branch from a larger break, start the braze weld at the end of the crack and progress toward the main break. After completing the repair, protect the casting from drafts and cold air to prevent uneven cooling. Don't place any stress on a braze-welded joint until it has cooled completely. Clean the finished deposit with a wire brush to remove any excess flux and oxides that have risen to the surface. The flux and oxides have active chemicals in them. If you leave them on the surface, they'll make the joint corrode rapidly.

Braze welding has limitations of which you must be aware. Breaks in high-carbon and tool steels should be braze welded only in an emergency and only if the lower strength and hardness of the filler metal are acceptable. *Do not* use braze welding if the repaired part will be subjected to severe conditions or if the temperature will be higher than 650°F. At temperatures from 500 to 600°F, the filler metal strength begins to be greatly reduced.

412. Silver brazing principles

This lesson covers the principles and procedures that are used in silver brazing. You can use silver brazing to join most common metals. The process is often called *brazing*, *silver soldering*, or *hard soldering*, but it's actually a brazing process using filler metal with high silver content. Silver-brazed joint success depends on the penetration of the brazing filler metal into the pores of the base metal surface, forming a strong bond between the parts. In silver brazing, the bond is produced by heating the base metal and adding silver alloy filler metal. The filler metal should melt and flow before the base metal melting point is reached.

Silver brazing filler metals

Silver brazing is best done with joints designed to permit *capillary attraction*. Lap joints are best suited for silver brazing because of the high strength obtained when the filler metal flows into the joint. Since the silver alloy filler metal flows at a low temperature, less heat is required.

Because of the low temperature needed, the base metal is not heated to temperatures high enough to impair its physical properties or to distort it. The process is quite simple and can be completed rapidly.

Silver alloy filler metals join most ferrous and nonferrous metals. Exceptions are aluminum, magnesium, and other alloys and metals with low melting points. The silver-brazed joint strength depends on the joint fit-up and the bond quality between the filler metal and the base metal.

In order for the silver-brazing filler metal to bond to the base metal, it must be heated with an oxyacetylene torch. The heat opens the metals grain structure, letting the filler metal penetrate along the grain boundaries on the base metals surface. This creates a strong bond between the filler metal and base metal. It is this bond that produces the high strength of a silver-brazed joint. No fusion takes place between the filler metal and base metal.

You should not subject silver-brazed parts to temperatures that exceed 500°F. At that temperature, the silver-brazed joint begins to weaken and becomes progressively weaker as the temperature increases. You can use silver brazing to repair and fabricate many metal parts.

Silver-brazing filler metal comes in several grades, with silver content ranging from 10 to 80 percent and with a melting point from 1,145°F to 1,640°F, depending on the alloy content. It comes in rod, strip, wire, and granulated form. The strip or ribbon form generally is used for fixed setups in which the filler metal is placed on the joint before heat is applied. The rod and wire forms are used mainly where it is preferable to apply the filler metal by hand.

Joint design

The joint that you design depends mainly on the base metal and the joint's purpose. These considerations are used to design a joint that meets the requirements for function, strength, and durability. The joint design is important because the preparation, fit-up, and results obtained with silver brazing differ from those of fusion or braze welding. Don't use silver-brazing alloy to fill large gaps. This alloy flows freely into narrow openings, and the strongest joint results from using very small clearances between the joint surfaces. The recommended joint clearance at brazing temperature is between 0.002 and 0.005 inch.

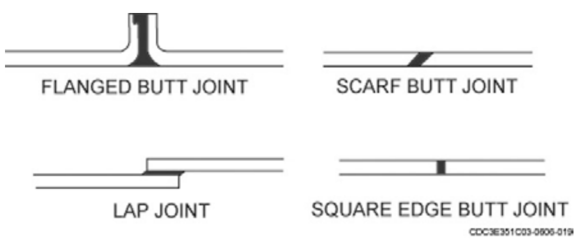


Figure 2–32. Silver-brazed joints.

There are various joint designs that are used in silver brazing. Two common joints are the lap joint and the square-edge butt joint. However, the butt joint can be modified to include the flanged butt joint and scarf butt joint, shown in figure 2–32.

The lap joint is the most common type of joint because it provides more area for capillary attraction. The joint is most efficient when the overlapping of the base metals equals or exceeds three times the thickness of the thinnest section, shown in figure 2–33.

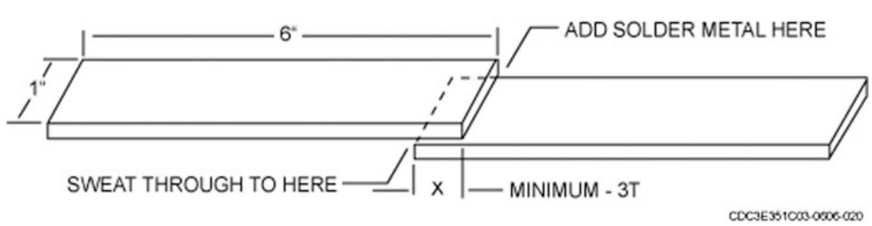


Figure 2–33. Silver brazing a lap joint.

Joint preparation

A clean, oxide-free surface is needed to ensure uniform quality and a sound, silver-brazed joint. Remove all grease, oil, dirt, and oxides from the base metal and the filler rod to get uniform capillary attraction throughout the joint. Use either mechanical or chemical cleaning. For a lot of rust and heavy oxidation, sandblasting works best. For grease and oil, use a suitable solvent or degreaser to remove it. Other cleaning agents and machines are the grinder, buffer, emery cloth, metal files, and acids. When you use chemical cleaners, wash the metal to remove any residue because residues can attack the base metal or form an undesirable film on the surface. You should tin the surface area that you cleaned as soon as possible to stop the oxides in the air from re-forming and lowering the quality of your brazing.

Silver brazing broken tools and parts require thorough removal of paint, lacquer, and any other coating. Plating, such as chrome or cadmium, must also be removed. The silver-brazing alloy must make contact with the clean surface of the original metal.

Flux

Flux is a substance that is applied to metal to improve bond quality in soldering and brazing. Flux is available in powder, paste, liquid, and solid form. It is made to do the following:

- React chemically with surface films, such as oxides, reducing them and cleaning the metal surfaces to receive the molten silver alloy.
- Form a protective film during the brazing cycle, keeping oxidation from forming at the elevated temperatures required for brazing.
- Help solder and brazing rods, including silver alloy to flow freely.

Using flux doesn't eliminate the need for cleaning the parts before silver brazing. The flux supplements the initial cleaning by dissolving, restraining, and otherwise rendering ineffective any contaminants that lower the joint's bond quality.

Make sure that you remove all of the flux after brazing is completed. Flux left on joints after brazing can weaken or corrode the joint. You can remove leftover flux by washing the joint area with hot water. If the joint can take a moderate heat shock, you can remove the flux easily by immersing the joint in water while the joint is still warm.

Apply the flux in powder form or dissolve it in water and apply it with a brush. The temperature at which the flux begins to flow freely is the proper temperature for applying the silver alloy. Many fluxes contain substances that are considered hazardous. Make sure that you are authorized to use them. You must also be aware of what to do in the event of an accident involving flux. You can find this and information on how to store and use flux in its material safety data sheet (MSDS).

The type of flux needed depends on the type of base metal being brazed. The table below shows some of the fluxes and rods that work best with the different types of base metals being brazed; however, a silver-based filler metal will work on all of these base metals.

AWS Brazing Flux	Base Metal	Filler Metal (rod)
3A	Copper, copper alloys	BCuP (Copper alloys)
3A	Ferrous and nonferrous metals, except aluminum and magnesium	BAg (silver)
3B	Stainless steels, carbon steels, low-alloy steels, copper	BNi (nickel)

Filler metal (rod)

Even though silver brazing implies that filler rods composed of silver are being used, there are different amounts of silver that are produced in the different rods. The amount of silver needed is determined by the type metal being brazed.

Copper, brass and bronze base metals

When brazing these metals, you may use a filler rod that is a copper-silver-phosphorous alloy. It is approximately 15 percent silver. When you braze copper, you do not need to use flux; however, you should use flux when brazing brass and bronze.

Stainless steel

When silver brazing stainless steel, select a filler rod that is 45 percent silver alloy. That will produce a good color match and provide for proper adhesion.

Tip size

The tip size depends basically on the thickness of the base metal. However, because of the melting point of the silver filler metal and the joint design, a large tip is recommended. This will allow for a shorter brazing time, resulting in less time for oxides to form.

Procedure

For silver brazing, follow these procedures:

1. Ensure the metal is properly prepared (cleaned).
2. Apply the correct flux to the base metal and the filler metal. The best way to apply the flux is by dipping or brushing.
3. Secure the base metals into position with clamps, jigs or some other type fixture.

   NOTE: Be sure that the base metals are not clamped together too tightly. You must have the proper joint clearance to allow the filler metal to flow freely.
4. Adjust the torch to a neutral or slightly carburizing flame and preheat the base metal being sure to keep the torch in constant motion. Heat both pieces evenly.

   NOTE: Don't let the inner cone touch the metal. It will cause the flux to burn. Also, holding the torch flame in one place too long can easily overheat the base metal and flux. When a part overheats, the capillary flow of the silver alloy is slowed. If this happens, you must re-clean the part, removing all oxides and foreign material.
5. Observe the flux. You start torching the filler metal to the joint after the flux is completely fluid. Continue applying the filler metal until you are sure it flows completely through the joint.
6. After joints are brazed, remove any flux residue or debris.

Additional guidelines

Low heat and cleanliness are very important in silver brazing. For large surfaces, preheat the metal well away from the joint, especially if you're brazing metals with high heat conductivity. Be careful in brazing metals of unequal thickness or unequal heat conductivity because all metal parts should reach the soldering temperature at the same time. On metals of unequal thickness, apply most of the heat to the thicker piece.

The small fillet that forms at the joint face while silver brazing indicates complete bonding through the joint. Figure 2–33 shows the dimensions, the overlap, and the location of the silver-brazing alloy for silver brazing a lap joint.

Dissimilar metals

When brazing dissimilar metals, follow the procedures described above. The main consideration is to ensure that both pieces are heated evenly.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

411. Braze welding principles

1. How does braze welding affect malleability? Why?

2. How do you prepare the joint to be braze welded?

3. After the parts to be braze welded have been beveled, what is the next step?

4. In braze welding ½-inch-thick cast iron, what flame should you use for depositing the bronze?

5. What happens if the base metal gets too hot while you're braze welding?

6. Why should you clean excess flux and oxides from a completed braze-welded joint?

412. Silver brazing principles

1. What joints should be silver brazed?

2. How does silver-brazing filler metal bond to the base metal?

3. At what temperature range does silver-brazing filler metal melt?

4. What is the recommended joint clearance at brazing temperature?

5. Name two common joints used in silver brazing.

6. What condition must the metal surface be in before silver-brazing filler metal is applied?

7. State the type of flame used for silver brazing.

8. When silver brazing two metals of uneven thickness, where should you apply heat the most?

Answers to Self-Test Questions

404

1. Cast iron and malleable iron usually show evidence of the sand mold. Low-carbon steel often shows forging marks, and high-carbon steel shows either forging or rolling marks.
2. Hold a sample of metal against an abrasive wheel and visually inspect the spark stream.
3. The length of the spark stream, the color, and the form of the sparks.
4. About 50 inches in length for stainless steel. About 65 inches in length for wrought iron.
5. By the ease with which the metal is chipped and the size of the chip.
6. Ferrous, Non-ferrous.

