The information contained in this document presents instructions for the safe storage and handling of compressed gases. It covers rules for handling compressed cylinder gases and cryogenic liquefied gases. Special precautions for specific gases — oxygen, fuel gases, acetylene, and inert gases — are provided. Also included are guidelines for the proper use of cylinders, regulators, manifolds, hoses, and fittings.
GENERAL RULES

More than a dozen gases commonly used in industrial plants are supplied in pressurized cylinders. The gases are supplied in this way simply because more gas can be shipped, stored, and distributed to a work station under high pressure than can be at atmospheric pressure. For example, about 251 cu ft of oxygen at 2400 psi can be held by a 1.6 cu ft container. If the oxygen were delivered at atmospheric pressure (14.7 psi) to a plant at sea level, 150 cylinders would be required.

Gases under high pressure can be hazardous if not used properly. Pressure is one problem and volume is another. A volume of gas that supports combustion will support 150 times more combustion per cylinder at 2400 psig than at sea-level atmospheric pressure. And oxidation reactions occur more rapidly in pure oxygen than in air. Some substances that are safe in air, such as petroleum-based lubricants, will spontaneously ignite in pure oxygen.

A third problem is the nature of the contained gas. Fuels burn. Oxygen supports combustion. Carbon dioxide has special characteristics. A slowly leaking cylinder of inert argon can deplete the oxygen in a room or work enclosure to the extent that people entering it will be asphyxiated without warning.

This chapter discusses many general rules for safe handling of compressed gases, and their cylinders and regulators. The second chapter will discuss special procedures that apply to certain gases and will outline problems that surround safe storage of compressed gases and safe use of cylinder manifolds, pipelines, and hose.

The Occupational Safety and Health Administration reports its regulations for using gas regulators, manifolds, and cylinders are among the 25 most frequently cited rules in industry. Most rules for the safe handling of high-pressure gases and their related equipment are based on common sense and experience. Rules are not static; they continue to be improved as more is learned. Although suppliers and distributors of compressed gases take steps to make their products and containers safe to use, certain rules must be followed in the plant.

Gases arrive at the plant in various forms and in different types of containers. For example, natural gas is delivered through a low-pressure distribution pipeline. Liquefied petroleum (LP) gases such as propane, propylene, and butane arrive as room-temperature liquids in low-pressure cylinders. MAPP gas (methyl acetylene propadiene, stabilized) is supplied as a room-temperature liquid under moderate pressure (about 94 psig). Most room-temperature, lower-pressure gases are fuels. These are flammable and have a special set of safe-handling requirements.

But oxygen, nitrogen, argon, hydrogen, and helium, among others, are supplied in gaseous form in high-pressure cylinders. Or, they may be shipped as super cooled (cryogenic) liquids in highly insulated containers. At atmospheric pressure, these gases will liquefy only at very low temperatures.

Carbon dioxide (CO₂) can be supplied as a solid, a liquid, or a gas. It is unusual because it solidifies directly from its gaseous state at -109 °F (-70 °C) at atmospheric
pressure. Liquid CO₂ cannot exist unless it is colder than 87.4 °F (30.8 °C) and simultaneously under a pressure of at least 60.4 psig. Conditions in a liquid on-site CO₂ receiver are usually zero °F (-18 °C) and 300 psig.

Carbon dioxide gas will solidify when it is released quickly from a unheated cylinder regulator. As the pressure suddenly drops, the regulator freezes solid. Nitrous oxide behaves similarly. In both cases electrically heated cylinder regulators are necessary to keep the gas and the regulator from freezing.

Acetylene also has special needs. As a liquid, it is chemically unstable and will detonate at the slightest shock. Pure liquefied acetylene is never used in conventional plant operations, but gaseous acetylene can be safe as long as special handling and storage rules are followed. The most important rule is that acetylene gas is unsafe at delivery pressures higher than 15 psig.

High-Pressure Cylinders

The most commonly used high-pressure gas cylinders are designed to hold gases at pressures to 2400 psig; some ultra-high pressure commercial cylinders will contain gas at pressures to 6000 psig.

The g in the psi pressure designation refers to pressure measurement in pounds per square inch at the cylinder regulator gauge. The gauge measures the gas in the cylinder at a pressure above the outside atmospheric pressure. If the gauge reads zero and the cylinder is at sea level, the cylinder still contains gas at 14.7 psi absolute pressure. Therefore, the primary safety rule for handling compressed gases is: An empty cylinder is never out of gas. The same handling rules apply to it that apply to a full cylinder of the same gas.

High-pressure cylinders come in a variety of pressure ratings and capacities. The most commonly used cylinders for oxygen, nitrogen, argon, and helium are rated at 2400 psig. The amount of gas in the cylinder will depend on the gas, because compressibility factors differ. At 2400 psig, a typical industrial cylinder will contain 251 cu ft of oxygen or about 291 cu ft of helium. Other commonly used cylinders are 2485 psig units, which contain 276 cu ft of oxygen, and 2640 psig cylinders, which contain 330 cu ft of oxygen.

The common 2400 psig, 251 cu ft oxygen cylinder weighs about 150 pounds, depending on the grade of steel used in the cylinder body. Each cylinder has a valve on top and a steel cap that screws over the valve to protect it from damage. Each valve has a safety device designed to release pressure if the cylinder pressure becomes too high.

If the valve of a high-pressure gas cylinder is broken off, the contents of the cylinder will jet from a hole about the diameter of a pencil. The escaping gas could have enough thrust to turn the cylinder into a rocket, depending on the cylinder’s size and weight.
General Handling Rules

The information already presented provides the basis for several important rules:

- Always chain gas cylinders upright to a wall, cylinder truck, cylinder rack, or post. This rule is especially important when the gas is in use because the regulator is on the cylinder valve and the cap is not in place. The rule does not apply to cylinder filling establishments.

- Always replace the cylinder cap when the cylinder is not in use and when it is being moved.

- Never lift a cylinder by its valve or its cap, or with chains, slings, or magnets. If a crane is needed to move a number of cylinders, the cylinders should be secured on a platform or cradle. A cylinder should never be dragged. Tilt the cylinder sideways and roll it along its bottom edge.

- Never place cylinders in hallways, passageways, or work areas where they could be hit by fork lift trucks or struck by falling objects. This rule applies to storing and using cylinders. Although a cylinder in use may be out of the way of fork lift trucks, a passing crane hook can hit it and knock off the regulator and the valve.

- Do not use cylinders as table legs to hold up other objects.

- Never hammer, pry, or wedge a stuck or frozen cylinder valve to loosen it, and never use a wrench. If a valve will not open by hand, call the gas distributor.

- Do not drop a cylinder.

- Do not allow grease, oil or other combustible materials to touch any part of a cylinder. This rule is especially important when oxygen cylinders are involved. Grease or oil that oxidizes very slowly in air will burst into flame in pure oxygen.

