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Preface

Introduction

The welding industry presents a continuously growing and changing series of opportunities for skilled welders. Even with economic fluctuations, the job outlook for skilled welders is positive. Due to a steady growth in the demand for goods fabricated by welding, new welders are needed in every area of welding such as small shops, specialty fabrication shops, large industries, and construction. The student who is preparing for a career in welding will need to

- have excellent eye–hand coordination.
- work well with tools and equipment.
- know the theory and application of the various welding and cutting processes.
- be able to follow written and verbal instructions.
- work with or without close supervision.
- have effective written and verbal communications skills.
- be able to resolve basic mathematical problems.
- work well individually and in groups.
- read and interpret welding drawings and sketches.
- be computer literate.
- be alert and work safely.

A thorough study of Welding: Principles and Applications in a classroom/shop setting will help students prepare for the opportunities in welding technology. The comprehensive technical content provides the basis for the welding processes. The extensive descriptions of equipment and supplies, with in-depth explanations of their operation and function, are designed to familiarize students with the tools of the trade. The process descriptions, practices, and experiments coupled with actual performance teach the critical fabrication and welding skills required on the job. The text also discusses occupational opportunities in welding and explains the training required for certain welding occupations. The skills and personal traits recommended by the American Welding Society (AWS) for its Certified Welder program are included within the text. Students wishing to become certified under the AWS program must contact the American Welding Society for specific details.

The National Center for Welding Education and Training, known as Weld-Ed, is a partnership between business and industry, community and technical colleges, universities, the American Welding Society, and government to promote welding education.

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Section 5

Related Processes

Chapter 32

Oxyacetylene Welding

OBJECTIVES

After completing this chapter, the student should be able to

- explain how to set up and weld mild steel.
- make a variety of welded joints in any position on thin-gauge, mild steel sheet.
- make a satisfactory weld on small diameter pipe and tubing in any position.
- explain the effects of torch angle, flame height, filler metal size, and welding speed on gas welds.

KEY TERMS

1G position
2G position
5G position
6G position
burnthrough
flashing
flat butt joint
heat sink
horizontal welds
keyhole
kindling point
lap joint
molten weld pool
out-of-position welding
outside corner joint
overhead weld
overlap
penetration
shelf
tee joint
torch angle
torch manipulation
trailing edge
undercut
vertical weld
weld crater

INTRODUCTION

Oxyacetylene welding is limited to thin metal sections or to times when portability is important. During the early years of welding, oxyacetylene was used to weld thick plate, 1 in. (25 mm) and thicker. Today, it is used almost exclu- sively on thin metal, 11 gauge or thinner. One of the arc welding processes is most often used today for welding metal thicker than 16 gauge. Some of the arc welding processes, such as GMAW, are replacing the gas welding processes on metals as thin as 28 gauge, Figure 32-1. Because of the expanded use of arc welding processes on thinner sections, we will concentrate on the use of gas welding on metal having a thickness of 16 gauge (approximately 1/16 in. [2 mm]) or thinner.

MILD STEEL WELDS

Mild steel is the easiest metal to gas weld. With this metal, it is possible to make welds with 100% integrity (lack of porosity, oxides, or other defects) and that have excellent strength, good ductility, and other positive char- acteristics. The secondary flame shields the molten weld pool from the air, which would cause oxidation. The atmospheric oxygen combines with the carbon monoxide (CO) from the outer flame envelope to produce carbon dioxide (CO2). The carbon dioxide will not react with the molten weld pool. In addition, the carbon dioxide forces the surrounding atmosphere away from the weld.

Abbreviations for Units				
Units	Standard		Metric	
Temperature	F	Fahrenheit	C	Celsius
Length	yd ft in.	yard feet inches	m cm mm	meter centimeter millimeter
Weight	lb oz	pounds ounces	kg g	kilogram grams
Liquid	gal qt pt oz	gallons quarts pints ounces	L	liters
Pressure	psi	pounds per square in.	kPa	kilopascal

TABLE 18-1 Common Abbreviations for Units of Measure

Factors Affecting the Weld

Torch Tip Size The torch tip size should be used to control the weld bead width, penetration, and speed. **Penetration** is the depth into the base metal that the weld fusion or melting extends from the surface, excluding any reinforcement. Because each tip size has a limited operat- ing range in which it can be used, tip sizes must be changed to suit the thickness and size of the metal being welded. Never lower the size of the torch flame when the correct tip size is unavailable. If the flame size or volume is lowered below the correct size by lowering the gas flow, the tip will overheat. If the flame is lowered significantly, the tip can overheat even without using it to weld. Overheated tips will backfire. Backfiring can cause dan- gerous flashback.

