

Compressed Gases & Systems

By **DAVID P. DIXSON**

This article describes some properties of and hazards associated with compressed gases and systems; it also discusses controls and safety precautions that should be considered during the design, construction and/or operation of compressed gas systems. The goal is to improve overall awareness of the general safety, health and environmental hazards related to these gases and systems.

Compressed gases introduce a variety of hazards to the industrial setting. These hazards include flammability, corrosivity, reactivity, toxicity, oxygen depletion and mechanical injury. In this context, a compressed gas is one stored or used at pressures greater than nominal atmospheric pressure (14.7 psia at sea level). A stored gas is defined as one placed in a state for a certain future purpose, and a used gas is one to be brought or put into service and made available. Although compressed gas containers are designed to meet rigid government specifications and are generally safe for their intended use, they can be dangerous if misused or abused. Compressed gas is supplied in cylinders and tube trailers, and through piping systems. Therefore, care must be taken to ensure that compressed gas containers are stored, handled and used in accordance with safe work practices.

ORDERING COMPRESSED GASES

To ensure facility safety, gases should be ordered in cylinders that a facility can safely accommodate. This usually means ordering the smallest volume necessary for a given job—that is, order only as many cylinders as may be needed rather than stockpile quantities for possible future use. If programmatic requirements or delivery problems create the need to order several cylinders, the facility manager must ensure

that sufficient, safe storage facilities are available before placing the order.

RECEIVING COMPRESSED GAS

The gas supplier should deliver all compressed gases in cylinders approved by the Dept. of Transportation (DOT) (49 CFR Parts 171-179) and the cylinders should be checked for gross defects before being accepted. At intermittent times thereafter, users should also inspect cylinders and compressed gas systems for the following:

- **Appropriate labels and warning.** Each cylinder must be clearly labeled and marked in a manner that identifies its contents and gives precautionary warnings; decals, tags and stencils may be acceptable. Color should never be used as the sole means for identifying cylinder contents. Any cylinder with an illegible label and/or marking should be returned to the supplier.

- **Testing information.** Each cylinder should have a label that indicates its current hydrostatic test date.

- **Condition.** Each cylinder should be in good condition and free of dents, arc burns, severe rust or corrosion.

- **Valve cap.** Each cylinder should have a protective valve cap in place when it is stored or not in use. In some cases, the cylinder may lack the thread needed to accept a valve cap. In such cases, the cylinder should be placed in a rack or box and vertically positioned to protect its valve.

•**Valve leaks.** If the cylinder assemblies leak, they should not be tightened in an attempt to eliminate the leak. Instead, a leaking cylinder should be removed from service and labeled as such.

•**System leaks.** In some cases, adjustments can eliminate these leaks. However, workers should not adjust systems that are under pressure or in a vacuum. In addition, nonsparking tools should be considered when adjusting systems that handle flammable or combustible gases. Before adjusting assemblies, personnel must know the correct direction in which to make such changes, since some connections have opposite threading.

STORAGE OF COMPRESSED GASES

A safe compressed gas cylinder storage area should be designated in any facility that regularly uses these gases. Storage areas should:

•be well ventilated. Cylinders that contain flammable, corrosive, toxic or otherwise-hazardous gases should be stored outside buildings and away from doors, windows and building air intakes. Hazardous gases may only be stored indoors in specially designed facilities. Inert gases may be stored inside provided there is sufficient space and adequate ventilation to prevent asphyxiation hazards.

•protect stored cylinders from heat, corrosive atmospheres, rain, snow accumulation and full sun; these areas must also prevent access by unauthorized personnel who may tamper with or damage the cylinders.

•be paved. This ensures the best accessibility to delivery truck drivers and for users with portable cylinder carts.

•allow cylinders to be positioned in an upright vertical position and secured from toppling over by being placed in a rack and secured with chains or similar devices.

The following precautions are recommended for cylinders stored in these areas:

•Valves should be shut off when cylinders are not in use.

•Cylinders with the capacity to contain more than 30 psig of a gas should have protective caps that are secured and hand tightened.

•Cylinders deemed empty should have the valve closed and be labeled "MT" or "empty." (An empty gas cylinder is one that contains 25 psig compressed gas or less.)