- Never use a cylinder unless the gas it contains is clearly stenciled on it or marked with a decal. Altering or defacing the name, numbers, or other markings on a gas cylinder is illegal and hazardous.

- Do not rely on the color of a cylinder to identify the gas inside. Suppliers use different color codes. Return an unidentifiable cylinder to the supplier.

- Keep cylinders away from electrical circuits and excessive heat. Cylinders are made of steel and therefore they will conduct electricity.

- Never ground a cylinder or place it near an electrical conductor, including piping, plumbing, or anything that might carry stray electric current.

- Never strike an arc or tap a welding electrode on a cylinder.

- Keep cylinders away from the sparks, hot slag, or molten metal that result from welding, cutting, machining, or foundry operations. Using or storing cylinders where they may get hotter than 130 °F (54 °C) violates Department of Transportation regulations. Keep cylinders out of direct sunlight. Gases expand when heated. The hotter a cylinder gets, the higher the gas pressure will become. A cylinder at 2400 psig and 70 °F (21 °C) will increase in pressure to 2451 psig at 130 °F (54 °C).

- Do not attempt to transfill gas from one cylinder to another.

If a cylinder that has been stored outside is frozen to the ground, use only warm water to free it. If the valve is frozen, use only warm water to thaw it, or bring the cylinder inside and let the valve thaw at room temperature.
Valves and Regulators

If a cylinder is leaking, mark it and put it outdoors, away from all sources of ignition. Post warning signs on it and keep it well away from other cylinders. Call the cylinder supplier or gas distributor.

High-pressure gas cylinders commonly are fitted with a back-seating valve. In use, the valve hand wheel must be turned so that the valve is fully open. Close the valve completely when the cylinder is not being used, even when the cylinder gauge registers empty. An empty cylinder contains residual gas. Furthermore, leaving the valve open exposes the cylinder to contamination.

- Always use the proper regulator for the gas in the cylinder. Gas regulators reduce the pressure inside the cylinder to a safe level for use. They are designed for use with specific gases, within prescribed pressure ranges. Different gases have different densities. The spring inside the regulator is designed to provide correct flow rate for a particular kind of gas. In addition, using the wrong regulator may cause some gases (acetylene, MAPP gas, oxygen) to react with the materials inside the regulator. For example, materials used in some regulators are not designed for oxygen and will ignite if used for oxygen. Plaques or decals on the regulator indicate which gas the regulator is designed for. Cylinder valve outlets and inlet connections on regulators also are designed to minimize the chances of using the wrong regulator. *

- Always check the regulator before attaching it to a cylinder. If the connections do not fit together readily, the wrong regulator is being used. Damaged threads on the connecting nut or valve outlet can also make a regulator difficult to attach and likely to leak.

Most gas-welding and flame-cutting accidents are caused by incorrect equipment set up and disassembly. Certain procedures should be followed in a specific sequence:

- Always “crack” the cylinder valve (open it slightly and close it immediately) before attaching a gas regulator to any cylinder—except a hydrogen or fuel gas cylinder. Cracking removes any dirt that may be lodged in the valve outlet, and prevents dirt from entering the regulator. Do not stand in front of the value outlet while cracking it, and do not point the outlet at anyone.

- Wipe the outlet with a clean, dry, lint-free cloth once the cylinder valve has been cracked. The threads and mating surfaces of the regulator and hose connections should also be cleaned before the regulator is attached.

- Always use a cylinder wrench or other tightly fitting wrench to tighten the regulator nut and hose connections. Using an oversized wrench, pliers or pipe wrench may damage the fittings and make it impossible to tighten them properly. A connection problem caused by dirty or damaged threads will result in leaks when the cylinder is used.

- Do not crack hydrogen and fuel gas cylinder valves. Merely wipe out the outlet connections with a clean, dry, lint-free cloth. Hydrogen is highly flammable and will ignite if it is released into the air too fast. Hydrogen burns with a colorless, nearly invisible flame. Burning hydrogen coming out of a cylinder might not be seen, but it will be felt.

- Attach the regulator securely before opening the valve wide.

- Stand to the side of the regulator when opening the cylinder valve. Cylinder regulators have a relief device to prevent excessive pressure from developing. High-pressure cylinder gauges have solid-front, safety-back construction. When subjected to excessively high pressure, the light-metal safety back will blow off to relieve the pressure. Even if the gauge glass breaks, the burst of venting gas can be startling. On rare occasions, old or

* For information on which connections are permissible for cylinders, see Compressed Gas Association pamphlet V-1. Pamphlet E-3 covers pipeline regulator connections.
improperly maintained oxygen regulators will ignite. But even a new oxygen regulator can burst into flame if the cylinder valve is suddenly turned on full. The quick burst of high-pressure gas from the cylinder into the regulator recompresses the oxygen inside the regulator and heats it to several thousand degrees Fahrenheit. Oxygen cylinders with regulators attached should always be opened slowly.

**Leaks and Contamination**

The time to discover oxygen in the fuel gas line, or fuel gas in the oxygen line, is before lighting the torch. Once regulators, hoses, and welding or cutting equipment have been attached and tested (test for leaks with soapy water), all lines should be purged before work is started. Purging also rids the lines of water vapor – a must if inert shielding gases for welding, blanketing, purging, or heat treating are being carried. The inert gases used to shield weld metal are very dry. If the water vapor is not removed, problems (from weld porosity to hydrogen embrittlement) will develop.

Purging a gas line involves opening the appropriate valve on the torch or depressing the trigger on the welding gun to allow new gas to enter the line and push out all the old gas. When a flammable gas is involved, the outflowing gas should be kept away from any ignition source.

Work should be performed in a well-ventilated area. Each torch valve should be held open until the line contains only pure gas. The two lines should be purged one at a time, and the torch valve on the other line should be closed. This action eliminates any explosive oxygen-fuel gas mixtures in a line and purges the torch.

Always use hoses, manifolds, and regulators with the gases for which they were designed. Following this rule prevents contamination of equipment and, ultimately, of welds or other work. In addition, some gases may react with each other inside the hose or regulator. (This condition will be discussed in detail in the second part of this series.)

Never hang tools, gloves, clothes, or spark lighters on top of the cylinder. They may interfere with the operation of the valve and prevent the gas from being shut off quickly in an emergency. In addition, clothes hung on an oxygen cylinder can become saturated with oxygen if there is a leak at the valve or connecting threads. Oxygen-saturated clothes will burn intensely if they come in contact with an ignitions source, even a small spark.

Specific procedures also should be followed when removing a regulator from a gas cylinder:

- Close the cylinder valve first.
- Bleed off the gas remaining in the regulator.
- Unscrew the regulator.

If a regulator were removed from an open-valved cylinder, the gas pressure would probably blow the regulator all the way across the work area.

