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Safe Handling, Storage, and Transport of Compressed Gas Cylinders

Lori M. Carpenter, CSP
Safety Specialist
Airgas USA, LLC
Old Forge, PA

Robert S. Giannini
VP Safety and Compliance
Airgas USA, LLC
Cheshire, CT

Introduction

Compressed gases are, by their nature, hazardous. They are all capable of creating environments that are either flammable, oxygen enriched, or oxygen deficient. Consider a gas as common as nitrogen, which comprises almost 80% of the earth's atmosphere. Even it can displace breathable oxygen in an enclosed space and cause asphyxiation.

There are over 200 different gaseous and related types of materials distributed in gas cylinders. Compressed gases are present almost everywhere, from health care centers where they supply critical oxygen to patients for breathing, to manufacturing environments where gases are used in welding, chemical or analytical operations, or to fuel powered industrial vehicles. Because gas containers are common in everyday activities, many times the dangers of these cylinders are overlooked and not given appropriate safety considerations. Something as simple as a sudden release of gas from a cylinder can cause it to become a powerful missile-like projectile.

Compressed gas hazards are varied, from the physical properties of the gases themselves, to the potential dangers associated with handling cylinders, to the special precautions necessary to safely move or store gas cylinders. Knowing the hazards associated with the gases your employees handle and the necessary precautions is imperative to maintain a safe working environment.

Hazards of Gases

There are a number of hazards that may be exhibited by gases. Most gases act as asphyxiants. Some gases may be flammable while others act as oxidizers. A gas may be toxic and/or corrosive.

A limited number of gases can exist as cryogenic liquids. However, a hazard common to all gases is that they will exert pressure within their container.

Some gases exhibit multiple hazards. Hydrogen, for example, which is common in many analytical labs and chemical processing environments, is under high pressure, is flammable, and can act as an asphyxiant.

Asphyxiant

Simple asphyxiants displace oxygen in the air and can lead to suffocation. Asphyxiation is the primary hazard associated with inert gases such as nitrogen, helium, argon, and carbon dioxide.

The effect of an asphyxiant gas can be seen if one immerses a burning candle in an atmosphere of pure carbon dioxide, which extinguishes the flame in a matter of seconds. Never deliberately breathe or allow others to breathe any compressed gas of any type, unless expressly warranted for breathing. To do so can deplete oxygen in the bloodstream and cause rapid suffocation and death. It may seem like fun to raise one's voice by inhaling helium, but deadly consequences can and all-too-often do result from this activity.

Flammable

Common flammable gases include acetylene, the most common welding and cutting fuel, hydrogen, methane, and liquefied petroleum gases such as propane or propylene. A flammable gas can only burn in a certain range of concentration in air. The lowest concentration at which a flammable gas can burn in air is known as its Lower Explosive Limit (LEL), and the highest concentration is known at the Upper Explosive Limit (UEL), above which the mixture becomes fuel-rich. The area between the UEL and LEL is known as the Flammable Range. In addition to traditional ignition sources, flammable gases can be ignited by static electricity. Acetylene can undergo violently explosive decomposition if pressurized above 15 psig after removal from the cylinder. Never pressurize or use acetylene outside a gas cylinder above 15 psig.

Pyrophoric

Gases that do not need a source of ignition to burn are known as pyrophoric and they can spontaneously ignite on contact with air. The most common example of a pyrophoric gas is silane, mainly used in fabrication processes for semiconductor devices. During transportation, a small amount of silane may leak across the cylinder valve's seat and be trapped by the vapor-tight outlet cap. Before removing this cap from a silane cylinder, check and confirm the valve is closed tightly. Always remove the valve's gas-tight outlet cap slowly to minimize the effect of a detonation, if any.

Oxidizer

An oxidizer is defined as a substance that can initiate combustion or increase the burning rate of a combustible material. Common oxidizing gases are oxygen and nitrous oxide. Oxygen, which is widely used in many industries and applications from healthcare to metal cutting applications, is often mistaken as a flammable gas because it can cause combustible materials to burn. However it is not a flammable gas – it is an oxidizer. Oxidizing materials are incompatible with combustible materials, particularly hydrocarbons such as oil, grease, or asphalt.