Other factors that can be changed to control the weld size are the torch angle, the flame-to- metal distance, the welding rod size, and the way the torch is manipulated.

1. have excellent eye–hand coordination.
2. work well with tools and equipment.
3. know the theory and application of the various welding and cutting processes.
4. be able to follow written and verbal instructions.

CAUTION

It is never safe to lower the flame size if the tip's flame produces too much heat for your welding job. Get a smaller tip or change your welding technique.

Torch Angle The **torch angle** and the angle between the inner cone and the metal have a great effect on the speed of melting and size of the molten weld pool. The ideal angle for the welding torch is 45°. As this angle increases toward 90°, the rate of heating increases. As the angle decreases toward 0° to the plate's surface, the rate of heating decreases, as illustrated in **Figure 32-2.** The dis- tance between the inner cone and the metal ideally should be l/8 in. to 1/4 in. (3 mm to 6 mm). As this distance increases, the rate of heating decreases; as the distance decreases, the heating rate increases, **Figure 32-3.**

Welding Rod Size Welding rod size and **torch manipulation** can be used to control the weld bead characteristics. A larger welding rod can be used to cool the molten weld pool, increase buildup, and reduce pen- etration, **Figure 32-4A, B,** and **C.** The torch can be manipulated so that the direct heat from the flame is flashed off the molten weld pool for a moment to allow it to cool, **Figure 32-5.**

CHARACTERISTICS OF THE WELD

The molten weld pool must be protected by the sec- ondary flame to prevent the atmosphere from contami- nating the metal. If the secondary flame is suddenly moved away from a molten weld pool, the pool will throw off a large number of sparks. These sparks are caused by the rapid burning of the metal and its alloys as they come into contact with oxygen in the air. This is particularly a problem when a weld is stopped. The weld crater is especially susceptible to cracking. This tendency is greatly increased if the molten weld pool is allowed to burn out, Figure 32-6. To prevent burnout,

- have excellent eye–hand coordination.
- work well with tools and equipment.
- know the theory and application of the various welding and cutting processes.
- be able to follow written and verbal instructions.

The sparks that occur as the weld progresses are due to metal components that are being burned out of the weldment. Silicon oxides make up most of the sparks, and extra silicon can be added by the filler metal so that the weldment retains its desired soundness. A change in the number of sparks given off by the weld as it pro- gresses can be used as an indication of changes in weld temperature.

An increase in sparks on clean metal means an increase in weld temperature. A decrease in sparks indicates a decrease in weld temperature. Often the number of sparks in the air increases just before a burnthrough takes place—that is, burning out the molten metal that appears on the back side of the plate. This burnout does not happen to molten metal until it reaches the kindling point (the temperature that must be attained before something begins to burn). Small amounts of total penetration usually will not cause a burnout. When the sparks increase quickly, the torch should be pulled back to allow the metal to cool and prevent a burnthrough.

THINK GREEN

Conserve Filler Metal

The short ends of both welding and brazing rods can be fused together so that the amount of scrap filler metal can be minimized, unlike most other filler metal such as SMAW, GMAW, and FCAW. Being able to use all of the filler metal can be a significant saving of shop funds and reduces waste materials.

EXPERIMENT 32-1

Flame Effect on Metal

The first experiment examines how the flame affects mild steel. Use a piece of 16-gauge mild steel and the proper-size torch tip. Light and adjust the flame by turn- ing down the oxygen so that the flame has excessive acetylene. Hold the flame on the metal until it melts and observe what happens, Figure 32-7. Now adjust the flame by turning up the oxygen so that the flame is neu- tral. Hold this flame on the metal until it melts and observe what takes place, Figure 32-8. Next, adjust the flame by turning up the oxygen so that the flame has excessive oxygen. Hold this flame on the metal until it melts and observe what happens, Figure

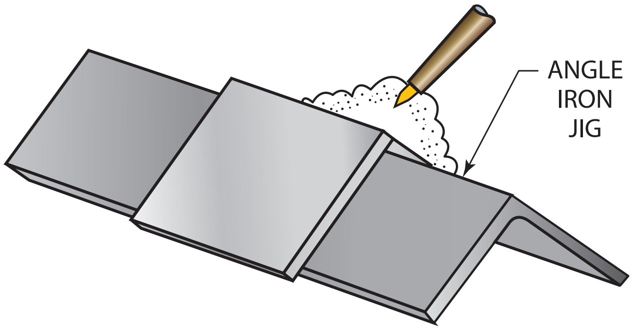


FIGURE 32-25 The keyhole in the root of the joint helps to ensure 100% root penetration. © Cengage Learning 2012

32-9. Repeat this experiment until you can easily identify each of the three flame settings by the flame, molten weld pool, sound, and sparks.

