Compressed Gases

1. Purpose / Background
Compressed gas cylinders can present a variety of hazards due to their contents, pressure, and cylinder weight. Hazards of gases include potential for fire and explosion, increased rates of combustion, exothermic chemical reactions, toxicity, corrosiveness, and risk of asphyxiation. If a gas cylinder tips over, in addition to the danger of crushing injuries caused by the heavy weight of a large falling cylinder, the cylinder can also become a dangerous projectile if its valve is sheared off. In this situation, the highly pressurized gas escaping through a small hole may cause the cylinder to move at an extremely high speed.

Due to these and other hazards, insurance carriers (FM Global), state fire codes, DOT and OSHA federal laws require the implementation of certain safety precautions. This SOP establishes requirements and guidelines for the safe storage, transport and use of compressed gas cylinders per the MIT EHS Policy.

2. Scope
This SOP describes specific requirements and guidelines for the procurement, storage, transport and use of compressed gas cylinders in laboratory and in non-laboratory spaces at MIT. Refer to the SOP on Cryogenic Liquids because these issues are outside of the scope of the Compressed gas SOP.

3. Prerequisites
No prerequisites are needed.

4. Procedures
4.1. Overall Guidelines

4.1.1. Compressed gas cylinders should be stored, transported and used in a manner to minimize the risk of injuries to personnel, environmental release and property damage.

4.1.2. Transport and use of compressed gases should only be performed by personnel who have been trained in and are knowledgeable of the hazards of the gas and proper safety precautions, including safe work practices, signs and symptoms of exposure, necessary protective equipment, and emergency procedures.
4.2. General Procurement and Inventory Management 

Requirements

4.2.1. Do not accept delivery of cylinders that are noticeably leaking, damaged or unlabeled. (29CFR 1910.253, MIT Purchasing Policies and Procedures)

Guidelines

4.2.2. Prior to first ordering any compressed gas, its hazards and required safety precautions should be reviewed. For flammable, pyrophoric, corrosive, or oxidizing gases or gases which pose a health hazard, this safety review process should involve a joint effort between the EHS Office and the user group(s) to review the hazards of the gas, planned procedures, design of process and safety systems, training needs for users, and emergency plans.

4.2.3. Poisonous and/or pyrophoric hydride gases typically require monitoring systems, which shut down the gas flow in the event of detection. Training on response protocols for these systems is done by the EHS Office (IHP).

4.2.4. To avoid storage of excess cylinders, order the smallest available returnable cylinder that contains the quantity of gas necessary for the work to be done in the near future. Also order the number of cylinders that can be restrained in your lab. Refer to the Flammable Liquids SOP for the Massachusetts State Building Code limits for upper floors. Contact the supplier for information about different cylinder sizes and pressures. As a guideline, a large (approximately 5 foot tall) steel cylinder full of high-pressure gas such as nitrogen generally contains about 200-300 cubic feet of gas at approximately 2000psi pressure. A 5-foot cylinder of carbon dioxide, which is filled in the liquid phase by weight, holds about 50 pounds at 900psi.

4.2.5. When cylinders are delivered, the driver must be able to secure the cylinder either inside the lab or immediately outside, if no one is in the lab. The researcher is responsible for moving the new cylinders into the lab on the same day and not using the drop off point for excess storage. The drop off/ pick up point must have brackets or chains to secure the cylinders. Note: The Department of Facilities does not allow cylinder
drop off/ pick up areas in the corridors above the Infinite Corridor and other corridors where there is a lot of traffic.

Non-returnable cylinders: Avoid ordering gas cylinders that cannot be returned to the supplier. The researcher will be asked by the Procurement Partner if they can order the desired gas in a returnable cylinder. If a non-returnable cylinder is the only way to obtain the gas, then EHS will send the following information to the responsible person. The MIT's Environmental Management Program assists in the transportation and disposal of unwanted cylinders from departments, labs and centers (DLC). These are typically small non-returnable cylinders, but EMP will handle all types and sizes. Submit a request via environment@mit.edu or the online hazardous waste chemical collection form for disposal of these cylinders. The Hazardous Waste Manager reviews the cylinder hazard type with the onsite vendor to determine if the material is safe to devalve, cut and recycle the scrap metal or if the cylinder should be shipped for disposal to an approved TSDF. In the event that the cylinder is shipped for disposal, the DLC will be charged and therefore provide an account number on their red tag for billing purposes. If the cylinder can be devalved on campus, no charge will be placed on the lab requesting the pickup.

4.2.6. When a very hazardous gas is ordered, the EHS Office will request that the vendor postpone the shipment until the researcher has completed the necessary steps to ensure that they will be able to safely use, store, dispose of or return the cylinder. This also includes the coordination of the delivery of the cylinder so the supplier and the Procurement Partner will not leave it on a loading dock.

4.2.7. Return unneeded cylinders to the supplier to minimize the amount of gas in storage. Suppliers charge a monthly rental fee for cylinders. The cost of cylinder rental quickly exceeds the cost of the gas.

4.3. General Storage and Restraining of Cylinders:

These requirements and guidelines apply to storage of gas cylinders before, during and after use unless otherwise specified.

Requirements

4.3.1. Gases that are toxic (NFPA health rating 3 or 4), pyrophoric gases, and nitrous oxide gas should be stored in an area secured from unauthorized access (i.e. a locked storage room or locked cage). (NFPA 55 and MIT policy on nitrous oxide)
4.3.2. Restrain all compressed gas cylinders of all sizes securely at all times to prevent them from falling. This applies to cylinders that are in service, in storage and are empty.

Secure each cylinder above its center of gravity, which is approximately 2/3 up the cylinder. Use a chain (1/4 inch in diameter) or belt restraint that is pulled tight around the body of the cylinder. If the restraint is not tight, too high or too low on the cylinder, a cylinder may tip with enough force to break the restraint or may slip out from under the restraint. The restraint should be securely attached to a wall or sturdy laboratory bench. Refer to http://web.mit.edu/environment/ehs/topic/compressed_gas.html for how to have the wall-brackets or chains installed. For situations in which a cylinder is needed in a location where anchoring the cylinder to a wall or bench is not practical, consider a freestanding cylinder stand or rack. (NFPA 45)

Note that cylinder carts are designed to secure cylinders with the caps on in order to safely transport these. Normally the cylinder is removed from the cart so it can be secured in the upright position before use. Welding carts are an exception because the cart is moved to many different areas to be used.