**Defective Equipment**

Faulty equipment should be taken out of service at the first sign of a leak or a mechanical problem. Keeping an eye on regulator gauges often reveals defects before they become serious. If the pointer on a regulator's low-pressure gauge creeps upward when the downstream line is closed, the regulator is defective. If the pointer fails to move from its stop pin when the regulator is pressurized, the gauge if faulty. If the pointer fails to return against the stop pin when the pressure is released, the equipment is defective and should be repaired.

Have defective equipment repaired only by properly qualified and authorized personnel. Even some welding distributors are not authorized to do this work. Playing amateur mechanic on high-pressure equipment is dangerous.
SPECIAL CONDITIONS

Some compressed gases pose special problems. Fuel gases in general are dangerous because they burn, but other gases can be hazardous for other reasons. Knowing the potential problems associated with each type is very important.

This second chapter discusses procedures that should be followed during hauling and use of some of these special gases, and reviews the causes and cures of flashbacks and backfires, storage procedures, manifolding, and caring for hoses and fittings. The first chapter outlined general rules for safe handling of compressed gases and their cylinders and regulators.

Oxygen

Special rules for handling oxygen are necessary because an oil or grease spot that may present no hazard in air will burst into flame in oxygen. And when oxygen under high pressure enters a regulator, recompression can heat the oxygen when it hits parts inside. The increased temperature may even be enough to ignite the valve seats. If the wrong regulator is used, some of the regulator materials may also ignite and the reaction can be intense enough to set fire to the metal regulator parts.

- Never oil or grease torches, regulators, hoses, cylinder valves, or anything else that will come into contact with oxygen. Do not place oxygen cylinders or equipment where oil or grease from machinery can drop on them.
- Clean oxygen-using equipment with a clean, dry cloth. If necessary, use soap and water, but rinse the equipment thoroughly and dry it before use. Never use organic solvents.
- Never handle oxygen-using equipment with greasy or oily hands or gloves.
- Use a lubricant specifically formulated for oxygen service if oxygen-using equipment must be lubricated. Follow the manufacturer’s instructions.
- Never allow a jet of oxygen to contact an oily surface or a greasy cloth, or to enter a fuel-oil or other storage tank unless it has been thoroughly cleaned according to approved procedures.*
- Never allow anyone to dust himself with an oxygen (or even a compressed-air) line. Clothes that are even partially saturated with oxygen or a fuel gas should be aired in a well-ventilated area for at least 15 minutes to remove the trapped gas. Do not smoke or approach an ignition source while clothes are being aired.
- Always call oxygen, air, and fuel gases by their correct names. Oxygen is occasionally incorrectly called “air”. A worker who wants air may get oxygen. High-pressure oxygen supplied to a well-lubricated air tool can cause the lubricant to ignite, damaging the tool and injuring the operator.
- Never use oxygen to run air tools. Oxygen and other gases should be used only for their intended purposes. Never use oxygen to blow out pipelines or to provide ventilation. The oxygen may cool the operator, but it also increases the oxygen content of the room. A spark that is inconsequential in air can be extremely hazard in an oxygen-enriched environment.

Fuel Gases

A number of fuel gases are commonly used: MAPP Gas (methyl-acetylene propadiene, stabilized), propane, propylene, propylene-based mixtures, acetylene, natural gas, liquefied petroleum (LP) gases, and hydrogen. All but hydrogen are under low pressure.

* Literature on cleaning is available from the American Petroleum Institute.
All fuel gases are potentially hazardous. They will burn and can explode when mixed with air or oxygen. Following are general rules that apply to all fuel gases:

- Always call a gas by its proper name. Never refer only to “gas”.
- Do not use a fuel gas for any purpose other than that for which it was intended.
- Treat fuel gases with respect. Follow the correct procedures for assembling and disassembling equipment (discussed in Chapter 1). Use only regulators and other equipment designed for the gas being used and always follow the manufacturer’s instructions.
- Never let a fuel-gas cylinder reach a temperature above 130 °F (54 °C).
- Always keep fuel-gas cylinders upright. Never use them on their sides. Use, move, and secure them with the same care used for high-pressure cylinders.
- Close the cylinder valve of a leaking fuel-gas cylinder, take the cylinder to a safe place outside and away from ignition sources, mark it, and call the supplier or gas distributor.

**Acetylene** Special care is needed when working with acetylene because it is highly unstable:

- Never use acetylene at a pressure above 15 psig. Acetylene is stored at moderately high pressures in specially constructed cylinders that contain a porous filler material. The material has minute cellular spaces to prevent “free” acetylene from collecting in pockets of appreciable size. The porous mass is wetted with acetone in which acetylene is then dissolved. The combination of porous filler and acetone allows the acetylene to be safely contained in the cylinder at 250 psig and 70 °F (21 °C). Withdrawal rate from gas cylinders shall not exceed manufacturers recommendations.
- Never open the cylinder valve more than one turn. Leave the valve key or wrench on the valve whenever the valve is open so that the valve can be closed quickly in case of fire or accident.
- Never allow the temperature of any part of the acetylene system to rise above 130 °F (54 °C).
- Never use an acetylene cylinder on its side. Keep it upright and chained to a cylinder truck, wall, or other safe, stable object so that it cannot be knocked over or otherwise damaged.

Neither acetylene nor MAPP Gas should be used in fuel-gas systems or pipelines made of copper or of copper-based alloys containing more than 67 percent copper, or when the gases may come in contact with silver-bearing materials such as those used in silver brazed pipeline joints. This precaution applies only to piping system, not to brass hose connections, torches, and tips.

Acetylene and acetylene-based chemicals can combine with copper or silver and form explosive acetylene compounds if they are in contact with the high-copper or silver alloys for a long time in the presence of moisture. Such compounds can explode if subjected to heat or mechanical shock.

Artificial odors are added to natural gas, propane, and propylene so that a leak can easily be detected. The gases can be smelled in concentrations of about one-fifth their lower explosive limit, a safety factor sufficient to allow the problem to be corrected.
Acetylene has a natural, pungently sweet odor and can be detected in air at a concentration of about half of its lower explosive limit. When acetylene is smelled, quick action is required. On the other hand, MAPP Gas has a very strong odor that can be detected in a concentration as low as $\frac{1}{360}$ that of its lower explosive limit.

“Harmless” Gases

Under certain conditions, otherwise harmless gases can kill. Inert gases such as argon, helium, carbon dioxide, and nitrogen can asphyxiate a person.

Welders have died inside the hold of a ship or inside a tank because the triggers of their gas metal-arc welding guns were left slightly depressed over a weekend and the shielding gas was not turned off. When they returned to work the following Monday, the shielding gas inside the enclosed space had pushed out all the air and they were asphyxiated.

