UMassAmherst | Environmental Health & Safety

Compressed Gases SOP

Compressed gases may present both physical and health hazards. The exact nature of these hazards depends on the type of gas, quantity, and procedure/apparatus in which it is used. These hazards generally include:

- High Pressure-The pressure contained within the gas cylinder creates a special hazard if the cylinder integrity is at all compromised. The pressure is generally sufficient to forcefully propel the cylinder in the case of sudden pressure release.
- Improper Cylinder Handling-Gas cylinders can be quite heavy and can cause significant injuries if they fall during handling. Additionally, cylinders can be damaged during falls, which can compromise cylinder integrity and lead to sudden pressure release.
- Asphyxiation-Sudden release of pressure from gas cylinders can rapidly displace oxygen leading to the possibility of suffocation.
- Fire or Explosion-Flammable and pyrophoric gases pose a risk of fire or explosion if there is possibility for contact with a source of ignition and/or reaction with air. Oxidizing gases can promote rapid combustion in organic materials, even in materials that might not burn under ordinary circumstances.
- Health Effects-Some gases can be toxic even in very low concentrations. Other gases can be corrosive to tissue or produce other deleterious health issues.

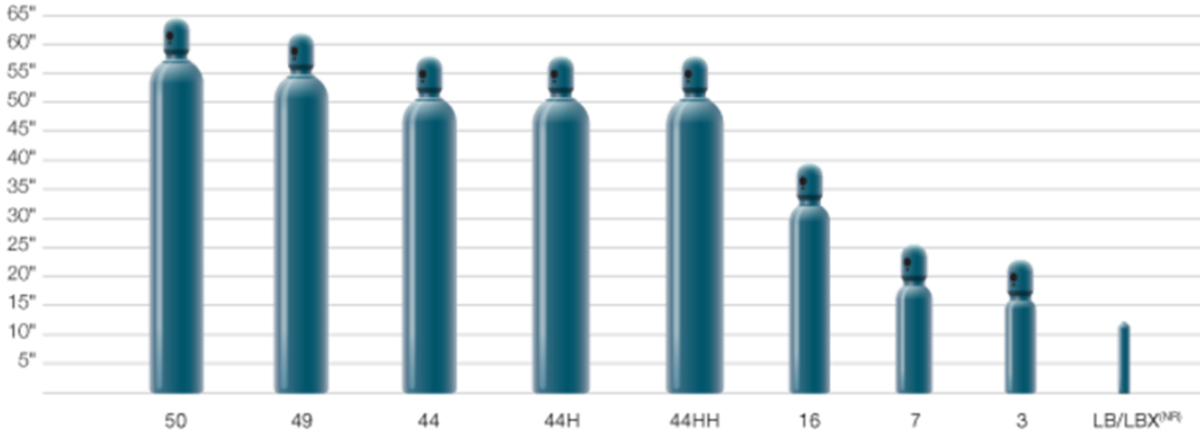
Given the many hazards, it is important that high pressure gases be handled, stored, used, and removed from service in ways that will mitigate these hazards. The follow provides general guidance to aid in this process.

Cylinder Information

Gas cylinders come in a variety of sizes. Common sizes of steel cylinders available from Airgas are shown in Figure 1. Cylinders can be made of other materials, such as aluminum, depending on the gas stored. Gases should always be purchased in the smallest amount needed for the planned work. This is especially true for toxic, pyrophoric, and flammable gases to minimize risk to health and safety and also to comply with building and fire code requirements. Some gases can undergo chemical changes during storage that can alter the purity of the gas or compromise the integrity of the cylinder. For these reasons, it is important to abide the manufacturer's recommended shelf life, and to purchase only what will be used within that period.

The one downside of purchasing small cylinders is that lecture bottles (the smallest size indicated in Figure 1) are not returnable to the vendor and must therefore be disposed of by the University.