4.3.3. Cylinder Position in Storage: Normally cylinders are stored in the upright position to maximize storage space, to segregate hazard classes and to separate full cylinders from empty ones. If gas cylinders are properly secured to prevent rolling, the CGA regulations allow cylinders to be stored in a horizontal position. Note that liquefied flammable compressed gas cylinders shall always be stored with the pressure relief device in direct communication with the vapor space of the cylinder. This type of cylinder is often used in the horizontal position such as on a forklift truck. (CGA)

4.3.4. For cylinders that are designed to accept a valve cap, store cylinders with caps securely attached whenever cylinders are not in use or are not equipped with a regulator. (CGA)

4.3.5. Almost all gases can act as simple asphyxiants by displacing the natural oxygen in the air. Ensure adequate ventilation of all enclosed areas in which concentrations of gas could build up during storage or use. (29 CFR 1910.253)

4.3.6. Inspect stored cylinders on a regular basis to detect signs of leaks or damage, and to ensure that cylinders are properly restrained and labeled. Label any damaged or defective cylinder as such and return to vendor. (29 CFR 1910.101)
4.3.7. Store cylinders away from flammable or combustible liquids and from other combustible materials, and away from corrosive chemicals or fumes which may damage the cylinders. (CGA)

4.3.8. Store pyrophoric gases, flammable gases, oxidizing gases, corrosive gases, and gases that pose health hazards separately from each other. Provide adequate spacing by segregation (generally at least 20 feet) and/or fire barriers as required by applicable codes (CGA, NFPA 51, NFPA 55).

4.3.9. Prominently post the storage area (if required by regulation) with “Caution Compressed Gas Storage” and the name or hazard class (i.e. flammable, corrosive, highly toxic) of the gases being stored. (CGA)

4.3.10. Do not deface or remove the label(s) applied by the gas supplier to identify cylinder contents. (CGA)

4.3.11. Ensure storage area temperatures do not exceed 125°F. Locate cylinders away from boilers, radiators, heaters and similar heat producing equipment. Avoid storage in areas which may reach subzero temperatures. (CGA)

4.3.12. Ensure storage area is not heavily trafficked or arranged such that mobile equipment such as a forklift truck may inadvertently come into contact with the cylinders. (CGA)

4.3.13. Avoid placing cylinders where they may become part of an electric circuit, such as against multiple outlet strips (CGA)

Guidelines

4.3.14. Gases should not be used in spaces such as cold rooms, warm rooms, and other areas which might not have adequate fresh air ventilation. If gases must be used in such areas, contact the Industrial Hygiene Program for assistance in determining if oxygen monitoring or other monitoring is required and/or for help in selecting a monitoring system with local alarms.

4.3.16. Wherever feasible, cylinders should be restrained singly, by use of a separate restraint system for each cylinder. If multiple cylinders must be restrained by a single restraint such as a belt or chain, the restraint system should be sufficient to prevent any of the cylinders from falling or rolling. Belts are designed for two cylinders maximum. Chains with heavy gauge links can hold multiple cylinders but the anchor point in the wall may be the weak link. Multiple cylinders may be ganged together with a belt or chain away from a
wall or other support structure, as long as there are enough cylinders to make it impossible for one or all of them to fall over. Cylinder storage racks that allow for restrained storage of multiple large cylinders are commercially available. Contact your gas supplier or EHS for more information.

4.3.17. Label cylinders to indicate whether they are “FULL”, “IN SERVICE”, or “EMPTY”. Store empty cylinders separately from full cylinders whenever possible.

4.3.18. If cylinders are stored outdoors, do not store directly on the ground. Ensure the area is well drained, protected from the elements including direct sunlight and vehicular traffic, and constructed of fire resistive material. Cylinder cages are designed for outdoor storage.

4.4. **General Transport: Requirements**

4.4.1. Cylinders should never be dragged, or lifted by the cylinder cap. Cylinders should never be rolled more than a few feet as necessary to get them into position on a cart or into position for storage or use. (CGA)

4.4.2. Remove the regulator and ensure the valve protective cap is fully seated on the cylinder threads prior to moving a cylinder. Unless cylinder is secured on a special hand truck designed to protect the valve, never move a cylinder with the regulator still attached. (29CFR 1910.253)

4.4.3. Secure cylinders in a basket or similar device if moving them using a crane or derrick. Do not use slings, ropes, or electromagnets for lifting cylinders. (29 CFR 1910.253)

4.4.4. Do not allow cylinders to be dropped or struck or permit them to strike against each other violently. The valve may be broken off and the release of pressure could create a rocket. (CGA, 29 CFR 1910.253)

4.4.5. **Transport of compressed gases over public roads:** This is strictly governed by Federal and State regulations. Any shipment of compressed gases that is to travel over public roads must comply with regulations regarding placards, quantity, packaging, and labeling. The use of vehicles, which are not designed to safely transport gas cylinders, creates safety hazards and should be discouraged, per the CGA. If there was car accident and the gas cylinder was damaged, this would increase the risk of injury to the passengers and the emergency responders. Therefore, it is
safest to have a vendor deliver and pick up the gas cylinders. Department and laboratory personnel who intend to ship or convey gas cylinders over public roads by Institute or personal vehicles must contact the EHS Office to determine whether this is allowed or prohibited by the regulations. If it is allowed, EHS can provide packaging and labeling instructions as well as advice about the safety of the project. (MIT Purchasing Policies and Procedures 4.2.11)

Guidelines

4.4.6. Use only a cylinder hand truck, forklift truck, cylinder pallet system or similar device with securing chain to move cylinders larger than lecture bottle size. Handle one cylinder at a time unless the system is specially designed to handle more.

