PLAN REVIEW	
Reviewer	***Date***
Eileen Carlson	9/3/2015
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Shane Carlson	2/15/2018
Shane Carlson	10/9/2018

Contact: Jim Slettedahl
(507) 925-4165

COMPRESSED GAS SAFETY

Purpose

Assure that employees handling compressed gases are adequately trained in the inherent hazards of the cylinders and their contents, as well as proper handling, storage, and use according to OSHA requirements. Compressed gas cylinders can present a variety of hazards due to their pressure and /or contents. This chapter of the safety manual covers requirements that must be followed for the use of all compressed gases. In addition to the standard required work practices for inert gases, hazardous gases may require additional controls and work practices including, but not limited to, the use of gas cabinets, gas monitors, emergency shutoffs, proper equipment design, leak testing procedures, and the use of air supplying respirators for certain highly toxic gases.

Policy

It is the policy of ECHO Charter School that all compressed gases be handled, stored, received and used in a safe manner consistent with this chapter. Compressed air shall not be used for cleaning or blow-down activities unless air pressure is regulated to below 30 psig and areas have been isolated from pedestrian traffic.

Hazards

Numerous potential physical and health hazards are associated with compressed gases, including explosion, poisoning, impact by containers, fire, asphyxiation and exposure related illnesses.

Hazard Control

- **Engineering Controls** - each gas application will have its own engineering controls depending on the types of hazards and application. Examples of engineering controls are:

  Fume hoods
  Gas Cabinets
  Ventilation systems
  Smoke detectors
  Sprinkler systems
  Flow Restrictors
  Scrubbers
  Leak Monitors
  Gas cylinder storage areas

- **Administrative Controls** - compressed gas program administrative controls include:

  Employee training
  Segregation of gas containers
  Inspections and audits
  Signs
  Assignment and use of PPE
  Identification of authorized employees
  Procedures for receipt, use and storage

Compressed Gas Cylinders

- Inspection of compressed gas cylinders. Each employer shall determine that compressed gas cylinders under his control are in a safe condition to the extent that this can be determined by visual inspection. Visual and other inspections shall be conducted as prescribed in the Hazardous Materials Regulations of the Department of Transportation (49 CFR parts 171-179 and 14 CFR part 103).

  Where those regulations are not applicable, visual and other inspections shall be conducted in accordance with Compressed Gas Association Pamphlets C-6-1968 and C-8-1962, which is incorporated by reference as specified in Sec. 1910.6.

- The in-plant handling, storage, and utilization of all compressed gases in cylinders, portable tanks, rail tank cars, or motor vehicle cargo tanks shall be in accordance with Compressed Gas Association Pamphlet P-1-1965

- Safety relief devices for compressed gas containers. Compressed gas cylinders, portable tanks, and cargo tanks shall have pressure relief devices installed and maintained in accordance with Compressed Gas Association Pamphlets S-1.1-1963 and 1965 addenda and S-1.2-1963

Compressed Gas Use Applications

Prior to use of any compressed gas, a review of the applicable requirement in the Engineering Controls and Work Practices and Procedures section must be conducted.

- Class 1 Application - Use of Inert Gases - Gases which are non-flammable and non-toxic, but which may cause asphyxiation due to displacement of oxygen in poorly ventilated spaces

- Class 2 Application - Use of Flammable, Low Toxicity - Gases which are flammable (at a concentration in air of 13% by volume or have a flammable range wider than 13% by volume), but act as non-toxic, simple asphyxiants (e.g.hydrogen, methane)

- Class 3 Application - Use of Pyrophoric Gases and Liquids - Gases or liquids which spontaneously ignite on contact with air at a temperature of 130 F or below.