•Cylinders that contain similar and/or compatible gas types should be grouped together. For example, oxidizing gases should be stored separately from flammable gases and combustible liquids. A flammable gas is one that when mixed with air is flammable in concentrations of 13 percent or less by volume in air or gas that has a flammability range wider than 12 percent in air, regardless of its lower flammable limit (the exception is hand-welding systems). Incompatible gases should be properly barricaded or separated. For example, to separate oxidizers and flammable cylinder, a facility should have five-ft.-high fire barriers with a half-hour fire rating or separate them by a distance of at least 20 ft.

•No cylinders should be stored in an exitway from the storage area.

MOVING COMPRESSED GASES

When moving cylinders, employees must observe several precautions.

•Valves should be closed before moving the cylinder.

•Unless the cylinder is part of a mobile system, such as a cart-mounted welding set, the regulator must be removed and the protective valve cap secured before transport.

•Never lift a cylinder by its protective cap.

•Move cylinders on carts or with other approved cylinder-transporting devices.

•During transport, avoid dropping, sliding and rolling cylinders or allowing them to contact sharp objects.

•Wear safety shoes or toe protection.

LOCATION OF COMPRESSED GASES

Compressed gases are used in various locations. Several general precautions should be observed during their use.

•Avoid locating cylinders in an exit passage or hallway, or near a heat source.

•Cylinders with no fixed needle valve to shut off the gas supply should have keys, handles or nonadjustable wrenches on the valve stem.

•For permanent installations, a permanent piping system—with its gas supply outside the building—is preferred.

•If the gas is toxic, flammable, reactive or corrosive, a specially designed piping system may be recommended.

Frequently Asked Questions

What are cylinders?

Heavy-walled containers designed, produced and tested for use with compressed gases. Many sizes and shapes are available and all should comply with DOT regulations. These regulations specify service pressures, serial numbering, inspection codes, and manufacturer and maker identification (which are normally located at the top of a cylinder).

What are the recommended pressure tests for cylinders?

Cylinders are tested hydrostatically with water at the time of manufacture and should be retested every five years; the test date is stamped on the cylinder. Acetylene cylinders are not hydrostatically tested with

water since it is too difficult to remove the water from the porous filler material; thus, they are visually inspected.

What are the recommended cylinder safety devices?

Cylinders typically have one or more safety relief devices to prevent rupture caused by pressure accumulation. However, cylinders that contain toxic gases are built to withstand greater pressures and not release their chemicals. For cylinders designed to release their contents, three safety devices are common; each works in a different manner.

•**Safety/pressure-relief valves.** These are part of the cylinder and are held closed by a spring. The seal's release point is based on the gas type;

it opens if the safe pressure limit is exceeded. Subsequently, the cylinder's pressure returns to the safe pressure limit; only then does the valve close.

•**Rupture discs (known as frangible or burst discs).** These discs are made of metal, burst at a set pressure limit; they displace all cylinder contents. Once burst, these discs cannot be reclosed.

•**Fusible plugs (known as fuse or melt plugs).** Made of metal, these are activated at a set temperature. They are used when a temperature level could initiate an explosive chemical reaction inside the cylinder. They act more quickly than rupture discs, melt before the chemical reaction can begin and release cylinder contents.

Why is ventilation crucial?

Well-designed and maintained ventilation systems capture and remove gases from the workplace. A work area should be assessed to determine the adequacy of the ventilation system. Some areas need an entire system of hoods and ducts, others simple exhaust fans, and others, based on the small amounts of inert gases used in the work area, need no special ventilation. If a ventilation system is needed, management must ensure that hoods, ducts, air cleaners and fans are made of materials compatible with the gases they will handle, and that the system is explosion-proof or corrosion-resistant to those same chemicals. The electrical components

•Flammable and toxic gas cylinders may be located inside buildings if they are installed in or feed into special ventilated enclosures with adequate ventilation rates.

Although these enclosures capture and remove gases that result from small leaks, they may not prevent gases from entering a laboratory if a gross release occurs. Such an event could occur if a regulator or pressure-relief device fails. A pressure-relief device is a system designed to relieve excess internal pressure in any type of pressurized system. These devices include safety valves, fusible plugs, rupture discs, and piping or tubing to an approved release point. It should be noted that fume hoods may not always provide adequate ventilation for operations involving hazardous gases.