4.5. Cylinder Regulators, Valves and Piping

Requirements

4.5.1. Ensure that the hazards and required safety precautions, including safe work practices, signs and symptoms of exposure, steps to take in case of an incident, and necessary personal protective equipment, are communicated to all who may work with or have exposure to a gas. Material Safety Data Sheets should be readily available. (CGA, NFPA 45 and OSHA Hazard Communication/Lab Standards)

4.5.2. Do not use compressed gas cylinders without regulators. (NFPA 45)

4.5.3. Use only Compressed Gas Association (CGA) connectors designed for the specific gas and rated pressure being used. The connectors differ for different types of gases; for example, connectors designed for flammable gases are reverse threaded and are tightened by turning the nut counterclockwise. To indicate this, the nut for a reverse thread connection will have a line inscribed around its circumference. (CGA, NFPA 45)

4.5.4. Position cylinder valves so that they are accessible at all times. Open valves slowly; do not force. Wear safety glasses and keep your face away from valve outlets and gauge faces while opening valves in case the gauge fails. (CGA)

4.5.5. Do not refill gas cylinders. (29 CFR 1910.253) Also do not add other gases to a cylinder.
4.5.6. Do not alter, repair, tamper with, or service compressed gas cylinders, valves, or relief devices. Contact the supplier for these services. (CGA)

4.5.7. Do not use a wrench or hammer to force a valve open or remove a cylinder cap. If a corroded valve is forced open, it may not close properly afterwards and may leak. You may break the valve causing the entire contents of the cylinder to leak. Contact the gas supplier to replace the cylinder if a valve is difficult to operate or if the cap is stuck. (29 CFR 1910.253)

4.5.8. Ensure any piping systems and associated equipment have been properly designed and labeled regarding the materials of construction, pressure ratings, emergency relief valves, need for venting and / or gas scrubbing capability, contents and compatibility. Be particularly careful to label long piping runs where the identity and source of the gas may not be obvious. (NFPA 45)

**Guidelines**

The safety guidelines for installing and using a two-stage regulator was expanded and moved to appendix A. This could be posted in the lab or included in the lab specific training.

The recommended maintenance for regulators was added. This is in appendix B.

4.5.9. Verify the contents of a cylinder before use by making a positive identification of the cylinder label. Do not rely on cylinder color to identify the contents. Consult the supplier if you have any questions about the identity of a gas in a cylinder.

4.5.10.

4.5.11. Do not use any type of homemade adaptors.

4.5.12. Avoid using flexible tubing (rubber, plastic, etc.) to carry anything but inert gases because it has weak wall strength, is prone to leakage, is not durable, and detaches easily. All tubing should be constructed of materials compatible with the gas being used. Check if the flexible tubing used for Bunsen Burners is rated for natural gas. The tubing is often the source of gas leaks.
4.5.13. Inspect all piping systems regularly for signs of leaks or deterioration. Always close the cylinder valve before attempting to stop leaks in the system.

4.5.14. In many cases it is safest to turn gas off at the source when it is not being used. To shut down a system carrying an inert gas, close the cylinder valve and vent the pressure from the rest of the system. For closed systems carrying toxic or pyrophoric gases, gas lines are often kept pressurized. When it is necessary to remove the gas from these systems, special procedures, such as nitrogen dilution, should be followed to safely remove and exhaust the gases from the system.

4.5.15. To minimize the risk of backflow and cylinder contamination, do not completely empty a cylinder. Consider a compressed gas cylinder empty when the cylinder pressure gauge indicates about 25 psig. At this point, close the valve, mark the cylinder empty, and move it to empty cylinder storage area. Consider the use of check valves for situations where backflow is of special concern.

### 4.6. Emergencies

#### Requirements

4.6.1. Report leaking cylinders to the supplier and the EHS Office. Notify personnel in the area about the leak. If you can safely shut off the gas, turn the cylinder valve by turning the adjusting knob COUNTER-CLOCKWISE until it stops. Evacuate the area if the leak poses a fire or health hazard to personnel. (MIT EHS requirement)

4.6.2. Only trained personnel shall respond to an emergency situation involving a compressed gas (CGA).

4.6.3. Gas users must develop a written Emergency Plan if they possess any quantity of extremely toxic (health rating 4), corrosive, or pyrophoric gases. Users possessing more than 75ft³ of flammable gases or more than 400ft³ of gases with a health rating 3, oxidizing or nonflammable gases should also develop a written Emergency Plan. (Laboratories with a Chemical Hygiene Plan covering their gases are exempt from this requirement of NFPA 55.) The Emergency Plan should cover:

4.6.3.1. What emergency equipment is available and where
4.6.3.2. A brief description of any testing or maintenance programs for the emergency equipment

4.6.3.3. An indication that hazards identification labeling is provided for each storage area

4.6.3.4. Location of posted emergency response procedures (including the MIT Emergency Response Guide)

4.6.3.5. The procedures whereby Material Safety Data Sheets (MSDSs) may be obtained for all gases stored on site

4.6.3.6. A list of responsible personnel who are designated and trained to be liaison personnel for the fire department

4.6.3.7. A list of types and quantities of compressed gases normally at the facility

Guidelines

4.6.4. Plan ahead for possible emergencies involving gases. All personnel who work in areas where a gas is used should be trained in how to respond to potential emergencies, including gas leaks and personnel exposure (see section 6).

4.6.5. In case of exposure to a gas that may pose health hazards, notify the victim’s supervisor and EHS. Assist victim and remove them from exposure if you can do so without risk of exposure yourself. Victims should report to MIT Medical if physically able, or if not physically able MIT police should be notified (dial 100). Obtain the MSDS for the gas and take it with the victim or present it to responders.

4.7. Engineering Controls and Design for Gas Use

The following requirements and guidelines should be followed regarding engineering controls and design features in addition to the requirements and guidelines listed in the sections for each type of gas. Consult the EHS Office Industrial Hygiene Program if assistance is needed.