Asphyxiation occurs rapidly and without warning. All possible precautions should be taken to ensure that an adequate oxygen supply is available. Neither respirators nor gas masks supply oxygen. They only filter or purify. If asphyxiation is possible, workers should be equipped with supplied air masks, or the area should be well ventilated to assure the availability of air suitable for breathing.

Backfires and Flashbacks

A backfire is the loud popping noise that occurs when a welding or cutting torch flame burns back into the torch tip and is extinguished. Backfires are caused by improper gas pressures; the torch tip touching the work to molten metal; an incorrect, loose, overheated tip; or dirt on a connection or one of the seats. Although they are more of any annoyance than anything else, backfires can be eliminated by following proper procedures.

Flashbacks are more serious. Instead of going out, the flame burns back into the torch beyond the mixing chamber, possibly even into the hoses, regulator, and cylinder. The result can be a disastrous torch or hose explosion. More serious flashbacks may cause the regulator, or even the cylinder, to explode.

A flashback requires immediate action. It is often accompanied by a shrill, squealing sound. If a flashback occurs, shut off the torch fuel-gas valve immediately; then shut off the torch oxygen valve. Quick action is needed because prolonged exposure to a flashback may cause the torch to burn. Allow a hot torch to cool before relighting. Purge all hose lines before relighting the torch.

The use of flashback arrestors will provide additional protection and help prevent flashbacks and backfires. Flashback arrestors can be used in both cylinder and pipeline applications.

It should be noted that no device can ever replace the necessity for safe operating practices and properly maintained equipment.

The same conditions that cause backfires may also cause flashbacks. Correct, well-maintained equipment and proper procedures should be used. Flashbacks are most frequently caused by the failure to purge the hose lines before lighting the torch.
One way to prevent the propagation of a flashback into the equipment supplying the torches is to install check valves between the torch gas inlets and the incoming oxygen and fuel gas hoses to keep unwanted gases from entering the hoses. For additional protection, check valves are often placed at the regulator hose connections as well. Check valves do not eliminate the need to purge hoses individually and to follow the proper setup and working procedures. These safety devices will prevent backflow into the lines only if they are maintained in serviceable condition.

Cylinder Storage

Rules for storing gas cylinders complement, but differ from, rules for using them. Although storage rules depend somewhat on the kind of gas in the cylinders, some general rules apply:

- Store all cylinders in designated areas.
- Store and use cylinders on a first-in, first-out basis.
- Label every cylinder with the name of the gas it contains. Never remove identifying labels.
- Chalk “MT” or “empty” on all empty cylinders.
- Keep all empty cylinders for the same kind of gas together. Separate full cylinders from empty ones.
- Keep fuel gas cylinders well away from oxygen cylinders. OSHA regulations require that oxygen cylinders in storage be separated from fuel-gas cylinders and combustible materials by at least 20 ft (6.09 m) or by a noncombustible barrier at least 5 ft (1.5 m) high and having a fire-resistance rating of at least half an hour.
- Store cylinders outside whenever possible, but always protect them from the weather and from direct sunlight. Cylinders that must be stored inside should be placed in a dry, well-ventilated storage area, preferably constructed of fire-resistant materials. The roof and walls should not leak. Exposure to damp air or to corrosive chemicals or fumes can rust cylinder valves. Serious accidents may occur when rust eats through a fuel-gas cylinder.
- Never store any gas cylinder where the temperature may rise above 130 °F (54 °C).
- Never store cylinders near elevators, truck-loading platforms, or gangways; under operating cranes; or where something might drop on them, hit them, or knock them over.
- Place caps on cylinders that are being stored or moved.
- Use the same safe practices for storing cylinders as for handling them. Do not use magnetic cranes. Do not lift cylinders by their caps. Cylinders other than liquid fuel-gas and acetylene cylinders may be stored horizontally when absolutely necessary. Fuel gases such as propane, propylene, and MAPP Gas are always liquid inside the cylinder; they become gas only when they exit the cylinder. Always keep these liquid cylinders upright to prevent a sudden burst of liquefied gas from coming out of the torch. Acetylene cylinders should always be stored upright. An acetylene cylinder that has been stored horizontally will emit a burst of acetone instead of acetylene.
- Keep unauthorized persons away from the cylinder storage area. Use a lock or fence if necessary.
- Never try to refill cylinders to mix gases in a cylinder or transfill gas from one cylinder to another.
- Make sure leaking cylinders or cylinders with stuck valves are properly tagged and moved to a safe outdoor location. Notify the supplier to pick them up.
When oxygen cylinders are stored, some special precautions must be observed:

- Store oxygen cylinders at least 20 ft (6.09 m) from fuel gases and other combustibles such as oil, grease, gasoline, paint, and dirty rags. Keep oxygen cylinders stored near combustibles behind a fire-resistant wall or barrier at least 5 ft (1.5 m) high.

- Post “No Smoking-Oxygen” signs around the oxygen storage area.

Special rules for storing fuel gases exist to keep leaks from becoming dangerous and to keep fires, should they occur, from spreading:

- Place conspicuous “No Smoking” signs around all fuel-gas storage areas.

- Never store fuel-gas cylinders in a room heated by an open flame.

- Keep fuel-gas cylinders at least 20 ft (6.09 m) from oxygen cylinders and well away from electrical equipment, open flames, and cigarette smoking.

- Never store anything else in an indoor storage area or building containing flammable gases.

Walls, partitions, floors, and ceilings of the room should have a fire-resistance rating of at least 1 hour, according to National Fire Protection Association (NFPA) standards. The walls or partitions should be continuous from floor to ceiling and should be securely anchored. At least one wall of the room should be an outside wall. Self-closing fire doors should be used and windows should be made of wired glass and set in metal frames with a fixed sash. Specific details for building, installing, and remodeling rooms for storing fuel gases are available from NFPA.

Limits as to how much fuel gas should be stored inside a plant have been set by NFPA. The association recommends that fuel-gas cylinder storage areas within 100 ft (30.4 m) of each other in buildings having other occupancy be limited to a total gas capacity of 2000 cu ft of acetylene or non-liquefied fuel gas (hydrogen, for example), or a total equivalent water capacity of 735 lb of LP or MAPP Gas.

Each LP gas has a different weight per unit of volume. The general equivalent-water capacity rule is used to restrict the total quantity of any LP gas stored in any one place to the volume occupied by 735 lb of water. Thus, never store more than 309 lb of propane, 368 lb of MAPP gas, or 375 lb of butane in any one location. These limits are designed to keep a fire, should one occur, as small as possible. The 2000 cu ft maximum on acetylene storage in one location means that not more than 6 acetylene cylinders of the common 240 lb or 300 cu ft size should be stored in one place.

If these limits are exceeded, the gases should be stored outside or in a building or room meeting NFPA fire-resistant construction recommendations.

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*See NFPA Pamphlet 51, Section 222.