405

1. Compression, tension, and shear or a combination of these (fatigue).
2. "Tension" stress is defined as resistance to longitudinal stress or pull and can be measured in pounds per square inch of cross section.
3. Strength, hardness, toughness, elasticity, plasticity, brittleness, ductility, and malleability.
4. A measurement of the resistance to being pulled apart when placed in a tension load.
5. Elasticity.
6. Gold.

406

1. A weld symbol provides only information on the weld type to use, while a welding symbol gives that information plus much more.
2. Welds on both sides of the joint.
3. A flag toward tail, under supplementary symbols.
4. Reference line, arrow, basic weld symbol, dimensions and other data, supplementary symbols, tail, and the specifications, process, or other reference. If necessary, a tail is attached to the reference line and is used to provide specific notations. If such notations are not required, the tail welding symbol and the standard location of the elements is omitted.

407

1. Metal thickness and its rate of heat conductivity and radiation.
2. The metal overheats, producing excessive scaling and loss of elements from the metal.
3. The *type* depends on the type of metal welded, and the *size* depends on the thickness of the metal welded.
4. Raise and lower the flame with a slightly circular motion while progressing in a forward direction to make beads without a rod. Move the flame slightly side to side when using a rod.
5. At a 45° to 60° angle to the plate surface with the flame always pointed in the direction of welding.
6. By varying the welding speed and the amount of metal deposited from the weld rod.
7. In the backhand method, positioning the welding rod and tip requires less transverse motion.
8. Flat, vertical, horizontal, and overhead.
9. The parts are at an angle greater than 45° and the seam runs vertically.
10. Force of gravity on the molten pool.
11. Drop or build up in the center of the molten pool which causes the bead to have a high crown.

408

1. Fillet weld.
2. Single-fillet, double-fillet, and joggled lap joints.
3. Double-fillet lap joint.
4. Joggled lap joint.
5. The area of the weld metal that has penetrated beyond the surface of the base metal.
6. Upper leg should equal the base metal thickness (T); the lower leg should equal 1½ times the thickness.
7. Slightly convex.
8. $^{1}/_{16}$-inch minimum.
9. 1½ inches.
10. With the un-melted edge of the upper sheet.
11. The weld was made with insufficient welding heat and too much welding rod was added.
12. Improper welding travel speed along the joint.

409

1. 100 percent.
2. Special edge preparation is not required.
3. Joints that have been prepared and welded on both sides.
4. Evenly spaced and progressively spaced.
5. (1) Use the correct tip size, (2) use the correct welding rod, (3) adjust the flame properly, and (4) manipulate the torch and rod properly.
6. Horseshoe shape.
7. 2 to 4 times the base metal thickness.

410

1. Fillet weld.
2. ¾ inch.
3. To permit easy fusion without excessive heating.
4. To maintain alignment of the vertical sheet.
5. Approximately 60° from horizontal.
6. To the upper edge of the molten pool.
7. To join the edges of sheet metal and to weld reinforcing plates in flanges of I beams or edges

411

1. Brazing has little effect on malleability; because of the lower temperature needed.
2. Clean the metal and grind off all sharp corners to produce round edges and a smooth, rounded surface.
3. Sandblast or sear the edges to remove the force carbon.
4. Neutral.
5. The filler metal will bubble and run off like water.
6. They cause corrosion if left on the metal surface.

412

1. Those designed to permit capillary attraction.
2. The heat of the torch opens the grain structure of the metal, letting the filler metal penetrate along the grain boundaries on the surface of the base metal.
3. 1,145 to 1,640°F.
4. 0.002 to 0.005 inch.
5. The lap joint and the square edge butt joint.
6. Clean and oxide-free.

7. Neutral to slightly carburizing.
8. On the thicker metal.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

19. (404) Which tests can you use to identify cast iron?
    a. Heat and twist.
    b. Chip and spark.
    c. Shear and flame.
    d. Quench and peel.

20. (404) The chip test identifies metal by the ease with which the metal is chipped and the chip
    a. form.
    b. color.
    c. width.
    d. size

21. (404) Which group of metals contains only *ferrous* metals?
    a. Aluminum and lead.
    b. Cast iron and steel.
    c. Copper and brass.
    d. Silver and gold.

22. (404) Which material can be classified as *nonferrous* metal?
    a. Tool grade steel.
    b. Stainless steel.
    c. Wrought iron.
    d. Aluminum.

23. (405) Which mechanical property of metal identifies the ability of a material to absorb shock, and to be deformed without rupturing?
    a. Elasticity.
    b. Hardness.
    c. Toughness.
    d. Wear resistance.

24. (405) Which mechanical property of metal is the ability of the material to return to its original shape after the load is removed?
    a. Elasticity.
    b. Hardness.
    c. Toughness.
    d. Wear resistance.

25. (405) Which mechanical property of metal is the ability of a material to deform permanently without breaking or rupturing?
    a. Ductility.
    b. Plasticity.
    c. Toughness.
    d. Shear strength.

26. (405) Which mechanical property of metal shows very little bending before breaking or shattering?
   a. Hardness.
   b. Elasticity.
   c. Brittleness.
   d. Toughness.

27. (405) Which mechanical property of metal is the ability of metal to stretch, bend, or twist without cracking or breaking?
   a. Ductility.
   b. Plasticity.
   c. Toughness.
   d. Shear strength.

28. (406) When you perform a weld correctly, the section where the weld is made will be
   a. weaker than the penetration zone.
   b. as strong as the penetration zone.
   c. weaker than the base metal.
   d. as strong as the base metal.

29. (406) A weld on the *arrow* side of a joint is indicated by placing
   a. the weld symbol below the reference line.
   b. the weld symbol above the reference line.
   c. no information on either side of the weld.
   d. a note alongside the welding symbol stating the side to weld on.

30. (406) Which weld symbol does *not* have any "side" significance in itself?
   a. V-groove.
   b. U-groove.
   c. Fillet.
   d. Spot.

31. (406) What purpose does the tail serve in a welding symbol?
   a. Indicates a field weld.
   b. Indicates a fillet weld.
   c. Provides travel directions.
   d. Provides specific notations.

32. (407) Selecting the proper tip size depends on the base metal
   a. width.
   b. height.
   c. length.
   d. thickness.

33. (407) Which oxyacetylene welding condition indicates you are using too large a torch tip?
   a. You hear a popping sound.
   b. There is poor penetration into the base metal.
   c. There is excessive scaling and metal element loss.
   d. There is adhesion between the base metal and filler rod.

34. (407) Selecting the proper filler metal size depends on the base metal's
   a. width.
   b. height.
   c. length.
   d. thickness.

35. (407) At what angle range do you hold the torch for forehand welding?
    a. 0° to 30°.
    b. 30° to 45°.
    c. 45° to 60°.
    d. 60° to 90°.

36. (407) Backhand welding is used *primarily* for welding
    a. square edges.
    b. light sections.
    c. heavy sections.
    d. tubular assemblies.

37. (407) When welding in any position, what force causes the molten pool to seek a lower level?
    a. Heat.
    b. Gravity.
    c. Pressure.
    d. Cohesion.

38. (407) In the horizontal welding position, you add filler rod to which edge of the molten pool?
    a. Left.
    b. Right.
    c. Upper.
    d. Lower.

39. (407) When you are welding in the overhead position, where in the puddle does the molten metal tend to build up?
    a. Side.
    b. Back.
    c. Front.
    d. Center.

40. (408) When properly made, which lap joint develops the full base metal strength?
    a. Butt.
    b. Joggled.
    c. Single-fillet.
    d. Double-fillet.

41. (408) When properly made, which lap joint keeps both surfaces on the same plane?
    a. Butt.
    b. Joggled.
    c. Single-fillet.
    d. Double-fillet.

42. (408) The term “toe” represents the weld face
    a. inner edge.
    b. outer edge.
    c. center portion.
    d. raised portion.

43. (408) The *throat* of a weld is the weld
    a. width from toe to toe.
    b. radius taken from weld center to each toe.
    c. dimension that extends across the root face.
    d. distance through the center of the weld from the root to the face.

44. (408) The lap joint throat thickness should equal the thickness of the
    a. lower leg.
    b. upper leg.
    c. base metal.
    d. penetration zone.

45. (409) Proper fusion into the side walls on a butt joint must be *at least*
    a. 1/16 inch.
    b. 1/8 inch.
    c. 3/16 inch.
    d. 1/4 inch.

46. (409) Edge preparation for butt joints (other than cleaning) is only required on metals over
    a. 1/16-inch thick.
    b. 1/8-inch thick.
    c. 1/4-inch thick.
    d. 3/8-inch thick.

47. (409) Which joint uses equally spaced tack weld to prevent the edges from being drawn together?
    a. Single-fillet lap joint.
    b. Double-fillet lap joint.
    c. Evenly spaced butt joint.
    d. Progressively spaced butt joint.

48. (409) Which joint is spaced so that the edges draw together as you weld?
    a. Single-fillet lap joint.
    b. Double-fillet lap joint.
    c. Evenly spaced but joint.
    d. Progressively spaced butt joint.

49. (409) How many times greater than the base metal's thickness is the butt joint bead width?
    a. 1 to 1½.
    b. 2 to 4.
    c. 4½ to 5.
    d. 6 to 8.

50. (410) Which joint is formed when one plate edge is welded perpendicular to the surface of another?
    a. Lap.
    b. Tee.
    c. Butt.
    d. Joggled.

51. (410) What weld type has a triangular cross section when a tee joint is welded?
    a. Fillet.
    b. Plug.
    c. Spot.
    d. Groove.

52. (410) How do you prepare tee joints on metal 1/8 to 1/2 inch in thickness if the joint can be welded from both sides?
    a. Single groove.
    b. Double groove.
    c. 45° double bevel.
    d. 60° single bevel.

53. (410) When you prepare a tee joint, you space the vertical sheet *approximately* how far above the horizontal sheet?
    a. 1/32 to 1/16 inch.
    b. 1/16 to 1/8 inch.
    c. 1/8 to 3/16 inch.
    d. No spacing required.

54. (410) In a tee joint, you add filler rod to which edge of the molten pool?
    a. Left.
    b. Right.
    c. Upper.
    d. Lower.

