



A LINCOLN ELECTRIC COMPANY



# OXY-FUEL SAFETY

ITS ALL ABOUT EDUCATION

# **OXY-FUEL SAFETY** “IT’S ALL ABOUT EDUCATION”



## **PURPOSE, SCOPE AND GOAL**

The purpose of this document is to provide a basic understanding of the elements involved in the different oxy-fuel processes and to offer guidelines for the safe and proper operation of the equipment used. The primary goal is to prevent personal injury and illness to individuals nearby or using the equipment for oxy-fuel cutting, welding, brazing and heating. In addition to the primary goal an attempt to protect all property and equipment from any damage resulting from the misuse or misapplication of these and other allied processes.

This presentation is intended only to offer a number of useful or important safety guidelines. It is not intended to be a substitute for a full hands-on operator safety-training program.

### **IT'S ALL ABOUT EDUCATION**

To some, when using oxy-fuel equipment accidents are considered almost inevitable. The actual truth is with a little knowledge and guidance damage and or personal injury can be avoided entirely. Our intent is to educate and inform operators about the gases involved, their function and a few of the more important elements of safe operation of this type of equipment. By following the guidelines and precautions outlined in this document, operators can protect themselves, others and the property around them from serious injury or possible damage when using this equipment improperly.

To educate, we first should explain that all oxy-fuel processes (brazing, cutting, welding and heating) all require a tremendous amount of energy in the form of heat. This energy, however can be a double-edged sword. The combustion or burning of a fuel gas in pure oxygen or combined with ambient air oxygen can produce all the needed heat and then some. The oxy-fuel process can produce temperatures of up to 6000°F in a concentrated spot or spread over a relatively large area. When released in a controlled manner: over an extended period of time, this heat energy can be a very useful and safe tool. Unfortunately, if misused the equipment will release the same tremendous amount of energy but the release is uncontrolled and immediate. This immediate release will result in an uncontrolled fire and/or explosion that can and will result in damage to equipment and property, serious personal injury and possibly even death.

Today, most oxy-fuel equipment manufactured to current existing industry standards and by reputable manufacturers is extremely safe, but only if used and maintained properly. Equipment that is not properly maintained or used by untrained or poorly trained operators can cause serious injury and or property damage. Even using additional auxiliary safety equipment like flashback arrestors, check valves and personal protection equipment (PPE) may not provide protection from the consequences of using poorly maintained equipment, improperly trained or complacent operators. Maintaining and using oxy-fuel equipment properly is extremely important for the operator, as well as for the safety of others in the immediate vicinity of the operation. Training all operators in the safe and correct use of the equipment is not only necessary for personal safety, but it also provides economic benefits by maintaining original performance and extending product life.

## THE COMBUSTION PROCESS

At this point, a general explanation of the combustion process itself and the principal elements composing it is required. To best explain the combustion process, please reference the Combustion Triangle illustrated in FIGURE 1.

**Figure 1 - FIRE TRIANGLE**



### COMBUSTION TRIANGLE

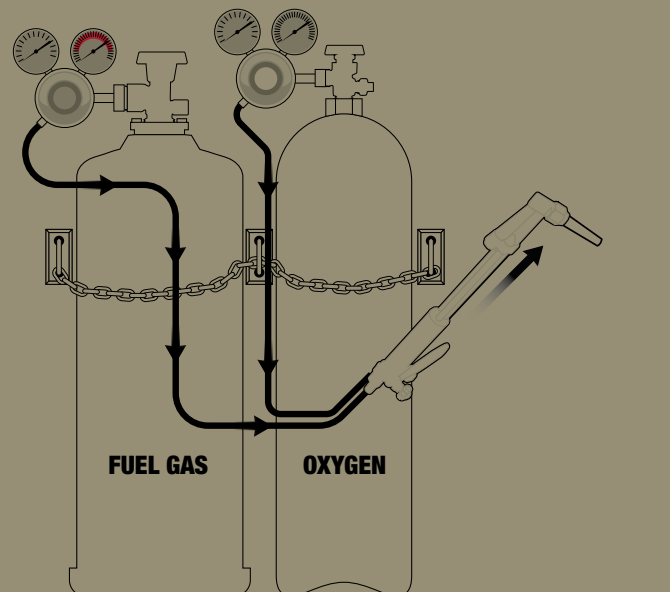
To start and maintain combustion or a fire three (3) basic elements are required: (1) Oxygen, (2) Fuel and (3) Ignition or heat. A fire cannot start or continue to exist without all three elements. Once combustion begins, removing any one or more of the three elements will stop combustion. Virtually all safety devices and safety procedures we will discuss during this presentation rely on this fact. The devices and the way they protect us rely on removing or preventing the existence of any one of the elements or combinations of them to prevent or stop an existing fire. This simple principle will be addressed with more detail in the Auxiliary Safety Device section of this document.