It is very important that operators always wear clean PPE when handling oxidizers. If clothing becomes saturated with oxygen, it must be removed and thoroughly aired out. Clothing that is saturated with oxygen may burn rapidly if exposed to any source of ignition, causing serious injuries to the wearer. Gloves contaminated with oil or grease can ignite in a stream of oxygen.

All equipment that comes into contact with oxidizers must be thoroughly cleaned to remove all hydrocarbons and other contaminants. It is important when handling oxidizers to open valves slowly to avoid rapid pressurization of piping or equipment. Rapid pressurization can cause enough heat to generate an ignition of any incompatible materials. Because of this, ball valves should never be used in oxygen service as they open too rapidly.

Air, especially that which is supplied in compressed gas cylinders, is often incorrectly referred to as oxygen, and vice-versa. Learn and train on the difference and never use oxygen instead of air. Oxygen is never to be used to power pneumatic tools or to fill self-contained breathing apparatus.

Toxic

Toxic gases may cause significant acute health effects at low concentrations. The health effects may include severe skin or eye irritation, pulmonary edema, neurotoxicity, or other potentially fatal conditions. Examples of toxic gases include: hydrogen sulfide, hydrogen chloride, carbon monoxide, and arsine. Gases are classified by DOT as toxic if their LC_{50} is less than 5,000 ppm. LC_{50} is a laboratory-determined concentration that is lethal to 50% of the test population.

Some gases, although not classified as toxic, pose respiratory effects and are labeled as inhalation hazards. An example of such a gas is anhydrous ammonia, which is labeled according to DOT as a non-flammable gas, but must also be stated as an inhalation hazard on shipping documentation.

Corrosive

Corrosive gases attack and deteriorate a number of materials including metals and living tissue. Corrosivity is often associated with gases that are also toxic such as chlorine and hydrogen chloride, used for water purification and many chemical processing applications. Systems to handle corrosive gases must be specifically designed and constructed of materials that are compatible with the product.

Cryogenic

Cryogenic gases are those in liquefied form with a normal boiling point below minus 130 degrees Fahrenheit. Typical examples of cryogenic gases are argon, helium, nitrogen, oxygen, and hydrogen. While carbon dioxide and nitrous oxide are not technically cryogenic, they can exist as very cold refrigerated liquids, exhibiting similar properties and possessing similar hazards as the true cryogens.

Never allow unprotected skin to come into contact with materials at cryogenic temperatures. This hazard can be illustrated by contacting a piece of raw steak with a pipe at liquid nitrogen temperature, which will cause a significant amount of the meat to freeze to the pipe in a short time. Many materials, both metallic and non-metallic, are not suitable for use with cryogenic liquids, as they may become brittle. This can be demonstrated by immersing a section of carbon steel pipe in a liquid nitrogen bath for a few seconds and striking it with a hammer, shattering it.

When a cryogenic liquid evaporates, the gas produced can occupy 850 times the volume of the liquid that produced it. This can be demonstrated by pouring a small amount of liquid nitrogen into a pipe and allowing it to expand with the resulting gas filling a plastic bag. If the expanding gas is trapped in a container or piping system, rapid pressurization causing possible failure of the container can result. All systems to handle cryogenic liquids must be equipped with relief devices wherever fluid can be trapped between valves or other s controls.

Appropriate PPE for handling cryogenic liquids includes: Safety glasses, full-face shield, long sleeves, and cryogenic gloves. Chemical gloves are not suitable for materials at cryogenic temperatures as can be demonstrated using hot dogs to simulate fingers. When immersed in liquid nitrogen, both the chemical glove and the hot dogs become embrittled.

When cryogenic liquids are released into the air, the expanding cold gas causes condensation of moisture in the air, creating a vapor cloud. The composition of the vapor cloud is mainly the evaporated cryogen, which will have displaced breathable air. Never enter a vapor cloud without a supplied-air respirator as the atmosphere may be asphyxiating. Even standing outside the vapor cloud could be dangerous as it still could be an asphyxiating atmosphere that has merely warmed up enough for the moisture to re-evaporate.

