

Recommended Practices for Oxyacetylene Welding of Steel



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An American National Standard

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Recommended Practices for Oxyacetylene Welding of Steel

1st Edition

Prepared by the
American Welding Society (AWS) C4 Committee on Oxyfuel Gas Welding and Cutting

Under the Direction of the
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

These recommended practices for oxyacetylene welding include the latest procedures to be used in conjunction with oxyacetylene equipment and the latest safety recommendations. Complete lists of equipment are available from individual manufacturers.



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This standard is subject to revision at any time by the AWS C4 Committee on Oxyfuel Gas Welding and Cutting. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS C4 Committee on Oxyfuel Gas Welding and Cutting and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS C4 Committee on Oxyfuel Gas Welding and Cutting to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Foreword

This foreword is not part of this standard but is included for information purposes only.

Oxyacetylene welding is alive and well in welding shops around the world. Oxyacetylene welding is very useful in maintenance and repair work. The process is flexible and mobile, and it can be used as a stand-alone process or as a supplement to other welding processes in large welding facilities concerned with both job-shop type work and industrial processes. This recommended practice will address only the use of acetylene because of its combustion and chemical reaction qualities. This is the first edition of the document.

The safety concerns are the same as those documented in C4.2, *Recommended Practices for Oxyfuel Gas Cutting Torch Operation*, C4.3, *Recommended Practices for Oxyfuel Gas Heating Torch Operation*, and ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

This recommended practice describes the equipment, applications, and safe practices for oxyacetylene gas welding operations. It can be used as a teaching and training tool for the safe operation of an oxyacetylene torch in welding operations. This recommended practice is intended for use by the oxyacetylene welder and/or his or her instructor. This document includes all the information necessary for the end user (welder) or management to oxyacetylene gas weld steel. While slower than arc welding, oxyacetylene welding produces high-quality welds. It is inexpensive, flexible, and mobile. It requires no electricity. It is clean and produces no slag or spatter. This recommended practice describes the process and provides information relating to equipment, safety, and operating procedures. Much of the information in this recommended practice is general in nature. There is a variety of equipment available from several manufacturers; therefore, it is recommended that each manufacturer's equipment manual be consulted for details about the operation of said equipment before putting it to use.

Acetylene is the only fuel gas suitable for welding of steel. The other alternative fuel gases (e.g., Propane, Propylene, and Natural Gas) are not really viable fuel gases for gas welding. This process (e.g., Oxyfuel Gas Welding) will be hereby known as Oxyacetylene Welding (OAW) in this recommended practice. Thus, Oxyacetylene Welding can be used for the welding of steel pipe and tubing, steel sheet metal, and small sized structural steel shapes and bars. This recommended practice is meant to be used in shops and for field maintenance. It does not cover welding in confined spaces, welding over coatings of any kind, and welding where there may be exposure to potentially hazardous substances. The process is generally not recommended for welding high-strength heat treatable steels such as that used on most modern automobiles. ICAR (Inter-Industry Conference on Collision Repair) no longer accepts the use of OAW for repairs. They recommend the use of Gas Metal Arc Welding (GMAW) for most repairs.

Comments and suggestions for the improvement of this recommended practice are welcome. They should be sent to the Secretary, AWS C4 Committee on Oxyfuel Gas Welding and Cutting, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166-6672.

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Recommended Practices for Oxyacetylene Welding of Steel

1. General Requirements

1.1 Scope. This recommended practice describes the equipment, procedures, and safe practices for the oxyacetylene welding of steel. This process is most commonly used for welding carbon steels; however, it is sometimes used on alloy steels, cast iron, aluminum, brass, bronze, copper, nickel, and tin. It is for manual welding using hand torches and is recommended for end users (welders) and management personnel associated with the oxyacetylene welding process.

Oxyacetylene Welding (OAW) is a process where a metal (usually an iron base alloy) is heated to its melting point by an oxyacetylene flame. A welding torch is used for this operation. OAW uses the combustion of acetylene gas in a mixture with oxygen. Acetylene is the fuel gas of choice because it has the ability, along with oxygen, to form a gaseous shield around the molten metal protecting it from ambient contaminants until the molten metal cools. Acetylene is also preferred because most of the heat is concentrated at the tip of the inner cone. This heat focus allows better control to move the weld pool. Virtually all the commercial fuel gases can produce temperatures high enough to melt most metals but acetylene remains the fuel gas of choice because acetylene has the higher combustion temperature. During the welding process, filler material may be added, but it is not always needed. The filler material is used to fill in, build up, and strengthen the weld. OAW is a better choice because the flame condition (reducing, natural, and oxidizing) is easy to adjust compared to other fuel gas mixtures. OAW is not suggested for the fabrication or repair of high-strength steels or heat-treatable metals. OAW is very widely used for maintenance and repair, where flexibility and mobility are important.

Although this recommended practice is not written with mandatory requirements, mandatory language, such as the use of “shall,” will be found in those portions of the document where failure to follow the instructions or procedures could produce inferior, misleading, or unsafe results.

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*, are included in Annex B of this recommended practice for information only.

1.2 Units of Measure. This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets ([]) or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

1.3 Safety. Safety issues and concerns are addressed in this standard, while some safety and health information is provided; some issues and concerns are not fully addressed herein as they are beyond the scope of this standard.

Safety and health information is available from the following sources:

American Welding Society:

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) ANSI Z87.1, *American National Standard for Occupational and Educational Eye and Face Protection*
- (3) AWS Safety and Health Fact Sheets
- (4) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies:

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

American Welding Society (AWS) standards:

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*

AWS A5.2/A5.2M, *Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding*

AWS F4.1, *Safe Practices for the Preparation of Containers and Piping for Welding and Cutting and Allied Processes*

American National Standards Institute (ANSI) standards:

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

ANSI Z87.1, *American National Standard for Occupational and Educational Eye and Face Protection*

Compressed Gas Association (CGA) standards:

CGA E-5, *Torch Standard*, Chantilly, VA: Compressed Gas Association

International Standards Organization (ISO) standards:

ISO 3821, *Gas welding equipment—Rubber hoses for welding, cutting and allied processes*

ISO 5175, *Equipment used in gas welding, cutting, and allied processes—Safety devices for fuel gases and oxygen or compressed air—General specifications*, Geneva: International Organization for Standardization

Military Performance Specification (MIL-PRF) standards:

MIL-PRF-25567E Dated 1998, *Performance Specification, Leak Detection Compound, Oxygen Systems*

National Fire Protection Agency (NFPA) standards:

NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*

NFPA 55, *Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks*

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3. Terms and Definitions

AWS A3.0M/A3.0, Standard Welding Terms and Definitions, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accommodate usage specific to this document.