Before actual welding is started, it is a good idea to find a comfortable position. The more comfortable or relaxed you are, the easier it will be for you to make uniformwelds. The angle of the plate to you and the direction of travel are important.

Place a plate on the table in front of you and, with the torch off, practice moving the torch in one of the sug- gested patterns along a straight line, as illustrated in Figure 32-10. Turn the plate and repeat this step until you determine the most comfortable direction of travel. Later, when you have mastered several joints, you should change this angle and try to weld in a less comfortable position. Welding in the field or shop must often be done in positions that are less than comfortable, so the welder needs to be somewhat versatile.

It is important to feed the welding wire into the molten weld pool at a uniform rate. Figure 32-11A and B show some suggested methods of feeding the wire by hand. It is also suggested that you not cut the welding wire into two pieces for welding. Short lengths are easy to use, but this practice often results in wasted filler metal. The end of the welding wire may be rested on your shoulder so that it is easy to handle. ◆

NOTE

Being able to use all of the filler metal can be a significant saving of shop funds and reduces waste materials. It is never safe to lower the flame size if the tip's flame produces too much heat for your welding job. Get a smaller tip or change your welding technique.

PRACTICE 32-2

Beading

Repeat Experiment 32-2 until you can control the change in the size of the molten weld pool, as shown in Figure 32-17. After the control of the molten weld pool has been mastered, you are ready to start adding filler rod. When selecting and adding filler metal, the following are some facts to remember.

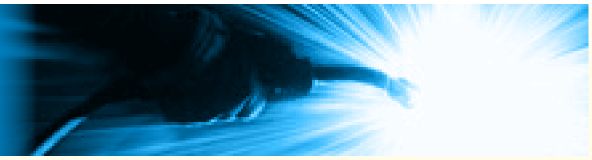
Selecting the proper size or correct diameter of filler metal will help control the weld bead width, buildup, and penetration. A large diameter filler rod can be used as a heat sink (something to draw off excessive heat) to keep the molten weld pool narrow, with little penetration and high buildup. As the diameter of the filler wire is decreased, the heat-absorbing effect decreases, and the molten weld pool becomes wider, with deeper penetration and reduced buildup. On thin metal. Another thing to remember when adding filler metal to a weld is to keep a smooth. ◆

Summary

In an ideal world we would all have the correct tip size for every job we attempted; however, in reality often the oxyfuel welding process is used for repair work when it is not possible to have an infinite selec- tion of tip sizes. Learning to control the heat input to the weld by changing the torch angle, height, or travel speed is important so that you can produce satisfactory welds under these service conditions. It is not safe or recommended that you turn down the flame below the tip's optimal operating capacity. Therefore, you must learn to control the heat by changing the angle, tip height, or travel speed.

Oxyacetylene welding is the process of preference for part-time and amateur welders. It allows them the greatest flexibility and is often the most forgiving. The most common problem OF welding presents is heat and weld distortion on large weldments. Because of the difficulty in controlling distortion and the time required to make large welds, other welding processes are often selected for such welds. That is not to say that large welds are not possible with OF welding; they just take more time and skill.

Confined Space Monitors: Tough Choices for Tight Spots



Reliable operation and proper features in a gas monitor are a must if you are working in a confined space.

Confined space—just the sound of it appears challenging to those who are even slightly claustrophobic. Read the Occupational Safety and Health Administration's (OSHA's) definition of a permit-required confined space—". . . an area with limited or restricted means of entry and exit: not designed for continuous human occupancy; potential to contain a hazardous atmosphere"—and it is apparent that these areas are somewhat less than desirable places to spend the workday. Unfortunately for many, entry and work in confined spaces are a fact of everyday work life.

Confined spaces exist in almost every industry and in every workplace. If you are an electrician, a plumber, a pipe fitter, a welder, a boiler maker, a carpenter, or an emer- gency service worker, chances are that at some point your daily duties will require you to enter a confined space and be challenged by the hazards that await there.