Pressure

One common hazard associated with all compressed gases is pressure. Pressure release could propel objects or the cylinder itself that may cause physical harm. Similarly, a high-pressure stream could be harmful by penetrating the skin causing tissue damage or embolism. Components in a compressed gas handling systems must be rated to withstand the pressure of the gas or catastrophic failure could occur.

The rating of the gas container can vary from as low as 25 to as much as 6,000 psi. High-pressure cylinders are constructed of a single piece of metal, typically steel or aluminum, and are designed to operate at pressures of at least 1,800 psig. Low-pressure cylinders are designed to operate at pressures of 500 psig or less, are fabricated by welding together several pieces of thinner steel, and are typically used to store and transport lower pressure or liquefied gases.

Acetylene cylinders are low pressure cylinders but they differ significantly from other gas cylinders because they are filled with a solid porous mass that is then saturated with a solvent, typically acetone, into which the acetylene gas is dissolved. This is necessary to keep the acetylene gas stable for transportation and storage at higher pressure in the cylinder and then remain safe for use.

Cryogenic liquid cylinders are well-insulated containers designed to deliver either cryogenic liquid or gas, so they may operate at widely varying pressures, from 22 psi for liquid withdrawal to 220 psi for gas withdrawal, but in some cases up to 500 psig for some applications.

Labeling

Required labels are applied by the gas supplier to identify the gas contents and other required information and should never be defaced or removed. Before using a gas, read the label to ensure it is the right gas and you are aware of its hazards. A shoulder label will indicate the name of the product, its primary hazard, it UN number, along with precautionary and first aid information. It will also contain the name of the manufacturer and the emergency contact number. As discussed earlier, some gases, such as carbon monoxide, have more than one hazard so the shoulder label will have 2 hazard diamonds. In the case of carbon monoxide, the primary hazard is toxicity and the secondary hazard is its flammability.

Cylinder color must never be relied on to identify a cylinder's contents. The only acceptable way to identify a cylinder's contents is to read the label. Containers not bearing a legible identification of the contents cannot be used and are not able to be legally transported. Contact your gas supplier to resolve any issues of questionable cylinder contents identification.

Valves and CGA Connections

All gas containers employ an inlet valve that restricts and controls the flow of gas to/from the cylinder. Valves have outlet threads to connect to equipment to utilize the gas. There are many outlet and connection thread configurations specified by the Compressed Gas Association (CGA). A particular outlet connection applies only to gases that share similar properties. For example, CGA 350 applies to flammable gases. The purpose of these different connections is to prevent the accidental connection of incompatible gases. This system can be demonstrated by attempting to connect an oxygen regulator (CGA 540) to a hydrogen cylinder valve (CGA 350). Many connection designs create a metal-to-metal seal while some utilize a washer in order to form a leak-tight seal. Although adapters do exist, they should never be used because they can defeat the system of separation.

The valve is the most vulnerable part of the gas cylinder and it must always be protected when the product is not in use, especially when the cylinder is being moved. Some cylinders have permanently-installed valve protective collars or rings, such that seen on a typical small propane cylinder used to supply a gas grill, but most cylinders have removable valve protection caps. Always keep valve protective caps installed whenever cylinders are being transported and any time they are not in use. If a cylinder were to fall without its valve protection in place, the valve could easily be damaged or, even worse, sheared off. If the valve on a high-pressure cylinder is sheared off, the rapidly escaping gas could propel the cylinder missile-like. When a cylinder is in-use, it must be secured to keep it from falling.

Hazards of Handling and Storage of Gas Cylinders and Containers

Cylinder Handling Requirements

Most compressed gas cylinders are very heavy and are often much heavier than they look. Many can weigh in excess of 200 lbs. Many common gases such as propane, carbon dioxide, and others, are present in the cylinder in their much denser liquid form, which makes them very heavy. Acetylene cylinders have a heavy filler material and solvent liquid inside, which makes them much heavier than they appear.

Gas cylinder weights, combined with their cylindrical configuration, cause them to be too unwieldy to control by manual movement, especially by those who don't do it all day. Always use a cart that is specifically designed for cylinders whenever they need to be moved. There are various cart designs available from several manufacturers depending on the application.

Personnel who handle cylinders must be trained in the safe handling and storage of compressed gases and instructed never to lift cylinders by their caps or using magnets. Never weld lifting attachments or other attachments to cylinders.