In a typical oxy-fuel application a cylinder or pipeline is the primary source of the oxygen required. The fuel is usually one of a number of common flammable gases like acetylene, LPG (Liquid Petroleum Gas), natural gas, etc.. Fuels too are supplied through pipelines or from gas cylinders. The ignition element of the triangle properly originates from an approved spark igniter - either electronic or flint-friction type.

Oxy-fuel equipment is purposefully designed to keep oxygen and fuel gas separate until absolutely required in a specific mix of the two. This is absolutely necessary for safety reasons. They should only be mixed together at the very last moment, usually immediately prior to ignition. They are then mixed, at a specific ratio in a device called a gas mixer. Oxygen and fuel gas should never be mixed anywhere else

in the system at any time not intended by design. Oxygen and fuel gas are relatively safe by themselves and/or mixed in the right location. Oxygen and fuel gas are extremely flammable and potentially highly explosive if not properly mixed and in the wrong equipment location. We call this "reverse Flow." We will discuss it further as well as how check valves prevent it, later in the Auxiliary Safety Device' section of this presentation.

**Figure 2 - PROPER DIRECTION OF FLOW**



### COMBUSTION THEORY

#### Do:

- Keep oxygen and fuel gas separate at all times, until required
- Refer to oxygen and fuel gases by their proper names, not "air" and "gas"
- Check for fuel leaks- fuel gases will burn readily in air alone
- Check for oxygen leaks – oxygen will vigorously support the combustion of all that will burn
- Keep workspace well ventilated and free of gases, fumes and combustible products
- Keep equipment contaminant free, especially free from oil and grease

#### Do Not:

- Use unapproved devices like matches or lighters to ignite torch flames
- Substitute oxygen for compressed air
- Weld, cut or heat on vessels of unknown origin or without proper preparation
- Operate equipment in areas containing other combustibles
- Use leaking or otherwise faulty equipment – repair or replace before using

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## GASES OF THE OXY/FUEL PROCESS

There are a number of hazards associated with the various oxy-fuel processes. A number of them directly relate to pure oxygen, oxygen in air and the type fuel gases used. Fuel gases are there to provide the fuel element for the fire and BTU energy needed. Pure oxygen, when added, provides the oxy-fuel flame with its extraordinarily high temperature and volatility. The 21% oxygen in air is what allows fuels to burn or explode even when pure oxygen is not available. Not only do the chemical properties of the gases themselves present issues, there are other additional physical hazards of the gases to consider. A number of these hazards are related to the way these gases are packaged, stored, delivered and provided for use in cylinders and/or pipelines.

### OXYGEN – IT’S CHEMISTRY

Oxygen chemistry is a special concern when it comes to safety. It is common knowledge that oxygen alone will not burn, but it does, however, vigorously support and accelerate the combustion of any material that will. The higher the oxygen purity and the greater the concentration, the easier, hotter and faster the fuel it is combined with will burn. In any oxy-fuel process, the flame’s tremendous energy results more as a result of the oxygen than from the fuel itself. The oxygen used for most processes is essentially 100% pure. Air-fuel flames, on the other hand, receive oxygen from approximately 21% that exists in ambient air. High purity oxygen, with the right ratio of fuel, allows the fuel gas to burn more vigorously and with the highest intensity possible. Leaking raw fuel, when lit, can and will burn readily in air making leaks of it hazardous. However, when fuel is combined with just the right amount of pure oxygen extremely hazardous fires and even explosions are possible. It is for this very reason too that many experts in the industry consider oxygen and not fuel, to be the more potentially dangerous of the two gases.

### OXYGEN REGULATOR FIRES

Cylinder oxygen is commonly packaged, stored and transported, under very high pressures. These pressures typically range from 2200 to 3000 pounds per square inch (PSIG). Oxygen, especially at these pressures, can become extremely hazardous. If oxygen equipment is not maintained and operated properly an extremely destructive and harmful phenomenon known as a regulator or heat of recompression fire can occur. For example, if an oxygen regulator on a full cylinder were to be opened too quickly the oxygen will enter the regulator and will recompress inside the regulator. The resulting friction of the oxygen molecules can produce temperatures of 1600 to 1800 degrees Fahrenheit. Normally, regulator materials of construction will not ignite at these temperatures. Under these conditions, oxygen is

present, ignition is present and all that’s needed is the fuel element.

If the oxygen regulator previously had been mishandled and allowed to become contaminated with foreign debris, especially oil or grease, a chain reaction could start, ultimately consuming the regulator’s interior. The resultant molten material will burn a hole through the regulator and escape at a pressure near or equal to the oxygen’s cylinder pressure. Heat of recompression or oxygen regulator fires virtually always result in serious injuries and property damage. The close proximity of the operator at the time, the fire and molten brass, etc. and the extremely high pressure almost guarantee it.