Additional definitions from AWS A3.0M/A3.0 are included in Annex B of this Recommended Practice.

acetone. A colorless, flammable, volatile, water-soluble liquid (C_3H_6O) used in acetylene cylinders to dissolve and stabilize acetylene gas under high pressure. Acetone is capable of absorbing 25 times its volume of acetylene gas under normal pressure and temperature.

acetylene. A flammable gas that has a molecule consisting of two, triple bonded carbon atoms with two hydrogen atoms (C_2H_2). Welding grade acetylene shall be used that meets the Compressed Gas Association (CGA) requirements. When mixed and burned with welding grade oxygen, it produces the highest fuel gas flame temperature obtainable. It is the more popular of the fuel gases used for Oxyfuel Gas Welding (OFW).

acetylene bottle. A non-standard term for **acetylene cylinder**.

acetylene cylinder. A gas cylinder, manufactured according to regulatory standards, such as the Department of Transportation (D.O.T.) in the United States, used for transportation and storage of acetylene gas only.

acetylene flame. The burning acetylene gas (an orangish colored flame) in air from a welding tip prior to the insertion of additional, non-atmospheric oxygen.

acetylene regulator. A gas regulator designed for use with acetylene only.

autogenous bead. A fusion bead made without filler metal (or material).

check valve. Between the torch and hose on both oxygen and fuel gas lines, a check valve is installed between the torch handle and hose to prevent the oxygen, fuel gas or oxygen-fuel gas mixture from being pushed back into either the equipment and/or cylinder.

coupling distance. A non-standard term for **torch height**.

cylinder safety cap. A metal cover used to protect gas cylinder valves.

hose. Flexible, gas tight, cylindrical medium used to carry gases from a gas regulator to the oxyfuel gas welding torch. For oxyacetylene usage, it is usually made of fabric and rubber.

industrial quality safety glasses/goggles. Eyewear that has industrial quality lenses (having appropriate safety lens marking) and side shield protection.

inner cone. The conical part of an oxyfuel gas flame adjacent to the welding tip orifice.

melting point. The temperature (solidus—where melting starts) at which a material begins to melt (liquefy).

mixer. A non-standard term for **torch mixer**.

orifice. Opening in the welding tip out of which gases flow.

outer envelope of flame. Region of flame where hydrogen and carbon monoxide are combined with air and burned.

oxygen. A gas formed of the element oxygen. Welding grade oxygen shall be used that meets the Compressed Gas Association (CGA) requirements. When it very actively supports combustion, it is called burning. When it slowly combines with a substance, it is called oxidation.

oxygen bottle. A non-standard term for **oxygen cylinder**.

oxygen cylinder. A gas cylinder manufactured according to regulatory standards, such as the Department of Transportation (D.O.T.) in the United States, used for transportation and storage of oxygen gas only.

oxygen regulator. A gas regulator designed for use with oxygen gas only.

oxyacetylene flame. Oxygen and acetylene gases mixed together and burned, creating the highest flame temperature of the different fuel gases used in oxyacetylene welding.

oxyacetylene welding torch. A device used in oxyacetylene welding for directing the heating flame produced by the controlled combustion of acetylene and oxygen gases.

reinforced bead. A fusion bead made with filler metal (or material).

reverse flow check valve. Between the torch and hose on both oxygen and fuel gas lines, a reverse flow check valve is installed to prevent the oxygen, fuel gas or oxygen-fuel gas mixture from being pushed back into either the equipment and/or cylinder.

spontaneous combustion. The type of combustion which occurs by self-heating (increase in temperature due to exothermic internal reactions), followed by thermal runaway (self-heating which rapidly accelerates to high temperatures) and finally, ignition.

tip. A non-standard term for **welding tip**.

torch angle. A welding tip moves at a travel angle of approximately 45° (degrees) and a work angle of approximately 90° (degrees) with respect to the line of travel on the base metal (material).

torch body. A non-standard term for **torch handle**.

torch handle. The device held by the welder to which the acetylene hose and oxygen hose are connected, then the acetylene torch valve meters the acetylene gas and the oxygen torch valve meters the oxygen gas, both gases (acetylene and oxygen) are thoroughly mixed and then the acetylene and oxygen gas mixture is delivered to the welding tip.

torch height. The height of the welding tip above the base material.

torch mixer. A separate assembly between the torch handle and the welding tip containing a mixing chamber. The torch valves in the torch handle control the flow of oxygen and acetylene resulting in a combustible mixture required for welding. These mixed gases then flow into the welding tip to be ignited in order to perform the welding application.

torch valve—acetylene. The part of the torch handle that controls the flow of acetylene into the mixing chamber.

torch valve—oxygen. The part of the torch handle that controls the flow of oxygen into the mixing chamber.

torch speed. The speed with which the welder moves the torch during the welding process.

4. Oxyacetylene Welding Process

Oxyacetylene Welding (OAW) was the first successful fusion welding process that used a flame produced by chemical combustion.

The use of a very hot gas flame for welding dates back to the late 1800s when a torch was designed for use in welding precious metals which burned a mixture of oxygen and hydrogen. This oxygen-hydrogen flame melted and welded platinum (which has a melting point much higher than either gold or silver) and was used in the jewelry trade. In 1895, a French chemist named LeChatelier showed that higher temperatures were possible when a combination of acetylene and oxygen was combusted. At about this time, a method for producing calcium carbide was developed by Willson and Morehead in North Carolina. Calcium carbide (CaC_2) is generated by the carbothermic reduction of lime (CaO) in a furnace at $\sim 3632^\circ\text{F}$ [2000°C]. Also, a machine for producing liquid oxygen was put into use in Indiana. In 1897, a method to stabilize acetylene in acetone was invented in France. This provided safer handling of this unstable gas. While pursuing his hobby of making rubies, John Harris of Cleveland, Ohio, decided to build the biggest and best ruby in the world. Accidentally, he “cut” the steel plate with an oxyfuel gas torch where the ruby had been partly formed. This resulted in the first flame-cutting of metal. Mr. Harris exhibited acetylene torches for the first time at the St. Louis World Fair in 1904. He later started the Harris Calorific, Inc. company which has grown into one of the largest independent manufacturers of calorific (meaning the science of heat) equipment in the country. Elmer Smith, the founder of the Smith Welding Equipment Company in Minnesota, was a pioneer in inventing and improving welding and cutting equipment. A little after the turn of the century, he invented a successful and safe welding torch. Gas welding and cutting became widely accepted and safely used by American industry.