Figure 1: Airgas Steel Cylinder Sizes



HP Steel Cylinder Size	DOT Specification	Service Pressure	Approximate Capacity†		Outside Diameter	Height*	Tare Weight**	Internal Water Volume††	
		psig	cu. ft.	liters	inches	inches	lbs.	cu. in.	liters
50	9809-1***	2900	335	9373	9	58.2	130	3051	50
49	3AA	2400	277	7844	9.25	55	143	2990	49
44	3AA	2265	232	6570	9	51	133	2685	44
44H	3AA	3500	338	9571	10	51	189	2607	44
44HH	3AA	6000	433	12261	10	51	303	2383	43
16	3AA	2015	76	2152	7	32.5	63	976	16
7	3AA	2015	33	934.6	6.25	18.5	28	427	7
3	3AA	2015	14	396.5	4.25	16.75	11	183	3
LB/LBX(NR)	3E	1800	2	53.8	2	12	3.5	27	0.4

* Without valve.
** With valve, nominal.
*** UN/ISO specification.
† For N_2 at 70°F 1 atm.
†† Nominal.
(NR) Nonreturnable cylinder. Price of cylinder included in the price of gas.
Note: LBX is an LB cylinder with a CGA valve other than 170 or 180.

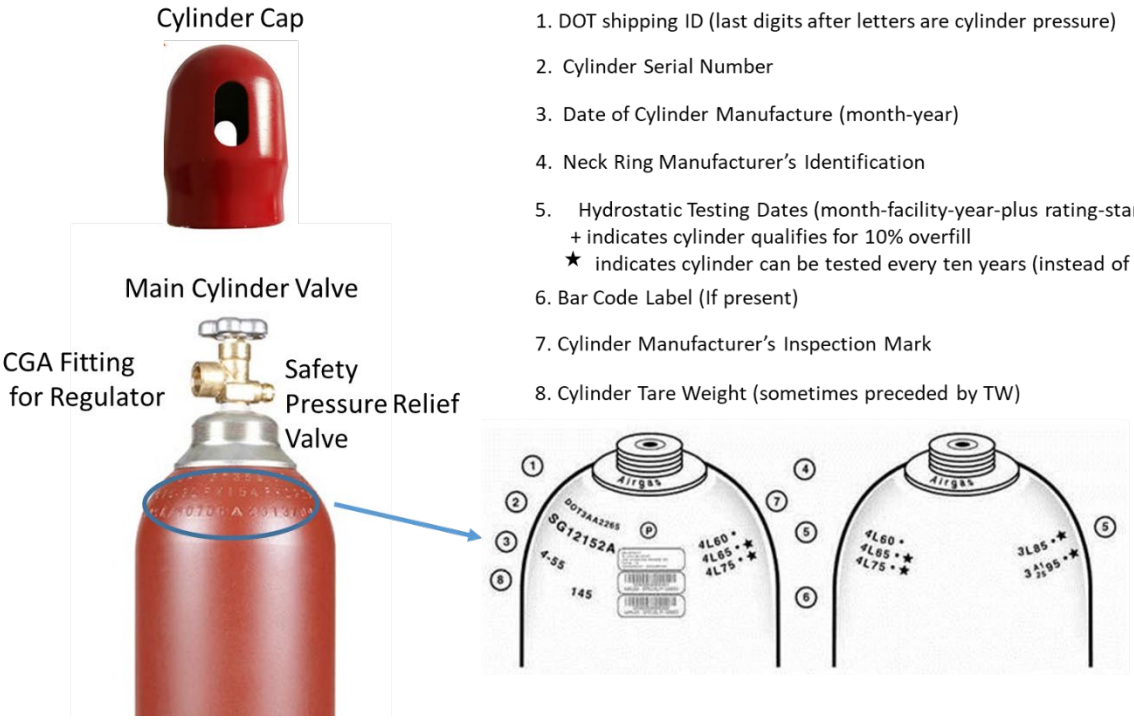
Larger cylinders are typically leased from the gas supplier and are returned when they are empty. Disposal cost for lecture bottles, even empty ones, can be quite large. However, due to the costs and complexity of complying with very specific storage and use requirements for flammable, toxic, and pyrophoric gases, the purchase and disposal of lecture bottles is preferable for these items.

Gas generators can be purchased that are capable of generating a variety gases, including hydrogen, oxygen, and nitrogen. They offer many advantages over traditional gas cylinders including providing a constant gas supply, and important safety features such as generation of gas as needed (which also facilitates compliance with and elimination of the need to handle gas cylinders. Gas generators can be quite expensive, and so these are not typically cost effective except for very high volume uses.