Requirements
4.7.1. Where compressed gas cylinders are connected to a manifold, the manifold and its related equipment shall be of proper design for the gases they contain at the appropriate temperature, pressure and flow. (CGA)

4.7.2. A suitable pressure relief device shall be used to protect a system using a compressed gas if the system has a pressure rating less than the compressed gas supply source and if, due to the gas capacity of the supply source or for any other reason, the system pressure rating may be exceeded. (CGA)

4.7.3. Gas Cabinets: Cylinders containing gases that pose health hazards (see section 4.8 for details), and pyrophoric gases (see section 4.10) shall be housed in mechanically ventilated gas cylinder cabinets or fume hoods; for pyrophoric gases the cabinet must be equipped with a sprinkler system. (NFPA 45)

4.7.4. Gas Monitors /Interlocks / Alarms: Cylinder cabinets, fume hoods or other locally ventilated enclosures are required to be equipped with a continuous gas monitoring system with gas and ventilation alarm when used to store gases with NFPA health hazard rating =4, or when used to store gases with NFPA health hazard rating =3 if the gases do not possess adequate warning properties. The alarm should warn of the presence of gases at a level that presents a hazard for life. (NFPA 55)

Guidelines

4.7.5. Gas Cabinets: Cabinets should be ventilated with 200 fpm face velocity at the cabinet window and labeled “Hazardous – Keep Fire Away”.

4.7.6. Gas Monitors /Interlocks / Alarms: Consideration should be given to providing monitoring, alarms and automatic shut off of gas flow upon other events besides gas detection, such as loss of power, high process pressure, loss of vacuum or loss of cooling.

4.7.7. Emergency Shut Off: Consider providing an emergency shut off button located at the area exit to activate gas shut off valves as well as to shut off processing equipment.

4.7.8. Emergency Backup Power: Consider providing emergency power for hazardous gas cabinet enclosure exhaust fans, alarms, and other system components. Contact the Department of Facilities for more information.
4.7.9. Scrubbers: Consider the need for scrubbing / treating hazardous gases prior to exhausting to the outside or upon upset conditions.

4.7.10. Flow Restrictors: When ordering highly toxic gases, consider the need for installing gas flow restrictors to limit the potential for hazardous rates of gas flow. Some highly toxic gases can be ordered in cylinders with restricted flow orifices.

4.8. Gases that Pose Health Hazards

Many gases pose health hazards (beyond a general asphyxiation hazard as described in section 4.3). Examples include hydrogen sulfide, chlorine (also corrosive), arsine, and phosphine (also pyrophoric). DLCs seeking more information on working with these gases should consult the EHS Industrial Hygiene Program.

Requirements

4.8.1. An Emergency Plan may be required for use of these gases – see section 4.6.

4.8.2. Ensure that gases with NFPA health hazard ratings 3 or 4, or 2 in the absence of adequate warning properties, are used and stored only in fume hoods (for lecture bottle size cylinders) or in mechanically ventilated gas cylinder cabinets (for larger cylinders). Leak detection is required inside the cabinet for toxic gases (see section 4.7.4). For gases without published NFPA ratings, the LC50 and other hazard data shall be compared to the criteria for assigning the NFPA ratings to determine which class the gas would fall into. For more information on these criteria, consult NFPA 704, Identification of the Hazards of Materials for Emergency Response. (NFPA 45)

Guidelines

4.8.3. Minimize the number of these cylinders kept in main indoor areas.

4.8.4. Toxic and pyrophoric gases should be run through double-contained (coaxial) lines whenever possible. For example, a ¼” stainless steel line may be run inside of a ½” stainless steel outer jacket. The outer jacket can be equipped to detect a leak in the inner line by means of either a vacuum or pressure gauge.
4.9. Flammable Gases:

Some commonly used flammable gases include acetylene, hydrogen, and carbon monoxide. In addition to following the general requirements and guidelines for compressed gases (sections 4.1 through 4.7), users of flammable gases and pyrophoric gases (see also section 4.10) should observe the following special requirements and guidelines.

Requirements

4.9.1. A flammable materials license from the Cambridge Fire Department permit may be required for storage of these gases. Contact DLC EHS Coordinator to make sure these gases are covered on a permit or license. (CFD)

4.9.2. An Emergency Plan may be required for use of these gases – see section 4.6. Set up your experiment so that you can remotely shut off the gas supply as you evacuate.

4.9.3. If flammable gas ignites, immediately shut off the gas supply only if you can do this safely. Although portable fire extinguishers of the carbon dioxide or dry chemical type are required to be available at flammable gas storage locations, personnel should not attempt to fight the fire. They should evacuate the fire area and report the fire by pulling the fire alarm and dialing 100 from a safe location. (CGA) A flammable gas fire is considered a non-incipient fire, per the MIT SOP on Control and Reporting of Fires.

4.9.4. Limit the amount of flammable gas in one area to 400ft³. This is slightly more than the amount in a full size cylinder. Systems containing more than 400ft³ of hydrogen shall be designed and operated according to the requirements of NFPA 50A, Gaseous Hydrogen Systems at Consumer Sites. (NFPA 50A, NFPA 55)

4.9.5. For heavier than air gases, permit only one flammable cylinder at a time, and provide positive ventilation in pits, basements, and other below grade areas. Labs in the basement of MIT buildings should consult with the EHS Office.
4.9.6. Electrical fixtures in areas where flammable and pyrophoric gases are stored should conform to NEC Class I division 2 requirements. (CGA) Consult with the EHS Office to determine if this applies to your lab.

4.9.7. When leak-testing a system containing a flammable gas, use only a flammable gas detector or a compatible leak detection solution such as soapy water. Never use a flame-producing device to test for leaks of flammable gases. (CGA)

Guidelines

4.9.8. Users of propane gas should follow these guidelines but also consult the SOP on Liquefied Petroleum Gas (Propane).

4.9.9. Store and use flammable gas cylinders in well-ventilated areas. While locally exhausted enclosures such as gas cabinets or fume hoods are preferable, use in well-ventilated laboratory areas may be acceptable. The EHS Office should be consulted to determine whether ventilation in a given area is sufficient to allow storage and/or use of flammable gases.