Adopt a "Let it Fall" policy for cylinders and train on it. If properly stored and handled, with their valve protective cap in place, cylinders are designed to safely withstand the impact of a fall. The human body is no match for a falling cylinder, so it is far safer to allow one to fall and let the safety factors that are inherent in cylinder design work. Failure to follow a "Let it Fall" philosophy can all-too-often lead to significant injury.

No adapters and no user filling of containers

Never attempt to adapt fittings from one cylinder or device to another. Gas handling components may not be compatible with other gases and may fail violently. Gases must never be transferred from one container to another by the user. In some cases, an improper rate of flow or incompatible component materials can cause an explosion.

Never transport cylinders in enclosed vehicles

Transporting cylinders in cars, vans, or in any enclosed vehicle is extremely dangerous and must be avoided. Never transport flammable gases in the passenger compartment or trunk of any vehicle. There are incidents every year when people disregard this advice, resulting in explosions that, in the best case, merely damage the vehicle involved.

Return cylinders with some residual product remaining

Always return cylinders to the supplier with 25 psig or more pressure remaining. This will help prevent a dangerous mixture or contamination from occurring in the cylinder or gas delivery system. Check valves are an important component of a well-designed gas delivery system, but should not be relied upon solely to prevent a back-flow condition.

Report any damage or related concern to the gas supplier.

Never modify, tamper with, paint, deface, obstruct, remove, or repair any part of the cylinder. This includes never lubricating any surface or part on a cylinder including its valve or protective cap. Lubricants can be incompatible with the gas product and their use could mask a more serious defect that should not be overlooked. Inform your gas supplier if you believe there is a possibility a cylinder has been contaminated or damaged and never conceal damage, contamination, or attempted repairs to cylinder.

General Precautions for Handling Cylinders

- Minimum PPE for handling cylinders includes: Safety glasses with side shields, heavy-duty (impact-resistant) leather gloves, and ANSI-approved safety shoes (with metatarsal protection recommended). Synthetic glove or clothing materials should never be used with oxidizers or flammable gases.

- All compressed gas cylinders in service or in storage shall be secured to prevent falling or rolling.
- Properly secured cylinders are to be stored in an upright position
- Gas containers stored or used in public areas must be protected against tampering or damage and shall not obstruct exit routes or other pedestrian aisle ways.
- Gas storage areas shall be prominently posted with the hazard class or name of the gases being stored.
- Cylinders shall not be used as rollers, supports or for any other purpose other than to contain and supply the gas products as intended
- Containers shall not be placed where they might become part of an electrical circuit
- Cylinders should be kept in a cool, shaded, well-ventilated area away from sources of heat or ignition.
- Compressed gas containers shall not be exposed to temperature extremes including any artificially-created low temperature or any environment exceeding 125^{o} F.
- When a container or valve is noticeably corroded, contact your gas supplier immediately.
- Compressed gas streams should not be directed toward any person.
- Never store cylinders near a source of heat, such as a furnace or water heater, or inside an enclosed vehicle or shed

<u>Storage Areas and Product Segregation</u>

Compressed gas storage areas shall be designed to accommodate the various containers of gases required by the user. Storage areas should be designed to be well ventilated, well drained, covered, and preferably of fire-resistive construction. Cylinder storage should include adequate spacing and/or segregation by partitioning in accordance with applicable codes so containers can be grouped together by the hazard class of the gas. Additional consideration should be given to separation of full and empty containers.

Oxygen cylinders in storage shall be separated from fuel gas cylinders or combustible materials a minimum distance of 20 feet or by a non-combustible barrier at least 5 feet high having a fire-resistive rating of at least 30 minutes.

Facility Inspection

It is recommended to include gas cylinders in users' facility inspection protocols. Regularly perform visual inspection of areas where cylinders are stored or used for proper labeling, usage, and storage.

Conclusion

Compressed gas cylinders can be found in nearly every workplace. Many employees come in contact with these cylinders directly or indirectly every day. Ensuring employee safety can best be achieved by fully understanding the hazards associated with the gases in use and communicating precautions and safe work practices fully to all affected individuals. Proper equipment and facility design, storage, and handling practices are all key to ensuring worker safety.

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