Gas cylinders can have a variety of safety features and markings, which identify the contents and various properties of the cylinder and contents. These are depicted in Figure 2. All cylinders have a main cylinder valve that opens or closes the cylinder. This valve does not regulate the pressure coming out of the cylinder. A pressure regulator is typically used to control the outlet pressure. Regulators are discussed in more detail later in this document. When regulators are not attached to cylinders, the cylinder cap must be in place on the cylinder to prevent damage to the main cylinder valve. If this valve were to be damaged in any way, uncontrolled release of the cylinder contents may result. As such, if a cap is stuck on a cylinder, never insert rods, wrenches, or other objects through the cylinder cap to open the cap. If a cap is stuck, try using a strap wrench or cylinder hand wheel wrench (Figure 3). If the cap is

still stuck, return the gas to the supplier and request a replacement. Most gases (with notable exceptions being pyrophoric and toxic gases) also have safety pressure relief valves, which are meant to vent cylinder pressure above a particular value to prevent catastrophic cylinder failure in the event of a fire or overfilling.

Figure 2: Gas Cylinder Parts and Markings

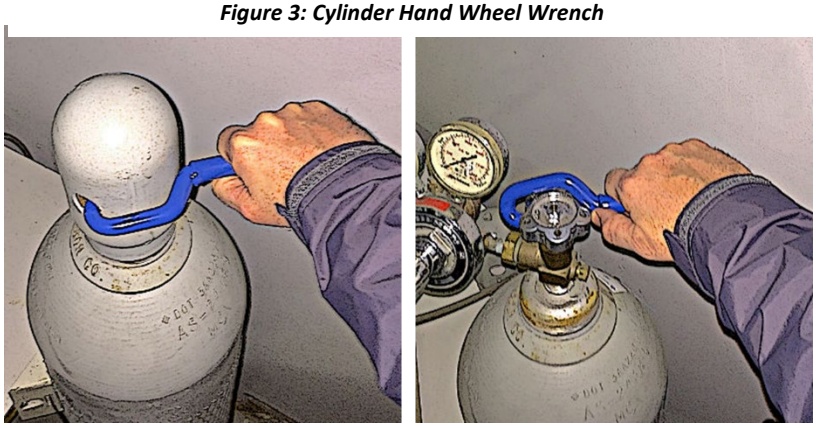


In addition to Department of Transportation (DOT) and manufacturer's labels identifying the contents of cylinders, they also have a variety of stamps indicating important information, including: date of manufacture, service pressure, and date of last hydrostatic test. Hydrostatic testing is required by the DOT for cylinders that are to be transported in commerce. Hydrostatic testing verifies cylinder integrity. Testing is generally required every five or ten years depending on the type of cylinder. Some cylinders require testing every three years. Cylinders should not be kept beyond the expiration of the hydrostatic test date to ensure that cylinders are safe for shipment and can be returned to the manufacturer. For example, hydrogen cylinders can become embrittled over time. Cylinders should also be visually inspected on a regular basis for signs of corrosion, cylinder fatigue, and valve problems.

The color of a gas cylinder is not a good means of identifying the contents. Most manufacturers generally use cylinder colors to indicate the grade or purity of the gas, not the identity. Always read the label on a gas cylinder to determine the type of gas it contains.

Storage and Handling

Figure 3: Cylinder Hand Wheel Wrench



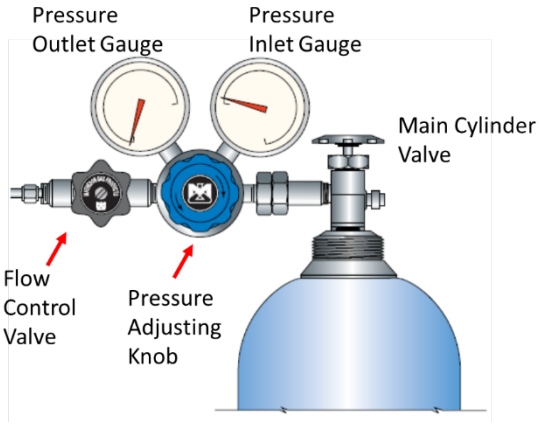
Cylinder and valve integrity are impacted by storage and handling conditions. As such, it is essential that gas cylinders are maintained properly. General storage and handling conditions for all gas cylinders include:

- Cylinders should be stored in well-ventilated areas.
- Always wear eye protection rated for protection from impact (i.e., ANSI Z87+ rated) when using or handling compressed gases.
- Cylinders of liquefied gases should be stored upright, unless there are specific directions on the cylinder indicating otherwise. Examples of liquefied gases include, but are not limited to, nitrogen, acetylene, carbon dioxide, ammonia, chlorine, hydrogen sulfide, and hydrogen chloride. Liquefied gases also contain higher volumes of gas at room temperature and pressure than the same sized cylinder of a compressed gas and thus present a greater asphyxiation potential.
- Cylinder caps must be in place whenever regulators are not attached.
- Cylinders must be affixed to walls, permanent benches, or other immovable objects. Do not use a single chain to secure more than six cylinders. Ensure the strap or chain is positioned at approximately 2/3 the height of the cylinder. Storage on approved carts (with the strap/chain in place) or stands is also acceptable. See Figure 4 for examples of appropriate storage.
- Store cylinders away from corrosive materials (e.g., acids and bases) which can damage the cylinder.
- Store gas cylinders away from sources of heat.
- Store empty cylinders away from full cylinders. Ensure that empty cylinders are labeled as such and are returned promptly to the manufacturer.
- Ensure that gas cylinders are stored such that they do not obstruct means of egress, electrical panels, eye washes, drench showers, access to hazardous materials or other items.
- Never move or a use a compressed gas cylinder unless you have been provided with hands on instruction from your PI or trained and authorized coworkers on how to do so.
- Cylinders must be transported on approved carts, with the strap/chain in place, and with a cylinder cap. Minimize walking of cylinders. Only walk cylinders very short distances to move these from the cart to the final storage location.

Figure 4: Appropriate Gas Cylinder Storage

Additional storage and handling requirements exist for gases that pose specific hazards. See the hazardous gases section below for additional information.

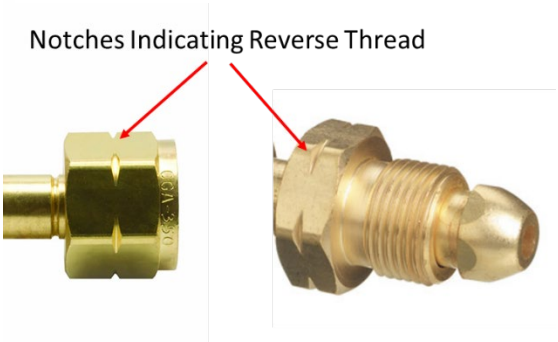
Figure 5: Gas Regulator



<u>Regulators: Connections</u>

Regulators (Figure 5) are used to control the amount of gas (i.e., pressure) that is released from a cylinder. Regulators connect to cylinders via a CGA (Compressed Gas Association) connection size that is specific to the gas and cylinder pressure. Not all gases are compatible with all types of regulator materials, and not all regulators are designed to handle all cylinder pressures. The differing CGA connections on regulators and cylinders prevent connection of incompatible regulators and gas cylinders. This is an important safety feature, and as such, adapters should never be used to alter the CGA connections on regulators or gas cylinders. The threading of the connection is also a safety feature. Flammable gases have reverse thread connections for regulators, which means the nut for the CGA connection for these regulators must be tightened in the opposite direction than what is required for other cylinders. Reverse thread connections can be identified visually by a notch inscribed on the circumference of the connecting nut (Figure 6).

Figure 6: Notches on Flammable Gas Regulators



Some regulators require a washer or spacer to be placed in between the regulator and gas cylinder. These regulators have a flat surface where the spacer fits and always have a female nut attachment to the cylinder. A new spacer should be used every time the regulator is connected to a gas cylinder to ensure a gas tight connection. These are available for purchase from the regulator supplier or manufacturer.

Never attempt to connect or remove a regulator unless you have been trained by your PI, or trained and authorized coworkers, on how to do so. Always wear eye protection rated for impact (i.e., with an ANSI Z87+ marking) when connecting, disconnecting, or using regulators. The following is a general approach for connecting and disconnecting a regulator to a gas cylinder.

- Always support the body of the regulator while hand tightening the CGA connection to ensure that excessive torque is not placed on the connection and then use an appropriate sized crescent wrench to completely tighten. Excessive torque can damage the threads.
- Never use Teflon tape, grease, or other aids to assist in connecting a regulator to a gas cylinder. These items can clog the flow of gas, damage the regulator, contaminate the gas for the application, and in some cases, react violently with the gas to produce hazardous situations.
- If a regulator does not fit appropriately on a cylinder for which the regulator is designed, first inspect the threading on the regulator. If the threads on the regulator are not damaged, return the cylinder to the manufacturer and get a replacement. If the threads are damaged, refer the

regulator to the manufacturer or other vendor for repair. Many gas suppliers, such as Airgas, will repair regulators for a fee.