Today, oxyacetylene welding is a welding process that produces the coalescence of metals by heating the workpieces with an oxyacetylene flame. These processes are used with or without the addition of pressure, and with or without a filler material. The oxyacetylene flame can also be used for brazing, cutting, heating and heat treating of metals, and is used in both the production and repair of weldments.

Oxyacetylene welding offers the following advantages:

- (1) Control by the welder over the temperature (e.g., heat input), independent of the addition of filler material;
- (2) Control by the welder of the size and shape of an OAW bead;
- (3) The equipment used is low in cost and easily moved; and
- (4) Different kinds of torch attachments allow for welding, brazing, soldering and cutting as well as for bending, preheating, postheating, straightening, and surfacing.

Oxyacetylene welding has the following disadvantages:

- (1) The process is not usually suggested for specialty metals such as high-strength steels, heat-treatable metals, or stainless steel; and
- (2) Although the weldments produced are of a high quality, the process is considered slow by today’s welding standards.

4.1 The Gases Used in Oxyacetylene Welding

4.1.1 Oxygen. Oxygen is colorless, odorless, and tasteless. It is the basis for all life on Earth and common in nature. The atmosphere is about 21% oxygen. Oxygen should always be called by its proper name, “OXYGEN,” and shall never be called “AIR.” Oxygen combines with various elements in a process called oxidation. It combines with metals to form oxides, such as rust, which is an iron oxide.

Fire is the process where oxygen rapidly combines with another material; this process is also called combustion. Most fires simply use the oxygen that is in the air. For welding, pure oxygen is used because it makes the acetylene burn more efficiently. It also has moisture and contaminants removed that could otherwise affect weldability and quality.

Pure oxygen can be supplied in many ways. It could be compressed into portable cylinders and delivered to shops. Larger shops may have oxygen piped to the shop’s welding stations from a large liquid oxygen container. This is called a piping (manifold) system. It is the most efficient way to supply large quantities of oxygen for welding.

4.1.2 Acetylene. Acetylene is a compound containing carbon and hydrogen. Its chemical formula is C_2H_2 . Acetylene is about 92.3% carbon and 7.7% hydrogen by weight. It is colorless, tasteless, and due to impurities, it often has a “garlic like odor.” Acetylene is slightly lighter than air and is unstable at pressures over 15 psig [100 kPa] (gauge pressure above atmospheric pressure at sea level). All acetylene regulators show a maximum of 15 psig [100 kPa] on the working pressure gauge. Above 15 psig [100 kPa], the scale of the gauge is red as an indicator.

A sufficient supply of acetylene should always be available. Acetylene gas is supplied in individual cylinders which may be distributed by manifolding cylinders together. An acetylene cylinder shall not be completely drained, nor shall the valve be left open on “empty” cylinders. This could result in contamination of the cylinder.

Acetylene can be used for all the flame processes. This includes welding, brazing, soldering, cutting, and flame hardening of parts. It provides the hottest flame; the temperature of the neutral welding flame is 6000°F [3300°C].

4.1.3 Combustion Process. In oxyacetylene welding, two metals are joined by melting and fusing their adjoining surfaces together. This is done by passing a gas flame over the base metal(s) until a molten weld pool is formed. A filler material may also be melted into the weld pool to help the base metal(s) flow together and form one piece. The energy for oxyacetylene welding comes from the burning of a fuel with oxygen. A ratio of 1 part oxygen to 1 part acetylene is first mixed in the torch handle. It then burns at the tip of the torch and is controlled by torch adjustment. The final combustion ratio of 2.5 parts oxygen to 1 part acetylene is reached by combining 1.5 parts oxygen from the atmosphere to complete combustion. This results in a hot outer envelope (2400°F [1300°C]) and a very hot inner cone (6000°F [3300°C]). Oxygen is the gas that supports combustion. Acetylene is the most popular fuel gas used with 99.95% pure oxygen to weld metal with the oxyacetylene welding process. The acetylene flame can be changed by adding various amounts of oxygen to produce the desired flame (e.g., temperature) for a specified weldment. The other alternative fuel gases (e.g., Propane, Propylene, and Natural Gas) are not really practical fuel gases for gas welding. Thus, oxyacetylene welding could be used for the welding of steel pipe and tubing, steel sheet metal, and small sized structural steel shapes and bars. This is because of its higher flame temperature when compared to other gas combinations, as well as its capabilities, portability, availability, and cost.

5. Safety with Oxyacetylene Welding

While not all health and safety issues are addressed, the following safety issues are relevant.

The welder, assistants, and observers shall take necessary safety precautions during oxyacetylene welding operations. The possible adverse results of welding cannot be overstressed. Potentially hazardous conditions are:

- (1) open flames and emitted infrared and ultraviolet light from the flames;
- (2) welding sparks and welding spatter; and
- (3) oxygen and acetylene gas and their storage cylinders, and
- (4) fumes and heat given off from welding.

5.1 Personal Protective Equipment (PPE). Protective clothing and equipment for oxyacetylene welding operations could vary with the size, nature, and location of the work to be performed.

Some or all of the following shall be required:

5.1.1 Shaded goggles, glasses, or face shields (suggested shade numbers):

- (1) Light welding, base metal under 1/8 in [3 mm] requires shade 4 or 5
- (2) Medium welding, base metal 1/8 in to 1/2 in [3mm to 13 mm] requires shade 5 or 6
- (3) Heavy welding, base metal over 1/2 in [13 mm] requires shade 6 or 8

NOTE: As a rule of thumb, start with a shade that is too dark to see the weld zone. Then go to a lighter shade which gives a sufficient view of the weld zone without going below the minimum suggested shade.

5.1.2 Hard hats

5.1.3 Protective clothing: flame resistant jackets, coats, hoods, aprons, leggings, spats, gloves, etc. Leather or woolen clothing is preferable to cotton. Synthetic material, which can melt or burn, shall not be worn during welding operations. Sleeves and collars should be kept buttoned. Pants and shirt cuffs should be eliminated. Pockets should be kept buttoned.

5.1.4 Respiratory protection may be required when there is inadequate ventilation. When in doubt, air sampling is recommended to determine if additional respiratory protection is required.

