Introduction

Compressed gases can be toxic, flammable, oxidizing, corrosive, inert, or some combination of these hazards. In addition to the chemical hazards, the amount of energy resulting from the compression of the gas makes a compressed gas cylinder a potential rocket. Appropriate care in the handling and storage of compressed gas cylinders is essential. For chlorine gas see the guidance document Chlorine Gas for Water Treatment. The following are six general recommendations.

1. Know and Understand Gas Properties: Know and understand the properties, uses, and safety precautions before using any gas or gas mixture. Consult Material Safety Data Sheets (MSDSs) for safety information on the gases that you will be using.
2. Check Equipment: Leak test lines and equipment before they are used. Lines and equipment should be designed and maintained to handle full cylinder pressure. Materials of construction should be compatible with the gases being used.
3. Develop Emergency Plans: Be aware of potential hazards and develop plans to cover all possible emergencies. Include information about the types of gases used on your laboratory's Emergency Information Poster.
4. Provide Personal Protection: Wear suitable protective clothing, including gloves and face protection. Safety equipment, such as self-contained breathing apparatus and fire extinguishers, should be located near hazardous areas. Stay well informed of the potential hazards of the gases with which you are working.
5. Follow Regulations: Follow all federal, state, and local regulations pertaining to the storage and use of compressed gas cylinders. Follow the National Fire Protection Association (NFPA) codes, especially for flammable products.
6. When in Doubt, Contact Environmental Health & Safety: If you are unfamiliar with the hazards associated with a particular gas or unsure of the correct handling and storage procedures, call Environmental Health & Safety at 6455.

Primary Hazards

The following is an overview of the primary hazards to be avoided when handling and storing compressed gases. (Note: Chlorine gas is covered under the chlorine guidance document; Cryogenic liquids and cylinders are covered under the Cryogenic SOP).

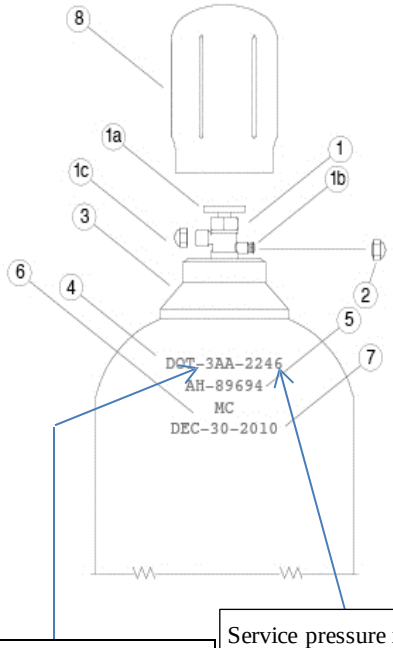
- Asphyxiation: Simple asphyxiation is the primary hazard associated with inert gases. Because inert gases are colorless and odorless, they can escape into the atmosphere undetected and quickly reduce the concentration of oxygen below the level necessary to support life. The use of oxygen monitoring equipment is strongly recommended for enclosed areas where inert gases are being used.
- Fire and Explosion: Fire and explosion are the primary hazards associated with flammable gases, oxygen, and other oxidizing gases. Flammable gases can be ignited by static electricity or by a heat source, such as a flame or a hot object. Oxygen and other oxidizing gases do not burn, but will support combustion of flammable materials. Increasing the concentration of an oxidizer accelerates the rate of combustion. Materials that are nonflammable under normal conditions may burn in an oxygen-enriched atmosphere.
- Chemical Burns: Corrosive gases can chemically attack various materials, including fire-resistant clothing. Some gases are not corrosive in their pure form, but can become extremely destructive if a small amount of moisture is added. Corrosive gases can cause rapid destruction of skin tissue.
- Chemical Poisoning: Chemical poisoning is the primary hazard of toxic gases. Even in very small concentrations, brief exposure to these gases can result in serious poisoning injuries.