55. (410) Which joint is not very strong and is used mainly to join sheet metal edges and weld reinforcing plates to I-beam flanges?
    a. Lap.
    b. Tee.
    c. Butt.
    d. Edge.

56. (411) Compared to fusion-welded joints, braze-welded joints are
    a. almost as strong.
    b. equal in strength.
    c. two times weaker.
    d. two times stronger.

57. (411) Which braze-welded joint develops the *highest* strength?
    a. J-bevel.
    b. Double V-bevel.
    c. Squared edge butt.
    d. Rounded V-groove.

58. (411) When braze welding, which flame do you use to tin the weld area?
    a. Neutral.
    b. Oxidizing.
    c. Carburizing.
    d. Slightly oxidizing.

59. (411) When braze welding, if the metal is *not* hot enough, the filler metal
    a. balls up and rolls off the base metal.
    b. bubbles and runs off the base metal like water.
    c. bubbles and spreads out evenly on the weld area.
    d. balls up and spreads out unevenly on the weld area.

60. (411) Do *not* use braze welding if the repair is subject to temperatures above
    a. 500°F.
    b. 550°F.
    c. 600°F.
    d. 650°F.

61. (412) Silver brazing is done *best* with joints designed to allow
    a. solder buildup.
    b. chemical fusion.
    c. limited solder flow.
    d. capillary attraction.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Oxyacetylene Cutting and Hard Surfacing

THE oxyacetylene welding outfit is not only used to weld parts together, it is also used for cutting and applying hard surfacing. In this unit, we will discuss both of these operations. Oxyacetylene cutting is a fast and an economical way to cut steel. You can use the cutting torch to make accurate fit-ups and prepare joint edges on the job without having to rely on time-consuming methods such as sawing or grinding.

3–1. Oxyacetylene Cutting and Forming

The equipment needed to cut steel includes a cutting torch or cutting attachment with cutting tips. Additional items are radial or multiple cutting machines and aids for manual cutting.

413. Performing oxyacetylene cutting and forming

You can use oxyacetylene equipment to cut and form metal components. The equipment used for cutting and forming is basically the same equipment used for welding; however, there are some differences. Since most of this equipment was covered in Unit 1, *Oxyacetylene Welding Equipment,* we'll focus on the equipment that is unique to the cutting operation.

Cutting equipment

The additional equipment used for cutting includes the torch, attachments, tips, machines, and aids that are used in cutting metal.

Cutting torch

A cutting torch uses a burning mixture of oxygen and acetylene to cut metal such as ¼-inch thick steel plate. To cut any metal, you start with a preheating flame. You set the preheating flame mixture by adjusting the two knobs on the torch. One knob controls oxygen flow and the other controls acetylene. The heat from the preheating flame prepares the metal for cutting. Next, you squeeze the torch trigger to direct a jet of high-pressure oxygen to sever the metal along the line of cut. To assist with supplying this higher pressure and volume, a cutting torch uses oxygen regulators that graduate to 400 psi.

NOTE: Make sure that hoses that you use can handle the 400 psi.

A cutaway view of a cutting torch is shown in figure 3–1. The main parts are the torch body and the head. At the rear of the handle are the oxygen and acetylene hose connections. A needle valve in the acetylene inlet connection controls the acetylene supply. The preheating oxygen is regulated by a preheat valve on the handles side. A high-pressure oxygen valve, operated by a trigger or lever, controls the cutting oxygen. In some cutting torches, the preheating oxygen and acetylene don't mix until they're in the cutting tip. These cutting torches have three gas tubes: one for high-pressure oxygen, one for preheating oxygen, and one for acetylene. In other cutting torches, the preheating oxygen and acetylene mix in the torch body in a common mixing chamber.

The torch shown in figure 3–1 has two gas tubes: one for high-pressure oxygen and one for the mixed oxygen and acetylene.

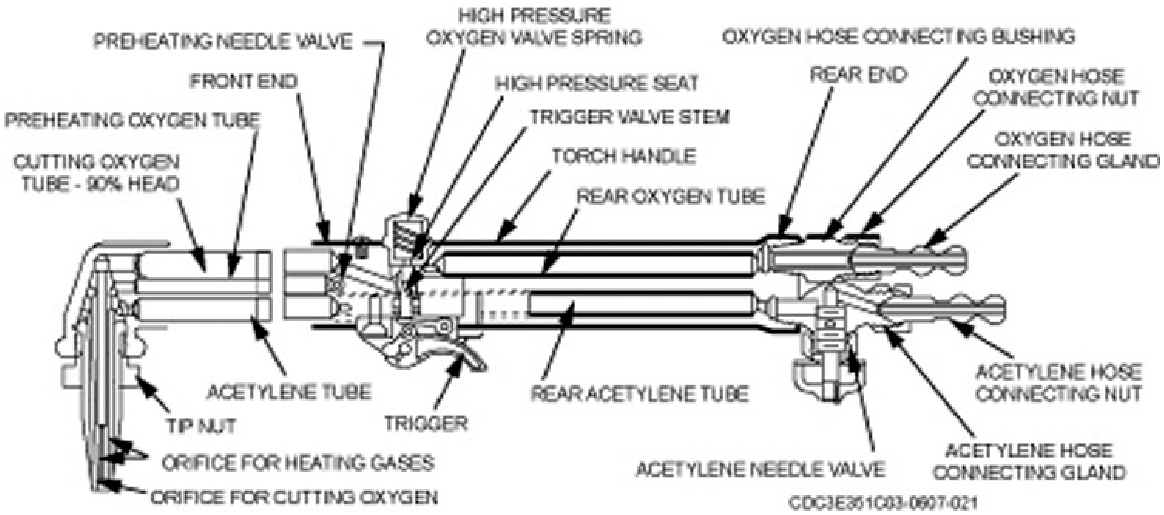


Figure 3–1. Cutting torch nomenclature.

Cutting attachment

The cutting attachment is constructed and operated in much the same way as a cutting torch. The cutting attachment fits the body of a standard welding torch, converting it quickly into a cutting torch as shown in figure 3–2. Since you don't need to disconnect the hoses, the change can be made quickly. This attachment is very useful for occasional cutting of lighter sections. It is *not* recommended for the constant cutting of heavy materials. Such work should be done with a regular cutting torch.

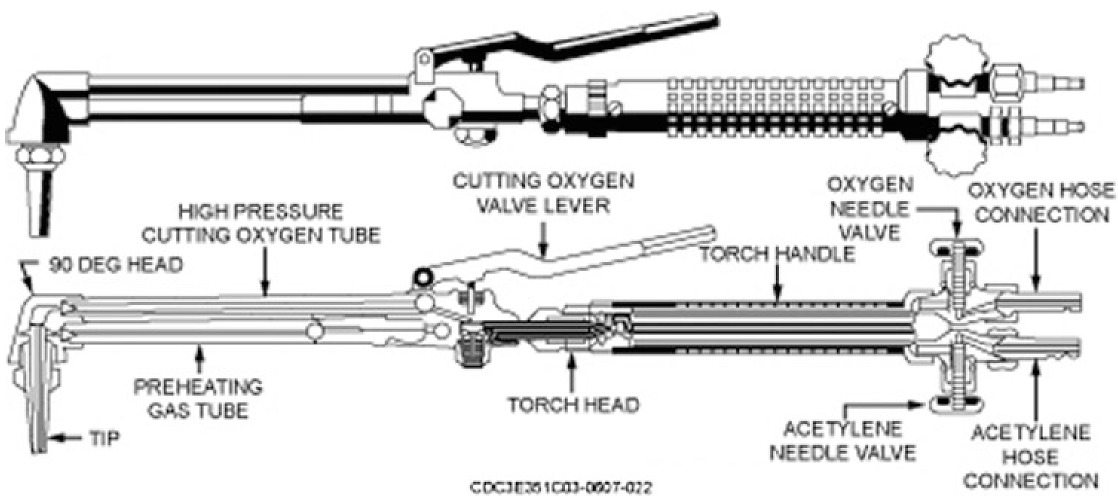


Figure 3–2. Cutting attachment.

Cutting tips

The taper-seated cutting tip is held in the cutting torch head by the tip nut. The tip has a central orifice through which the cutting oxygen flows. This central orifice is surrounded by several preheating holes (orifices), as shown in figure 3–3. Cutting tips with cutting and preheating orifices of various sizes are available for cutting practically any thickness of metal and are supplied in various lengths for special jobs. Angled tips are also used under certain conditions. Many special operations, such as, gouging, hole piercing, and rivet cutting are done with cutting tips designed for the purpose. Figure 3–4 shows some different designs.

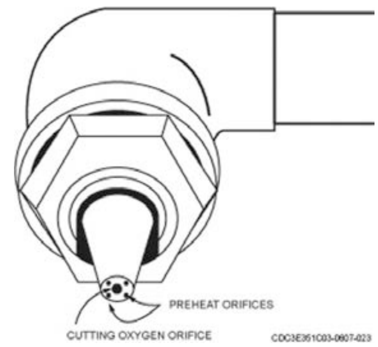


Figure 3–3. Cutting tip.