5.2 Eye Protection. Industrial quality eye protection shall always be worn when welding. All helpers and observers shall also wear industrial quality eye protection. Also, the welder shall protect their eyes from the glare of the flames and heat with a protective face shield with the proper filter shade plate or protective face mask “goggles” with the proper shaded filter plate.

Industrial quality safety glasses or industrial quality safety goggles shall always be worn when welding. Even when wearing a clear face shield, industrial quality safety glasses or industrial quality safety goggles shall be worn when welding. Even if the face shield is properly secured and adjusted, welding sparks or spatter can reach the eyes.



Courtesy of The Ohio State University Extension



Courtesy of The Ohio State University Extension

Figure 1—Industrial Quality Safety Glasses

Figure 2—Industrial Quality Safety Glasses

If prescription eyeglasses are required for visual assistance, then Figure 3 is the better option while oxyacetylene welding. Industrial quality safety glasses shall be used if prescription glasses are not required for visual assistance.



Courtesy of The Ohio State University Extension

Figure 3—Industrial Quality Safety Glasses

Neither the glasses seen in Figure 4 nor the goggles seen in Figure 5 are suggested for oxyacetylene welding because these glasses/goggles are only recommended for temporary applications (e.g., like touring an industrial company/facility). These glasses/goggles scratch very easily, lack comfort and do not provide the overall protection of Figures 1, 2, and/or 3.



Courtesy of The Ohio State University Extension

Figure 4—Industrial Quality Safety Glasses—Temporary



Courtesy of The Ohio State University Extension

Figure 5—Industrial Quality Safety Goggles—Temporary

5.2.1 Face Shields. In addition to very bright visible light, flame and molten metal give off infrared rays and ultraviolet rays, which could injure eyes. For large welding tips, the brightness can be nearly that produced when arc welding. To protect eyes from the glare of the flames, from heat, and from small flying particles, the welder shall wear a protective face shield (see Figure 6) with the proper filter shade or protective face goggles with the proper shaded filter plate and clear cover plate. When welding thicker plate or large iron castings, use a protective face mask (see Figure 7) with the proper shaded filter plate and clear cover plate. Always wear industrial quality eye protection under the face shield.



Courtesy of The Ohio State University Extension

Figure 6—Tinted Protective Face Shield



Courtesy of The Ohio State University Extension

Figure 7—Tinted Protective Face Mask

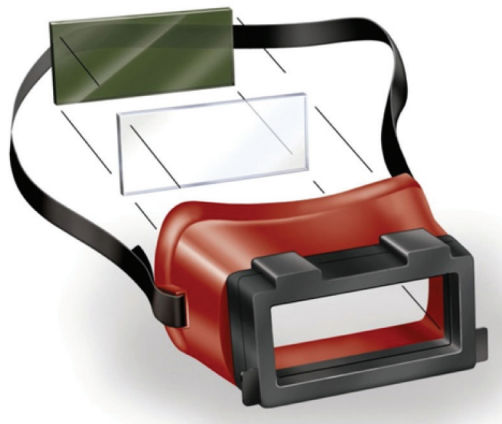
Filters are made with different shades and are marked to show the degree of filtering. Nothing less than a No. 4 filter (light green) shall be used for light welding. The darker shade of No. 6 (dark green) shall be used when welding plate and iron castings. Sometimes a darker filter makes seeing welds more difficult. Normally, a No. 5 shade of green filter is used for most welding. The clear cover plate is made of clear glass or plastic to protect the more expensive filter plate. Clean both plates before beginning to weld.

The goggles (see Figure 8) and mask (see Figure 9) for welding are not suggested because they only protect eyes during the process and give little or no face and neck protection.



Courtesy of The Ohio State University Extension

Figure 8—Oxyacetylene Welding Goggles



Courtesy of The Ohio State University Extension

Figure 9—Oxyacetylene Welding Mask

A clear protective face shield (see Figure 10) shall always be used when cleaning materials before, during, and after welding. Whenever using a grinder and/or wire wheel, a clear protective face shield shall be used over industrial quality eye protection. The clear protective face shield should provide protection to the rest of the face and neck.



Courtesy of The Ohio State University Extension

Figure 10—Clear Protective Face Shield

5.3 Footwear, Clothing, and Gloves. Proper footwear having hard soles with leather uppers shall be worn when the welder and others are in the shop or laboratory. Safety steel toed footwear is recommended. After an exposure assessment has been completed, the welder and any helpers shall also wear suitable oil free clothing made from durable, flame-resistant materials, which resist burning and withstand heat such as:

- (1) treated cotton,
- (2) treated canvas ducks or
- (3) leather.

This should protect skin from flames, welding sparks and spatter and hot materials. In a short period of time, flames and sparks can cause a severe burn. Protect people who are watching nearby with a suitable, nonflammable screening.

Protect hands and arms by wearing gauntlet leather welding gloves (see Figure 11). Gauntlet leather welding gloves can give at least a 4 in [100 mm] covering of the wrist and up the arm. These gloves are also insulated which helps to protect the forearm, wrist, and hand from sparks, spatter, and hot metals.



Courtesy of The Ohio State University Extension

Figure 11—Gauntlet Leather Welding Gloves

A leather protective cape or cotton protective jacket should cover from the shoulder to the wrist (see Figures 12 and 13).



Courtesy of The Ohio State University Extension

Figure 12—Leather Cape



Courtesy of The Ohio State University Extension

Figure 13—Protective Cotton Jacket

When performing out of position (horizontal, vertical, and overhead) welding, welding (skull) caps should be worn to protect the top of the head (See Figure 14).



Courtesy of The Ohio State University Extension

Figure 14—Welder's Cap

Earplugs (see Figure 15) provide better hearing protection for ears, not only from sound, but also from spatter and/or sparks when doing horizontal, vertical, and overhead welding. Earmuffs (see Figure 16) are more convenient to use, but can limit the protection provided by the welding mask.



Courtesy of The Ohio State University Extension

Figure 15—Ear Plugs



Courtesy of The Ohio State University Extension

Figure 16—Ear Muffs

5.4 Ventilation. Welding produces fumes and gases that can be harmful to health. The welder shall avoid breathing these fumes and gases by keeping their head away from the welding plume. Always have enough ventilation to exhaust the fumes and gases away from the breathing zone. Due to fumes and gases associated with oxyacetylene welding, a forced ventilation system shall use explosion proof motors.