Symptoms of exposure may be delayed.

- High Pressure: All compressed gases are potentially hazardous because of the high pressure stored inside the cylinder (even low pressure cylinders). A sudden release of pressure can cause injuries by propelling a cylinder or whipping a line.
- Improper Handling of Cylinders: Compressed gas cylinders are heavy and awkward to handle. Improper handling of cylinders could result in sprains, strains, falls, bruises, and broken bones. Other hazards such as fire, explosion, chemical burns, poisoning, and cold burns could occur if gases accidentally escape from the cylinder due to mishandling.

Handling, Storage, and Use of Gases

Only person's familiar with the hazards should handle compressed gas cylinders.

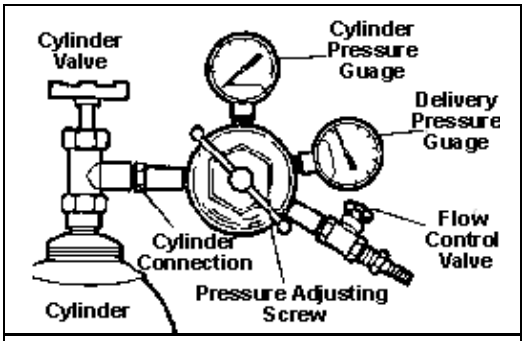


GAS CYLINDER PARTS

1. Cylinder Valve
   a. Valve Handwheel
   b. Valve Outlet Connection
   c. Pressure Relief Device
2. Valve Outlet Cap
3. Cylinder Collar
4. DOT Specification
5. Serial Number
6. Manufacturer's Symbol
7. Test Date
8. Cylinder Cap

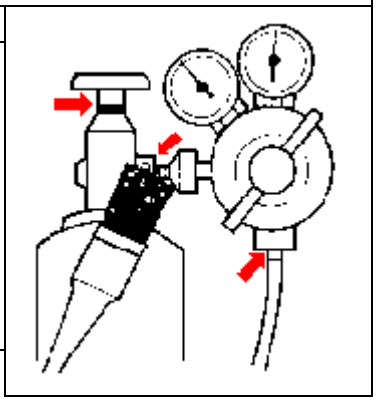
Material of the tank
3AA, Steel
3Al, Aluminum

Service pressure in PSI



Reduce the pressure of a compressed gas through a manufacturer's specified regulator attached to the cylinder valve.

Test cylinders for leaks each time you use them. Use an appropriate leak-test solution or detection equipment to check for leaks, never use flame. Make sure the solution is compatible with the gas being tested. Refer to the drawing on the right for examples of areas to test.



All cylinder movement should be done with a compressed gas cylinder cart.

Always secure the cylinders when in storage or use.

Cylinders secured with a chain or strap must have the chain or strap attached 2/3 of the way up on the cylinder.

Compressed gas cylinders should not be subjected to any mechanical shock that could cause damage to their valves or pressure relief devices. Cylinders should not be dropped, dragged, slid, or used as rollers for moving material or other equipment.

Cylinder caps perform two functions. First, they protect the valve on the top of the cylinder from damage if it is knocked over. Second, if gas is accidentally released through the valve, the cap will vent the gas out of both sides, minimizing the likelihood that the cylinder will topple. Cylinder caps should not be removed until the cylinder is secured in place and ready for use.

Regulator Selection

Check the regulator before attaching it to the cylinder. Be sure you are using the proper regulator for the particular gas that is inside the cylinder. If the regulator connections do not readily fit together, the wrong regulator is being used. Do not force connections to fit, as you may permanently damage the threads. See Regulator Selection, Installation, and Operation

Cylinder Storage Precautions

Several precautions should be taken during storage of compressed gas cylinders. Full and empty cylinders should be stored separately. Cylinders should be stored upright and secured at all times.