GAS LEAK DETECTION

Compressed gas systems should be routinely inspected for possible leaks. An unusual drop in cylinder pressure (as indicated by gauge reading) often signals a leak. However, a leak can also be detected by the sound of gas escaping through a small hole in the assembly, which can be caused by a poorly connected joint or a hole in the piping.

In some cases—for example in cryogen systems—the material may become stressed due to thermal expansion and contraction, pressure or vacuum stresses, or the angles at which piping sections are bent to create an assembly. This may cause a failure or a crack in an assembly or the piping.

Typically, cracking occurs in piping that runs along the outside surface of a bent elbow, or along long, straight sections. In these situations, the material is heavily stressed along the outside bend or along the unsupported or reinforced sections of piping.

Leaks are also common at the connection joint between two couplings or a piping-to-coupling connection that has been over-tightened or not properly tightened. Thus, systems should be assembled to ensure that piping walls are not overly thinned by manipulation into elbows; the straight section has interim reinforcement with anchors or couplings; coupling and connections have adequate thread lock sealant or thread tape applied; and connections are properly tightened.

In checking for leaks before the system is brought into full service or as part of routine maintenance, two techniques can be considered. A person can use a handheld portable gas detector to monitor general combustible gases or a specific gas. Then, a soap-and-water solution can be applied to all joints and stress points; any small bubbles observed would indicate a leak. Before a new system is activated or an out-of-service system is brought back into full service, it should be pressurized with an inert gas and leak tested. Under no circumstances should a system be tested for leaks using a source to ignite the leaking gas.

COMPRESSED GAS LEAKS

If a leaking cylinder is discovered, safety is the primary concern. Thus, the

hazards of the compressed gas and cylinder must be evaluated. In most cases, the emergency management and response provider should be contacted and their recommendations followed. Beyond that, the following general precautions should be observed; however, the specific circumstances must be evaluated in each case to ensure safety.

•A leaking cylinder should be immediately removed from service.

•A leaking cylinder should not be moved or transported unless such movement does not present a significant safety hazard. If the cylinder is relocated, it should be placed at least 20 ft. away from ignition and flammability sources (e.g., smoking areas). When possible, allow the room's exhaust ventilation system to control the hazard.

•A safety zone should be designated around the cylinder and posted.

SPENT CYLINDERS

As a precaution, a cylinder should be removed from service when it reaches 25 psig. Before the gas supplier retrieves cylinders for refilling, supply valves should be closed off, pressure regulators removed and valve caps attached and secured. Dust covers for valve outlets (when provided) should also be attached to cylinder valves.

COMPRESSED GAS SYSTEM COMPONENTS

Pressure-Relief Devices

Relief devices, except for rupture or fusible disks, should be periodically

should be evaluated for their intrinsic safety as well.

What is recommended for storing compressed gas cylinders?

Cylinders should be stored in compliance with company and/or regulatory recommendations. The amounts and types should be based on those recommendations as well.

What is recommended when receiving compressed gas cylinders?

Inspect each cylinder for damage and proper labeling before accepting it from the supplier. Check each cylinder for the current hydrostatic test date as well. Ensure that labels are intact and match other cylinder markings. Relying on color as an identifier for compressed gas is not recommended—different manufacturers use different colors and exposure to sunlight can affect color; furthermore, some people are color blind.

What is recommended when transporting cylinders?

The cylinder cap or valve protection must be in place during transport. A cylinder may be rolled along its bottom edge for a short distance, but hand carts and trolleys are preferred. Always secure the cylinder to the device before moving.

What are the recommended storage temperatures for gas cylinders?

Follow the supplier's recommendations, but never expose cylinders to temperatures above 125°F or less than -20°F unless they are designed for such use. If a cylinder is frozen in place, apply warm water to the interface; in no case should heat be applied directly to a cylinder.

What are general recommendations regarding use and discharge from a compressed gas cylinder and specific recommendations about certain types of gases?

General recommendations.

At the site, secure the cylinder with chains or guards. Remove the cap only after it is secured. Never open a damaged valve. If valves, fittings or threads are stuck, lubrication is not recommended. Use only recommended valves and fittings for the cylinder and compressed gas type because valves are not designed to be compatible with all gases. Employees should be trained to not free a hand wheel with a pipe wrench or a similar tool if the hand wheel gets stuck; such action could damage the valve seat or spindle. Open valves slowly since many accidents occur when valves are opened too quickly (which creates high-pressure passage past the seats to the valve; this can create temperature damage to the regulator and valve seats that can burn them out).