- It is a good idea to perform a leak check when regulators are first attached to gas cylinders. This can be accomplished by using a soap solution, or other appropriate product like Snoop, that is compatible with the gas. Bubbles indicate a leak. Never use a flame to leak check for flammable or oxidizing gases.
- Always ensure the main cylinder valve is closed and bleed the pressure from the regulator before attempting to remove the regulator.

Regulators: Types

There are two main types of regulators: single and dual stage regulators. Single stage regulators reduce the outlet pressure in one step, while dual stage regulators reduce the pressure through two steps. The outlet pressure of single stage regulators can vary with overall cylinder pressure. As such, for applications where control is required for constant outlet pressure, single stage regulators should not be used. Dual stage regulators can be used alone, however, additional forms of pressure and flow control may be necessary for applications using flammable or toxic gases or where very precise pressure or flow control is necessary. For low pressure items, such as certain liquefied gases or lecture bottles, flow control valves can be used in lieu of regulators. It is important to understand that flow control valves do not control pressure, and therefore, overall system design must be carefully considered for safety purposes when flow control valves are used in the absence of a regulator.

Most regulators have two gauges (see Figure 5). The gauge closest to the main cylinder valve is the pressure inlet gauge. This gauge measures the gas pressure in the cylinder. Some single stage regulators that do not have an adjustable outlet pressure only have this gauge. For single and dual stage regulators with adjustable outlet pressure, a second gauge is provided to monitor the outlet pressure. Outlet pressure adjustment is accomplished by turning the pressure adjusting knob. Pressure gauges should never be used at more than 75% of the maximum face reading. Different regulators are designed to provide different ranges of outlet pressures. As such, ensure the regulator you are using is appropriate for the required pressure of the application. Some, but not all, regulators have an additional flow control valve.

Regulators do require maintenance. Refer regulators for service per the schedule specified by the manufacturer. Do not use regulators that leak, exhibit pressure bleed, have gauges that do not read 0 in the absence of pressure, or have other problems. Most regulator manufacturers will repair regulators for a fee. Gas supply companies, such as Airgas or Middlesex, etc., also have similar services.

Regulators: Use

The following is a general procedure for using a regulator that is attached to a gas cylinder. Never use a regulator for the first time without being trained by your PI or trained and authorized coworkers on how to do so. Always wear eye protection rated for impact (i.e., with the ANSI Z87+ marking) when working with gas cylinders.

- With the regulator attached to the cylinder, turn the pressure adjusting knob counterclockwise until it is loose. If a flow control valve is present (e.g. on a two stage regulator), ensure it is

open. The pressure inlet and outlet gauges should both read 0 when no gas is present. If either of the gauges do not read 0, do not use the regulator. Refer it for repair or replace it.

- Open the main cylinder valve slowly. The needle on the pressure inlet gauge should move to indicate the cylinder pressure. Open the main cylinder valve completely and then back off ¼ turn.
- Ensure the system either has a pressure relief valve to relieve pressure or is rated to contain a set pressure. Never exceed the manufacturer's pressure ratings. When using glass, ensure the glass is rated for the pressure used. Always leak test new and reconfigured connections.
- Adjust the pressure control knob to the desired outlet pressure. The outlet pressure is monitored on the outlet pressure gauge. This should not exceed the rated pressure for the system.
- If gas flow is stopped for more than a brief period, close the main cylinder valve and bleed the pressure from the regulator to prevent damage to the regulator.
- Never let gas cylinders go entirely empty. Always leave a small amount of pressure in the cylinder (e.g. on the inlet gauge) to prevent contamination of the cylinder.

Hazardous Gases

Corrosive, flammable, oxidizing, pyrophoric, and toxic gases present additional specialized physical and health hazards. These additional hazards necessitate specific requirements for handling, use, and storage. Many of these requirements can be quite specific and depend on the type, concentration, and quantity of gas used and stored, and the overall features of the experimental apparatus. For this reason, it is always a good idea to consult with EH&S prior to ordering, storing, and using hazardous gases. Some general requirements are given below.