- Cylinders should not be stored near radiators or other heat sources.
- Gases should be used and stored only in a well-ventilated area.
- Never store gases for longer than one year without use. Always screw on an appropriate gas cap on cylinders that are not in use.
- Protect cylinders from corrosion due to weather or chemicals.
- Gases should be stored in the order in which they are received and will be used.
- When in storage, empty or full the caps must be on and the labels viewable.
- Segregate empty cylinders from full cylinders.
- It is essential that when handling or storing cylinders containing toxic or corrosive gases that the plug or cap nut is always replaced in the valve outlet when the cylinder is not in use or connected to an operational system.
- Use tables 1 and 2 below for proper segregation and storage amounts.

Table 1: Separation of Gas Containers, Cylinders, and Tanks by Hazard Class (Source: NFPA Code, §55)

Gas Category	Other Gas	Unstable Reactive, Class 2, 3, or 4	Corrosive	Oxidizing	Flammable	Pyrophoric	Toxic or Highly Toxic
Toxic or Highly toxic	—	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	—
Pyrophoric	—	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	—	6.1 m (20 ft)
Flammable	—	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	—	6.1 m (20 ft)	6.1 m (20 ft)
Oxidizing	—	6.1 m (20 ft)	6.1 m (20 ft)	—	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)
Corrosive	—	6.1 m (20 ft)	—	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)
Unstable Reactive, Class 2, 3, or 4	—	—	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)
Other Gas	—	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)	6.1 m (20 ft)

Table 2: Maximum Allowable Quantity of Gases per Laboratory (Source: NFPA Code, §55)

	Unsprinklered Areas		Sprinklered Areas	
Materials	**No gas cabinet, gas room, or exhausted enclosure**	**Gas cabinet, gas room, or exhausted enclosure**	**No gas cabinet, gas room, or exhausted enclosure**	**Gas cabinet, gas room, or exhausted enclosure**
Corrosive Gas				
Liquefied	68 kg (150 lb)	136 kg (300 lb)	136 kg (300 lb)	272 kg (600 lb)
Nonliquefied	23 m^3 (810 ft^3)	46 m^3 (1620 ft^3)	46 m^3 (1620 ft^3)	92 m^3 (3240 ft^3)
Cryogenic Fluid				
Liquefied	0 L (0 gal)	170 L (45 gal)	170 L (45 gal)	170 L (45 gal)***
Nonliquefied	170 L (45 gal)	340 L (90 gal)	340 L (90 gal)	681 L (180 gal)
Flammable Gas				
Liquefied	114 L (30 gal)	227 L (150 gal)	227 L (60 gal)	454 L (120 gal)
Nonliquefied	28 m^3 (1000 ft^3)	28 m^3 (2000 ft^3)	28 m^3 (2000 ft^3)	56 m^3 (4000 ft^3)
Highly Toxic Gas				
Liquefied	0 kg (0 lb)	2.3 kg (5 lb)	0 kg (0 lb)	4.5 kg (10 lb)
Nonliquefied	0 m^3 (0 ft^3)	0.6 m^3 (20 ft^3)	0 m^3 (0 ft^3)	1.1 m^3 (40 ft^3)
Nonflammable Gas				
Liquefied	No Limit	No Limit	No Limit	No Limit
Nonliquefied	No Limit	No Limit	No Limit	No Limit
Oxidizing Gas				
Liquefied	57 kg (15 gal)	114 kg (30 gal)	114 kg (30 gal)	227 L (60 gal)
Nonliquefied	43 m^3 (1500 ft^3)	85 m^3 (3000 ft^3)	85 m^3 (3000 ft^3)	170 m^3 (6000 ft^3)
Pyrophoric Gas				
Liquefied	0 kg (0 lb)	0 kg (0 lb)	1.8 kg (4 lb)	3.6 kg (8 lb)
Nonliquefied	0 m^3 (0 ft^3)	0 m^3 (0 ft^3)	1.4 m^3 (50 ft^3)	2.8 m^3 (100 ft^3)
Toxic Gas				
Liquefied	68 kg (150 lb)	136 kg (300 lb)	136 kg (300 lb)	272 kg (600 lb)
Nonliquefied	23 m^3 (810 ft^3)	46 m^3 (1620 ft^3)	46 m^3 (1620 ft^3)	92 m^3 (3240 ft^3)