**See NFPA Pamphlet 51, Sections 6516 and 6517 for details.
Manifolds

Sometimes plants need more gas flow than they can get from single cylinders. One solution is a bulk compressed gases supply. With this arrangement, gas is piped from a storage tank in back of the plant. Another common method is to use manifold devices that allow two or more cylinders to be ganged to increase gas flow rates. When acetylene is used, manifolding is the only way to increase the bulk flow of fuel beyond that available from a single cylinder. Manifolding increases the safety problems, because it increases the amount of gas being handled and used at one time. Certain rules should be followed by manifolding gas cylinders:

- Use fuel-gas manifolds and high-pressure (more than 250 psig) oxygen manifolds that are approved by Factory Mutual or Underwriters Laboratories for the gas used. The manifolds must be able to withstand pressures and must be leak free. When manifolds are tested, an oil-free noncombustible gas such as dry nitrogen, should be used.

- Use manifolds and parts only with the gases they are approved to handle.

- Label all low pressure (less than 250 psig) oxygen manifolds clearly.

- Install an approved flash arrester between cylinder and coupler block whenever acetylene cylinders are coupled to a manifold. If no more than three cylinders are being used outdoors, one flash arrester installed between the coupler block and the regulator is acceptable.

- Have at least one valve key or wrench available at the manifold for emergency closing of valves not equipped with a handwheel. Leave more than one key or wrench on the cylinders.

- Have approximately equal pressure in gas cylinders connected to discharge simultaneously through a common manifold. If a full cylinder at 2400 psig and a three-quarters empty cylinder at about 600 psig are connected to feed into the same line, the gas in the full cylinder will tend to back up into the nearly empty cylinder instead of feeding into the pipeline or hoses.

Procedures for placing manifolds help reduce the risk of fire damage:

- Do not use a fuel gas manifold with a capacity larger than 3000 cu ft if acetylene or nonliquid fuel gases are used indoors unless the manifolds are placed in a room built to NFPA fire-resistant standards. Above this capacity, the building must meet NFPA requirements or the gas must be stored in a separate outdoor location.

- Keep fuel gas manifolds at least 50 ft (15.2 m) apart. You can use two or more in one room if they are separated.

- Locate oxygen manifolds for pressures above 250 psig and capacities above 6000 cu ft, or below 250 psig and capacities to 12,000 cu ft, outdoors or in a building constructed to NFPA requirements. No combustible materials may be kept within 20 ft (6.09 m) of the manifold.

- Be sure that manifolds connected to bulk (more than 20,000 cu ft) oxygen supplies meet NFPA standards for bulk oxygen systems.

- Be sure that high pressure (above 250 psig) oxygen manifolds are at least 20 ft (6.09 m) from combustible materials or fuel-gas manifolds, or are separated by a barrier at least 5 ft (1.5 m) high that meets NFPA standards has had a fire-resistance rating of at least half an hour.

- Never put oxygen manifolds inside any acetylene generator room.
Hoses and Fittings

Welding hoses are subjected to a lot of wear and tear and can cause a great deal of trouble. It is important that they are used and cared for properly.

Never use just any available hose for welding applications. Welding hoses are specially designed for particular gases and pressures. Select a hose designed for the gas and pressures that will be used. Never use a compressed-air hose, which may contain oil, for oxygen. A fire or explosion could result. Hoses for oxy-fuel gas service shall comply with Rubber Manufacturers Association IP-7 specification for welding hose.

Welding hoses are normally color coded to prevent mix-ups. The generally recognized hose colors are red for acetylene and other fuel gases, green for oxygen, and black for inert gases and compressed air. Hoses with leaks, burns, worn spots, or any other defects are dangerous and unfit for use. They should be fixed or disposed of. There are several safe procedures for handling welding hoses:

- Do not use hoses with too many repair connections. Even if the connections are gastight, little gas will flow through the hoses. A noticeable pressure drop and even a flashback may occur.
- Protect hoses from sparks, hot metal, and slag. Do not drag a hose over sharp objects, and keep it away from oil and grease to prevent deterioration and the chance that oil will come in contact with oxygen.
- Do not run hose where it can be damaged by nearby equipment. Suspend a hose over a passageway to keep it from being stepped on or run over by trucks. If the hose cannot be suspended, protect it with planks.
- Prevent kinking or tangling the hose. Kinking will weaken the hose and, if done repeatedly, may cause it to leak or fail. Never kink or crimp the hose to stop gas flow temporarily when changing a torch. Shut the gas off at the regulator.
- Use no more than 4 in. of tape for each 12 in. of hose if parallel lengths of oxygen and fuel-gas hoses must be taped together to keep them from tangling. If the entire hose is taped, damage or leaks may not be noticed.
- Keep hose lengths as short as possible. Gas pressure between the gas supply and the torch drops as the hose gets longer.

Caring for hoses should include safe procedures for lighting a torch. Purge oxygen and fuel-gas hoses of mixed gases before lighting the torch. Always use a friction lighter or a pilot light to light the torch; never use matches. When equipment is shut down for any length of time, the cylinder valves should be closed and the hoses drained. Purge both hose lines before relighting the torch.

Purging is also a good way to keep shielding-gas hoses dry. If these lines are not well purged and very dry, the welds will be extremely porous.

Welding hose requires special fittings designed to withstand severe service conditions. Any hookups or repairs should be made with approved fittings. Never use ordinary pipe fittings, or fittings designed for compressed air. Acetylene and fuel-gas fittings have left hand threads to prevent them from being accidentally connected to oxygen fittings.
If a hose is worn, cut, burned, or otherwise damaged, remove the bad section and splice the two good ends together, using approved fittings and the proper ferrules or clamps. Do not use ordinary wire or another substitute to secure fittings to hoses, and do not do makeshift repairs with tape. Improper repairs lead to gas leaks and hose blowouts. Never use copper tubing for splicing hose. Acetylene could react with copper and cause an unexpected explosion.

**Gas Leaks**

Check for gas leaks at the fittings every time equipment is set up. Apply soapy water to the valves, joints, connections, and around the regulator gauges. If bubbles appear, a leak is present.

If gas can be smelled, the equipment should be shut down immediately and the leak's location should be determined. A hose torch that is suspected of leaking should be immersed in a tub or pan of water. Watch for bubbles. Never try to repair leaks on cylinder valves or safety plugs. Contact the cylinder supplier. Following are some rules for safely looking for leaks:

- Never use an open flame to test for leaks.

- Depressurize the hose, regulator, or torch if a leak is found. If the leak is at a threaded connection, open the connection and wipe the sealing surfaces with a clean, dry, lint-free cloth. Check the threads to make sure they are clean and that they are not stripped or bent. Damaged fittings should be replaced. Tighten the connection and repressurize the system.

Test again for leaks. If any are found, depressurize the system again and attach a tag marked "Danger-Do Not Operate-Leaks." Return the equipment for repair.
Most gases used in plants are also available as cryogenic liquids. Among the most common are oxygen, nitrogen, argon, helium and hydrogen.