Courtesy of The Ohio State University Extension

Figure 17—Inadequate Ventilation



Courtesy of The Ohio State University Extension

Figure 18—Good Ventilation—Natural and/or Mechanical

Welding some metals, such as galvanized (zinc coated) steel, produces unsafe fumes. When these metals are being welded, even greater attention shall be given to proper ventilation. Lead or cadmium-plated metals are especially dangerous and shall be avoided in welding applications.

5.5 Avoiding Fires and Burns. Neither oxygen nor acetylene cylinders shall be used in an enclosed area or enclosure. Oxyacetylene equipment can charge (buildup) an explosive, flammable or asphyxiating (smothering) atmosphere in an enclosed area. A welder shall not weld for at least 15 minutes after contamination of clothing with oxygen. In an oxygen rich atmosphere, a spark from a nearby process may cause clothing to burst into flames.



Courtesy of The Ohio State University Extension

Figure 19—Oxygen from Welding Torch Blowing Dirt from Arm

Oxygen shall never be used as a substitute for compressed air nor as any kind of ventilation. Atmospheric air only should be used for ventilation.

Fire can be prevented by never allowing combustible materials to come in contact with sparks, hot metal, or the torch flame itself. Combustible materials should be kept out of the welding area. Remember, sparks can travel (fly) as much as 35 ft [11 m]. The welder must always be aware of what is in the work area. Oil and grease shall never come in contact with cylinders and cylinder valves. Any exposure to sparks, open flame or other sources of excessive heat could promote conditions favorable for unwanted and dangerous fires.



Courtesy of The Ohio State University Extension

Figure 20—Sparks on Waste

5.6 Safe Use, Handling, and Storage of Gas Cylinders. To safely store, handle, and use oxygen and acetylene, begin with the use of Compressed Gas Association (CGA) approved cylinders that shall be clearly marked—“Oxygen” (oxygen approved cylinders) or “Acetylene” (acetylene approved cylinders). All cylinders shall be secured upright in a cabinet, to the wall, around a post/column or in a cart with a suitable safety/support chain or other approved cylinder holder mechanism. Oxygen and acetylene cylinders shall be stored away from the welding area.



Courtesy of The Ohio State University Extension

Figure 21—Securing Cylinders to a Wall

When in storage, full cylinders should be separated from empty cylinders and oxygen cylinders should be separated from acetylene cylinders. Oxygen and acetylene cylinders shall be separated by a minimum distance of 20 ft [6.0 m] or by a noncombustible barrier that is at least 5 ft [1.5 m] high that has a fire-resistance rating of at least one-half hour (e.g., standard concrete block wall at least 5 ft [1.5 m] high).

Cylinder valves shall be closed, and cylinder safety caps replaced on all cylinders that are empty or not in use. All empty cylinders shall be marked accordingly and kept segregated from full cylinders. Any unused gas shall not be released from any cylinder. For further information, refer to NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*; NFPA 52, *Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks*; and NFPA 55, *Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks*.

Cylinder storage areas shall be posted with the name of the gas and No Smoking restrictions. There shall be adequate spacing between oxygen and acetylene storage areas unless a fire-rated barrier is installed between the two (see OSHA and other local regulations). In seismic areas, special restraints might be necessary to prevent the cylinders from falling over.

The cylinder safety cap shall be left in place on full cylinders until the cylinder is safely secured (chained) where it will be used. Regulators should be removed, and the cylinder safety caps installed whenever the welding operation has ceased for the day. All cylinders should be moved by cart with the cylinder safety cap in place and in an upright position. No cylinders should ever be dropped or knocked over.



Courtesy of The Ohio State University Extension

Figure 22—Moving Cylinders by Cart

If acetylene cylinders are moved while in a horizontal position, they shall be placed upright for 30 minutes before use. This allows the acetone with acetylene in suspension to settle back into the cylinder. When cylinders are in an upright position, chain or steady them in some way to keep cylinders safely upright and vertical. If valves cannot be opened by hand, do not use pliers or a wrench to open them. Return the cylinder with the cylinder safety cap in place to the compressed gas distributor when empty or no longer being used.

Any action that could cause cylinders to be damaged by impact shall be avoided. Slings or magnets shall never be used to move cylinders. Cylinders shall not be lifted by the cap. Cylinders shall never be used as rollers or supports. Cylinder valves are to be closed when the work is finished. Valves on empty cylinders are to be closed with the protective cylinder safety caps in place. Cylinders shall be chained or secured in an upright position while in storage or being moved. All empty cylinders should be marked with "MT" (empty) in chalk. Empty cylinders should be returned to the compressed gas distributor promptly. Compressed gas cylinders are safe as long as they are handled properly.

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

Under no circumstances shall anyone try to fill one cylinder from another. This operation is extremely hazardous and can result in an explosion of gases or cylinder rupture, resulting in extreme personal injury.

5.7 Leak Detection Products. Oil shall never be used on regulators and torch fittings. If oil or petroleum products come in contact with pressurized oxygen, these products could ignite and cause a very serious explosion and/or fire.

Every time a cylinder (e.g., oxygen and/or acetylene) is exchanged, the connection shall be checked for leaks with a leak detection product containing no oil or petroleum products meeting the MIL-PRF-25567E Dated 1998, *Performance Specification, Leak Detection Compound, Oxygen Systems*.

An approved leak detection product shall be used if any of the following occurs:

a connection was broken between:

- (1) a regulator and a hose/check valve/flashback arrester; or
- (2) a check valve/flashback arrester and a hose; or
- (3) a hose and a torch handle/check valve/flashback arrester; or
- (4) a check valve/flashback arrester and a torch handle.

A Military Performance Specification (MIL-PRF) approved leak detection product may be found at a local compressed gas distributor/welding supply dealer or use the internet to locate a MIL-PRF approved leak detection fluid.

If one of the possible leaks mentioned in the paragraph above occurs, the oxygen tank valve shall be opened slowly and fully. The oxygen regulator should be adjusted to its proper static working pressure with the oxygen torch valve closed. With the oxygen torch valve closed, the oxygen side of the oxygen acetylene system shall be checked for leaks with a MIL-PRF approved leak detection product.

After the oxygen side of the oxyacetylene system has been checked for leaks, the acetylene tank valve should be opened slowly, at least one full turn, but never more than one and a half turns. The acetylene regulator should be adjusted to its proper static working pressure with the acetylene torch valve closed. With the acetylene torch valve closed, check the acetylene side of the oxygen acetylene system for leaks with a MIL-PRF approved leak detection product.