4.9.10. Cylinders and piping containing flammable or pyrophoric gases should be grounded if the buildup of static electricity could present an ignition hazard. Consult with the EHS Office to determine if this applies to your lab.

4.9.11 Flashback arrestors are recommended for use with hydrogen and other flammable gases and may be obtained from the Procurement Partner for gases. Flashback arrestors are attached downstream of the regulator and can be reset and reused when cylinders are replaced.

4.10. Pyrophoric Gases:

Pyrophoric gases include many of the semiconductor gases, such as silane, diborane, and phosphine, many of which are also highly toxic. In addition to the requirements and guidelines for general compressed gas use (sections 4.1 through 4.7), and for flammable gases (section 4.9) and in many cases toxic gases (section 4.8), users of pyrophoric gases should observe the following requirements and guidelines:

Requirements
4.10.1. An Emergency Plan may be required for use of these gases – see section 4.6.

4.10.2. Pyrophoric gases are required to be stored in ventilated, sprinklered gas cylinder cabinets. See section 4.7 for engineering controls and design considerations for pyrophoric gas systems. More information on safety design requirements for use of compressed gases in semiconductor fabrication facilities (clean rooms) can be found in NFPA 318. (NFPA 45 & 318)

The numbers changed back to 4.9 here and the next section was 4.10 before I added this note.

4.10.3. Cylinders containing pyrophoric gases shall be equipped with normally closed automatic shutoff valves that incorporate restricted flow orifices (NFPA 318). Specify this when submitting your order to the Procurement Partner for gases.

Guidelines

4.10.4. Users should notify the EHS Office when setting up a new process involving pyrophoric gases.

4.10.5. Processes and systems should be designed and constructed only by those knowledgeable and experienced in these areas.

4.10.6. Before use, systems should be evacuated, vacuum tested, and pressure checked with inert gas at pressures two to three times anticipated working pressures. This certification should be done by a qualified vendor. A regular leak test procedure and testing schedule should be instituted and followed before and after use. This should be done by the lab users.

4.10.7. Before disconnecting any system that has contained a pyrophoric gas, the system should be thoroughly purged with an inert gas. Any area of the system where the gas might “pocket” or collect should be submitted to extensive purging. The system should be designed to minimize this because it increases the risk of a fire or explosion.

4.11. Acetylene:
Acetylene is extremely flammable. In addition to the general requirements and guidelines for compressed gas use (sections 4.1 through 4.7), and for flammable gases
(section 4.9), users of acetylene should observe the following requirements and guidelines:

**Requirements**

4.11.1. Indoors, limit the amount of acetylene gas connected to manifolds to 3000ft³. (NFPA 51)

4.11.2. Use steel piping with acetylene. Do not use unalloyed copper tubing, valves or fittings with acetylene as it reacts with these materials. (NFPA 51)

4.11.3. Use a pressure regulator at the discharge of an individual cylinder to reduce the gas pressure to 15psi or less. Using acetylene at a pressure greater than 15psi can result in an explosion. (CGA)

4.11.4. Do not open an acetylene cylinder valve more than one and a half turns of the spindle. (29 CFR 1910.253)

4.11.5. Rooms designed for storage of acetylene shall meet the requirements of NFPA 51, Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting and Allied Processes. (NFPA 51)

4.11.6. Always store, transport and use acetylene cylinders in an upright position to prevent loss of acetone, which stabilizes the acetylene. (29 CFR 1910.253)

4.11.7. Do not place anything on top of an acetylene cylinder when in use, as this may damage the safety device or interfere with the quick closing of the valve. (29 CFR 1910.253)

**Guidelines**

4.11.8. If an acetylene cylinder has not been stored upright, do not use it. Contact supplier to return cylinder if improper storage has occurred.

4.11.9. For more information on requirements on acetylene gas manifolds, portable outlet headers, or piping, see 29 CFR 1910.253.

**4.12. Anhydrous Ammonia:**

Anhydrous ammonia is extremely irritating and corrosive (NFPA health rating=3). It is also slightly combustible (NFPA rating=1). In addition to the requirements and guidelines for general compressed gas use (sections 4.1 through 4.7), and for gases that
pose health hazards (section 4.8), users of anhydrous ammonia should observe the following requirements and guidelines:

**Requirements**

4.12.1. All piping, tubing, and fittings shall be made of material suitable for anhydrous ammonia service. Do not use galvanized materials, cast iron, brass or copper pipe, or soldered joints for ammonia distribution piping. Use extra heavy steel pipe where the pressure exceeds 125psi. (29 CFR 1910.111)

**Guidelines**

4.12.2. Follow the procedures for flammable gases (section 4.9); however, natural draft ventilation is acceptable and ordinary lighting fixtures may be used. (FM 7-50)

4.12.3. Ammonia cylinders may be arranged to discharge either gaseous or liquid ammonia. When it is necessary to manifold together two or more cylinders for discharge of liquid ammonia, install a check valve in the discharge line at each cylinder.


4.13. **Oxygen Gas:**

Oxygen gas concentrations greater than 25% greatly increase the rate of combustion of many common materials. In addition to following the requirements and guidelines for general use of compressed gases (sections 4.1 through 4.7), users of oxygen gas should be aware of the following requirements and guidelines for oxygen gas:

**Requirements**

4.13.1. Use only regulators designed for and dedicated to use with oxygen gas. (NFPA 45)

4.13.2. Do not use grease or oil for lubricating regulator connections, gauge connections or other parts of the oxygen piping system, since reaction of oxygen gas with grease or oil could result in a fire. Label components with a statement such as “oxygen – use no oil”. (CGA, 29 CFR 1910.253)

An official hardcopy of this document exists in the EHS Office or on the EHS website. See Legal Disclaimer at: http://web.mit.edu/environment/shared_content/disclaimer.html
4.13.3. Oxygen concentrations in work areas, other than hyperbaric chambers, should never exceed 23.5% by volume. (CGA)

Guidelines

4.13.4. Oxygen cylinders and manifolds should be located outdoors, if possible, or in detached buildings. If oxygen must be kept indoors, it should be located in a cut-off room of non-combustible construction. (FM 7-50)

4.13.5. Never use oxygen as a substitute for compressed air.

4.14. Corrosive Gases:
Corrosive gases include hydrogen fluoride and chlorine (both are also highly toxic). In addition to following the requirements and guidelines for general use of compressed gases (sections 4.1 through 4.7) and health hazard gases (section 4.8), users of corrosive gases should be aware of the following guidelines:

Requirements

4.14.1. An Emergency Plan may be required for use of these gases – see section 4.6.

Guidelines

4.14.2. Check that eyewash and shower facilities are available in close proximity to the gas use area. Verify what the first aid procedure is for the gas that you are using.