*** Gas cabinet required or exhausted directly outdoors or to exhaust

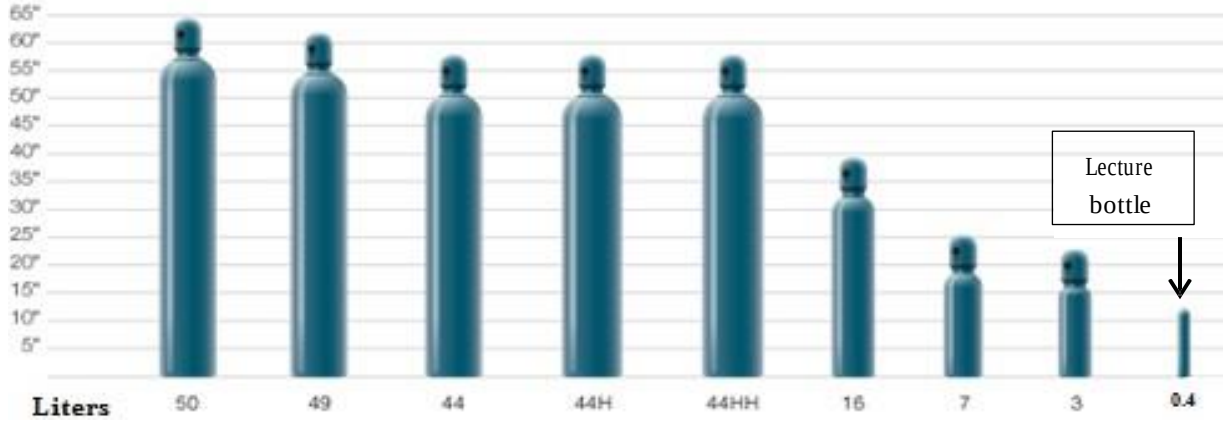
- Oxidizers and flammable gases should be kept at least 20 ft. away from combustible materials and/or incompatible gases or substances. Storage areas that have a non-combustible wall at least 5 ft. in height and with a fire resistance rating of at least 30 minutes may be used to segregate gases of different hazard classes in close proximity to each other.
- Toxic/Poison gases must be stored in a chemical fume hood or in a properly ventilated gas cabinet.
- Inert gases are compatible with all other gases and may be stored together.

Hydrogen (H2)

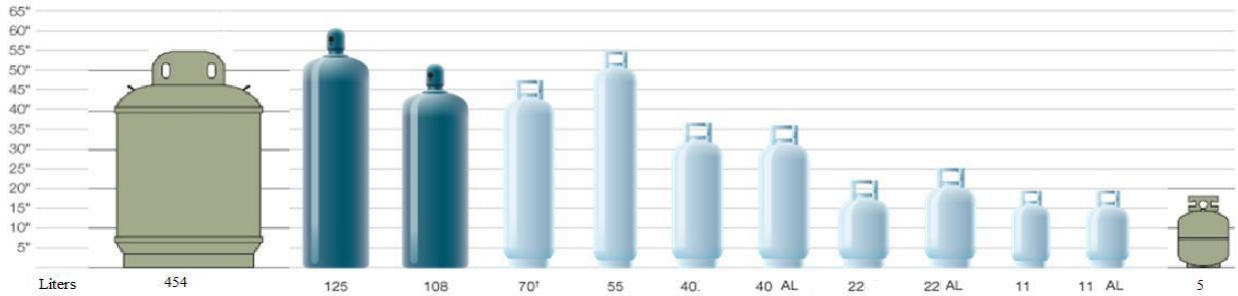
- Hydrogen is a colorless, odorless, tasteless, highly flammable, and nontoxic gas. Due to this high flammability of hydrogen (lower flammable limit of 4% by volume) special safety precautions in addition to the safety precautions mentioned above must be taken:
- Hydrogen gas should never be stored near oxygen, chlorine, or other oxidizing gases. These materials must be separated by at least 20 feet or an appropriate gas cylinder cabinet must be used.
- Cylinders must be located at least 25 feet from open flames, ordinary electrical equipment, and/or any ignition source.
- Hydrogen gas must never be stored below grade, or below the ground of the terrain which surrounds the building.
- Labels identifying cylinders as "Hydrogen" must be visible and free of obstructions.
- When attaching a regulator or control valve do not partially open, or 'crack', the hydrogen cylinder valve. This may lead to self-ignition of the hydrogen.