Proper equipment maintenance and slowly opening high-pressure oxygen cylinders are the keys to preventing oxygen regulator fires caused by the heat of recompression. See “Attaching a High-Pressure Oxygen Regulator” discussed further on in this document for more safety information on this subject.

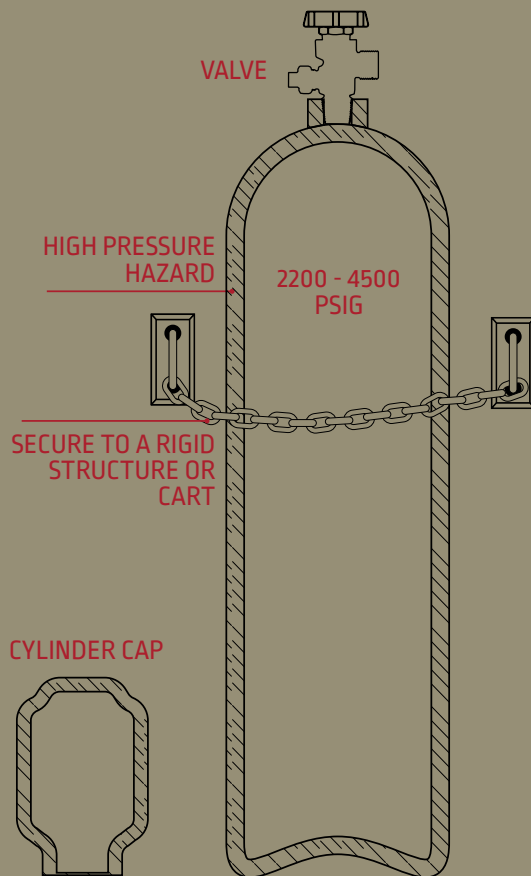
**Figure 3 - OXYGEN REGULATOR FIRE**



### HIGH PRESSURE CYLINDER HAZARD

Cylinder oxygen is commonly available at pressures of up to 3000 PSIG. Suddenly releasing the pressure at even half of that amount, the steel cylinder can become an uncontrollable flying missile. An example of this incident is an uncapped and unsecured cylinder falling and having its valve sheared off releasing all its pressure at one time. Gas suppliers should ensure all high-pressure cylinders have caps to prevent valves from being broken off while in transit, storage or otherwise not in use. It is important to make certain all cylinders are secured to an approved carrier or rigid structure to prevent hazards.

**Figure 4 - OXYGEN CYLINDER**



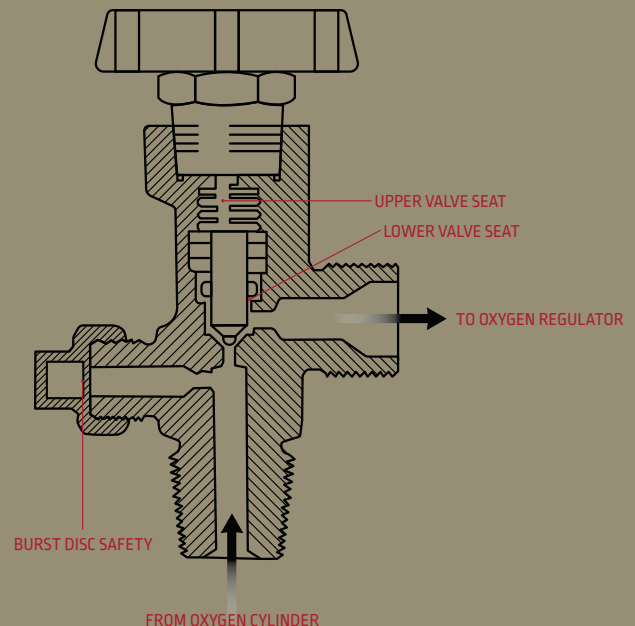
## ATTACHING A HIGH-PRESSURE OXYGEN REGULATOR

Special care should be taken when attaching a regulator and when opening an oxygen cylinder valve. First make sure all other downstream valves are closed and regulator pressure adjustments are backed out and move freely. "Crack" valve to blow out debris and with a smooth jawed wrench attach and tighten regulator. When opening the cylinder valve operators should position themselves so that they are not directly in front of or directly behind the regulator. The cylinder valve should be located between operator and the regulator itself. Next, the operator should face away while slowly and carefully opening the valve to allow the regulator to fully pressurize. Oxygen cylinder valves, as well as LPG and all other high-pressure (500 PSIG or greater) gas cylinder valves, should be opened fully while in use. These valves all include an extra seat to help prevent leaks while open and in use.