If a Military Performance Specification (MIL-PRF) approved leak detection product is not available, a non-petroleum soap (such as Ivory®¹) mixed with water in a thick solution may be used as a substitute. Leak testing with a soap mixture should only be used in an emergency when a MIL-PRF approved leak detection product is not available. Testing with an acceptable leak detection fluid is always better than not testing the system for leaks. A flame shall never be used to test for leaks, as this can result in serious injury to personnel and/or equipment.

After the connections between the regulator and the torch handle have been checked and no leaks have been found, there still could be a leak within the torch handle. This might occur at one of the torch handle valves, where the welding tip attaches to the torch handle or at the end of the welding tip. Use a MIL-PRF approved leak detection product to detect a leak at one of these locations. If a leak is found, the torch handle and welding tip shall be returned to a local compressed gas distributor/welding supply dealer for further evaluation ending with proper repair and/or replacement.

If both the cylinder pressure gauge and working pressure gauge show a loss in pressure with both the cylinder valve closed and the regulator pressure adjusting screw turned out until loose, then there is a possible problem of a leak in the regulator itself. If the connection between the cylinder and regulator check out as tight, as do all other connections in the oxygen acetylene system, the regulator shall be returned to a local compressed gas distributor/welding supply dealer for further evaluation ending with proper repair and/or replacement.

¹ Ivory® is a registered trademark of The Procter & Gamble Company.

5.8 Safe Working Environment. The operation of oxyacetylene welding equipment shall be done only in areas free of conditions or materials that may be hazardous to the welder or others. The welder must always be cautious of the possibility of fire. The following is a summary of some important safety considerations.

(1) A torch shall never be lighted where chlorinated solvent vapors are present. Any exposure of such vapors to heat will result in the formation of phosgene (an extremely poisonous gas), hydrochloric acid fumes, and other corrosive or toxic products.

(2) The welder shall never use a flame on a closed vessel or pipeline that has contained gasoline or other flammable or explosive materials without first making sure it has been properly prepared for the welding operation.

(3) When welding materials containing lead, the welder must always be sure adequate ventilation exists. Similar precautions shall be taken when welding other toxic metals such as cadmium and zinc.

(4) The welder shall always have adequate ventilation and respiratory protection when working in areas where fumes or gases might exceed safe breathing limits. AWS F4.1, *Safe Practices for the Preparation of Containers and Piping for Welding, Cutting, and Allied Processes* should be consulted for details.

(5) Adequate ventilation (a supply of fresh air for breathing) prevents being overcome by hazardous fumes when working in confined areas. High levels of oxygen in a confined space can increase the risk of fire or explosion. Even low concentrations of carbon monoxide are toxic.

(6) A torch shall not be used in a confined area without having an assistant on hand outside the confined area. A safety line might be required. Also know what is on the other side of the workpiece being welded.

(7) Not only the welder, but all involved with welding must know the location of the nearest fire extinguishers and how to use them properly.

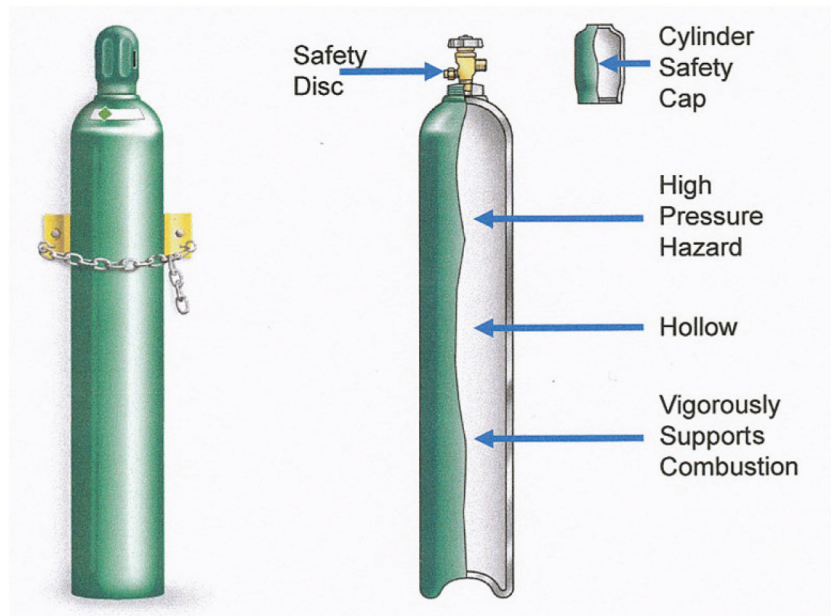
(8) The welder shall never weld on top of concrete or asphalt without protecting it with metal or other suitable material. Concrete can spall violently (explode) from the applied heat of the torch or slag.

(9) The welder should protect the hose from sparks, hot objects, sharp edges, or open flames. The human body shall never be used to support hoses during the welding operation.

6. Equipment and Supplies for Oxyacetylene Welding

6.1 Cylinders

6.1.1 Oxygen Cylinders. Oxygen of high purity (99.5%) is normally stored in high-pressure steel cylinders of various sizes. It is compressed at about 2200 psi [15 000 kPa]. The term psi means pounds of force per square inch. That much pressure can be very dangerous if the cylinder is not handled and stored properly. The welder shall ensure that sufficient pressure and flow capabilities are available for the work to be done. Any cylinder must never be completely drained or left with the valve open especially on “empty” cylinders. This could result in contamination of the cylinder. Apparatus manufacturer’s literature should be consulted for pressure and volume requirements.



Courtesy of The Ohio State University Extension

Figure 23—Oxygen Cylinder

Cylinder safety caps shall always be in place when cylinders are moved in the shop. If the cylinder valve is damaged, escaping high pressure gas may cause the cylinder to become almost like a rocket. Serious injuries could result.

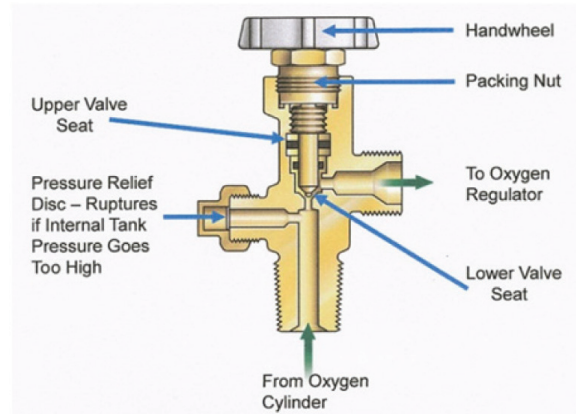
Oxygen vigorously accelerates combustion. Improper use of oxygen might result in fire or explosion. Equipment damage or a serious personal injury might result from improper use of oxygen.