Liquefied gases. Manual and special-liquid flow regulators are available. In addition, some liquefied gas cylinders have educator tubes that allow liquid to be drawn from the cylinder.

Nonliquefied/dissolved gases. Automatic pressure regulators (single-stage and double-stage) are available to reduce gas pressure. Double-stage devices deliver more-constant pressure and more-precise flow rates.

What is a "dog bone" and how should it be used?

A dog bone is a securing device. It is a metal object in the shape of a dumbbell with rings on its ends. Once valve caps have been secured atop the cylinder, two cylinders are secured to each other by slipping the ends of the rings over their valve caps. A dog bone is used if the facility does not have enough securing devices

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checked and calibrated for proper setting and operation. Annual checks for those in service and handling corrosive gases are suggested. A corrosive gas is one that destroys or irreversibly alters the container in which the gas is packaged (e.g., a cylinder or piping system) by chemical action at the site of contact. It is recommended that those in service and those handling benign gases be checked every three years. Relief devices should be tagged with operating information and the calibration due date recorded. A maintenance schedule should be established when the system is installed.

For hazardous gases, pressure-relief devices should be safely vented to a compatible collection system. If chemical reactions can cause pressure increases, additional pressure-relief provisions may be necessary. National Fire Protection Assn. Standard Publication 69, "Explosion Prevention Systems," provides these specifications.

REGULATORS OF COMPRESSED GASES

Release of high-pressure gas from cylinders can be hazardous unless adequate means are available to reduce the pressure to usable levels and/or for controlling gas flow. Accordingly, pressure-reducing regulators should always be used when withdrawing cylinder contents to provide a constant safe working pressure. All regulators and connectors should be assessed against applicable ANSI standards.

Single-stage regulators are available

for certain uses; however, two-stage regulators typically deliver a more-constant pressure for more widely varying operating conditions. Thus, they are preferred. These devices have two gauges: one to indicate cylinder pressure and one to indicate delivery pressure. Needle valves may be used to provide fine adjustment of small flow rates from regulators.

When cylinders are used in a manifold system, the regulator should be part of that system. The user should select and install an appropriate regulator for the gas in use. Selection will depend on four factors: 1) specific gas and operating pressures; 2) range of delivery pressures for the system; 3) degree of accuracy of delivery pressure; 4) appropriate flow rates.

With all regulators, the following precautions should be observed:

- Regulators should be double-staged and approved by a nationally recognized testing laboratory or assessed against other qualified standards (e.g., ANSI).
- Regulators for oxidizing agents should be oil-free.
- Regulators should not be interchangeable between incompatible gases.
- Mechanical shielding should be provided for regulators and pressure system components, if necessary, to secure them against mechanical damage.
- Regulators should meet vendor specifications for the given gas and cylinder pressure.
- Use a regulator with a delivery gauge range approximately 1.5 times the maximum operation pressure (MOP) and

at least 1.2 times the maximum allowable working pressure (MAWP). MOP is the highest pressure expected during normal operation, usually 10 to 20 percent below MAWP. MAWP is the pressure at which a system is safe to operate, and it is the maximum setting for the primary pressure-relief device. Gauges are more accurate in the midrange, and regulators are designed to operate at about half the range of the delivery gauge.

•Inspect regulators regularly to ensure that they are in safe working condition. If any defects are found, it is best to arrange for factory service, since expert repair and calibration is necessary for continued reliability and safety. For reactive gases, special recommendations may be necessary. A reactive gas is one that reacts with other materials (including water) to produce undesirable byproducts such as heat or flammable or toxic gases.

•Never change the delivery gauge on a regulator; instead, use a regulator with the desired delivery range or use supplemental gauges, if necessary. Regulators have internal safety devices to protect the delivery gauge; changing the gauge defeats that protection. Defective gauges should be returned to the manufacturer for repair or replacement.

•Never use an adapter.

•Never interchange any incompatible CGA fittings. If a regulator does not fit to the cylinder's CGA valve, it should not be forced to fit. Poor fit may indicate that the regulator is incorrect for the given type of gas.

FAQs

(e.g., chains) for the number of cylinders in the storage area.