Liquid oxygen is frequently delivered to a plant – and even to a construction site – and then vaporized for use in flame cutting, welding, metallizing, or heating. Other uses include oxygen injection into a foundry cupola and oxygen-based processes such as paper-pulp bleaching and steelmaking.

Liquid nitrogen is also very common. A variety of processes have been developed that use the liquid primarily because of its high refrigeration values. Examples include freezing food, stripping scrap rubber from tires and cables, and removing parting lines and risers from plastic injection-molded parts. It is even used as super-cold quenchant for high-alloy steels to transform retained austenite.

The availability of large volumes of liquid helium has made possible the rapid development of superconductivity. And these examples are only a few from some of the major industrial gases.

The key to the expanding use of cryogenic liquids is economics. The cost of delivering and storing the liquid is often lower than buying the gas in compressed gases cylinders. At room temperature (70 °F/21 °C) and atmospheric pressure, nitrogen occupies 700 times as much space as the same amount of nitrogen in liquid form. The reduction in cost for containers, demurrage, shipping, and storage is enormous.

However, handling liquefied gases that are stored and used at very low temperatures requires some special knowledge and special precautions. To use these gases safely, the plant engineer and employees must know the specific properties of each liquefied gas and its compatibility with other materials, and must follow some common sense procedures.

**Characteristics of Cryogenic Liquids**

A cryogenic liquid has a normal boiling point below -238 °F (-150 °C). The most commonly used industrial gases that are transported, handled and stored at cryogenic temperatures are oxygen, nitrogen, argon, hydrogen, and helium. Three rare atmospheric gases—neon, krypton, and xenon—are used in the liquid state. Natural gas, liquefied natural gas (LNG) or liquid methane, and carbon monoxide also are handled as cryogenic liquids, although they are not usually classified as industrial gases. Liquefied ethylene, carbon dioxide, and nitrous oxide are transported and stored as liquids, but are not classified as cryogenic.

Handling cryogenic liquids in large volumes is not new. Liquid oxygen was first shipped by tank truck in 1932, and today it is common to see portable liquid containers, cryogenic trailers and trucks, and railroad tank cars hauling large quantities of liquefied gases across the country. Cryogenic tanker ships transport LNG overseas, and aircraft move other liquefied gases, especially liquid helium, from one place to another.
Many safety precautions that must be taken with compressed gases also apply to liquefied gases. However, some additional precautions are necessary because of the special properties exhibited by fluids at cryogenic temperatures.

Both the liquid and its boil-off vapor can rapidly freeze human tissue and can cause many common materials such as carbon steel, plastic, and rubber to become brittle or fracture under stress. Liquids on containers and piping at temperatures at or below the boiling point of liquefied air (-318 °F or -194 °C) can cause the surrounding air to condense to a liquid.

Extremely cold liquefied gases (helium, hydrogen, and neon) can evenly solidify air or other gases to which they are directly exposed. In some cases, even plugs of ice or foreign material will develop in cryogenic container vents and openings and cause the vessel to rupture. Following the supplier’s operating procedures can help prevent plugging. If a plug should form, contact the supplier immediately. Do not attempt to remove the plug; move the vessel to a remote location.

All cryogenic liquids produce large volumes of gas when they vaporize. For example, 1 volume of saturated liquid nitrogen at 1 atmosphere vaporizes to 696.5 volumes of nitrogen gas at room temperature at 1 atmosphere. The volume expansion ratio of oxygen is 860.6 to 1. Liquid neon has the highest expansion ratio – 1445 to 1 – of any industrial gas.

Vaporized in a sealed container, these liquids produce enormous pressures. For example, when 1 volume of liquid helium at 1 atmosphere is vaporized and warmed to room temperature in a totally enclosed container, it has the potential to generate pressure of more than 1,450 psig. Because of this high pressure, cryogenic containers usually are protected with two pressure-relief devices; a pressure-relief valve and a frangible disc.

Relief devices should function only during abnormal operation and emergencies or when gas is not being withdrawn from the tank or cylinder. If they are triggered, the system should be checked for loss of insulating vacuum or for leaks. Do not tamper with the safety valve settings. Report leaking or improperly set relief valves to the gas supplier and have them replaced or reset by qualified personnel. Similarly, all safety valves with broken seals or with any frost, ice formation, or excessive corrosion should be reported.

Most cryogenic liquids are odorless, colorless, and tasteless when vaporized to a gas. As liquids, most have no color; liquid oxygen is light blue. However, whenever the cold liquid and vapor are exposed to the atmosphere, a warning appears. As the cold boil-off gases condense moisture in the air, a fog that extends over an area larger than the vaporizing gas forms.
TREATING COLD-CONTACT BURNS

Workers will rarely come in contact with a cryogenic liquid if proper handling procedures are used. In the unlikely event of contact with a liquid or cold gas, a cold contact “burn” may occur. Actually, the skin or tissue freezes.

Medical assistance should be obtained as soon as possible. In the interim, the following emergency measures are recommended:

- Remove any clothing that may restrict circulation to the frozen area. Do not rub frozen parts, as tissue damage may result.
- As soon as is practical, immerse the affected parts in warm water (not less than 105 °F or more than 115 °F, or 40 °C to 46 °C). Never use dry heat. The victim should be in a warm room, if possible.
- If the exposure has been massive and the general body temperature is depressed, the patient should be totally immersed in a warm-water bath. Supportive treatment for shock should be provided.
- Frozen tissues are painless and appear waxy and yellow. They will swell and be painful and prone to infection when thawed. Do not rewarmed rapidly. Thawing may require 15 to 60 minutes and should continue until the pale blue tint of the skin turns pink or red. Morphine or tranquilizers may be required to control the pain during thawing and should be administered under professional medical supervision.
- If the frozen part of the body thaws before the doctor arrives, cover the area with dry sterile dressings and a large, bulky protective covering.
- Alcoholic beverages and smoking decrease blood flow to the frozen tissues and should be prohibited. Warm drinks and food may be administered.

General Safety Practices

The properties of cryogenic liquids affect their safe handling and use. The table presents data to help determine handling procedures. None of the gases listed is corrosive at ambient temperatures, and only carbon monoxide is toxic.

The liquids are listed by decreasing boiling point. Although xenon boils above -238 °F (-150 °C), it also has been included. Natural gas is not listed because it is a mixture of methane and other hydrocarbons; its boiling point depends on its composition. However, natural gas is primarily methane and methane data is included.