Oxygen shall never be used to blow dirt from clothing or work areas. Any smoldering material could burst into flame, and oxygen can increase the intensity of fires caused by sparks or flame.

Oxygen must never be used in pneumatic tools, to clean equipment, dust off clothing, provide ventilation, and for any other application not intended for pure oxygen.

Oil, grease, and dust are highly combustible when mixed with pure oxygen under pressure and can cause spontaneous combustion (sudden fire), or explosion. Oil or grease must never be used on cylinder or station valves, connections, or fittings, or around oxygen equipment. Other sources of oil and grease must also be avoided around oxygen equipment as a violent reaction could occur.

The flow of oxygen from the cylinder is controlled by a high-pressure valve that is opened and closed by turning a hand wheel located at the top of the cylinder. The hand wheel should be turned slowly counterclockwise to allow a gradual pressure to load in the regulator. With oxygen, the valve, as with other high pressure cylinders, shall be opened fully for safety to prevent leaks and to get adequate gas pressure and volume. The oxygen cylinder valve is a double-seated valve and should be either shut completely or opened all the way to prevent leaks.



Courtesy of The Ohio State University Extension

Figure 24—Oxygen Valve

There are many sizes of oxygen cylinders that can be used on farms, in small shops and in industry. The sizes of cylinders are based on the cubic feet of gas they contain.



Table 1—Oxygen Cylinder Shapes and Information

Cylinder Nomenclature	20CF R BO	40CF G GO	80CF Q RO	125CF S SO	150CF S SO	200CF K MO	250CF K LO	300CF T LO
Cylinder	20 cu ft	40 cu ft	80 cu ft	125 cu ft	150 cu ft	200 cu ft	250 cu ft	300 cu ft
Volume	570 L	1100 L	2300 L	3500 L	4300 L	5700 L	7100 L	8500 L
Weight	11 lb	27 lb	46 lb	62 lb	68 lb	101 lb	115 lb	134 lb
w/ Valve & Cap	5 kg	12 kg	21 kg	28 kg	31 kg	46 kg	52 kg	61 kg
Outside Diameter	5 in 13 cm	6 in 15 cm	7 in 18 cm	8 in 20 cm	8 in 20 cm	9 in 23 cm	9 in 23 cm	9.25 in 24 cm
Height	18 in*	22 in*	36 in	47 in	51 in	55 in	55 in	60 in
w/ Valve & Cap	46 cm	56 cm	92 cm	119 cm	120 cm	140 cm	140 cm	152 cm
	*No Safety Cap	*No Safety Cap						
Approximate Capacity	21 cu ft 0.6 cu m	46 cu ft 1.0 cu m	95 cu ft 3.0 cu m	143 cu ft 4.0 cu m	156 cu ft 4.4 cu m	224 cu ft 6.4 cu m	277 cu ft 7.9 cu m	333 cu ft 9.4 cu m
Service Pressure	2 015 psi 140 bar	2 015 psi 140 bar	2 015 psi 140 bar	2 265 psi 155 bar	2 015 psi 140 bar	2 015 psi 140 bar	2 265 psi 155 bar	2 400 psi 165 bar

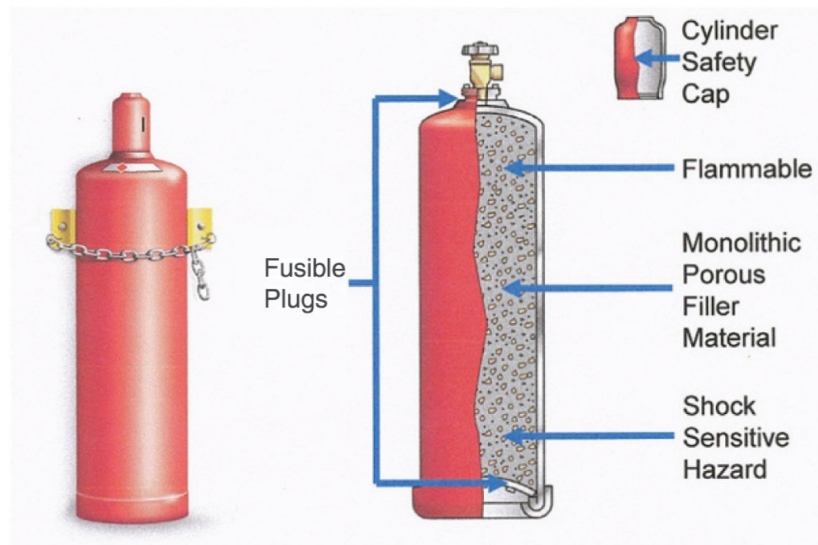
Due to the size of the oxygen cylinders, they are usually placed on a two-wheel cart to make moving easier wherever welding is to be done.

Oxygen cylinders are equipped with a safety relief valve(s) to allow the gases to drain slowly in case heat raises the pressure beyond the safety load of the cylinder. The oxygen cylinder has a pressure disk that will rupture (break apart) when the internal cylinder pressure exceeds 3300 psi [22 800 kPa].

The pressure in a full cylinder of oxygen is about 2200 psig [15 000 kPa] at 70°F [21°C]. Oxygen should be supplied to welding torches at pressures ranging upward from about 2 psig [14 kPa] to 45 psig [310 kPa].

Like all compressed gas cylinders, oxygen cylinders shall be stored in an upright position with chains or cables to hold them in place. Always follow ANSI/AWS/CGA rules for storing compressed gases.

6.1.2 Acetylene Cylinders. Acetylene is never sold in bulk because it is so sensitive to shock and because it is unstable under pressure. Acetylene comes in cylinders of various sizes. The smallest common size cylinder has 10 cu ft [5 L] at 250 psi [1700 kPa]. The largest common size contains about 390 cu ft [180 L] at 250 psi [1700 kPa].



Courtesy of The Ohio State University Extension

Figure 25—Acetylene Cylinder

Acetylene cylinders have a special design. They are filled with a porous material made up of small cells or pockets. The porous material is saturated (soaked) with acetone, and acetylene is dissolved in the acetone. Because the acetylene is dissolved in acetone, the cylinders can be filled at pressures up to 250 psi [1700 kPa] without the potential of the acetylene exploding.