- Class 4 Application - Use of Corrosive, Toxic, and Highly Toxic Gases - Gases which may cause acute or chronic health effects at relatively low concentrations in air

- Class 5 Application - Use of Compressed Gases in Fume Hoods

Gas Use Requirements - Engineering Applicability

Required Controls	Class 1	Class 2	Class 3	Class 4	Class 5
Gas Cabinet	-	✓1	✓	✓	-
Interlocks	✓2	✓2	✓2	✓2	✓2
Emergency Off Button			✓	✓	
Equipment Enclosed & Ventilated	-	✓1	✓	✓	✓
Smoke Detection	-	✓2	✓2	✓2	✓2
Sprinkler Protection	-	✓3	✓3	✓3	✓3
Emergency Power to Exhaust Ventilation	-	-	✓4	✓4	✓4
Pneumatic Shutoff Valve	-	✓5	✓	✓	✓
Scrubber	-	-	-	✓2	✓2
Vacuum Pump Purge & Interlock	-	-	✓	-	-
Flow Restricting Orifice	-	✓	✓	✓	✓
Ventilation Alarms	-	-	✓	✓	✓
Eyewash & Showers	-	-	-	✓6	✓6
Purge Panel	-	-	✓	✓	✓
Gas Monitor	-	-	✓8	✓8	✓8
Piping & Fittings	✓	✓	✓	✓	✓
Hardware	✓	✓	✓	✓	✓

Gas Use Requirements - Administrative & Procedural Applicability

Notes

✓1 Not required if flow-restricting orifice is installed in a cylinder valve. May be required for semiconductor applications

✓2 Based on the outcome of hazard review

✓3 Required in lab and inside gas cabinet for new installations

✓4 For new installations

✓5 Typically not required, may be required for semiconductor applications

✓6 For corrosive gases

✓7 See Fume Hood Use

✓8 See Gas Monitoring for details

✓9 See Hazard Review

✓10 See Cryogenic Liquid

Engineering Controls / Design Considerations

This includes a listing of typical engineering controls, referenced in the matrix above. In some cases, Building Codes may require additional controls. Additional controls or deviations from the controls listed below may also be appropriate for the application such as those required by the OSHA Process Safety Management Program or EPA's Risk Management Program. The appropriate controls should be identified through the hazard review process.

1. Gas Cabinets - With the exception of cylinders containing a non-toxic, flammable gas, and cylinders used in fume hood applications, hazardous gas cylinders must be housed in gas cylinder cabinets. These cabinets must be equipped with sprinkler protection, and must be constructed and ventilated according to State code requirements. These requirements include, but are not limited to, the need to provide 200 fpm airflow at the cabinet window.

2. Interlocks - In addition to automatic shutoff of gas flow due to loss of power or ventilation (described below), it will often be appropriate for an automatic shutdown of gas flow due to conditions such as high system pressure, high gas delivery pressure, loss of vacuum, loss of cooling, or other conditions identified through the hazard review process.

3. Emergency Off - Where gases are used in gas cabinets, the emergency off buttons should be located at the lab doorway. Activation of this button will cause pneumatic valves to shut, stopping gas flow. Typically, this button should kill electrical power to hazardous lab equipment as well.

4. Equipment Enclosures and Ventilation - Experimental apparatus using hazardous gases should be contained in an enclosed and exhausted tool enclosure. These enclosures must be connected to the exhaust ventilation system. Ventilation rates must be sized to allow for 100 fpm of airflow through the largest open enclosure door. Mass flow controllers carrying hazardous gases must be housed in a separate ventilated enclosure (or in an enclosed compartment of a larger tool enclosure) so that 100 fpm exhaust flow is available at the largest open door to the enclosure. All components should be readily accessible for maintenance.

5. Smoke Detection - All labs using hazardous gases will have a smoke detector, which is connected to the building alarm system. In certain cases, it may be necessary to interlock smoke detector activation with the shutdown of hazardous gas flow.

6. Sprinkler Protection - Where hazardous gases are contained in gas cabinets, sprinkler protection should be provided to the interior of the gas cabinet. In some cases, this protection is required by code. Sprinkler protection is recommended in all labs using hazardous materials.

7. Emergency Power - Emergency power is recommended to power exhaust fans connected to hazardous gas enclosures. In certain cases, this protection is required.

8. Pneumatic Shutoff Valves - All corrosive, toxic, flammable, and pyrophoric gases will contain a normally closed pneumatic shutoff valve, rated for at least full cylinder pressure, and located immediately downstream of the cylinder valve. This valve will shut in the event of power failure, remote actuation of an emergency off button (see this topic), or other appropriate conditions such as hazardous gas alarm activation.