- Always handle cryogenic liquids carefully. They can cause frostbite on skin and exposed eye tissue. When spilled, they tend to spread, covering a surface completely and cooling a large area. The vapors emitted by these liquids are also extremely cold and can damage delicate tissues.
- Stand clear of boiling or splashing liquid and its vapors. Boiling and splashing always occur when a warm container is charged or when warm objects are inserted into a liquid. These operations should always be performed slowly to minimize boiling and splashing. If cold liquid or vapor comes in contact with the skin, first aid should be given immediately. (See “Treating Cold-Contact Burns.”)
Cryogenic liquids are stored and transported in a wide range of containers.

**Special Precautions**

Some liquefied gases require special precautions. For example, when oxygen is handled, all combustible materials, especially oil or gases, should be kept away. Smoking or open flames should never be permitted where liquid oxygen is stored or handled; “no smoking” signs should be posted conspicuously in such areas.

Oxygen will vigorously accelerate and support combustion. Because the upper flammable limit for a flammable gas in air is higher in an oxygen-enriched air atmosphere, fire or explosion is possible over a wider range of gas mixtures.

Liquid oxygen or oxygen-enriched air atmospheres should not come in contact with organic materials or flammable substances. Some organic materials – oil, grease, asphalt, kerosene, cloth, tar, or dirt containing oil or grease – react violently with oxygen and may be ignited by a hot spark. If liquid oxygen spills on asphalt or on another surface contaminated with combustibles (for example, oil-soaked concrete or gravel), no one should walk on, and no equipment should pass over the area for at least 30 minutes after all frost or fog has disappeared.

- Never allow any unprotected part of the body to touch uninsulated pipes or vessels that contain cryogenic fluids. The extremely cold metal cause the flesh to stick fast to the surface and tear when withdrawn. Touching even nonmetallic materials at low temperatures is dangerous.

Tongs should be used to withdraw objects immersed in a cryogenic liquid. Objects that are soft and pliable at room temperature become hard and brittle at extremely low temperatures and will break easily.

Workers handling cryogenic liquids should use eye and hand protection to protect against splashing and cold-contact burns. Safety glasses are also recommended. If severe spraying or splashing is likely, a face shield or chemical goggles should be worn. Protective gloves should always be worn when anything that comes in contact with cold liquids and their vapors is being handled. Gloves should be loose fitting so that they can be removed quickly if liquids are spilled into them. Trouser should remain outside of boots or work shoes.
<table>
<thead>
<tr>
<th>Safety Properties of Cryogenic Fluids</th>
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<tbody>
<tr>
<td><strong>Xenon (Xe)</strong></td>
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<tr>
<td><strong>Krypton (Kr)</strong></td>
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<tr>
<td><strong>Methane (CH₄)</strong></td>
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<td><strong>Oxygen (O₂)</strong></td>
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<tr>
<td><strong>Argon (Ar)</strong></td>
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<tr>
<td><strong>Carbon Monoxide (CO)</strong></td>
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<td><strong>Nitrogen (N₂)</strong></td>
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<tr>
<td><strong>Neon (Ne)</strong></td>
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<tr>
<td><strong>Hydrogen (H₂)</strong></td>
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<tr>
<td><strong>Helium (He)</strong></td>
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<tr>
<td><strong>Boiling point, 1 atm</strong></td>
</tr>
<tr>
<td>F: -163</td>
</tr>
<tr>
<td>C: -108</td>
</tr>
<tr>
<td><strong>Melting point, 1 atm</strong></td>
</tr>
<tr>
<td>F: -169</td>
</tr>
<tr>
<td>C: -112</td>
</tr>
<tr>
<td><strong>Density, boiling point, 1 atm</strong></td>
</tr>
<tr>
<td>lb/cu ft: 191</td>
</tr>
<tr>
<td><strong>Heat of vaporization, boiling point</strong></td>
</tr>
<tr>
<td>Btu/lb: 41</td>
</tr>
<tr>
<td><strong>Volume expansion ratio, liquid at 1 atm boiling point to gas at 60 °F, 1 atm</strong></td>
</tr>
<tr>
<td>559</td>
</tr>
<tr>
<td><strong>Flammable</strong></td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td><strong>Inert-Gas Precautions</strong></td>
</tr>
</tbody>
</table>

Any clothing that has been splashed or soaked with liquid oxygen, or exposed to a high gaseous-oxygen atmosphere should be changed immediately. The contaminated systems should be aired for at least an hour until they are completely free of excess oxygen. Workers exposed to high-oxygen atmospheres should leave the area and avoid all sources of ignition until the clothing and the exposed area have been completely ventilated. Clothing saturated with oxygen is readily ignitable and will burn vigorously.

Finally, oxygen valves should be operated slowly. Abruptly starting and stopping oxygen flow may ignite contaminants in the system.

The primary hazards of inert-gas systems are rupture of containers, pipelines, or systems, and asphyxiation. A cryogen cannot be indefinitely maintained as a liquid even in a well-insulated container. Any liquid, or even cold vapor trapped between valves, has the potential for causing enough pressure buildup to cause violent rupture of the container or piping. The use of reliable pressure-relief devices is mandatory.

Loss of vacuum in vacuum-jacketed tanks will increase evaporation in the system, causing the relief devices to function and vent the product. The vented gases should be routed to a safe outdoor location. If the gases are not vented outdoors, adequate ventilation must be maintained; instruments should be used to monitor the area.

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*Helium does not solidify at 1 atmosphere pressure.

**Oxygen does not burn, but will support combustion. However, high oxygen atmospheres substantially increase combustion rates of other materials and may form explosive mixtures with other combustibles. Flame temperatures in oxygen are higher than in air.

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*See NFPA No. 70(15) and NFPA 68, "Explosion Venting Guide (14)," for additional information.

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19
Flammable Gas Precautions

Smoking or open flames should not be permitted where flammable fluids are stored or handled. Clothes that minimize ignition sources should be worn in atmospheres that may contain concentrations of flammable gases.

All major stationary equipment should be properly grounded. Ground connections should be provided between stationary and mobile equipment before any flammable gas is loaded or unloaded. All electrical equipment used in or near flammable-gas loading and unloading areas, or in atmospheres that might contain explosive mixtures, should conform to National Fire Protection Association (NFPA) standards 50B (Liquid Hydrogen) and 59A (Liquefied Natural Gas) or to Article 500 of the National Electrical Code (NEC). When flammable cryogenic liquids and gases are handled inside, adequate positive mechanical ventilation is necessary. Electrical equipment and wiring must conform to Article 501 of the NEC.*

Flash-off gas from closed liquid-hydrogen containers used or stored inside should be piped through a laboratory hood to the outside, or should be vented by other means to a safe location. If hydrogen is vented into ductwork, the ventilation system should be independent of other systems, and sources of ignition must be eliminated at the exit.