- All work with pyrophoric and toxic gases must be reviewed and approved by the ICSC and EH&S prior to acquisition of the materials or commencement of work. A pyrophoric gas is defined as a gas or mixture of a gas with an auto-ignition temperature in air of 54.4°C or less. A toxic gas is defined as a gas or mixture of a gas with an NFPA health hazard rating of 3 or 4. These items must be stored and handled in very specific ways to comply with building and fire code regulations, including (but not limited to):
    - Storage in ventilated enclosures, which in some cases must be gas cabinets (which may further need to be internally sprinklered)
    - Possible need for gas leak detection with interlocked shut off valves
    - Possible need for orbital welding of connections
    - Possible need for back-up power on exhaust and other systems
    - Possible need for scrubbing of exhaust
    - Specialized emergency action plans
    - Specialized security plans
- Oxidizing gases (e.g., oxygen) must be separated by at least 20 feet from flammable gases (e.g., hydrogen) or by a rated fire barrier. Oxygen should be plumbed with compatible lines.
- Storage of flammable gases must comply with building and fire code regulations. To ensure compliance, contact EH&S if you possess more than two size 300 (or 49, depending on manufacturer) cylinders of a flammable gas in a particular space.

- Ensure that all regulator and gas system materials are compatible with the gases that are used.
    - Never use copper with hydrogen. Copper can become embrittled on prolonged contact with hydrogen.
    - Always use stainless steel or Monel with corrosive gases. These gases will corrode other types of metals rapidly.
    - Plastic tubing is frequently not appropriate for use with hazardous gases. If plastic tubing is to be used, ensure that it is approved by the manufacturer for the particular application and that the manufacturer's directions for use are strictly followed.
- Purge air from systems that are to be filled with hydrogen or other flammable gases with an inert gas prior to introduction of the flammable gas when possible.
- Use flash back arrestors when possible with flammable gases, particularly hydrogen.
- Check valves should be used in systems connected to incompatible gases (e.g., flammable and oxidizing).
- Excess flow control valves detect uncontrolled flow and shut off gas flow under these conditions. These excess control valves should be used for all hazardous gases when possible.
- Minimize connections that occur outside of ventilated enclosures. Use welded, leak-proof connections when possible.
- Leak detection (i.e., gas sensors) should be used for hazardous gases, particularly in areas where connections capable of leaking are outside of a ventilated enclosure, and may be required in some situations.

Return or Disposal

Returnable cylinders, which are empty or no longer in use, should be returned to the manufacturer promptly. This avoids prolonged storage and saves money as these cylinders typically have rental or cylinder lease fees. Empty or unused lecture bottles that are not returnable should be referred for hazardous waste disposal.

Shipment of some gases, particularly those that are toxic or pyrophoric, can be a complicated process. Frequently these items cannot simply be returned to the manufacturer by requesting a pickup as is done with other gas cylinders. Separate arrangements have to be made with freight companies to comply with the stringent shipping regulations. As such, only individuals with appropriate DOT training should initiate and sign shipping documents for these items to avoid fines and legal liabilities. Please contact EH&S to assist with the return of toxic and pyrophoric gases.

Leaking Cylinders

If a gas cylinder containing a toxic, flammable, pyrophoric, or corrosive gas ever develops a leak, if a large leak occurs in a gas cylinder containing a non-hazardous gas, or if a small leak occurs in an area :

- Evacuate the area and building
- Activate the fire alarm on the way out
- Call EH&S at 413-545-2682 to report the identity of the gas, cylinder size, and location

For small cylinder leaks involving non-hazardous gases in well-ventilated areas:

- Evacuate the area
- Call EH&S at 413-545-2682

References and Regulations

Massachusetts Fire Code, 527 CMR: https://www.mass.gov/regulations/527-CMR-100-massachusetts-comprehensive-fire-safety-code

Massachusetts Building Code, 780 CMR: https://www.mass.gov/handbook/ninth-edition-of-the-ma-state-building-code-780

NFPA 45 and 55: https://www.nfpa.org/Codes-and-Standards

Design and Safety Handbook For Specialty Gas Delivery Systems:

5th ed.:
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Millenium ed.:
https://chemistry.osu.edu/sites/chemistry.osu.edu/files/Safety%20and%20Design%20Handbook.pdf

Matheson Guide To Regulators:
https://www.mathesongas.com/pdfs/litCenter/SpecGas&EquipmentBrochures/Guide%20to%20Regulators.pdf

Airgas Catalog: http://airgassgcatalog.com/catalog/