In addition, before lighting, the operator should remember to properly

purge both gas systems eliminating the possibility of internal explosive mixtures due to reverse flow. Operators should follow the specific purging instructions offered by the original equipment manufacturer.

**Figure 5 - OXYGEN CYLINDER VALVE**



### **Do:**

- Secure cylinders to a rigid structure or place in an approved carrier when in use
- Inform gas supplier immediately of damage or signs of abuse to cylinders
- Keep work area free from potential combustibles
- Keep the cylinder valve positioned between the operator and the regulator when opening
- Keep equipment clean and free of contaminants, especially grease and oil
- Turn and face away from equipment while opening oxygen valves - slowly
- "Crack" valve and blow out possible debris before attaching oxygen regulator
- Call oxygen by its proper name
- Store oxygen and fuel gases properly separated

### **Do Not:**

- Use gas cylinders for uses other than they were intended
- Use or attempt to fill cylinders with gases other than those intended
- Expose oxygen or other cylinders to open flames or other sources of ignition
- Expose high-pressure cylinders to sources of excess heat
- Wear or use oil contaminated personal protection equipment when working with oxygen
- Substitute oxygen for compressed air
- Attempt to light or use torch oxygen equipment without properly

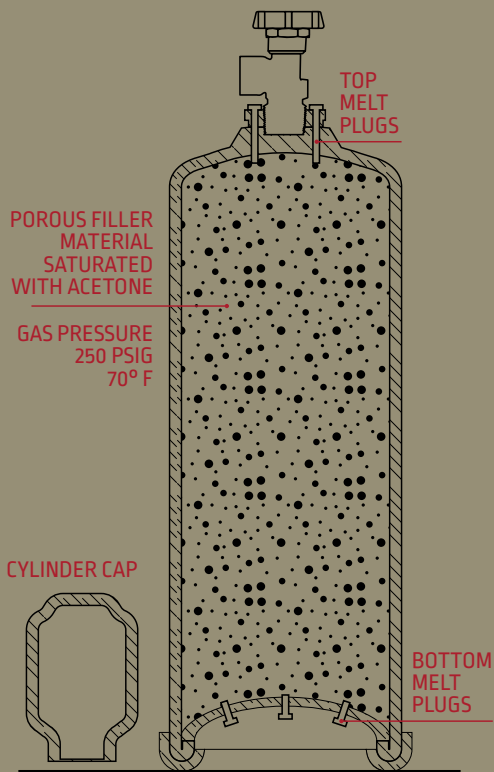
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purging the system prior to use

## FUEL GASES

All fuel gases are obviously hazardous because they are flammable. They will burn in air alone, ignite readily, produce a lot of heat and their flame is self-sustaining even in plain air. Combined with the right amount of oxygen, fuel gases become extremely dangerous and potentially explosive. There are a number of common, yet different, fuel gases. Each gas has its own unique chemical and physical properties with differing hazards for each. Fuel gases also differ in the way they are packaged, stored and delivered. Some gases require different safety procedures for handling and while in use. Three of the most commonly used fuel gas types are acetylene, liquid petroleum gases (LPG) and natural gas (methane).

**Figure 6 - ACETYLENE CYLINDER**



## ACETYLENE FUEL GASES

Acetylene for our industry is usually produced by combining calcium carbide and water. The resulting gas is captured and dissolved in liquid acetone to help stabilize it. The acetone/acetylene mix is stored, transported and used out of very special cylinders that are unlike any other in our industry. Acetylene cylinders are not hollow like most other gas cylinders. At manufacture and before use, the

hollow cylinder shell is filled (entirely) with a semi rigid, extremely porous filler material having the consistency like that of plaster of Paris. Liquid acetone is then added to the filler material and the acetone absorbs slightly pressurized (approximately 250 PSIG) acetylene gas as a means to keep it compressed and stable.