4.14.3. Store corrosive gases in dry areas and for the shortest time possible to minimize the hazards associated with corrosion of valves and regulators.

4.14.4. Use a diaphragm gauge with corrosive gases that would destroy a steel or bronze gauge. Check with the supplier for more information.

4.14.5. Be particularly aware of the need to open valves slowly and gently. Never force open a valve on a corrosive gas cylinder because the valve may not re-close properly if it has become corroded. Contact the EHS Office and place the cylinder near an exhaust hood or in a vented gas cabinet.
4.14.6. Check equipment and lines frequently for leaks because metals can become brittle or corrode when used with corrosive gases.

4.14.7. Remove regulators after use and flush with dry air or nitrogen.

5. Roles & Responsibilities

5.1. Departments, Laboratories and Centers (DLCs)

DLCs shall ensure that compressed gas cylinders are handled, stored and used according to the requirements listed in this SOP. DLCs should also follow the guidelines described in this SOP whenever possible.

DLCs are responsible for ensuring that Lab-Specific Chemical Hygiene and/or Job-Specific HAZCOM training is made available and provided to DLC employees by the DLC on a timely basis (see section 6).

DLCs using or storing compressed gases are required to periodically inspect gas cylinders and to maintain records of inspections (see section 7.0 and 8.0). They are also required to list gas cylinders and toxic gases in PI Space Registration.

5.2. EHS Office

Is responsible for ensuring that:

5.2.1. General Chemical Hygiene training and MIT Overview HAZCOM training, which are provided by the EHS Office, are available and kept up to date.

5.2.2. Support and assistance is available to the DLCs for trainings provided by the DLCs including Lab-Specific Chemical Hygiene training and Job-Specific HAZCOM training.

5.2.3. The effectiveness of the compressed gas cylinder program is evaluated on a periodic basis.

5.3. Individuals Using Compressed Gas Cylinders

Have the responsibility for ensuring that:

5.3.1. They attend the required trainings and implement the general requirements and the specific precautions required for the compressed gas being used.
5.4. Department of Facilities

Has the responsibility for ensuring that:

5.4.1. Installation of wall brackets and other gas cylinder safety equipment (provided by the cylinder user) is completed in a timely manner after a request is received.

5.5. Procurement Partner for Compressed Gases

Has the responsibility for:

5.5.1 Reporting safety hazards related to compressed gases to the EHS Office. They will work with the EHS Office and EHS Coordinators to correct these hazards.

5.5.2 Contacting the researchers who order non-returnable cylinders to determine if there is a returnable cylinder that would be an acceptable alternative.

5.5.3 Checking that a safety plan has been approved by EHS before confirming any orders that are delivered to dormitories and offices.

5.5.4 Being a technical resource on compressed gas safety and working with EHS to evaluate the safety of situations.

5.5.5 Removing unsafe cylinders from campus as soon as possible.

6. Training

Several options are available for compressed gas cylinder training at MIT. The EHS Office will oversee the development and support of these training options.

6.1. Laboratory Work Areas:

Users of compressed gas cylinders in laboratory work areas are required to complete training as described below:

6.1.1. General Chemical Hygiene Training - Required for all users of hazardous chemicals in laboratories, including compressed gases. Available from EHS, in web-based or live formats.
6.1.2. Lab-Specific Chemical Hygiene Training – Required for all users of hazardous chemicals in laboratories, including compressed gases. Provided by the PI, supervisor, EHS Coordinator, or EHS Representative within the DLC. Training and support for those in the DLC providing this training will be available from EHS.

6.1.3. Hydrogen Fluoride (HF) Training – Required for all users of anhydrous hydrogen fluoride gas as well as hydrofluoric acid liquid.

6.2. HAZCOM (non-lab) Work Areas:

Users of compressed gas cylinders in HAZCOM work areas are required to complete training as described below (see the MIT HAZCOM Program for more information):

6.2.1. Overview HAZCOM Training – Required for all users of hazardous chemicals in HAZCOM areas, including compressed gases. Available from EHS, in web-based or live formats.

6.2.2. Job-Specific HAZCOM Training – Required for all users of hazardous chemicals in HAZCOM work areas, including compressed gases. Provided by the PI, supervisor, EHS Coordinator, or EHS Representative within the DLC. Training and support for those in the DLC providing this training will be available from EHS.

7. Monitoring Requirements

DLCs using or storing compressed gases should periodically inspect gas cylinders, tubing, hoses, piping, regulators and manifolds for wear, abrasion, cuts, corrosion or other evidence of damage. Gas cylinders and toxic gases should be listed in PI Space Registration.

8. Record Management

Records of gas cylinder inspections, which are performed as part of the semi-annual DLC EHS inspections, shall be maintained by the DLC EHS Coordinator and EHS. Written records of weekly laboratory inspections are optional. If generated, these records should be maintained in the laboratory.