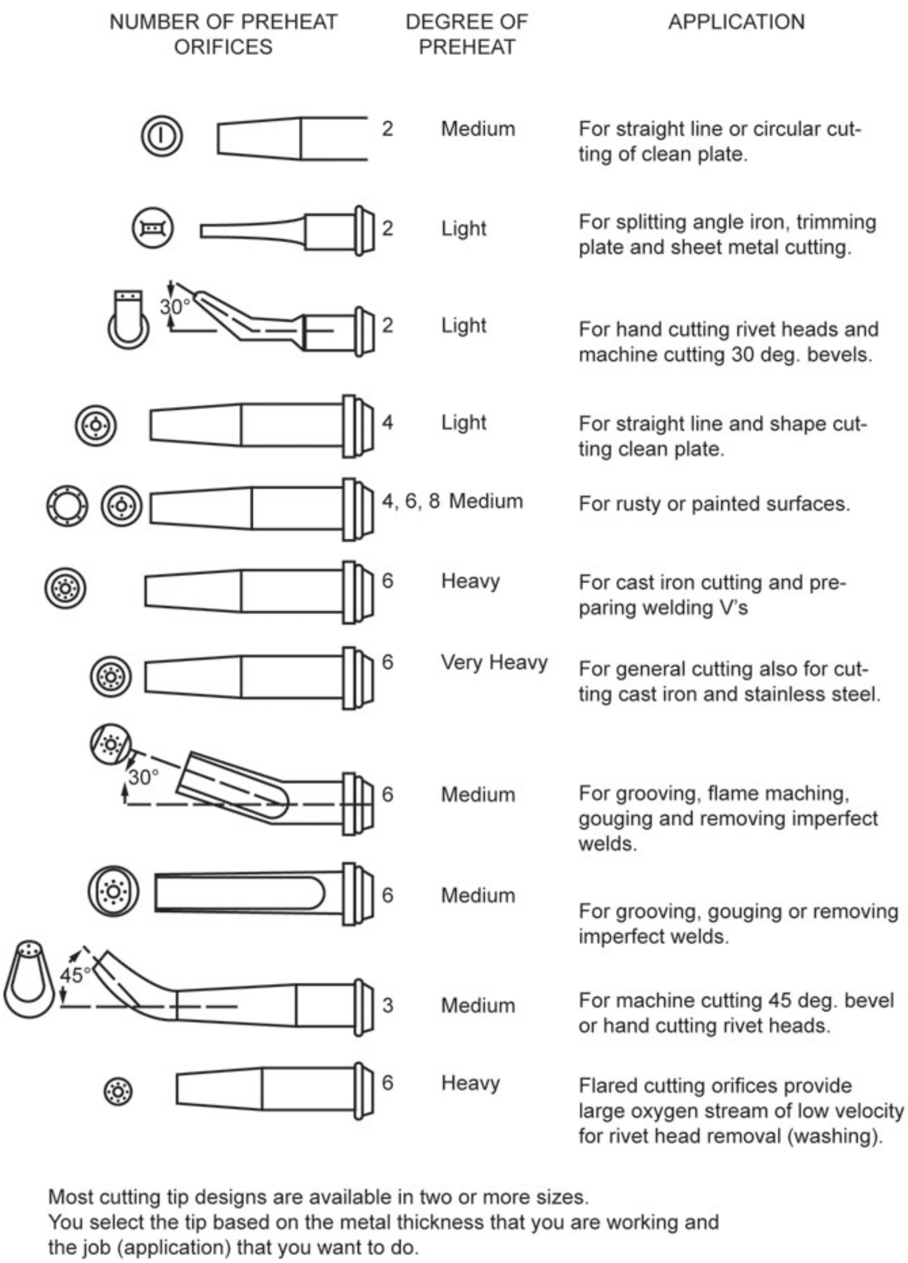


Figure 3–4. Cutting tip designs and uses.

Cutting machines

Although many cutting machines are available and identified by commercial trade names, they're usually classified according to how they control and do their work. Cutting machines have been improved by the use of electronic and magnetic devices to control torch movement. Many machines can be computer programmed to automatically cut a variety of shapes to include circles, squares, bevels, angles, and unique curves.

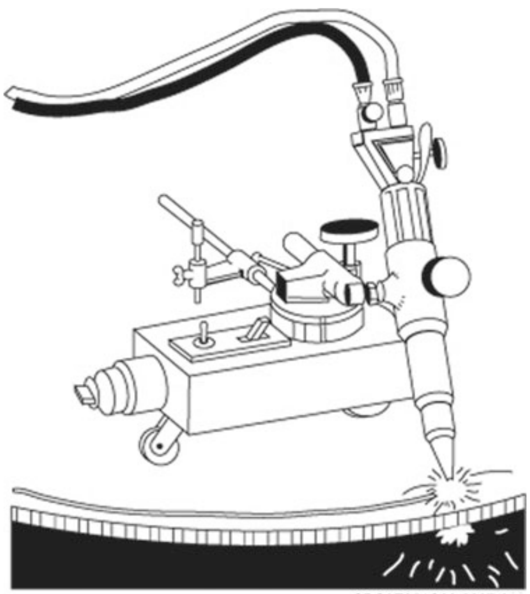


Figure 3–5. Circle cutting machine in operation.

To make uniformly clean cuts on steel plate, motor-driven cutting machines support and guide the cutting torch. The machine does straight-line cutting and beveling by guiding the torch as the machine travels along a straight line on steel tracks. It cuts arcs and circles by guiding the torch with a radius rod pivoted about a central point, as shown in figure 3–5.

Cutting aids

A cutting aid is any device that helps you with a desired operation. It can be a simple straightedge, such as a piece of angle iron for straight-line cutting; a circular cutting attachment for cutting circles; or a sheet metal pattern for cutting specific shapes and angles.

Cutting factors

To cut metal by the oxyacetylene process, there must be rapid metal oxidation in a localized area. Heat the metal to a bright red or "kindling" temperature and direct a high-pressure jet of oxygen against it. This oxygen blast combines with the hot metal and burns it to an oxide. The intense heat that's produced from the oxygen blast helps maintain the kindling temperature along the cutting path. As you move the torch down the cutting path, the oxygen blast blows the oxide out the backside of the metal, leaving a narrow slot or "kerf" that separates the metal.Only the metal in the oxygen jet path is acted upon. In straight line cutting, a narrow kerf with uniformly smooth and parallel walls is cut. A skilled worker, using a mechanically guided and controlled torch, can make very accurate cuts. Heavy steel plates that can't be cut economically by mechanical methods can be cut and smoothly with a cutting torch.

Practically all metals combine readily with oxygen when they're heated to a high temperature. However, some can't be cut successfully by this method because their oxides have a higher melting point than the parent metal. Oxides mix with the parent metal when they're melting, instead of separating from it. This problem occurs when you cut nonferrous metals, such as aluminum and copper.

Low and medium carbon steels can be cut successfully with a cutting torch without any special metal preparation. You can cut high carbon tool steels if you first preheat the whole section properly. For ordinary tool steel, black heat is usually sufficient, although some alloy tool steels require full red heat. Cast iron is harder to cut than steel because it melts at a lower temperature than its oxide. Chromium and stainless steels require a special process.

Procedures

To cut metal with the oxyacetylene cutting torch, first select the right tip size and adjust the regulators for the correct pressure. Figure 3–6 gives recommended pressures and tip sizes to use to cut various thicknesses of low carbon steel.

Light the torch and adjust the preheating flame to neutral with the torch needle valves, open the cutting oxygen valve and again adjust to a neutral flame. Because of rapid oxidation, the oxygen actually separates the metal. Make sure the metal on both sides of the line of cut is free from scale and heavy rust deposits. To start the cut, hold the torch perpendicular to the work with the inner cone of the preheating flame slightly above the metal surface.

Plate Thickness	Tip Size Nr	Acetlylene Pressure, lbs per sq inch	Oxygen Pressure, lbs per sq inch
1/4 in	0	3	25 to 30
3/8 to 1/2 in	1	3	30 to 40
3/4 to 1 in	2	3	40 to 50
1 1/2 in	3	3	45 to 50
2 in	4	3	50 to 55
3 to 4 in	4	4	55 to 65
5 to 6 in	6	5	55 to 60
8 to 10 in	7	6	60 to 70
12 in	8	6	70 to 80

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Figure 3–6. Recommended pressure for cutting low carbon steel.

When a red heat has been reached, open the cutting oxygen valve slowly until it is fully open, as shown in figure 3–7. If you start the cut properly, a shower of sparks falling from the opposite side will indicate that the cut is penetrating all the way through the metal. If you use proper pressures and cutting speeds, you can cut the metal without interruption. If you’ve made the cut properly, it will be a clean, narrow kerf, comparing favorably with a cut made by sawing.

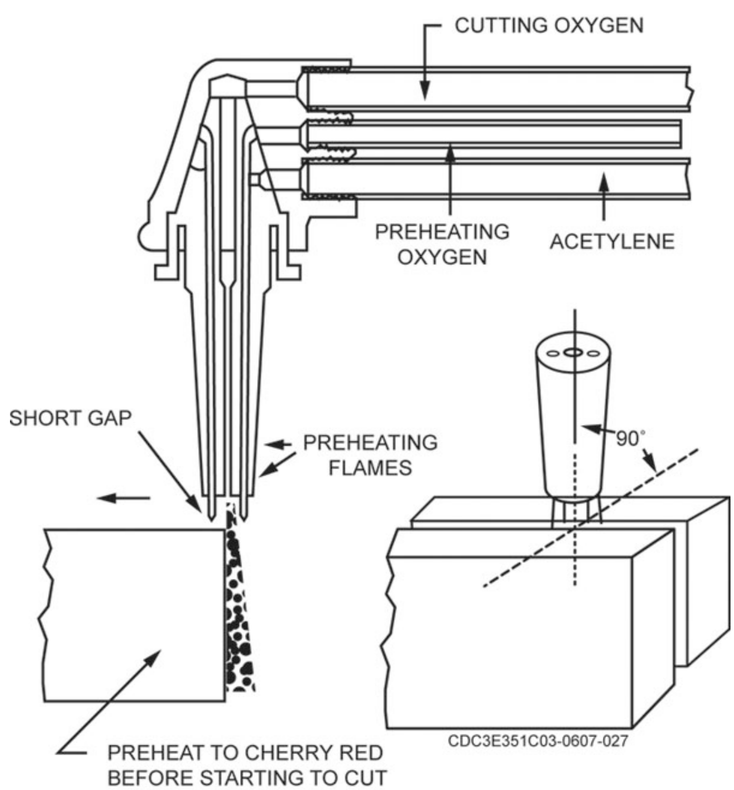

Figure 3–7. Starting a cut.

Figure 3–8 illustrates different results obtained in oxyacetylene cutting, considering such factors as oxygen pressure, preheating, and travel speed. Figure 3–8 shows work views, drag, and direction of cut. If the speed is too fast, the metal isn't preheated enough to continue the cut (fig. 3–8, top drawing). To restart, direct the flame slightly behind the point where you lost the cut.When the metal is preheated properly, resume cutting. If the speed is insufficient, the metal is overheated which results in rounded top edges (fig. 3–8, middle drawing). Your preheating and speed is correct when you have good clean kerf and sharp top edges (fig. 3–8, bottom drawing).