Acetylene under pressure, above 15 PSIG and in its free state, can be extremely unstable, shock sensitive and can self-detonate. Its molecules of hydrogen and carbon may disassociate (break apart) producing heat, thus causing a chain reaction that can result in an instant release of energy - an explosion. These two conditions, being stabilized in acetone and its molecules disbursed evenly throughout the extremely porous filler material, are what allows acetylene to be safely stored in volume, transported and used out of cylinders. In the United States using acetylene gas at 15 PSIG (@70°F or more) is considered to be extremely hazardous to health and equipment. In a properly constructed cylinder and dissolved in acetone, it is permissible to have acetylene in cylinders up to 250 PSIG @70°F. Acetylene has a relatively low withdrawal rate adding further to its safety limitations. The ability to provide the proper fuel gas volume to the flame during an oxy-fuel process is an absolute necessity for safe operation. Too little fuel or too much oxygen for a given amount of fuel can force the flame to retreat into the equipment resulting in possible equipment damage and personal injury. It frequently does enough damage to make the equipment unusable in the future. During filling, it takes time for the acetone in a cylinder to absorb acetylene gas. During use it takes time for the acetone to release it. Be aware of acetylene's limited withdrawal rate and how to compute it. The actual amount of time can be stated as a fraction of the specific cylinder's rated contents in standard cubic feet per hour (SCFH) when full - Example: "The 1/7th rule". There are other "Capacity Withdrawal Rules" (1/10th and 1/15th) that may be used for certain rules applications, but the "1/7th rule" is the most universal. The 1/7th rule states that the operator can safely use 1/7th of a cylinder's full capacity per hour. For example, the operator can safely withdraw 30 SCFH of acetylene per hour from a cylinder rated at 210 CF when full, allowing the operator to use a heating tip that requires 30 SCFH or less to operate. An operator should never over-withdraw fuel gas cylinders, as it may cause the flames to burn in the wrong direction!

## ADDITIONAL ACETYLENE CYLINDER CONSIDERATIONS

Valves on acetylene cylinders are physically different from the valves on high-pressure cylinders and those associated with Liquid Petroleum Gas (LPG) cylinders. While in operation, these valves should also be opened to a different number of turns while in use. Acetylene cylinder valves should not be opened more than 1 to 1-1/2 turns. Low-pressure acetylene cylinder valves are not equipped with the extra top seat or seal as do valves for high-pressure gases like oxygen and LPG gases and apparently, conditions with acetylene use are different and the ability to close it quickly in an emergency is

a more important issue. Acetylene cylinder valves are fast acting. They will open wide enough not to cause flow restriction or starvation issues once it has opened at least ¼ of a turn. Acetylene cylinders also feature unique thermally activated pressure relief devices. When exposed to high temperatures, the valves are designed to relieve excess pressure, in a controlled manner, preventing the cylinder from exploding. Acetylene is shock sensitive so incidents and other evidence of abuse, like cylinder wall dents, should be reported to the gas supplier as soon as possible.

## ACETYLENE & ACETYLENE CYLINDERS

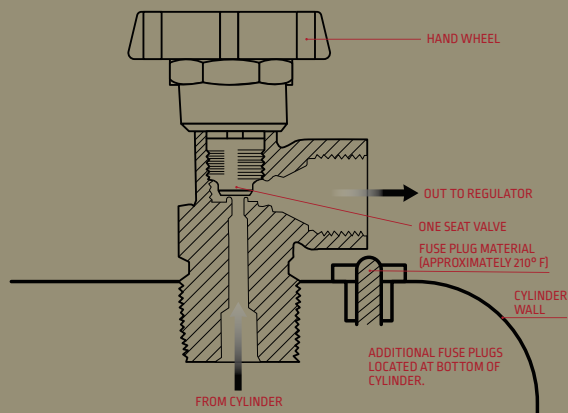
### Do:

- Call it “acetylene” not “gas” or “fuel”
- Move any leaking cylinders to a well-ventilated area
- Always use acetylene cylinders in a vertical position
- Secure cylinders to a rigid structure or attach to an approved cart while in use
- Select the proper size and/or number of cylinders required for the application
- Store oxygen and acetylene properly separated or with a proper physical barrier between them
- Open cylinder valve 1 to 1-1/2 turns while in use
- Always inform supplier of any dents or other damages to cylinders

### Do not:

- Tamper with or obstruct in any way acetylene high temperature safeties
- Drop acetylene cylinders or subject them to physical abuse or shock
- Use acetylene at pressures greater than 15 PSIG
- Expose acetylene cylinders to open flames or other sources of ignition
- Exceed the fuel gas volume storage limit for LPG
- Exceed the maximum recommended gas withdrawal rate of the cylinder (typically 1/7th the capacity/hr)

**Figure 7 - ACETYLENE CYLINDER VALVE & FUSE PLUG SAFETY**



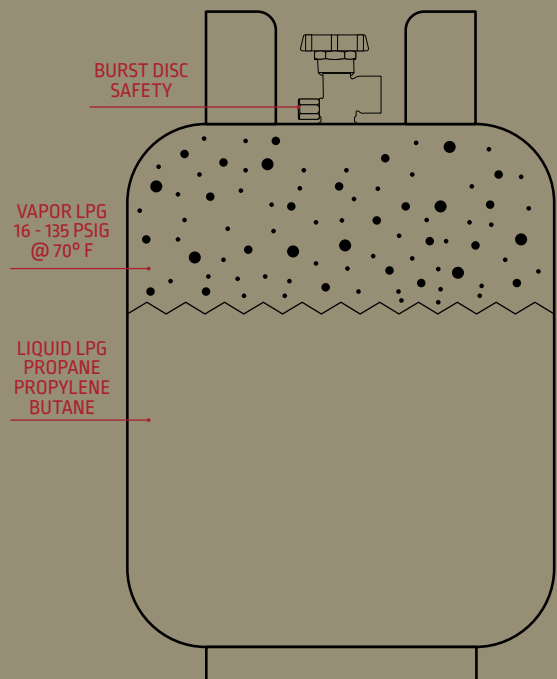
## LIQUID PETROLEUM GAS (LPG)