9. References

9.1. Standards

The following references are available at or through the EHS Office:

OSHA 29 CFR 1910.103 – Hydrogen

OSHA 29 CFR 1910.104 – Oxygen (bulk systems)

OSHA 29 CFR 1910.111 – Storage and Handling of Anhydrous Ammonia


OSHA 29 CFR 1926.350 Gas Cutting and Welding

CGA-P1, Safe Handling of Compressed Gases in Containers (incorporated by reference into OSHA 1910.101)

DOT 49 CFR, Parts 171 - 179

Factory Mutual Global – Data Sheet #7-50 – Compressed Gases in Cylinders

Factory Mutual Global – Data Sheet #7-55/12-28 – Liquefied Petroleum Gas

NFPA Standard 45, Fire Protection for Laboratories Using Chemicals

NFPA Standard 50A, Gaseous Hydrogen Systems at Consumer Sites

NFPA Standard 51, Oxygen-Fuel Gas Systems for Welding and Cutting

NFPA Standard 55, Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders.

NFPA Standard 318, Protection of Semiconductor Fabrication Facilities


ANSI Standard B31.1, Pressure Piping

ANSI Standard B57.1, Compressed Gas Cylinder Valve Outlet and Inlet Connections

ANSI Standard Z48.1 – Method of Marking Portable Compressed Gas Containers to Identify the Material Contained

SEMI FI, Specification for Leak Integrity of High-Purity Gas Piping Systems and Components, 1996

An official hardcopy of this document exists in the EHS Office or on the EHS website. See Legal Disclaimer at:  http://web.mit.edu/environment/shared_content/disclaimer.html
SEMI S4, Safety Guideline for the Segregation / Separation of Gas Cylinders Contained in Cabinets

SEMI S18-1102, Environmental, Health and Safety Guidelines for Silane Family Gases Handling

9.2. Other SOP/ SOGs
Cryogenic Liquids

Fire Extinguishers Portable

Flammable and Combustible Liquids

Liquid Petroleum Gas (Propane)

9.3. Supplementary Documents
MIT Environmental, Health and Safety Policy

MIT HAZCOM Program

9.4. Helpful Websites
Compressed Gas Association: http://www.cganet.com/

OSHA Regulations: http://www.osha.gov/

10. Definitions
10.1. Adequate warning properties: A toxic gas is said to have adequate warning properties if it can be reliably detected by smell, taste or irritation at levels below the PEL and/or TLV. Consult the Industrial Hygiene Program for information on the warning properties of a particular gas.

10.2. Asphyxiant Gas: A gas which may have little or no specific toxic effect, but which can bring about unconsciousness and death by displacing oxygen in air. When the percentage of oxygen in the air decreases below about 18%, reduction of physical and intellectual capabilities may occur without the victim being aware. At very low levels of oxygen, unconsciousness can occur immediately after one or two breaths, and death will follow shortly. Almost any gas can serve as an asphyxiant if released in an unventilated space.

10.3. Compressed Gas: Any gas or mixture of gases exerting an absolute pressure exceeding 40 psi at 68°F (21°C), or an absolute pressure greater than 104psi at

An official hardcopy of this document exists in the EHS Office or on the EHS website.
See Legal Disclaimer at: http://web.mit.edu/environment/shared_content/disclaimer.html
129°F (54°C), or both, or any liquid flammable material having a Reid vapor pressure greater than 40psi at 100°F (38°C).

10.4. Corrosive Gas: A gas that in contact with human tissue causes destruction by chemical action.

10.5. Cut-off room: a room which has either one or two exterior walls and which is at least one-hour fire rated. Storage of hazardous gases in cut-off rooms is preferable to storage in main working areas. See chapter 4 of NFPA 30 for more information.

10.6. Explosive or Flammable Limits (Lower and Upper – LEL and UEL): The minimum and maximum concentration of a gas or vapor in air within which the mixture will burn or explode when exposed to an ignition source.

10.7. Flammable Gas: A gas mixture of 13% or less (by volume) with air that is ignitable at 14.7 psia or has a flammable range with air of at least 12% regardless of the lower limit. National Fire Protection Association (NFPA) flammability rating=4.

10.8. Health hazard: a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees.

10.9. LC50: The concentration of a gas in air that causes death in 50% of animals (or humans) tested.

10.10. NFPA health hazards ratings: a rating system developed the National Fire Protection Association which ranks materials, including gases, on a scale of 0-4 based on the health risk they pose to firefighters. Details are in NFPA 704.

10.11. Oxidizing Gas: A gas that, in the presence of an ignition source and a fuel, supports and may vigorously accelerate combustion.

10.12. Permissible Exposure Limit (PEL): The maximum amount or concentration of a chemical to which a worker may be exposed without respiratory protection under OSHA regulations. Can be expressed as a Time Weighted Average (averaged over 8 hours) or as a ceiling value that should never be exceeded.

10.13. Pyrophoric Gas: A highly flammable and reactive gas that may spontaneously burn or explode when released into the air.
10.14. Specific Gravity: The density of a gas relative to air (specific gravity of air equals 1). Indicates how many times heavier a gas is than air at the same temperature. In the absence of appropriate ventilation, gases with specific gravity less than 1 will collect near the ceiling of a room or space; gases with specific gravity greater than 1 will collect at the lowest level of a room or space.

10.15. Threshold Limit Value (TLV): The time-weighted average concentration, for a normal 8-hour workday and 40-hour workweek, to which nearly all workers may be repeatedly exposed without adverse effects. The American Conference of Governmental Industrial Hygienists has developed TLVs to be used as guidelines.
Appendix A

Safety Guidelines for Cylinder Valves and Regulators

Wear eye protection
The cylinder valve must be easily accessible so anyone can shut off the gas quickly in an emergency.

Inspect the regulator before using it:
- Is it the correct one for the gas?
- Examine the condition of the threads and fittings. Clean off dust or dirt.
- The high pressure (inlet) gauge has twice the rating of the cylinder.
- The low pressure (output/ discharge) gauge has approximately twice the pressure rating of the regulator, which is on the regulator label.

Check the manufacturer’s specifications for each regulator (on their website or in the catalog) to ensure that all gauges and needle valves are within the pressure range. This is to prevent these from being blown off and injuring someone.