CYLINDER SIZES

High Pressure Steel

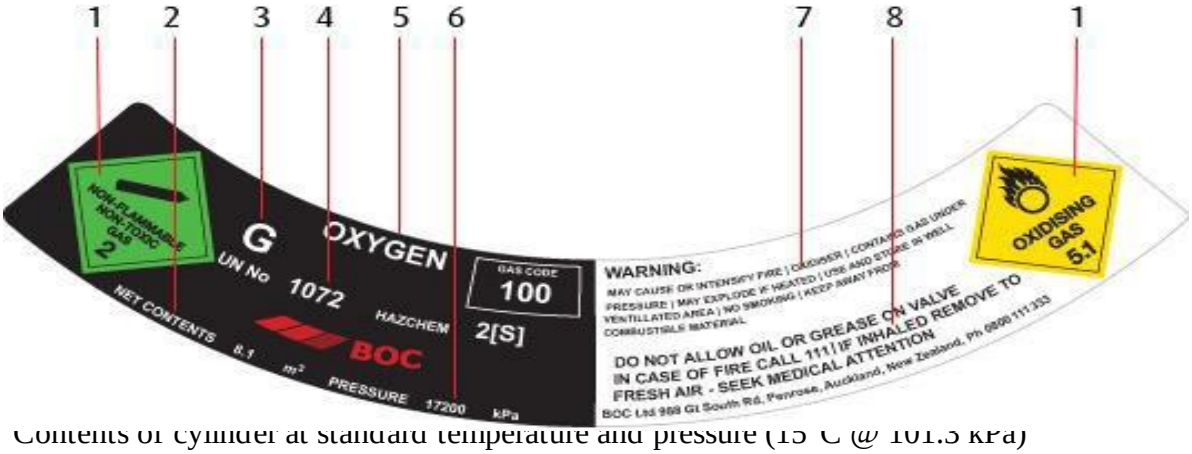


Low pressure steel and aluminum (AL)



Order the smallest possible cylinder for your work. Gas cylinders must be inspected at least every five years by the distributor or manufacture.