LPG gases are a class of common fuel gases that include propane, propylene, butane, mixes of and proprietary mixes (sometimes with additives) based on these gases. All are the type gases that are liquids while under pressure in a cylinder. They are stored as liquids but are allowed to vaporize for use. Under pressure, a vapor space forms above the liquid (Figure 8). The gas will remain in a vapor over liquid condition at average ambient temperatures and at pressures between 15 and 135 PSIG (depending on the specific gas). As the vapor is withdrawn and the pressure drops, the liquid will begin boiling in order to replace the vapor in the space above the liquid. Once the rated pressure of the specific LPG gas is reached the vaporization will cease.

LPG gas cylinder withdrawal rates are directly dependent upon:

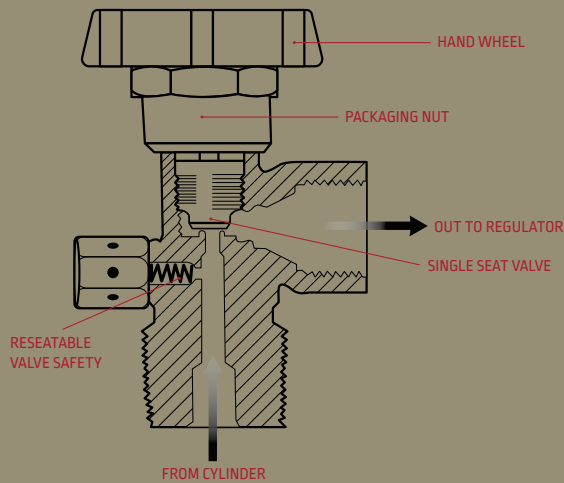
- The size of the cylinder,
- Ambient air temperature
- The degree of fullness of the cylinder

**Figure 8 - LPG CYLINDER**



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Figure 9 - LPG VALVE



LPG, unlike acetylene, is not shock sensitive and it can be used at full cylinder pressure. Like acetylene, LPG gases have gas withdrawal limits. However, the limits are a multitude higher especially when comparing British Thermal Units (BTUs) output. Acetylene is lighter than air allowing it to dissipate more rapidly to a non-explosive limit in air when leaking. LPG molecules are generally heavier than air and have a propensity to accumulate in low spots like mine shafts and boat hulls, forming flammable air-fuel mixtures. LPG cylinders are of thin wall steel construction and are hollow. They can be damaged but unless the damage results in a leak, they do not present the same dented cylinder safety issues that exist with acetylene cylinders. When in use, LPG cylinder valves are to be opened all the way to the top. The valve is equipped with a second seat to help prevent leaks. The valve is also equipped with a pressure relief safety that will reset itself once the excess pressure is vented to the atmosphere.

## LIQUID PETROLEUM GAS (LPG) & CYLINDERS

### Do:

- Always use in an upright position
- Call liquid petroleum gases by their proper names, “Propane”, “Propylene”, etc..
- Store oxygen and LPG properly separated or with a proper physical barrier between them
- Report any cylinder damage to the gas supplier
- Move any leaking cylinders to a well-ventilated area
- Select the proper size and number of cylinders required for the application

### Do Not:

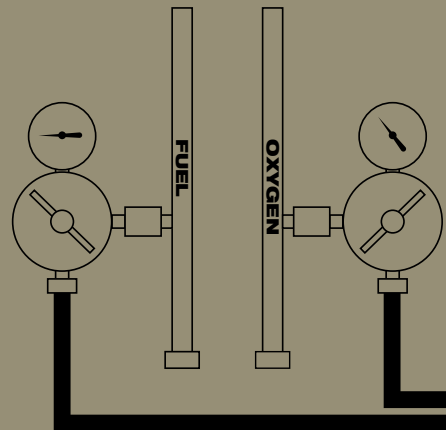
- Substitute liquid withdrawal cylinders for vapor withdrawal cylinders

- Expose LPG cylinders to conditions of extreme heat
- Tamper with or block cylinder safeties
- Artificially heat LPG cylinders with unapproved methods
- Store or use LPG in confined and/or unapproved spaces
- Store LPG cylinders properly separated from oxygen cylinders
- Open LPG cylinder valves all the way when in use
- Exceed the fuel gas volume storage limit for LPG