Note:
The adjusting knob rotates clockwise to increase output pressure and counter-clockwise to decrease pressure. Turn the knob COUNTER-CLOCKWISE until it stops when you have finished using the gas.

Do not use Teflon tape on CGA fittings or valve threads to prevent leaking. The tape may become powdered and get caught on the gas pressure regulator poppet causing full pressure downstream. Most valve outlet connections are designed with metal-to-metal seals; use washers only if indicated.

Never lubricate a regulator or fittings. Inlet fittings are designed to be installed dry. Brass is used for less than 3000psi. Stainless is used for more than 3000psi

Attach a regulator to a cylinder:
1. Use the proper size wrench.
2. Remove the cylinder valve cap.
3. Inspect the cylinder valve for damaged threads.
4. Remove foreign material.
5. Screw the regulator onto the tank by hand until it is finger tight. Support the regulator so that it is not sagging under gravity; this ensures good coupling between the regulator and cylinder. Then use a correctly fitting wrench to tighten the coupling/ inlet nut securely.
6. Check that all downstream equipment is rated for pressures above the maximum regulator outlet pressure

Opening the cylinder valve and Operating the regulator:
1. Stand with the cylinder valve between you and the regulator gauges.
2. Turn the regulator adjusting knob COUNTER-CLOCKWISE until it stops (closed position).
3. There should be no output pressure.
4. Place both hands on the cylinder valve and open it slowly, allowing the pressure to rise gradually in the regulator until the high pressure (inlet) gauge indicates how much pressure is in the cylinder.
5. If you hear hissing, immediately close the cylinder valve. Spray the regulator with soapy water and fix the leaks indicated by the bubbles. Do not use Snoop because it is not compatible with some materials inside the regulator.
6. Slowly turn the regulator adjusting knob clockwise while watching the gauge until the desired output pressure is reached. Opening the cylinder valve quickly may cause damage to the regulator valve and seals.
7. When the high pressure gauge indicates the maximum pressure, open the cylinder valve fully.
8. Spray the piping/ tubing with soapy water to check for leaks.

Removing the regulator when changing cylinders and returning empties:
1. Close the cylinder valve by turning the adjusting knob COUNTER-CLOCKWISE until it stops.
2. Vent the gas safely:
   - Either vent the gas until there is no pressure in the regulator and/or the system.
   - Or isolate the system and vent the gas by turning the adjusting knob clockwise until there is no pressure trapped inside the first stage of the regulator. This pressure could release projectiles.
3. Close the regulator by turning the adjusting knob COUNTER-CLOCKWISE until it stops.
4. Disconnect any low pressure equipment that is connected to the high pressure cylinder.
5. Remove the regulator and attach it to another cylinder or store it so it will be protected from damage and cover the inlet/ outlet fittings.
6. Replace the valve cap on the empty cylinder and mark it MT. Request a pick up from the Procurement Partner.

Adapted from the Airgas catalog and Scott Specialty Gases website.
Appendix B

Regulator testing and maintenance

The EHS Office recommends that labs follow a maintenance schedule such as one of the following. Consult with the Procurement Partner about checking regulators, manifolds, tubing, etc. after a fire or some other type of cause of high temperature and humidity.

Scott Specialty Gases Recommended Schedule  This schedule should be used as a general guide. Be sure to follow the manufacturer instructions supplied with your regulator.

<table>
<thead>
<tr>
<th>Type of Gas</th>
<th>Leak Check</th>
<th>Creep Test</th>
<th>Inert Purge</th>
<th>Overhaul</th>
<th>Replace1*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncorrosive</td>
<td>Monthly</td>
<td>Annually</td>
<td>NA</td>
<td>5 years</td>
<td>10 years</td>
</tr>
<tr>
<td>Mildly Corrosive</td>
<td>2x month</td>
<td>6 months</td>
<td>at shutdown</td>
<td>2 years**</td>
<td>4 years**</td>
</tr>
<tr>
<td>Corrosive†</td>
<td>2x month</td>
<td>3 months</td>
<td>at shutdown</td>
<td>1 – 2 years**</td>
<td>3 – 4 years</td>
</tr>
</tbody>
</table>

1 More frequent overhaul or replacement may be required for regulators installed in a corrosive ambient environment.

* If diaphragms are neoprene or another elastomer, they may dry out and require more frequent replacement.

** If regulators are not properly installed and used, or if a poor grade of gas is used, or if purging is not properly done, overhaul and/or replacement may be required more frequently than indicated.

† For regulators used in toxic or corrosive gas applications, care should be taken to ensure proper precautions are followed, as recommended by Scott.

NA Not applicable.

Scott Specialty Gases
http://www.scottecatalog.com/ScottTec.nsf/TSData?SearchView&Query=regulator&start=1
Refer to the sections on Pressure regulators--Maintenance schedule and test that labs can do
Visual Inspection:

- Carefully examine the entire regulator.
- Check condition of outlet and inlet.
- Look for worn threads and damage.
- Check to see if gauges are damaged.

Check for Pressure "Creep":

- Put regulator onto an appropriate cylinder with at least 1500 psi.
- Make sure pressure adjusting valve is completely free by turning it counterclockwise.
- Slowly open the cylinder valve until it is fully open.
- Set low pressure gauge to approximately 20 psi, then close off the downstream pressure. Record set pressure. Check pressure after 30 minutes and record the pressure.
- If pressure setting has increased, remove regulator from service and send out for evaluation.

Functional Test of Regulator:

- Close regulator by turning the pressure-adjusting valve counterclockwise until key is fully released.
- Close the cylinder valve and drain the downstream line.
- The low pressure gauge will indicate zero. Record low pressure gauge reading. The high pressure gauge will read full pressure. Record initial high pressure.
- If the low pressure gauge does not read zero when all pressure is removed, it may be damaged and must be replaced.
- Check high pressure gauge reading after at least 30 minutes. Record high-pressure reading. Any pressure drop will indicate leakage.
- Release pressure in regulator by turning pressure adjusting-key clockwise. After venting, fully release pressure-adjusting key by turning it counterclockwise.