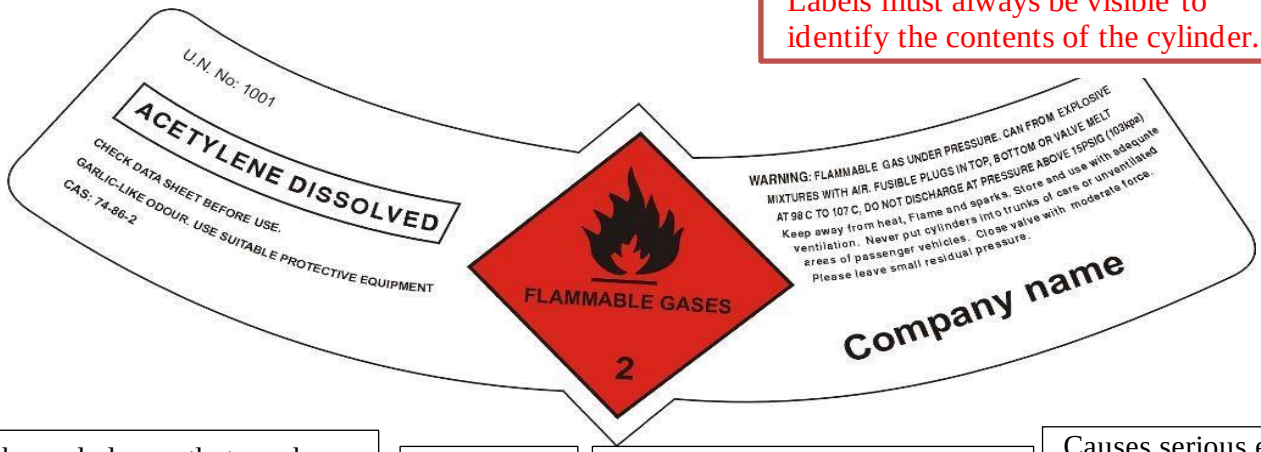
LABEL EXAMPLES



1.
2. Contents of cylinder at standard temperature and pressure (15°C @ 101.3 kPa)
3. Cylinder size
4. United Nations numbering system for safe handling, transport and storage
5. Gas name and grade
6. Nominal filling pressure at standard conditions (for permanent gas)
7. Caution – indicated major hazards*
8. General safety information*

*Always refer to Material Safety Data Sheets (MSDS)

Labels must always be visible to identify the contents of the cylinder.



Other hazard classes that can be encountered	Corrosive	May cause cancer, fertility, issues, or organ damage	Causes serious eye or *skin irritation*

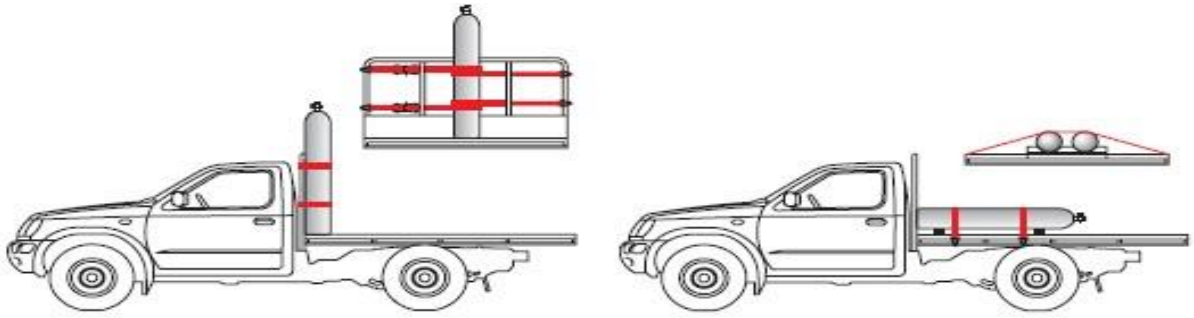
Transporting Compressed Gases on Site

Personnel may move compressed gas cylinders under the following conditions only:

- They have received and documented that they have adequate training.
- The valve is closed, the regulator has been removed and the safety cap is securely in place.
- An appropriate cart is used. A cylinder card is required for tanks over 35'" in height, another cart or dolly will work for smaller cylinders. The cylinder must be secured on the cart.
- "Hand Rolling" cylinders is not permitted.
- Lab personnel may not move large (>35" in height) cylinders between floors of a building or outside of a building. Contact the department technician or the vendor for transport.

Large cylinders moved by vehicle should follow the guidelines above as well as the following:

- Transport large cylinders in an open or well ventilated vehicle.
- Properly secure the cylinder from moving.



Properly secured cylinder for transport

Things to Keep Away from Cylinders

Several precautions should be taken to prevent the release of high-pressure gases, fire, and explosion. Compressed gas cylinders should not be exposed to sparks, flames, or temperatures above 125°F. Cylinders should not be places where they could come into contact with any electrical apparatus or circuits.