## NATURAL GAS

The third most common gas used for oxy-fuel processes is natural gas. Some authorities believe it to be the most widely used by volume. Natural gas is comprised of a mixture of gases, but methane is the most prominent of the mixtures. Unlike most other fuel gases in our industry, natural gas is generally not commonly available in cylinders. Hazards associated with high gas pressures and other hazards related to cylinders, like attaching or detaching cylinder regulators, cylinder valve issues, securing cylinders, etc, generally do not exist when using natural gas. Natural gas is also lighter than air. This fact generally makes it safer than the other heavier fuel gases because leaks dissipate readily in the air. When it does leak it rarely combines with air to its flammable or explosive limit. Oxy-natural gas pipeline applications are typically the safest of all oxy-fuel applications. It burns cooler and more stably.

Figure 10



Pipeline Gases for greater safety

Advantages over cylinder gases:

- Fewer central cylinder storage limits
- Less interruptions and downtime
- No securing cylinders
- Fewer concerns regarding confined spaces
- Less individual exposure to high-pressure gas
- No exposure to hazards
- Less clutter in work area
- Inherent CGA “C” station safety standards



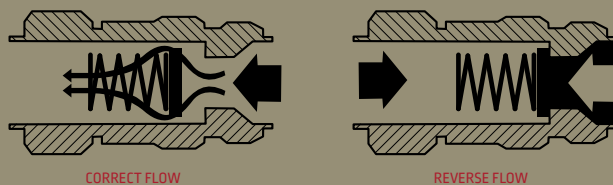
## DEVICES FOR ADDITIONAL OXY FUEL SAFETY

Oxy-fuel equipment manufactured to currently acceptable national industry standards is generally as safe as it can be, assuming that the equipment is operated and maintained properly. Over time, however, normal wear and tear, operator abuse, and human complacency can and will make the best equipment unsafe even with the best of intentions. To compensate, the industry as a whole has developed and made available numerous passive safety devices to assist in injury prevention and reducing facility and equipment damage. Two of the most successful and accepted devices of this kind are check valves and flashback arrestors.

### CHECK VALVES

Check valves (CVs) are one-way gas flow valves. These devices are designed to control the direction of flow of the oxygen and fuel gases. If they are limited to flowing in the right direction the probability of them forming an explosive mixture in the wrong area(s) of the equipment, preventing damage and injury, is reduced. Check valves prevent what we refer to as to as “reverse flow” incidents. They are typically the most frequently used least damaging but because of their frequency they are probably in total the most damaging. Check valves should be checked frequently because they contaminate easily, fail to function properly and give a false sense of security. This is the main reason companies advanced to using flashback arrestors because of their additional level of security and protection.

Figure 11 - CHECK VALVE FUNCTIONS

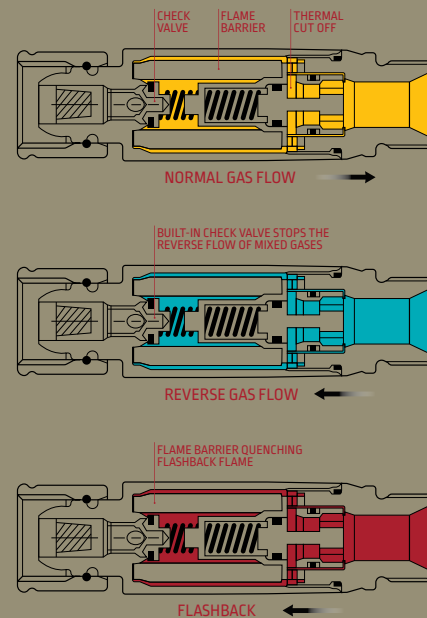


### FLASHBACK ARRESTORS

Flashback arrestors (FBAs) are special devices with a flame barrier device made to stop (arrest) an actual fire, preventing further damage. They typically include check valves, but the most important feature the “flame barrier.” Check valves do not stop fires. They are devices that can only prevent gases from reverse flowing and forming hazardous mixtures in the wrong equipment location(s). Even when the check valve in a Flash Back Arrestor (FBA) is not working properly, the flame barrier will still stop an actual fire from traveling further back into the system. FBAs, therefore, are a kind of second line defense intended to

protect the operator and the equipment from further serious damage or personal injury.

Figure 12 - FBA FUNCTIONS



Exercise caution when selecting the proper FBA capacity or adding additional FBAs to gas lines. All FBAs are restrictive. Compensating for restrictions should be done before lighting. Improper selection or use can make conditions worse than not having any FBA protection at all.