Acetylene shall not be generated, piped (except in approved cylinder manifolds), or utilized at a pressure in excess of 15 psig [100 kPa] (gauge pressure) or 30 psia [200 kPa] (absolute pressure). Use at higher pressures is hazardous, resulting in the possibility of acetylene spontaneously decomposing or acetylene explosion from sudden shock or heat.

Acetylene separates from the acetone in the cylinder before it is used. For many years, the 1/7 rule of thumb has been that the maximum withdrawal from a single cylinder is 1/7 of its contents of the cylinder per hour. That is, a 300 cu ft [140 L] cylinder can supply about 42 cu ft [20 L] of acetylene per hour without the possibility of drawing acetone from the cylinder into the acetylene regulator and possibly the hose. Acetone can damage either the regulator or hose. If a higher volume is needed, several cylinders must be manifolded together.

There are many sizes of acetylene cylinders that can be used on farms, in small shops and in industry. The sizes of cylinders are based on the cubic feet of gas they contain.

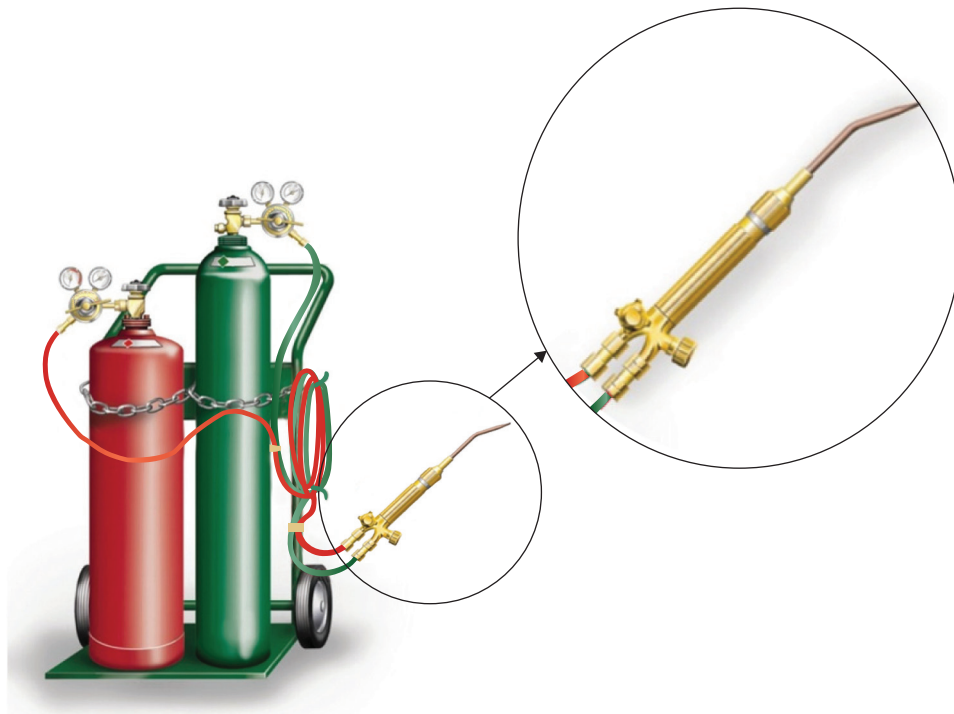


Table 2—Acetylene Cylinder Shapes and Information

Cylinder Nomenclature	S-10 MC	S-40 B	S-75 WQ R #3	S-100 WC S #3.5	S-145 WS S #4	WM-200 WM M #4.5	WM-250 WM M #5	W-300 WK L #5
Cylinder	10 cu ft	40 cu ft	75 cu ft	100 cu ft	145 cu ft	200 cu ft	250 cu ft	300 cu ft
Volume	283 L	1100 L	2100 L	2800 L	4100 L	5700 L	7100 L	8500 L
Weight	13 lb	27 lb	47 lb	59 lb	77 lb	105 lb	122 lb	140 lb
w/ Valve & Cap	5.9 kg	12.0 kg	21.0 kg	26.0 kg	35.0 kg	48.0 kg	55.0 kg	64.0 kg
Outside Diameter	4 in 10 cm	6 in 15 cm	7 in 18 cm	7 in 18 cm	8 in 20 cm	10 in 25 cm	10 in 25 cm	12 in 30 cm
Height	14 in*	20 in*	31 in	37 in	40 in	42 in	44 in	47 in
w/ Valve & Cap	36 cm	51 cm	79 cm	94 cm	102 cm	107 cm	112 cm	120 cm
	*No Safety Cap	*No Safety Cap						
Acetone	1 lb	5 lb	9 lb	12 lb	18 lb	26 lb	31 lb	38 lb
Solvent	0.5 kg	2 kg	4 kg	6 kg	8 kg	12 kg	14 kg	17 kg
Acetylene Capacity	10 cu ft 0.3 cu m	40 cu ft 1 cu m	75 cu ft 2 cu m	100 cu ft 3 cu m	145 cu ft 4 cu m	200 cu ft 6 cu m	250 cu ft 7 cu m	300 cu ft 9 cu m

The acetylene cylinders are designed to a settled service pressure of 250 psig at 70°F for a withdrawal rate of 1/7 of cylinder capacity per hour.

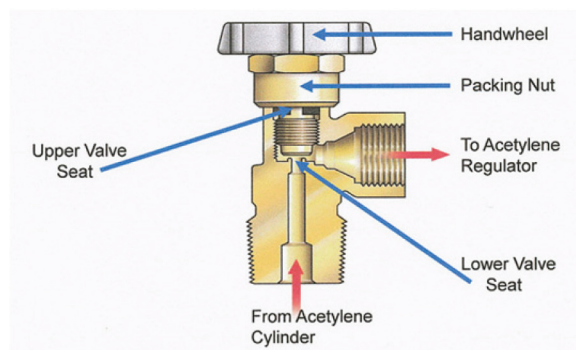
Due to the size of the acetylene cylinders, they are usually placed on a two-wheel cart to make moving easier wherever welding is to be done.



Courtesy of The Ohio State University Extension

Figure 26—Oxygen and Acetylene Welding Setup on a 2-Wheeled Cart

Acetylene cylinders are equipped with a safety relief valve(s) to allow the gases to drain slowly in case heat raises the pressure beyond the safety load of the cylinder. The acetylene cylinder has two fusible plugs on the top neck ring and several on the bottom of the acetylene cylinder which may melt and release the acetylene when the outside temperature of the cylinder exceeds 250°F [120°C].



Courtesy of The Ohio State University Extension

Figure 27—Acetylene Valve