Cylinders are usually successively anchored to one another in the shape of an inverted pyramid with the top single cylinder being secured against or to the building. No more than two to three layers of cylinders should be secured in this manner, however, since the anchor for the first cylinder may not be able to hold the weight of many cylinders. Also, the number of cylinders secured in this manner should not pass a safe use point. The safe use point is that point, were a cylinder to tip over, where enough force would be generated to injure a person or damage the tipped cylinder, another cylinder or the initial cylinder building anchor.

Therefore, the number of cylinders secured using dog-bones should be critically evaluated.

Use of these devices should also be evaluated if they are used to secure cylinders that contain gases which could ignite due to a spark. If a cylinder tipped over and struck another object, causing a spark, it might create sufficient energy to ignite a flammable or combustible gas. If a combustible or flammable gas cylinder were (unknowingly) leaking at a concentration above the LEL/LFL, this turn of events could ignite that gas.

What is recommended when closing/opening a valve? A valve should be gently opened and closed. It is best to open the valve approximately three full revolutions. In an emergency, if the valve must be closed quickly, one should leave the valve keys in place. In addition, an employee should not use excessive force to shut off or open a cylinder valve, nor

should s/he shut off the gas at the regulator.

What equipment hazards might be associated with compressed gases?

Equipment should be clean, maintained and compatible with the gases used. For example, as noted, acetylene in contact with copper, silver, mercury or their alloys that include brass or bronze containing ≥ 65 percent copper is explosive. Ammonium degrades brass and reacts with mercury to form an explosive compound. Acetylene under pressure can explode and should not be used outside a cylinder at a pressure greater than 15 psig. If an acetylene bottle is left on its side and the cylinder is open for a given time before it has been righted, the cylinder could emit a burst of acetone solvent when the valve is opened.

What is the recommended method for handling "empty" gas cylinders?

Nonliquefied/dissolved (acetylene) gases. As gases are used, the reading on the gauge drops. When the gauge hits zero, the cylinder is not actually empty; it still contains gas at atmospheric pressure. Thus, one should keep a slight positive pressure on the cylinder (25 psig) to avoid draw back into the cylinder or the assembly system, and to minimize any contaminant being drawn into the cylinder.

Liquefied gases. Since the pressure in a liquefied gas cylinder remains constant at a given temperature as long as liquid remains in the cylinder, the only way to know whether the cylinder is empty is to weigh it. The cylinder's empty tare weight is stamped on its side. It is recommended that the net weight be recorded. It is also best to try to maintain a slight positive pressure in the liquefied gas cylinder to prevent contaminants from being drawn into the cylinder.

•Stand to one side of the gauge face when opening or activating a regulator gauge.

PROCESS PIPING OF COMPRESSED GASES

To ensure optimal safety, piping should be made of materials compatible with the feed gas or its derivatives. These materials should be utilized throughout the piping that will be in contact with the specific gas. High-pressure gas and hazardous materials should be piped following requirements of ANSI B31.1(3) "Power Piping of the ASME Code for Pressure Piping" and NFPA 55 "Standards for the Storage, Use and Handling of Compressed and Liquefied Gases in Portable Cylinders."

For flammable gases, flashback arrestors may be recommended, particularly in work processes that involve an open flame or other ignition source. In no case should pipe be run through a wall, floor or ceiling plenum without following appropriate fire protection codes. Developing the penetration for the piping through a fire-rated structure may compromise fire protection and/or the fire rating of the wall, ceiling or floor.

Piping lines from remote cylinder locations should be firmly supported or attached to building components. Unsupported piping/tubing lines can lead to safety hazards such as crimping, bending or cracking of piping, which could lead to leakage. Also, long runs of flexible plastic tubing may not be appropriate due to weakened wall strength of such runs.

Piping/tubing lines from remote gas sources should be properly labeled regarding any physical hazard (e.g., high pressure, flammability) and content (e.g., hydrogen, compressed air) in order to best protect employees.

SUPPLEMENTAL CONSIDERATIONS FOR COMPRESSED GASES

Despite precautions taken to ensure safe system design, construction and operation, failures may still occur. Common scenarios include the following.

•The incorrect gas is utilized. In all cases, the chemical or trade name should be marked on the bottle, and this information should be verified. Affixing a piece of duct tape with a handwritten note regarding the cylinder's contents is not acceptable.