Asphyxiation

All gases except oxygen will cause asphyxiation by displacing breathable air in an enclosed workplace. They should be used and stored in well-ventilated areas. Only oxygen will support life. The presence of these gases cannot be detected without instrumentation. Asphyxiation can be sudden or may occur slowly without the worker being aware of the situation.*

Unless large quantities of inert gas are present, the problem is easily prevented by using proper ventilation at all times. Nitrogen should be vented outside to safe areas. Analyzers with alarms should be installed to alert workers to oxygen-deficient atmospheres. Constant monitoring, sniffers, and other precautions should be used to survey the atmosphere when personnel enter enclosed areas or vessels. When it is necessary to enter an area where the oxygen content may be below 19 percent, self-contained breathing apparatus or a hose mask connected to a breathing-air source must be used. A conventional gas mask will not prevent asphyxiation.

Most personnel working in or around oxygen-deficient atmospheres rely on the buddy system for protection. However, unless equipped with a portable air supply, a co-worker may also be asphyxiated upon entering the area to rescue an unconscious partner. The best protection is to provide both workers with a portable supply of respirable air. Life lines are acceptable only if the area is free of obstructions and one worker is capable of lifting the other rapidly and easily.

*Refer to Safety Bulletin 58-2 (7) from the Compressed Gas Association for additional information.
**Training**

The best single investment in safety is trained personnel. Some workers will need detailed training in a particular type of equipment, cryogen, or repair operation. Others will require broader training in safe handling practices for a variety of cryogenic liquids. The following subjects should be familiar to everyone involved in using, handling, storing, or transferring cryogens:

- Nature and properties of the cryogen in both its liquid and gaseous states.
- Operation of the equipment.
- Approved, compatible materials.
- Use and care of protective equipment and clothing.
- First-aid and self-aid techniques to employ when medical treatment is not immediately available.
- Good housekeeping practices.

Good housekeeping is essential to safety. Few cryogens are spontaneously hazardous, but each liquefied gas poses another hazard.

Liquid oxygen may form mixtures that are shock sensitive with fuels, oils, or grease. Porous solids, such as asphalt or wood, can become saturated with oxygen and also become shock sensitive. Ignition is more likely with weaker sparks and lower temperatures than would be required in air.

Flammable gases such as hydrogen and methane are lighter than air. At normal temperatures, they will rise, but at the first temperatures that exist just after evaporation from the liquid state, the saturated vapor is heavier than air and tends to fall. Wind or forced ventilation will affect the direction of the released gases and must be considered during disposal of any leaking fluid.

The location and maintenance of safety and firefighting equipment are important. Outside personnel also should be informed of all necessary safeguards before entering a potentially hazardous area. In general, maintaining good housekeeping rules and demanding a high level of worker conduct everywhere in the plant will minimize negligence.

**Safe Storage Recommendations**

Cryogenic liquids are stored and transported in a wide range of containers from small Dewar flasks to railroad tank cars. Only equipment and containers designed for the intended product, service pressure, and temperature should be used. If any questions arise about correct handling or transport procedures, or about the compatibility of materials with a given cryogen, the gas supplier should be consulted.

Cryogenic liquids ordinarily should not be handled in open containers unless they are specifically designed for that purpose and for that product. Cryogenic containers should be clean and made from materials, such as austenitic stainless steels, copper, and certain aluminum alloys, suitable for cryogenic temperatures.
Cryogens should be transferred into warm lines or containers slowly to prevent thermal shock to the piping and container and to eliminate possible excessive pressure buildup in the system. When liquids are transferred from one container to another, the receiving container should be cooled gradually to prevent shock and reduce flashing. High concentrations of escaping gases should be vented so that they do not collect in an enclosed area.

- **Do not drop warm solids or liquids into cryogenic liquids.** Violent boiling will result and liquid can splash onto personnel and equipment.

- **Avoid breathing vapor from any cryogenic liquid source except for liquid-oxygen equipment designed to supply warm breathing oxygen.** When cryogenic liquids are being discharged from drain valves or blowdown lines, open the valves slowly to prevent splashing.

Smoking should never be permitted.

Two types of portable liquid-storage vessels are generally used to hold and dispense cryogenic liquids—nonpressurized Dewar containers and pressurized liquid cylinders.

Dewar containers for liquids are open-mouthed, non-pressurized, vacuum-jacketed vessels usually used to hold liquid argon, nitrogen, oxygen, or helium. Some of these containers are designed for lightweight liquids such as helium and for maximum holding times; their internal support system cannot hold some of the heavier cryogens, such as argon. When they are used be sure that no ice accumulates in the neck or on the cover and causes a blockage and subsequent pressure buildup.

Laboratory Dewar flasks with wide-mouthed openings have no cover to protect the liquid. Most are made of metal, but some smaller units are of glass.

Liquid cylinders are pressurized containers, usually vertical vessels, designed and fabricated according to U.S. Department of Transportation specifications. There are three major types: for dispensing liquid or gas, for gas withdrawal only, and for liquid withdrawal only. Each type of liquid cylinder has appropriate valves for filling and dispensing and is adequately protected with a pressure-control valve and a frangible disc.

Some liquid cylinders can be handled manually, but it is preferable to move them using portable handcarts. A strap should be used to secure the cylinder to the handcart to keep it from slipping off.

Liquid cylinders should never be lifted by the ring by crane. Lifting hook connections are supplied on some models. Consult the manufacturer of the vessel or gas supplier for specific recommendations.

An unusually cold outside jacket on a cryogenic vessel indicates some loss of insulating vacuum. Frost spots may appear. A vessel in this condition should be drained, removed from service, and set aside for repair. Such repairs should be handled by the manufacturer or qualified company.

Cryogenic containers must be handled very carefully. They should not be dropped or tipped on their sides.
**Transfer Lines** Many types of filling or transfer lines are used to handle the flow of cryogenic fluids from one point to another – small, insulated copper or stainless steel lines; large-diameter rigid lines; or flexible hose systems, vacuum jacketed lines, or other insulated systems.

Liquids can be transferred by three methods; the simplest is gravity. In this case, the height of the stored liquid serves as the transfer medium. Pressurized transfer uses the vapor pressure of the product, or pressure from an external source, to move the liquid to the lower-pressure receiving container.

Various types of cryogenic pumps are also available. Flow rates may vary from less than one to several hundred gpm. The product should be in liquid form in the transfer lines. Any vaporization of liquid within the system may cause excessive pressure drop and two-phase (liquid and gas) flow and cavitation that is detrimental to the operation of cryogenic pumps.

Short transfer lines used for intermittent service are normally not insulated, but lines used for continuous transfer of cryogens usually are. All liquid transfer hoses should have dust caps.

Vacuum-jacketed lines are required to transfer liquid hydrogen and liquid helium because of their extremely cold temperatures and low heats of vaporization. Vacuum-jacketed lines occasionally are used for in-plant transfer of atmospheric cryogenic fluids to reduce costly line and flash-off losses.

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All data set forth herein is provided for general information only and is based on generally accepted tests and on published data from standard technical reference works. The accuracy or completeness of any such information, test or data is not warranted in any way.