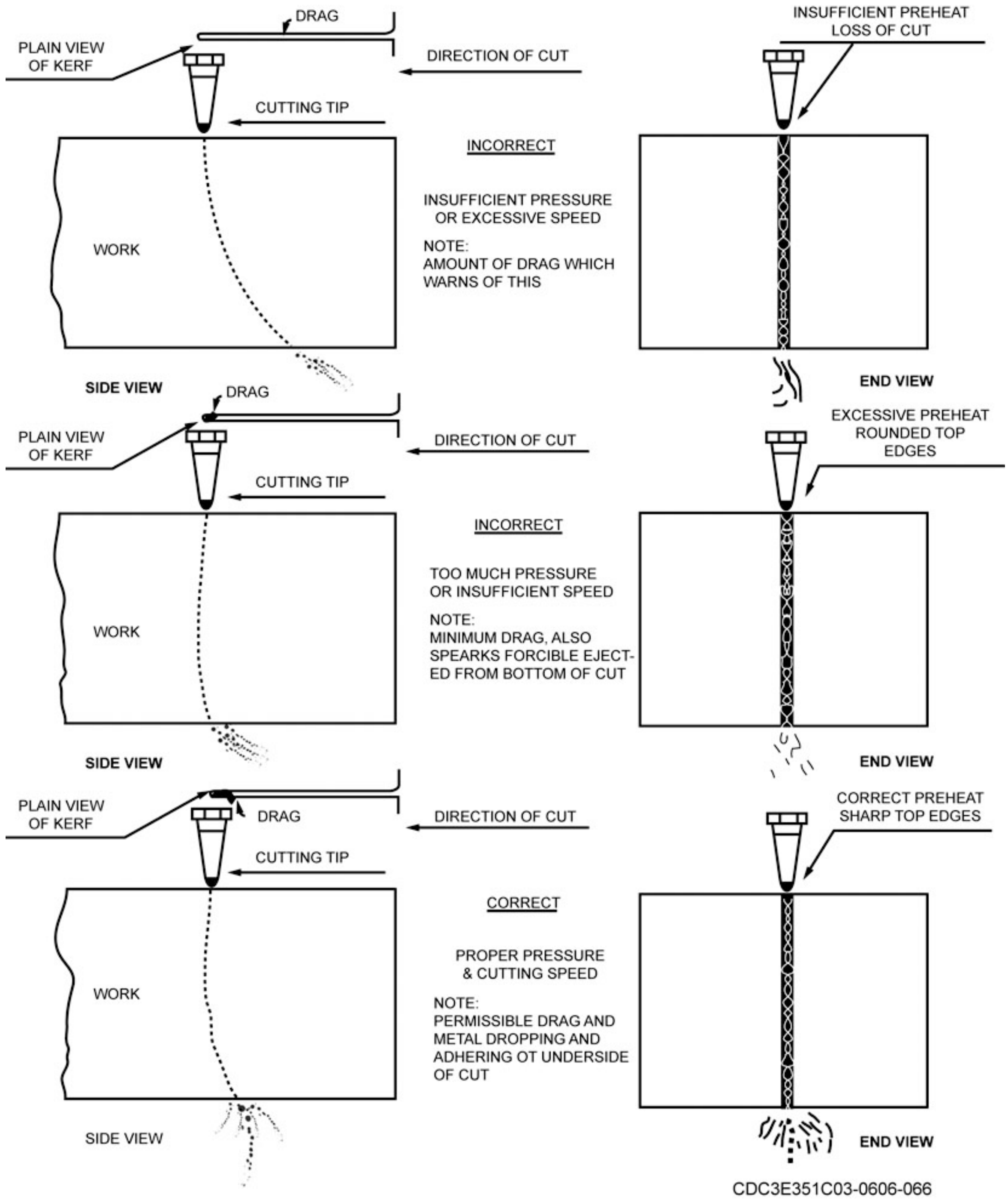

Figure 3–8. Cutting results.

Metal composition

The metal’s composition determines how effectively you can cut it with the oxyacetylene cutting torch.

Carbon steels

Carbon steel whose carbon content does not exceed 0.35 percent can be cut without special procedures. For higher carbon steels, be careful to keep from forming a hard layer at the edge of the plate. To avoid this, preheat the plate edges in advance of the cut. Use preheating temperatures of 500 to 600°F in cutting steels in this class.

Chromium and stainless steels and other alloy steels, which formerly could be cut only by melting, can now be cut by oxidation (cutting torch). Iron powder or a special nonmetallic powdered flux is added to the cutting oxygen stream. The iron powder oxidizes quickly, generating high heat. This high heat, in turn, melts the heat-resistant oxides that normally protect the alloy steel from the action of the oxygen. These molten oxides are flushed from the cutting face by the oxygen blast, and the cutting oxygen continues to react with the iron powder and cuts its way through the steel. When nonmetallic flux is added to the cutting oxygen stream, the flux combines chemically with the heat-resistant oxides and produces a slag of a lower melting point, which is washed or eroded out of the cut. This exposes the steel to the action of the cutting oxygen.

Without iron powder or nonmetallic flux, cutting these steels is a melting process. The best way to cut using the melting method is to position a steel welding rod or steel plate along the line of cut. The heat developed by the reaction of the oxygen with the rod or plate is high enough to melt a slot in the stainless steel, producing the cut.

Safe cutting practices

During all cutting, you must be safety conscious because you are using equipment that can cause severe burns, fires, and most deadly, an explosion. You must stay alert to prevent damage to equipment, real property, and injury to people in the work area, including yourself. To help you, follow these safety rules:

1. Always get a permit from technical services at the base fire department before using a cutting torch outside of the immediate shop area.
2. Never dismantle or salvage magnesium parts with an oxyacetylene cutting torch.
3. Never cut new or used drums, barrels, tanks, or other containers until they have been thoroughly cleaned and free of all hazardous and combustible material. Do the cutting as soon after the cleaning as possible. Drums and barrels should have their heads removed with a drum deheader before heat is applied to them.
4. Move combustible materials to a safe location or move your work to a safe distance from such materials. Set up sheet metal guards or flame-resistant blankets if needed.
5. Do *not* cut material in a position that permits sparks, hot metal, or the severed section to fall on the cylinder, hose, or your legs or feet.
6. Always wear proper clothing, such as high-top shoes, gloves, and clothing without cuffs. Cuffs can collect hot metal and cause a serious burn.
7. Use a fireguard if the work requires protection against fire.
8. When you stop cutting for short periods, release the regulator adjusting screw.
9. Close the complete outfit down before you leave the job.

Cutting tasks

Several cutting operations can be done with the cutting torch. Among these are straight-line cutting, circular cutting, hole-piercing, beveling, cutting round stock, and flame gouging. Let’s take a look at them now.

Straight-line cutting

For straight-line cutting, mark the cut line clearly with center punch marks or clamp a guide bar into position to guide the torch accurately (fig. 3–9). The latter method is preferred for long cuts.

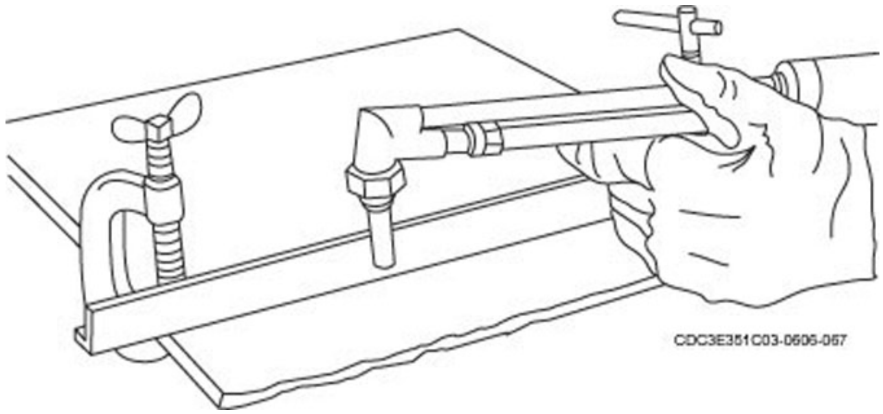

Figure 3–9. Straight-line cutting.

Circular cutting

Circular cutting with a cutting torch is done best with a circular cutting attachment like the one shown in figure 3–10. This attachment has a rod with a clamp attached to one end. The clamp fits the torch head. The rod has an adjustable center point that can be set to the desired radius. When you're starting the cut away from the metal edge, drill or pierce a small hole through the metal in the scrap portion a short distance from the circular outline. Start the cut from the edge of this small hole.

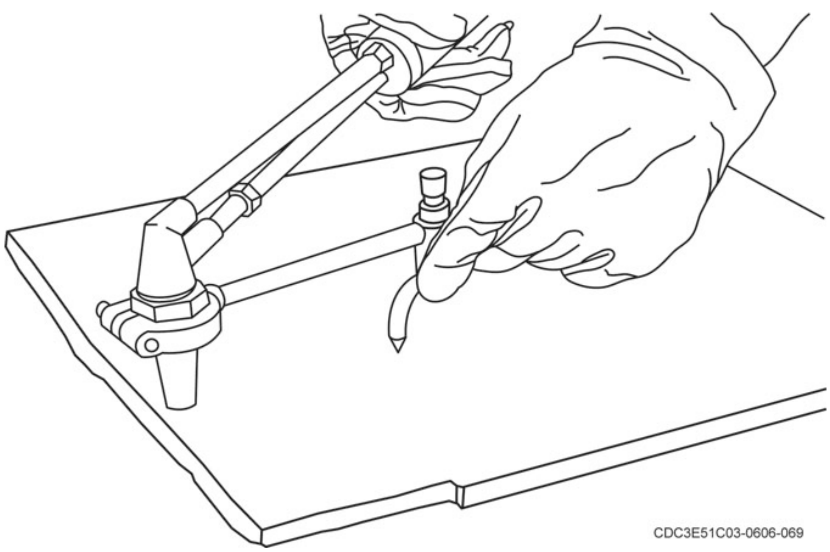

Figure 3–10. Using a circle cutter.

Hole-piercing

To pierce a hole, more time is needed to heat the metal to a kindling temperature than is needed for edge cutting. When the desired spot is sufficiently heated, raise the torch about ½ inch above the normal position for cutting, and open the cutting oxygen valve slowly. After burning through the metal, lower the torch to the normal height of the work and complete the cut. Try to keep slag from plugging the cutting orifice. This usually happens if the torch is held too close to the work when the cutting oxygen valve is opened.

Beveling

Torch control during beveling is harder than straight square-edge cutting. The proper speed and a steady hand on the torch are essential for you to get a smooth bevel cut. A chalk line is used to indicate the beveled top edge. A metal straightedge clamped into position serves as a guide to help you maintain the right torch angle. The angle made by the cutting oxygen with the surface of the metal produces the bevel.

Cutting round stock

To cut round stock, use a chisel to raise a burr on the surface of the metal where the cut is to begin. The burr makes it possible to start cutting without prolonged heating. Start the cut at the side, about 90° from the vertical centerline, as shown in figure 3–11. After starting the cut, raise the torch to the vertical position and hold it in this position for the remainder of the cut. Hold the flame the same distance from the surface of the metal as you would for cutting sheet stock.

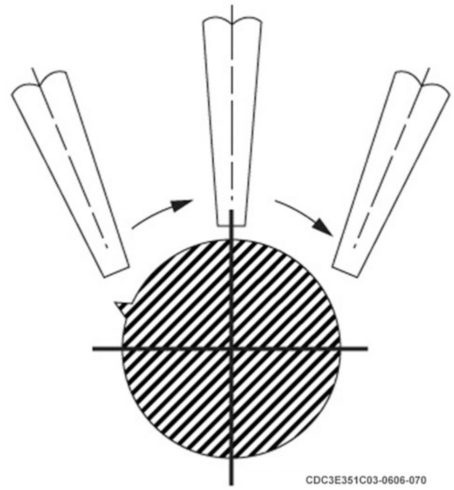

Figure 3–11. Cutting round stock.