### SOME CAUSES OF “REVERSE FLOW” & OR “FLASH BACK”

- Running out of either gas during operation
- Improper tip settings or size selection
- Improper gas pressure settings
- The wrong or faulty equipment
- Unsafe equipment
- Improper equipment operation or maintenance

### PERSONAL PROTECTIVE EQUIPMENT (PPE)

Properly outfitting an operator with the correct PPE should be paramount for their personal health and safety. Whether it is a workplace mandate or an operator’s choice, proper PPE provides the best protection during normal operation of equipment as well as in the event of an unexpected harmful event. Here are some suggested recommendations. However: you should follow all requirements for your specific conditions when known.

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Figure 13 - PPE

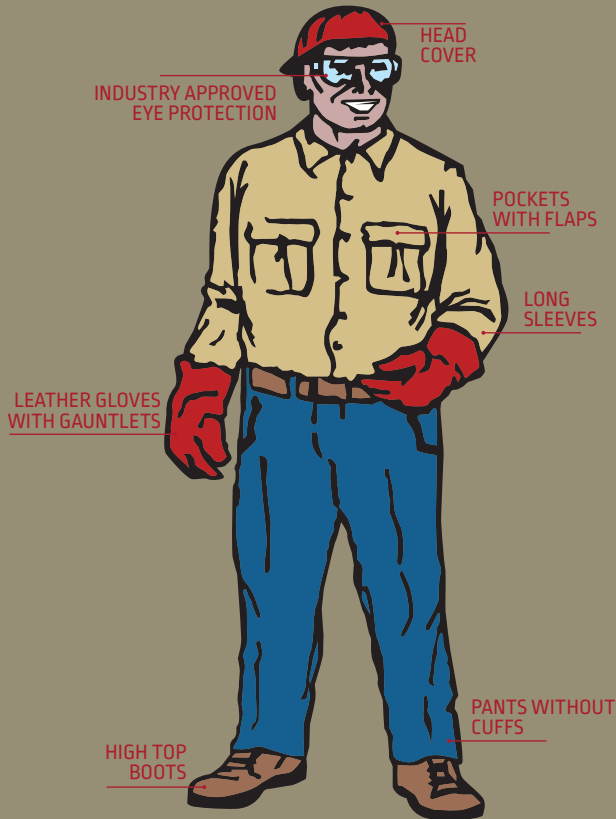
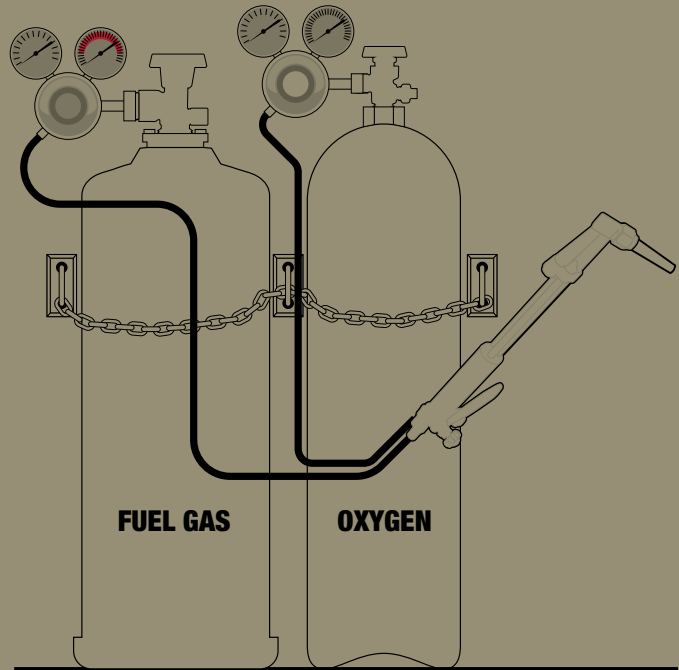


Figure 14 - TYPICAL OXY-FUEL CYLINDER SET-UP



NOTES

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## ADDITIONAL PPE INFORMATION

- Head protection – Head covers protect from flame, heat and metallic sparks. Recommend the use of hard hats for some work environments.
- Eye protection – Industry approved eye cover with side shields protects from harmful rays, dirt and impact. (See ANSI Z49.1, etc. for specifics).
- Face protection – Full-face shields are recommended and required in some work environments.
- Upper body protection – Button down, long sleeve, flame resistant, shirts with flaps over pockets, are minimum requirements. Leathers or similar wear may also be required depending upon the application.
- Hand protection – Leather or similar material gloves with gauntlets covering the shirt cuffs provide flame, heat and spark protection. Additional hand heat shields are recommended for heavy cutting, etc..
- Lower torso protection – Flame resistant or flameproof pants with pocket flaps and no cuffs provide mid-body and leg protection.
- Foot protection – High-top leather or similar boots at a minimum. Steel toe boots are highly recommended.



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