Smoking and open flames should not be permitted in areas used for storage of oxygen or flammable gas cylinders. Never permit oil, grease, or other combustible substances to come into contact with oxygen or other oxidizing gas cylinders, valves, and systems.

Returning Cylinders

When returning an empty cylinder, close the valve before shipment, leaving 25 psig of residual pressure in the cylinder. Replace the valve cap and any valve outlet caps or plugs originally shipped with the cylinder. If repair is needed on a cylinder or its valve, be sure to mark it and return it to the supplier.

Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed.

In both cases contact the supplier for proper shipping. Improper shipping can result in large fines and possible prison time.

Handling of Leaking Cylinders

Most leaks occur at the valve in the top of the cylinder and may involve the valve threads, valve stem, valve outlet, or pressure relief devices. Personnel should not attempt to repair leaking cylinders.

Where action can be taken, without exposure to workers, **(if trained)** move the cylinder to an isolated, well-ventilated area and contact EH&S at 6455 or 2788. If the cylinder contains a flammable or oxidizing gas move the cylinder away from combustible materials and contact EH&S at 6455 or 2788.

Whenever a large or uncontrollable leak occurs, evacuate the area/building and immediately **call 911.**

Regulator Selection, Installation, and Operation

(From Airgas web site; http://www.airgas.com/content/details.aspx?id=7000000000247)
The primary function of a regulator is to reduce high-pressure gas in a cylinder or process line to a lower, usable level as it passes from the cylinder to a piece of equipment. A regulator is not a flow control device. It is used to control delivery pressure only.

Since there are numerous hazards and potential for contamination associated with specialty gases—hazards that vary with the gas, the equipment used, and with the particular application— it is necessary to take the proper precautions to assure safety in high-pressure gas control. Contamination can occur during cylinder change out or from an improperly specified regulator or other component in your gas delivery system.

Before performing any operation with which you are not familiar, seek the advice of an experienced individual. In addition to adhering to the safety and operating rules provided here, the user should be aware of the additional safe operating practices peculiar to each piece of equipment and each application.

Note: Never use any regulator for gases other than those for which it is intended.

The following is applicable to pressure regulators used with flammable, oxidant, corrosive, inert, or toxic gases, when it is necessary to reduce cylinder supply pressure to a lower use pressure.

How Regulators Work

Single-Stage Regulators

High-pressure media enter the regulator through the inlet into the high-pressure chamber (see Figure 1). When the adjusting knob is turned clockwise, it compresses the range spring and exerts a force on the diaphragm, which pushes the valve stem open. This releases gas into the low-pressure chamber, exerting an opposing force on the diaphragm. An equilibrium is reached when the spring force on the diaphragm is equal to the opposing force of the gas in the low- pressure chamber.

In a single-stage regulator, delivery pressure increases as cylinder pressure decays, because there is less gas pressure exerted on the valve stem. Thus, frequent adjustment of the control knob is required to maintain constant delivery pressure. This does not pose a problem, however, with pipelines and liquefied gas products where inlet pressure is maintained relatively constant.

Two-Stage Regulators

A two-stage regulator functions similarly to two, single-stage regulators in series. The first stage reduces inlet pressure to a preset intermediate pressure, typically 350 to 500 psig. By adjusting the control knob, the second stage reduces the intermediate pressure to the desired delivery pressure.

Like the single-stage regulator, outlet pressure from the first stage of the two-stage regulator rises as cylinder pressure decreases. However, instead of passing out of the regulator, the gas flows into the second stage where the pressure is moderated. Thus, delivery pressure remains constant even as cylinder pressure decays, eliminating the need for frequent control knob adjustment.

Selecting the Proper Regulator

Line and Cylinder Regulators

Line regulators are typically point-of-use regulators serving low-pressure pipelines. They are also used in conjunction with high-pressure cylinder regulators that limit the inlet pressure to 250 to 400 psig. Cylinder regulators are available in either single-stage or two-stage models for high- purity, general purpose, or special service applications.