•Pressure gauges and regulators fail occasionally, often violently releasing cylinder contents, and scattering shattered glass and metal pieces. To prevent this, gauges with stand-offs and blowout backs or front-facecover plates should be used. In addition, the gauge blowout plugs should not be covered and users should wear safety glasses and stand to the side of regulators when setting pressure, or connecting/disconnecting or adjusting the system. It is also best to locate compressed gas systems in well-ventilated areas.

•Improper gas is connected to the system. Management must ensure that the correct gas is being attached to the assembly system.

•Cylinder valves occasionally leak. Employees should be trained not to force cylinder valves that stick. As noted, leaky cylinders should be stored outside until the supplier can retrieve them. If necessary, consult with the safety representative or gas supplier regarding the safest handling procedures.

•Gas penetration into the body. Gases under pressure may have enough force to penetrate the skin and enter the blood stream. To avoid this hazard, proper leak-test procedures should be used. In addition, fingers should be kept away from leaking high-pressure jets or orifices discharging gas.

•Cylinders taken

out of service but not placed in a location where gas can safely bleed off. The gas supplier should be contacted and emergency management notified. No ignition sources (e.g., smoking) should be allowed near the cylinder if it contains flammable/combustible gases.

SPECIFIC COMPRESSED GASES

Before using any compressed gas, one must know its properties and specific use recommendations. As a first step, it is best to consult references such as the *Matheson Gas Data Book* and applicable MSDS (Baker and Mossman). Following are recommended guidelines and considerations for the use of flammable gases, compressed air, acetylene, toxic/corrosive gases, oxygen and oxidizing gases, and liquefied compressed gases.

Flammable Gases

Flammable gases should not be stored or used near open flames, hot surfaces, electrical power lines or underground electrical equipment, or adjacent to oxidizers. Flammable gas systems should be located in well-ventilated areas with intrinsically safe and explosion-proof electrical wiring. If such a system is used inside of a structure, the effluent from the system and from pressure-relief devices should be vented outside the building, away from windows and air intakes, or into suitable ventilation systems. In no situation should flammable gas piping be located in concealed or low-lying spaces where leaking gas could accumulate undetected. Flammable gas detectors and alarms may be desirable in some applications.

It is best to use metal piping whenever possible and appropriate. Use of non-metallic tubing, particularly plastic tubing, should be avoided (although short lengths—less than five ft.—may be acceptable if gas pressure is low and the pressure rating is known). Plastic and nonmetallic tubing are prohibited in cable trays or permanent installations where the tubing is attached to building walls, hidden from sight or subject to physical damage.

Compressed Air

Compressed air (often used with hand and portable power tools and machinery) should not be used for cleaning purposes unless pressure has been reduced to less than 30 psig at the nozzle, chip guards are installed and appropriate PPE is worn. The safe-relief valve for the pressure receiver of a compressed air system should be set at 10 percent of the receiver's MAWP. A valve should not be placed between the safety valve and the compressed air receiver, and the hand-held nozzle should have a positive means of activating the compressed air system and should automatically shutoff the system when released.

What is recommended to manage empty cylinders?

Employees must know to close the valve on an empty cylinder in order to prevent draw back of moisture or contaminants into the cylinder and should manage it as if it were full since it does, in fact, still contain gas. Empty cylinders should be labeled "empty" or "MT," separated from full cylinders and kept away from incompatible materials.

What PPE should be used when working with compressed gases?

PPE should be worn only after other hazard control methods are implemented and determined not to thoroughly protect employees. In such cases, MSDS should be reviewed for general guidance in selecting appropriate PPE. Factors to be considered when selecting PPE include avoiding skin contact, protecting eyes and face, and preventing the inhalation of harmful gases. However, in all cases, safety glasses with

sideshields should be worn when working with compressed gases.

What should be done when an emergency develops? Evacuate the area, alert other personnel and report concerns to the local emergency response provider. An employee exposed to harmful chemicals should obtain necessary medical aid and, if necessary, discard contaminated clothing. All employees should know the location of emergency eyewash and shower stations should they come in contact with chemicals.

For more information about compressed gases and systems, visit the Compressed Gas Assn. website at www.cganet.com. The site includes information on relevant publications, standards and safe handling procedures.

The entire compressed air system should be installed so that it cannot be damaged by environmental elements. In addition, traps should be installed to collect oil and moisture that could accumulate in the assembly. The safety valve should be inspected and tested frequently as well.