Flame gouging

By flame gouging, you can remove a narrow metal strip from the surface of steel plate, forgings, and castings. Flame gouging differs from other flame cutting because the cut does not go all the way through the metal (fig. 3–12). By using a tip that delivers a relatively large jet of oxygen at low velocity and by controlling and manipulating it properly, you can gouge a smooth, accurately defined groove out of the metal surface. You can use different tips and torch manipulations to vary the width and depth of the groove. There are two flame-gouging techniques. In the first, make the groove progressively across a plate, as in removing metal from the back of a weld or in preparing remote cracks for welding. In the other, gouge out a small area, as in removing isolated weld defects.

Figure 3–12. Flame gouging.

Progressive gouging

To start the cut for progressive gouging, hold the torch with the end of the tip at a 20° angle to the horizontal. Direct the preheat flame to the starting point until the surface reaches red heat; then gradually open the cutting oxygen lever. To start the cut, lower the angle of the torch to produce the depth of cut required. The groove depth depends on the tip size, the travel speed, and the angle between the cutting oxygen stream and the work. The speed that you move the torch greatly affects the gouge that you make. Moving too fast makes a gouge that is shallow and narrow while moving too slow makes a gouge that is wide and deep. To cut a deep groove, increase the torch angle in relation to the groove and decrease the speed correspondingly. To make a shallow groove, reverse the procedure. The groove contour depends on the tip characteristics and operating conditions. If your cutting oxygen pressure is too low, the cutting has a washing effect, leaving ripples in the bottom of the groove. If your oxygen cutting pressure is too high, the cut is advanced nearest the surface ahead of the molten pool. This results in cutting loss and is especially common when cutting shallow grooves.

Spot gouging

To gouge out a single spot, as in spot gouging a weld defect, first mark the surface the area to be removed. Adjust the preheat flame to slightly oxidizing. Preheat a point slightly to the rear of the defect and start the cut in the usual way. Gradually increase the torch angle so that the oxygen jet is directed downward, making the cut increasingly deeper. Defects can be detected during gouging because they appear as dark spots in the molten zone. Hold the torch with the preheating flame about $^{1}/_{16}$ inch above the plate surface during the cut. To eliminate the need for raising a burr to start the cut, you can use an oxidizing preheat flame to provide enough concentrated heat for starting the cut.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

413. Performing oxyacetylene cutting and forming

1. What are the functions of the cutting attachment?

2. How is the cutting tip held in the cutting torch head?

3. For what are the outer orifices on a cutting tip used?

4. List some of the aids that can help you in cutting operations.

5. How does the oxygen stream affect the red hot metal?

6. What do we call the space that is developed in the metal from the cutting action?

7. Which metals can be oxyacetylene cut without special preparation?

8. How should you adjust the torch flame for cutting low carbon steel?

9. What can you add to the cutting oxygen stream to let you cut chromium or stainless steels?

10. Why must you be safety conscious when using oxyacetylene cutting equipment?

11. Match each procedure in column A with the correct type of cutting operation in column B. Items in column B may be used only once.

Column A	*Column B*
____ (1) Clamp a guide bar into position.	a. Circular cutting.
____ (2) Set the adjustable center point to the correct radius.	b. Straight-line cutting.
____ (3) Remove surface metal.	c. Hole-piercing.
____ (4) Raise the torch about ½ inch above the normal position and open the cutting oxygen valve slowly.	d. Beveling.
____ (5) Raise a burr on the surface where the cutting is to begin.	e. Cutting round stock
____ (6) Use a chalk line to indicate the top edge and a clamped straightedge as a rest.	f. Flame gouging.

3–2. Hard Surfacing

Hard surfacing, or hard facing, is the process of applying extremely hard alloys to the surface of a softer metal to increase its resistance to wear, abrasion, corrosion, or impact. This section covers how to perform this procedure.

414. Performing hard surfacing

In most cases, you can apply hard-surfacing alloys to the point, surface, or edge of any part by the oxyacetylene process. Treated with these alloys, the wearing surface of drills, tools, bits, cutters, and other parts will outwear the common steels by 2 to 40 times, depending on the type of alloy used and the service to which the part is subjected.

Alloys used for hard surfacing

No single hard-surfacing material is suitable for all applications. Many hard-surfacing alloys have been developed to meet requirements for hardness, toughness, shock, wear resistance, and other qualities. These alloys are generally separated into five broad groups as described in the table below:

HARD-SURFACING ALLOYS		
Group	**Description**	**Use**
1	Mainly iron based alloys with less than 20% of alloying elements. The alloying elements are chromium, tungsten, manganese, silicon, and carbon. They have greater resistance to wear than any machine steel. They also have good shock resistance and toughness.	To build up badly worn sections before a final harder, hard-surfacing alloy is applied. For rock crushers and similar equipment where resistance to shock and impact is most important and hardness is only secondary.
2	Iron-based alloys with 50 to 80% iron and more than 20% alloying elements. These alloying elements are mainly chromium, tungsten, manganese, silicon, and carbon. Small percentages of cobalt and nickel are sometimes added. Some of the alloys in this group have the property of “red hardness”; that is, they remain hard even when they’re at a red heat.	For the final hard, wear-resisting surface after the part has been built up.
3	Nonferrous cobalt, chromium, and tungsten alloys, as well as other nonferrous hard surfacing metals. Some of these alloys also have the property of red hardness. They’re available in different grades. All are highly resistant to wear but possess a special toughness and strength for various purposes.	For the valve seats in internal combustion engines.

HARD-SURFACING ALLOYS		
Group	**Description**	**Use**
4	Carbide materials or diamond substitutes that are the hardest and most wear resistant of all hard-surfacing materials. Some of the alloys contain 90 to 95% tungsten carbide, with the rest being cobalt, nickel, iron, or similar metals that add strength, toughness, heat resistance, and impact strength. Some are almost pure tungsten carbide and contain no alloying elements. This group is supplied in the form of small castings to be bonded onto the wearing surface of other metals in a process known as hard setting.	For the wearing parts that come in contact with earth, sand, and gravel. These include the blades of road scraping equipment, rotary drill bits, power shovel teeth, and similar parts. The rods for these uses are borium and cobalt borium
5	Crushed tungsten carbides of various sizes. They're fused to strips of mild or low alloy steel embedded in hard-surfacing material or high-strength rods, or they're packed in lengths that are applied to the wearing surface as welding rod. Crushed tungsten carbides are also available in loose form as granular powder to be sprinkled onto the wearing surface and melted into it. The materials in this group, although more expensive than other types, are used for many purposes because of their long life.	For the wearing parts that come in contact with earth, sand, and gravel. These include the blades of road scraping equipment, rotary drill bits, power shovel teeth, and similar parts. The rods for these uses are borium and cobalt borium.

Which metals can be hard surfaced?

You can apply hard-surfacing materials to most metals and alloys. Since the melting points of brass and bronze are very low, hard surfacing is *not* always satisfactory on these metals. In some cases, you can preheat heavy sections to a red heat and hard face them using the group 3 alloys. Hard surfacing is not recommended for *high-speed steels* because of their brittleness and the shrinkage cracks that develop in the base metal after hard surfacing. Also, aluminum and aluminum alloys *cannot* be hard faced. The table below shows which metals and alloys you can hard-surfaced successfully if you follow the appropriate procedures.

Appropriate Metal Hard-Surfacing Procedures	
Metal	**Can Be Hard Surfaced Successfully**
Plain carbon steels (low and medium)	if the carbon content is 0.50 or below.
High carbon steels	if certain heat treatment processes are followed. Contains 0.50% carbon or higher. Heat-treat the base metal before and after hard surfacing to remove hardness and brittleness and prevent cracking.
Low carbon alloy steels	in some cases, depending on the base metal composition. Heat treatment is required after hard surfacing.
Manganese steels	if you use the shielded metal-arc process only. Use the work-hardening alloys and with alloys that bond easily with these metals.
Stainless steels (including the high chromium and chromium-nickel steels)	if you know the mechanical properties of a particular stainless steel to avoid decreasing its corrosion resistance after hard surfacing. Uniform heating and cooling help to prevent the warping or cracking caused by the higher expansion in the stainless steel
Gray cast iron	because gray cast iron is malleable iron. The surface beneath the hard-surfacing layer will become hard. Some of this hardness can be removed by reheating the metal to about 1,500°F
Copper and copper alloys	because they have high heat conductivity and comparatively low melting temperatures. In some instances, you can hard-face them in the same way as for brass and bronze.
Monel metal	readily.

Metal preparation

You must clean the metal surface before hard surfacing it. Your goal is to remove all scale, rust, dirt, and foreign substances. The preferred method is grinding, machining, or chipping. If you can't use these methods, you can prepare the surface by filing, wire brushing, or sandblasting. The latter methods aren't as satisfactory because the small particles of foreign matter remaining on the surface must be floated out during the hard surfacing. Round all the edges of grooves, corners, and recesses to keep from overheating the base metal.

Surface preheating

You take the same precautions in preheating for hard surfacing as for welding a base metal. Before you apply the hard surfacing, you should anneal steel in the heat-treated condition, if possible. When it's impossible or undesirable to anneal high carbon steel, deposit the hard face by the transition bead method. First deposit a thin layer of stainless steel, such as the 25 percent chromium and 20 percent nickel rod, or the 18 percent chromium and 8 percent nickel rod. Then build up the section to roughly the original dimension, using an 11 to 14 percent manganese or high-strength rod. Finish by hard surfacing with one of the group 2 alloys. If you need to heat the metal to the critical temperature after hard surfacing, we recommend using oil instead of water as the quenching medium because water is more likely to crack the hard surfacing layer.

Flux application

You don't need flux to apply hard-surfacing materials with the oxyacetylene torch, but when you're depositing the hard-surfacing material in more than one layer, flux helps to remove the scale and oxides that have formed on the base metal. This applies particularly to hard-surfacing cast iron in which a cast iron welding flux is satisfactory. The flux film on the molten pool reduces the deposited material's cooling rate, permitting gas, oxides, and slag inclusions to come to the surface. This results in a harder and more solid-surface layer.

Flame adjustment

Use a carburizing flame to apply hard surfacing to a metal surface (fig. 3–13). The exact acetylene amount needed in the flame is found by adjusting the acetylene during the initial rod deposit. This is sometimes referred to as excess acetylene. The oxyacetylene flame gives close control over the operation and produces a smooth deposit. Adjust the flame to produce a quiet pool with good flowing qualities for the hard-surfacing material you are using.