Know the Hazards

Some of the hazards in confined spaces are easily recog- nized. It can be relatively easy to see the potential for falls or entrapment from cave-ins or falling equipment. However, it is the unseen atmospheric hazards that present the greatest danger in a confined space. The lack of breathable oxygen, the potential for explosion due to dangerous levels of combustible gases, or the presence of deadly poisonous gas vapors, such as carbon monoxide, cannot be seen. Therefore, you must rely on the readings of a portable gas- monitoring instrument to alert you of potential danger.

Before you drop down a manhole or crawl into a tank car, following are some considerations concerning the gas monitor you choose and the procedures you follow to ensure your safety.

Choosing the Right Sensor

Make sure the sensors in the instrument you are using are appropriate for the confined space. Many people con- sider a confined space monitor to be the same as a four-gas instrument containing sensors for oxygen, combustible gas, carbon monoxide, and hydrogen sulfide. Although it is true that most confined spaces potentially contain some hazards related to one of these gases, it is not true for all. If you are entering a space that may contain chlorine, an instrument with carbon monoxide and hydrogen sulfide sensors is of little use. Many instruments offer you the abil- ity to change the sensors to match the hazard you will encounter. These instruments provide greater flexibility and value in a wide variety of applications.

A gas-monitoring instrument must be durable and able to withstand harsh conditions. Although a portable gas detector is certainly a sophisticated piece of electronic.

Working in confined spaces poses potential hazards that require special precautions. American Welding Society equipment, it is still a tool. As such, it is subjected to the rig- ors of the environment it is used in, just as is any other tool. It is dropped, dunked, or caught up in other equipment, and all the while it must still provide a potentially life-sav- ing service. Be certain the instrument you choose is con- structed in a manner that will not let its, or your, survival in a tough environment be left to chance.

Confined space preentry tests require remote sampling of the atmosphere from outside the space. Therefore, the instrument you choose must have the capability of using a remote sample pump. The pump must be able to draw an adequate sample flow over the distance required to cover the entire space. The pump also should be able to detect and clearly inform you if the sample line

FIGURE 32-1 Gas metal arc welded (GMAW) on 16-gauge mild steel. Larry Jeffus

is blocked, thereby preventing gas flow to the instrument and its sensors.

Be certain that the sample tube material you are using with the pump is of high quality and is compatible with the vapors that you expect to encounter. Some highly reactive gases, such as chlorine, nitrogen dioxide, and hydrogen chloride, may be absorbed into the walls of the tubing and scrubbed from the sample stream. Never use sample tubing made of materials containing silicone rubber compounds. The silicone vapors may off-gas from the tubing and poison catalytic bead-type combustible gas sensors, leaving the instrument unable to detect explosive gases. Sample tubing made of urethane or FEP (Teflon) is generally suitable for most applications.

Check the Power

A gas monitor should be able to operate from a variety of power supplies. Rechargeable batteries are generally best for portable monitoring instruments because the com- bustible gas sensors used in the detectors consume large amounts of battery power. Extended confined space opera- tions often require instrument run times beyond the capac- ity of the rechargeable batteries. The ability to replace the rechargeable battery pack with disposable alkaline or lithium battery cells will certainly come in handy in these sit- uations. In addition, make sure that the instrument is capa- ble of running the required amount of time when the sample pump is being used. Some sample pumps use the instrument's battery for power and reduce the run time of the instrument much more than you might expect.

Know the detection limits of the instrument. There are clear differences in the measuring ranges of sensors in vari- ous instruments. As a rule of thumb, the monitor should be capable of measuring concentrations approaching the immediately dangerous to life and health (IDLH) level of the target gas. All catalytic combustible gas sensors require a minimum background oxygen concentration be present to respond accurately. Be aware of what that level is and make sure the instrument you choose can be used with a dilution apparatus. By doing so, you will ensure the accuracy of the combustible detector when sampling from an inert or oxygen-deficient atmosphere.

Calibrate Often

Beware of claims that instruments do not need to be tested or calibrated on a regular basis. Know one thing for sure: the only way to ensure a gas monitor will respond to gas is to test and verify its operation with known concentra- tions of the target gases prior to each use. For example, someone using the instrument before you might have dam- aged one of the sensors, resulting in no difference in the response of a catalytic or an electrochemical gas sensor used in a clean atmosphere from one that has failed catastrophi- cally. Regular calibration and functional testing will guaran- tee that the instrument and its sensors are working properly. Whether or not it is done is up to you. If calibration and test- ing are too difficult and cumbersome for you to do on your own, docking systems and service programs are available to perform these tasks automatically on your instruments and to document the results.