Acetylene

Acetylene poses special hazards. At high pressure, it is inherently unstable and can detonate; at relatively low pressure, acetylene may violently decompose in its free state. To prevent these hazards, acetylene cylinders contain a porous-mass filler material which has minute cellular spaces so that no pockets of an appreciable size remain where "free" acetylene in the gaseous form can collect. This filler is saturated with acetone or another suitable solvent into which acetylene dissolves. This allows the acetylene to be contained in such cylinders at moderate pressures (up to 250 psig) without danger of explosive decomposition. If the acetylene cylinder is not in use or connected for use, it should be stored upright, with the valve end up and a valve cap securely hand-tightened.

Because acetylene forms explosive compounds on contact with certain metals, including copper and brass with ≥ 65 percent copper, system components should be suitable for acetylene service. For example, it should be free of silver brazing or a copper-alloy material. Welded, flanged or threaded joints should join assemblies. When appropriate, an acetylene system should feature pressure-relief devices set at 15 psig or less; flash arrestors and backflow prevention devices may be recommended in piped systems. To permit emergency shut off, the shut-off wrench or key for the acetylene cylinder should always be left in position when it is in use.

Toxic/Corrosive Gases

Nickel carbonyl and fluorine are examples of toxic and corrosive gases. Such gases should be confined entirely within systems approved by the company's safety representative. A hazard evaluation may be recommend in some cases.

When corrosive gases are used, cylinder valves should be manipulated frequently to prevent sticking. When the system is not in use, cylinder valves should be closed, and the entire system flushed with a dry inert gas (e.g., nitrogen). Fluorine systems should be cleaned and passivated before use.

OXYGEN/OXIDIZING GASES

Oxygen and gas mixtures that contain large quantities of oxygen react chemically with organic materials to produce heat. This reaction can occur with explosive violence. Thus, all combustible materials and potential sources of ignition should be kept away from oxygen or gas mixtures that contain high concentrations of oxygen. Substances that are normally considered noncombustible can burn in the presence of oxygen as well. The following precautions should be considered when designing a system that will handle oxygen.

- Use copper or austenitic stainless steel piping for oxygen service systems.
- Never permit oil, grease or other combustible substances to come in contact with equipment used for oxidizing gases.
- Use oxygen regulators only for oxygen service. Using an oxygen regulator with other gases may cause hydrocarbon contamination, rendering the regulator unfit for further oxygen use.
- Remove all combustible material from oxygen supply piping systems and containers before placing the systems or containers into service.
- When using fuel/oxygen systems, oxygen backflow prevention, flashback prevention and excessive backpressure control devices should be installed to prevent the cross mixing of oxygen and the fuel source.
- Purge the system using nitrogen, carbon dioxide or oil-free air. Refer to the Compressed Gas Assn.'s pamphlets (bulletins CGA C-1 through C-19) for guidance when cleaning oxygen systems.

Liquefied Compressed Gases

In a cylinder, liquefied gases exist in liquid and gaseous form at a pressure equal to the vapor pressure of the particular gas. Liquefied compressed gases—which include carbon dioxide, nitrous oxide, sulfur dioxide, chlorine, and liquefied petroleum gases—are usually stored at pressures less than those of nonliquefied compressed gases, but storage pressures are still well above final-use pressures. Therefore, pressure regulators and pressure-relief devices may be used.

Safely handling liquefied compressed gases requires a thorough knowledge of their physical and chemical properties. Equipment designed and used to handle these products should comply with the strict regulations and standards governing their storage, transport and handling.

SUMMARY

Through the implementation of controls that begin with the proper design of a compressed gas system, hazards associated with its use can be minimized. However, to maintain a safe, operable system, continuous inspections and maintenance are necessary.

Because of the various hazards associated with pressure systems that include storage energy and contained hazardous/toxic gases, the operator and user of a compressed gas systems can unknowingly be faced with an unsafe condition. The recommendations outlined here are designed to minimize employee exposure to these hazards. ■

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David P. Dixon, CSP, CHMM, works with the University of California at Los Alamos (NM) National Laboratory, where he provides institutional safety support to the laboratory's ESH Div. He holds a B.S. in Natural Resources Management and an M.S. in Environmental Science from the University of Alaska, Fairbanks.

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