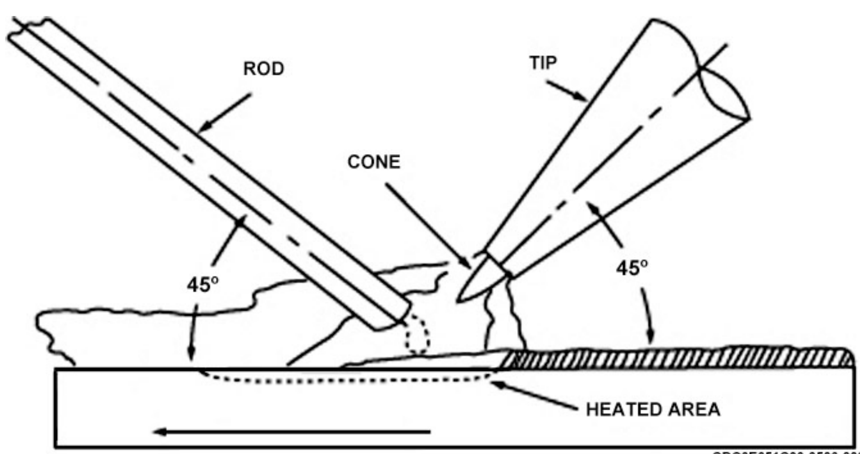

Figure 3–13. Hard surfacing with oxyacetylene.

Determine deposit thickness

In most cases, you can rebuild worn sections with hard-surfacing deposits ranging from $^{1}/_{16}$- to ¼-inch thick. When you're depositing hard-surfacing material in excess of ¼-inch, rebuild the parts with a group 1 alloy to $^{1}/_{16}$ to $^{1}/_{4}$ of the finished size. Add the final hard-surfacing materials as a group 2 or group 3 alloy. You need to allow some excess to permit grinding and forming to the finished dimensions.

When you apply the harder and more brittle group 4 or group 5 hard-surfacing materials, either as a final hard-surfacing deposit or as a single layer, control the deposit shape carefully. It's important to transmit impact or shock loads through the hard-surfacing metal into the tougher base metal. Corners, sharp edges, and built-up sections that aren't backed up by tough base metal will chip or break off in service.

Torch hard surfacing

Hard surfacing can be done in either of the two ways illustrated in figures 3–14 and 3–15. The oxyacetylene flame permits close control to produce a smooth deposit. The flame easily removes scale and foreign matter particles, and you can form edges and corners easily. This is particularly important if the hard-surfacing deposit must be ground to close dimensions. Use the flame to control the hard-surfacing alloy penetration into the base metal, since some alloys are puddled into the base metal and others are merely "sweated" onto the base metal. Use a tip two sizes larger than you'd need to weld a metal of the same thickness. When you apply any of the hard-surfacing alloys or materials to steel, determine the exact acetylene amount (excess acetylene) needed in the flame by varying the acetylene during the initial rod deposit. Adjust the flame to give a quiet pool and good flowing quality for your particular hard-surfacing material. In some cases, when you're hard surfacing a thin edge or building up a desired shape with hard-surfacing materials, you can use a copper mold or backup strip. Check the following information concerning the groups of alloys.

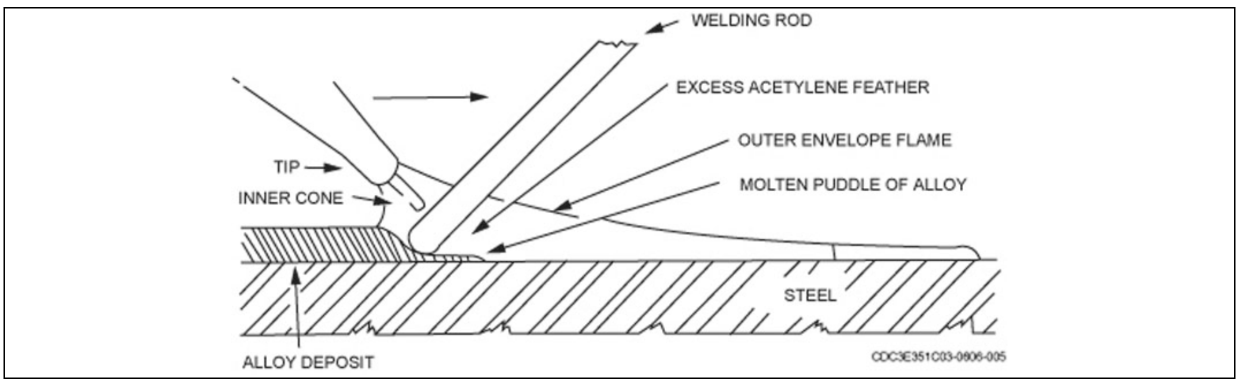

Figure 3–14. Hard surfacing, forehand method.

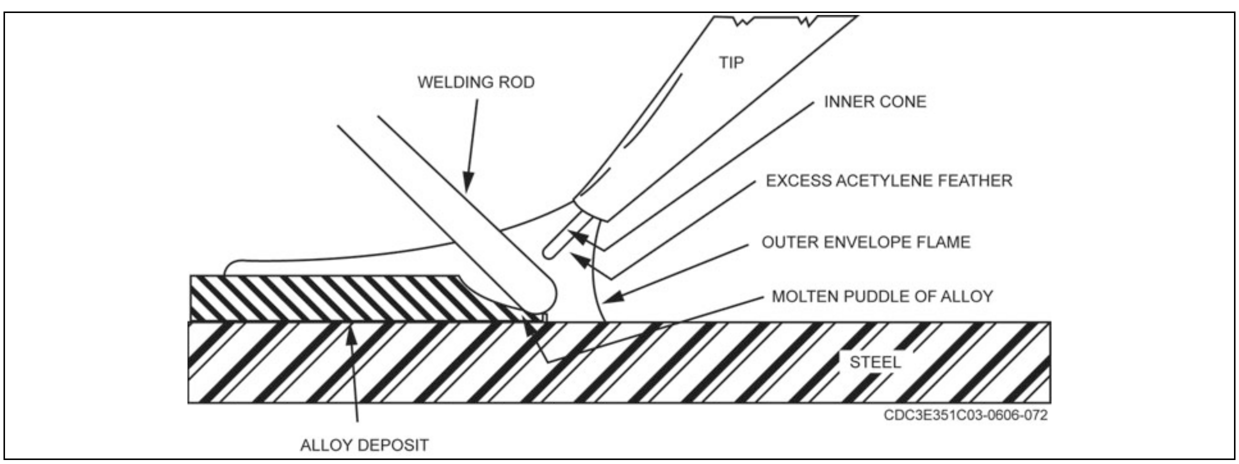

Figure 3–15. Hard surfacing, backhand method.

Hard-Surfacing Alloy Groups	
Group	**Information**
1	When you apply group 1 hard surfacing alloys to steel, adjust the flame to a slight excess of acetylene to prevent the puddle from boiling. If you need greater hardness in the deposit, increase the acetylene in the flame. Puddle the hard-surfacing rods into the base metal enough to get good fusion without diluting the hard-surfacing material with the base metal, thereby softening it. Oil-quenching group I deposits are possible without any loss of wear resistance or toughness.
2	Apply these hard-surfacing alloys to steel in the same way as the group 1 alloys. “Sweating” is not advisable. Adjust the flame to an excess of acetylene with a feather roughly twice the length of the inner cone. The penetration of these hard-surfacing metals into the base metal doesn’t affect the hardness of the deposit materially, as their carbon content is high. To eliminate porosity and shrinkage cracks, reheat the hard-faced part to an even temperature throughout, and then immediately pack it in lime or some other material that retards cooling. *Don’t* quench the deposits made with this group of alloys.
3	The hard-surfacing alloys in this group are nonferrous and should be sweated onto the surface without stirring or puddling the rod or melting the surface of the base metal. Adjust the flame to an excess of acetylene to prepare the base metal, allow free spreading of the alloy, and prevent oxidation ahead of the heated zone. Bring a small area to be hard faced to a sweating temperature. At the proper temperature, the hard-surfacing material will melt and spread evenly over the surface. Control the deposit thickness when you’re using the flame to spread the molten metal over the surface.
4	Some tungsten carbide materials, such as that in-group 4, are available as inserts in various sizes and shapes. Groove the base metal surface with a cutting torch. Space the inserts evenly to get uniform wearing qualities. Weld an insert to the end of a steel welding rod and melt the groove in the base metal. At this point, push the insert into place and melt enough welding rod to cover the insert completely. Repeat this procedure until the surface is covered with the desired number of inserts.
5	The alloys in group 5 are crushed tungsten carbides embedded in steel strips, rod, or tubes. Tube borium is made in the form of mild steel tubes filled with crushed particles of screen tungsten carbide (borium). Applying this alloy as thinly as 0.010 to 0.015 inch makes it possible to hard-face thin cutting edges and equipment that require a thin overlay. Adjust the flame to an excess of acetylene with a feather about four times the length of the inner cone. Heat the base metal to the sweating temperature. Avoid puddling, since in a thick deposit borium particles settle away from the deposit. Deposit the alloy with a minimum amount of penetration. Figure 3–16 shows typical applications of hard surfacing on gear teeth, an exhaust valve, and a rocker arm.

Finishing

Many parts that are hard surfaced, like those shown in figure 3–16, require finishing to specific dimensions or shapes. If this is the case, be very careful to apply enough hard-surfacing alloys to allow for grinding to given specifications.

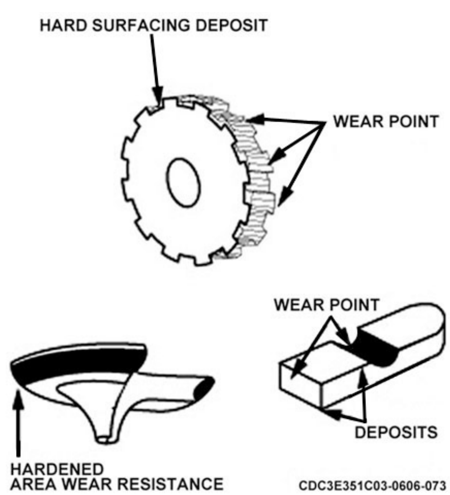

Figure 3–16. Hard-surfacing applications.

Hard-surfacing deposits must be grounded or machined to specific shapes. (**NOTE:** Any tool that you use must be harder than the surfacing material. If not, it will dull quickly, and you'll waste time and effort.) A fast and efficient way for you to make detailed shapes for finishing hard-surfacing deposits is to use a carbide coated rotary file.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

414. Performing hard surfacing

1. What special requirements have hard-surfacing alloys been developed to meet?

2. Why aren't high-speed steels recommended for hard surfacing?

3. Why is it difficult to hard surface brass, bronze, copper, and copper alloys?

4. How are the corners and edges prepared for hard surfacing?

5. What flame is used to apply hard-surfacing deposits?

6. How are the hard-surfacing alloys bonded to the base metal?

7. How are hard-surfacing alloys finished for use?

Answers to Self-Test Questions

413

1. It converts a welding torch into a cutting torch and is used for intermittent cutting of lighter sections.
2. By the tip nut.
3. Preheating.
4. A straightedge, a circle cutting attachment, and a sheet metal pattern.
5. The oxygen stream combines with the hot metal to burn it to an oxide, which generates the intense heat used for cutting.
6. Kerf.
7. Steels of low and medium carbon content.
8. Use the torch needle valves to adjust the flame to neutral, then open the cutting oxygen valve and adjust the flame to neutral again.