Keep Monitoring

Whether to monitor continuously or not is an often- asked question. Usually, confined space atmospheres are tested before entry to complete the required permits, and then the gas monitor is put back on the truck until the next test. Unfortunately, the work done while in the confined space may create an unseen hazard. Chemical reactions with solvents during cleaning processes in tanks or vapors produced during maintenance operations, such as welding, can build up dangerous gases in a confined space while you work. Continuous monitoring of the space's atmosphere during the entire entry will ensure there is no danger.

An instrument capable of activating a remote alarm will also alert your partner watching from outside to hazardous conditions.

There are so many choices and so little room for error. Make sure you take time to know and understand the haz- ards of confined space operations and ensure you have the right equipment. It could save your life.

Article courtesy of the American Welding Society.

Glossary

The terms and definitions in this glossary are extracted from the American Welding Society publication AWS A3.0-80 Welding Terms and Definitions. The terms with an asterisk are from a source other than the American Welding Society. Note: The English term and definition are given first, followed by the same term and definition in Spanish.

A

***abrasives.** Materials that are usually sharp and are used to clean or grind a surface. They may be used as a powder such as sand to blast the surface or they may be formed into disks or stones to be used by a grinder.
abrasivos. Materiales que son por lo general ásperos y que se uti- lizan para limpiar o pulir superficies. Pueden venir en polvo, como arena, para bruñir las superficies, o en forma de discos o piedras para ser usados por una esmeriladora.

***absolute pressure.** The sum of the gauge pressure and the atmospheric pressure.
presión absoluta. La suma de la presión manómetro y la presión atmosférica.

absorptive lens. A filter lens designed to attenuate the effects of transmitted and reflected light.
lente absorbente. Un lente de filtro diseñado para disminuir los efectos de la luz y la reflexión de la luz extraviada.

acceptable criteria. Agreed upon standards that must be satis- factorily met.
criterios aceptables. Las normas sobre las que se ha llegado a un acuerdo y que deben cumplirse en forma satisfactoria.

acceptable weld. A weld that meets all the requirements and the acceptance criteria.
soldadura aceptable. Una soldadura que satisface los requisitos y el criterio aceptable prescribida por las especificaciónes de la soldadura.

***acetone.** A fragrant liquid chemical used in acetylene cylinders. The cylinder is filled with a porous material and acetone is then added to fill. Acetylene is then added and absorbed by the acetone, which can absorb up to 28 times its own volume of the gas. **acetona.** Un liquido fragante químico que se usa en los cilindros del acetileno. El cilindro se llena de un material poroso y luego se le agrega la acetona hasta que se llene. El acetileno es absorbido por la acetona, la cual puede absorber 28 veces el propio volumen del gas.

***acetylene.** A fuel gas used for welding and cutting. It is produced as a result of the chemical reaction between calcium carbide and water. The chemical formula for acetylene is C_2H_2. It is color- less, is lighter than air, and has a strong garlic-like smell. Acetylene is unstable above pressures of 15 psig (1.05 kg/cm2 g). When burned in the presence of oxygen, acetylene produces one of the highest flame temperatures available.
acetileno. Un gas combustible que se usa para soldar y cortar. Es producido a consecuencia de una reacción química de agua y

B

calcio y carburo. La fórmula química para el acetileno es C_2H_2. No tiene color, es más ligero que el aire, y tiene un olor fuerte como a ajo. El acetileno es inestable en presiones más altas de 15 psig (1.05 kg/cm2 g). Cuando se quema en presencia del oxígeno, el acetileno produce una de las llamás con una temperatura más alta que la que se utiliza.

***acicular structure.** A fine micrograin structure found in rapidly cooled steel.
***estructura acicular.** Una estructura micro granulada fina que se encuentra en el acero que se ha enfriado con rapidez.

actual throat. See throat of a fillet weld.
garganta actual. Vea garganta de soldadura filete.

***adaptable.** Capable of making self-directed corrections; in a robot, this is often accomplished with visual, force, or tactile sensors. **adaptable.** Capaz de hacer correcciones por

***absolute pressure.** The sum of the gauge pressure and the atmospheric pressure.
presión absoluta. La suma de la presión manómetro y la presión atmosférica.

absorptive lens. A filter lens designed to attenuate the effects of transmitted and reflected light.
lente absorbente. Un lente de filtro diseñado para disminuir los efectos de la luz y la reflexión de la luz extraviada.

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Apendix