High-Purity Regulators

High-purity regulators are designed and constructed to provide diffusion resistance and easy cleanup. Metal diaphragms and high-purity seats and seals minimize or eliminate outgassing and inboard diffusion. These regulators should be capable of containing and removing contaminants during cylinder change out. Only bar stock body regulators should be used for these gases.

General Purpose Regulators

General purpose regulators are designed for economy and longevity. They are recommended for noncorrosive general plant, pilot plant, and maintenance shop applications where diffusion resistance is not required. These types of regulators are not for analytical or high purity applications.

Special Service Regulators

Special service regulators are specifically constructed for special applications including oxygen, acetylene, and fluorine service and high-pressure, ultra-high-pressure, and corrosion service. To make your selection easier, this catalog lists the proper regulator for almost every gas, pressure, and situation. Simply look up the gas or mixture for your application and you will find the appropriate regulator listed under “Recommended Equipment.” CGA valve outlets are also noted for each gas and gas mixture. The regulator must be equipped with the appropriate CGA connection for the cylinder valve outlet.

Putting the Regulator into Service

1. Identify the regulator. Check the label and the inlet and outlet gauges. Ascertain that the high-pressure gauge is suitable for the pressure of the cylinder or source system.
2. Inspect the regulator. Check the regulator for evidence of damage or contamination. If there is evidence of physical damage or foreign material inside the regulator, contact your customer service representative for return information.
3. Inspect the cylinder valve. Check the cylinder valve for evidence of damage or contamination. Remove any foreign material before attaching the regulator.
4. Attach the regulator. Fasten the regulator to the cylinder and tighten the inlet nut securely.
5. Close the regulator. To close the regulator, turn the adjusting knob to the full counterclockwise position.

The regulator must be closed before opening the cylinder valve.

Safety-Checking the System
With the regulator adjusting knob turned fully counterclockwise, place both hands on the cylinder valve and open it slowly, allowing the pressure to rise gradually in the regulator. Stand as shown with the cylinder valve between you and the regulator. When the high-pressure gauge indicates maximum pressure, open the cylinder valve fully.

Always close the cylinder valve when product delivery is not needed. Do not leave it open when the equipment is unattended or not operating.

Adjusting the Pressure
Turn the adjusting knob clockwise and establish the required use pressure by referring to the low-pressure gauge. Make sure that the cylinder valve is easily accessible.

Precautionary Measures
1. Never exchange the discharge (low-pressure) gauge for one of lower pressure. The gauge may rupture if the adjusting knob is unintentionally turned too far.
2. Check diaphragm regulators for creep (leakage of gas from the high pressure to the low- pressure side when the adjusting knob is turned fully counterclockwise).
3. Provide check valves. Back-pressure protection is needed to prevent damage to the regulator. Gas from a high-pressure system can flow back into the regulator.

REMOVING THE REGULATOR FROM SERVICE

Removing the regulator from Service
1. Close the cylinder valve.
2. Vent the gas. Vent the gas in the regulator and/or system, or isolate the system, and vent the gas in the regulator by turning the adjusting knob clockwise so that no pressure is tripped inside the regulator. If the gas is flammable, corrosive, toxic, or an oxidant, take appropriate measures to render it innocuous by employing a suitable disposal system before venting the gas to the atmosphere.
3. Close the regulator. After relieving all the gas pressure, turn the adjusting knob counterclockwise as far as it will go.
4. Disconnect low-pressure equipment. All low-pressure equipment connected to sources of high pressure should be disconnected entirely or, if not, independently vented to the atmosphere as soon as the operation is either over or shut down for an extended period of time.
5. Disconnect the regulator.
6. Protect the regulator. If the regulator is to remain out of service, protect the inlet and outlet fittings from dirt, contamination, or mechanical damage.
7. Replace the cylinder outlet seal and valve cap.

Small propane cylinders and calibration gas cylinders need to be given to EH&S for proper disposal.