9. Iron powder or a special nonmetallic powdered flux.
10. Because you’re using equipment that can cause severe burns, fires, and an explosion.
11. (1) b.
    (2) a.
    (3) f.
    (4) c.
    (5) e.
    (6) d.

414

1. Requirements for hardness, toughness, shock and wear resistance, and other qualities.
2. Because of their brittleness and the shrinkage cracks that develop in the base metal after hard facing.
3. The melting temperature for these metals is relatively low.
4. They are rounded.
5. Carburizing.
6. By being puddled into the base metal or merely sweated onto it.
7. They’re grounded or machined with a tool that is harder than the surface material.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

62. (413) A cutting torch uses oxygen regulators that graduate up to what pounds per square inch (psi)?
    a. 100.
    b. 200.
    c. 300.
    d. 400.

63. (413) What is the *slot* made during oxyacetylene cutting?
    a. Kerf.
    b. Slice.
    c. Relief.
    d. Incision.

64. (413) Which single factor determines whether you can cut a particular metal with a cutting torch? The metal's
    a. heat treatability.
    b. composition.
    c. thickness.
    d. hardness.

65. (413) To do straight-line cutting with a torch, *first* mark the line of cut clearly with
    a. pencil lines.
    b. scribed lines.
    c. chalk marks.
    d. center punch marks.

66. (413) What step makes it possible for you to cut round stock without prolonged preheating?
    a. A flame gouged surface.
    b. A raised burr on the stock.
    c. A varied cutting oxygen pressure.
    d. A torch tip one size larger than normal.

67. (414) Which method is the *preferred* way to remove rust, scale, and dirt before hard surfacing?
    a. Grinding or chipping.
    b. Filing or wire brushing.
    c. Chemical dipping or flaming.
    d. Sandblasting or hand sanding.

68. (414) Which flame should you use to apply hard-surfacing materials to a metal surface?
    a. Neutral.
    b. Oxidizing.
    c. Carburizing.
    d. Slightly oxidizing.

Glossary

Terms

Acetone—A colorless and very flammable liquid that is used to fill air spaces in the porous material that is inside of an acetylene gas storage cylinder. The acetone absorbs the acetylene gas to stabilize it for safe storage.

Acetylene—A colorless gas that is made from two parts carbon and two parts hydrogen. When burned with oxygen, it produces an extremely high flame temperature.

Alloy—A combination of metal and one or more elements mixed together to create specific properties.

Annealing—A heat treatment process that eats metal to cherry red and then cools it slowly to reduce brittleness, restore ductility, relieve stress, and control grain size.

Austenite—A grain structure found in steel that contains a combination of cementite, ferrite, and pearlite.

Backhand welding—A welding technique in which a welding torch or gun is directed opposite to welding progress.

Backfire—A short pop sound coming from the torch flame. Sometimes causes the flame to go out.

Base metal—The metal or alloy that is welded, brazed, soldered, or cut.

Black iron—Low-carbon steel that is available in various forms such as sheets and angle.

Brass—An alloy of copper and zinc. Brass is soft, easily worked, and is resistant to corrosion.

Braze welding—A welding process variation that uses a fuller metal with a liquid temperature above 450 degrees (C) 840 degrees (F) and below the base metal's solid state. Unlike brazing, in braze welding, capillary action does not distribute the filler metal into the joint surfaces.

Brazing—A group of welding processes that joins materials by heating them to brazing temperature with a filler metal that is liquid above 450 degrees (C) 840 degrees (F) and below the base metal's solid state. Capillary action distributes the filler metal between the closely fitted laying joint surfaces.

Brazing filler metal—The metal that fills the capillary joint clearance and is liquid above 450 degrees(C) 840 degrees (F) but below the base metal's solid state.

Brittleness—A metal property that allows very little bending before breaking.

Bronze—An alloy of copper and tin. Bronze is harder and more expensive than brass.

Butt joint—A joint between two members aligned approximately in the same plane.

Capillary attraction—An action that occurs when melted filler metal makes contact with a base metal and flows between closely fitted joint surfaces to fill the space. It is used in brazing and soldering.

Casting—Forming a metal part by pouring or forcing molten metal into a mold.

Carbon steel—Steel that has carbon added to increase hardness.

Cementite—A grain structure found in steel that contains iron carbide and forms a mechanical mixture with austenite at room temperature.

Cold forming process—Uses force to shape metal while it is cold. Cold forming also increases strength and hardness.

Compressive strength—A metals resistance to being crushed by a force.

Copper—Metal that is malleable, easily worked, and very resistant to corrosion.

Critical temperature—A set temperature that each metal has that determines certain characteristics such as hardness.

Cupola furnace—A blast furnace with a cylindrical shaft that is used to melt iron.

Dead soft steel—Low carbon steel that is usually called black iron.

Ductility—A metal property that lets it be permanently bent, stretched, or formed without breaking.

Drawing process—Shapes metal by pulling it through a die.

Edge joint—A joint between the edges of two or more parallel or nearly parallel members.

Elasticity—A metal property that shows how much force of pull, bend, twist, or squeeze that metal can take and still return to its original shape.

Ferrite—A grain structure found in steel that contains a compound of iron and other elements that are soft and ductile.

Flashback—A very dangerous condition where the torch flame moves into or beyond the torch's mixing chamber.

Flux—A compound used prior to soldering to clean metal, aid solder flow, and reduce oxidation.

Forehand welding—A welding technique in which the welding torch or gun is directed toward the welding progress.

Free carbon—A Carbon that is not chemically bound in a molecule.

Free hand grinding—Method of using a hand held grinder without any attachments or guides.

Friction—Represents the resistance that an object has to moving or rubbing against another surface.

Forging process—Requires metal to be heated to a plastic like state so that it can be hammered into shape.

Fusion—Molten metal that is mixed together.

Fusion welding—Heating metals to a molten state to allow them to be joined together.

Galvanized iron—Low carbon steel that has a coating of zinc for corrosion resistance.

Grain structure—Pattern formed by the crystalline material found in all metals.

Hardness—A metal property that shows penetration resistance to an applied force such as drilling.

Hardening—A heat treatment process used to heat metal to a cherry red color and then cool it quickly. This action increases hardness in the metal.

Heat treatment—A process used to increase metal hardness.

Hot forming process—Uses force to shape metal that is above its critical temperature. Hot forming softens metal and reduces stress.

Ironworker—A heavy-duty machine designed to shear and bend thick steel plate, cut pipe, angle iron, punch holes, and notch ferrous and non-ferrous metals.

Kerf—A slot made in metal by a cutting torch.

Kindling temperature—A metal's preheating temperature that must be reached before cutting with an oxyacetylene cutting torch.

Laying surface—The mating (joining) surfaces of two metal members that are in contact or are in proximity to each other.

Lap joint—A joint between two overlapping members in parallel planes.

Lead—A soft metal that is not very strong but does resist chemicals and radioactive rays. It is also a component of solder.

Liquid state—The lowest temperature at which a metal or an alloy stays completely liquid.

Malleable—Metal that can be shaped or formed by hammering.

Martensite—A grain structure found in steel that's formed when steel, containing austenite is quenched quickly.

Metal, ferrous—Metal that contains iron.

Metal, Non-ferrous—Metal that does not contain iron.

Monel—An alloy that contains nickel, copper, iron, manganese, and cobalt. It is hard and ductile with good working qualities.

Pearlite—A grain structure found in steel that contains iron and iron carbides that form a fingerprint like structure.

Physical bond—A surface bond produced by applying a substance to the surface of another to join material together, as in brazing.

Plenum—An air distribution enclosure located above or below the air handler unit.

Pneumatic—A tool that is powered by compressed air.

Preheating—A process that heats metal to a certain temperature to prepare it for surfacing, welding, or cutting.

Propane tinner's furnace—A portable propane-gas-fired furnace that heats soldering coppers.

Quenching—A process to rapidly cool an item by contacting the item with fluids or gases. For example, using oil or water to cool hot metal.

Regulator—A gauge type device that is used with oxyacetylene gas welding and cutting. It shows and controls gas volume and pressure as it moves from the cylinder to the torch.

Silver brazing—A brazing process that process that uses silver to bond metal by capillary action between the closely fitted surfaces. The brazing temperature to use the silver filler must be above 450 degrees(C) 840 degrees (F) and below the base metal's solid state.

Silver soldering—A nonstandard term for brazing with a silver-based filler metal.

Soldering—A welding process to join metal by heating and melting a filler metal or alloy to a temperature of less than 840 degrees and less than the melting point of the metal to be joined.

Soldering coppers—Tools that are fire heated and then used to heat metal for the soldering process.

Soldering irons —Tools that are electrically heated and then used to heat metal for the soldering process.

Solid state—The highest temperature at which a metal or an alloy stays completely solid.

Spot welding—A welding process that confines the fusion of the molten pool to a spot sized area by using heat and pressure in a controlled sequence.

Stainless steel—A steel alloy that contains nickel, chromium, carbon, manganese and silicon. It is hard and resists scratches and corrosion. It is available in sheets that have a dull or polished finish.

Sweating—A soldering process where metal is heated and solder is flowed into a joint or seam.

Tee joint—A joint between two members located approximately at right angles to each other in the form of a"T".

Tensile strength—A metals resistance to a force that is trying to tear it apart.

Tinning—A process to apply a solder coating to soldering coppers and other metals that are to be soldered; reduce oxidation, and aid in solder flow.

Tinner's furnace—A gas fired furnace installed in a shop to heat soldering coppers.

Wear resistance—A metal property that shows the ability to resist cutting or abrasion by a sliding motion that is applied under pressure.

Weldment—An assembly of components that are joined by welding.

Wrought metal—Metal that has been shaped by force while it is in solid form.

Zinc—A medium soft metal that is very resistant to corrosion. Zinc is commonly used to coat black iron.

Abbreviations and Acronyms

AA Aluminum Association; aluminum alloy

AFOSH Air Force Occupational Safety and Health

AISI American Institute and Steel Institute

AMS Aeronautical material specifications

ANSI American National Standards Institute

ASTM American Society for Testing Material

AWS American Welding Society

BCE Base Civil Engineer

C Celsius

CFM cubic feet of air per minute

CFR Code of Federal Regulations

DOT Department of Transportation

F Fahrenheit

FPM feet per minute

MSDS Material Safety Data Sheet

MT empty

OC on center

ppsf pounds per square foot

psf per square foot

psi pounds per square inch

RPM revolutions per minute

SAE Society of Automotive Engineers

T thickness

Student Notes

Student Notes

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