9. Scrubbers - When hazardous waste gases are generated, it is often advisable to treat/react these gases prior to exhaust from the building. This may involve the use of bubblers in a fume hood or sophisticated units for larger scale hazardous gas processes. Note that in some cases (e.g. minimal volumes of hazardous gases produced) scrubbers may be not necessary or even unadvisable. Where scrubbers are used, they need to be carefully reviewed as part of the hazard review. Maintenance requirements and procedures need to be clearly understood and followed.

10. Vacuum Pumps - Vacuum pumps used for hazardous gases need to be carefully selected. Depending on the gases being pumped, special precautions may be necessary. For processes where pyrophoric gases are used, pumps need to be continuously purged with nitrogen, with loss of nitrogen flow causing the pyrophoric gas supply valves to close. Pumps used for oxygen service will need to be prepared for this services that includes the elimination of hydrocarbon oils for use due to flammability concerns. In some cases, such as the use of highly toxic gases, vacuum pumps will need to be housed in a ventilated enclosure.

11. Flow Restrictors - A means to limit hazardous gas flow rates to just over maximum flow needed must be installed immediately downstream of each hazardous gas cylinder. For small-scale experiments, such as fume hood use, a needle valve is sufficient. For large cylinders a flow restricting orifice, installed by the gas supplier in the cylinder valve or installed in the gas purge panel is required.

12. Ventilation Alarms - All ducts connected to enclosures used to exhaust hazardous compressed gas cylinders or gas-carrying components must be connected to a ventilation alarm. Typically, activation of this alarm will cause pneumatic gas supply shutoff valves to close.

13. Eyewash and Showers - A safety shower or eyewash with a wand is required to be present in areas where corrosive gases are used or stored.

14. Purge Panels - Where corrosive, pyrophoric, or toxic gases are in use, the gas installation must include means to adequately purge the area between the

cylinder valve and the regulator with an inert gas prior to breaking these connections for maintenance or cylinder change. Inert gases used for this purpose must be used solely for this purpose and not connected to other apparatus. Failure to adequately purge cylinders can result in lack of ability to close the cylinder valve or "regulator creep" which allows full cylinder pressure to be transferred to the low-pressure side of the regulator.

15. Piping and Fittings - All gas piping must be compatible with the gases used and capable of withstanding full cylinder pressure. For example, tygon tubing should never be used with hazardous gases or low hazard gases unless one end is open to atmosphere. Fittings should be selected based on the service needs. Face seal or welding fittings should be used for hazardous gas service wherever possible. All gauges and components subject to leakages that carry hazardous gases must be contained in an exhausted enclosure.

16. Hardware - Never lubricate, modify, force, or tamper with a cylinder valve. Use the appropriate regulator on each gas cylinder. Adaptors or homemade modifications can be dangerous. Assure all components of the experimental apparatus that can handle full cylinder pressure or are otherwise protected. Oil or grease on the high-pressure side of an oxygen, chlorine, or other cylinder of an oxidizing agent can lead to an explosion. Whenever back siphoning of chemicals into the cylinder might be a problem, use multiple traps or check valves.

Work Practices and Procedures

1. Hazard Review - A hazard assessment is required for the following processes involving the use of hazardous gases:

a New or relocated equipment using a toxic, corrosive, or pyrophoric gas.

b New or relocated equipment using a flammable gas in a non-standard application analytical equipment fuel gases, welding, cutting, brazing, and small scale use in fume hoods are considered standard applications.

c Existing gas installations should be self-inspected by the work area supervisor against the requirements listed in this section.

d Existing installations using hazardous gases that are considered to present a significant risk or show design deficiencies will have a hazard review conducted.

2. Training - All persons handling or using cylinders must have basic training. Review of the information contained in this section, review of any additional information in the written safety plan for all work areas, and hands-on assistance by an experienced gas user will meet this minimum requirement. Additional compressed gas safety training can be obtained through the Safety Department.

3. Hazard Information - The gas user must be thoroughly familiar with the properties of each gas they are using. A review of a good quality SDS is

necessary.

4. Ordering - All gas cylinders used at the District may only be ordered and received through _____. This allows for leak testing of highly toxic gases during the receipt process building.

5. Receiving - Be sure the cylinder tag (don't rely on cylinder stenciling or color coding) indicates the gas you have ordered. Hazardous gases (flammable, pyrophoric, toxic, corrosive) must be transported directly from the shipper to the end use location. No staging of hazardous gases is permitted. Low hazard gases (e.g. inert gases, oxygen, freon) may be stored temporarily in designated locations that provide means for securing cylinders with chains or straps.

6. Leak Testing - Toxic, corrosive, and pyrophoric gases must be leak tested at the following intervals; receiving, installation, disconnect/shipping. Highly toxic gases are leak tested by the Safety Department prior to delivery to the user. The end user is responsible for other leak test intervals. It is key that toxic gases be leak tested prior to removal from their exhausted enclosures and subsequent transport.

7. Storage -- For short-term use of hazardous gases, always select the smallest returnable cylinder available. Non-returnable cylinders are strongly discouraged. If non-returnable cylinders must be used, you must have a way to treat the remaining contents of the cylinder so that the cylinder valve can be removed prior to disposal. In cases where the gas will be used over an extended period of time (several months to more than one year), you should order a gas quantity that will last for three to six months. Corrosive gases should be returned to the gas supplier within one year to avoid regulator and cylinder valve problems due to corrosion. In storage, restrain cylinders of all sizes by straps, chains, or a suitable stand to prevent them from falling. Segregate full cylinders of low hazard gases from "empty" cylinders awaiting return to the vendor. Assure hazardous gas cylinders are constantly stored in a suitable exhausted enclosure as described in Engineering Controls.

   Do not expose cylinders to temperatures higher than about 50 C. Some small cylinders, such as lecture bottles and cylinders of highly toxic gases are not fitted with rupture devices and may explode if exposed to high temperatures. Never place cylinders where they may become part of an electric circuit. Avoid areas that are damp or subject to other corrosive materials. Do not store flammables and oxidizers together. Keeps cylinders in storage upright, secure, and interlocked into a compact group. Protect cylinders stored outside from standing water by providing proper drainage. Where outdoors storage is necessary, an overhead cover is necessary to avoid sunlight and rain.

8. Transporting Cylinders - Hazardous gas cylinders must be transported directly from the gas supplier to the end user storage location, unless an exhausted and

approved "staging" area has been constructed. Cylinders must never be transported without valve protection caps in place. Never move a cylinder with a regulator attached! Cylinders larger than lecture bottle size should be chained or strapped to a wheeled cart during transport to ensure stability. Transportation of cylinders must be done by trained personnel using approved trucks.

9. Shipping - Promptly remove the regulators from empty cylinders, leak test hazardous gases, and replace the protective caps at once. Mark the cylinder "MT". Never bleed a cylinder completely empty. Leave a slight pressure to keep contaminants out. Toxic, corrosive, and pyrophoric gases must remain in their exhausted enclosures until shipped back to the supplier.

10. Changing Cylinders - Special procedures are required for changing toxic, corrosive, and pyrophoric gases and liquids. A proper cylinder purge panel is needed for high hazard gases, along with an adequate purge procedure. Persons changing gas cylinders requiring SCBA must work with a partner who is identically equipped.

11. Changing Pump Oil - Hazardous gases may be absorbed into vacuum pump oils. Personnel performing vacuum pump oil changes on pumps used with highly toxic gases must use SCBA for pump oil change. Hot pump oil should be allowed to cool prior to c hanging.

12. Other Equipment Maintenance Considerations - Consider equipment maintenance needs in advance. Consider reaction byproducts (e.g. use proper skin and eye protection when cleaning process chambers or vacuum pumps). "Low hazard" gases, such as freons, will generate chlorine and fluorine decomposition products. Be sure to LOCK OUT upstream gas lines leading to equipment prepared for maintenance. Compressed gases are a hazardous energy source requiring lockout procedure. Be sure to adequately purge lines following lockout procedures and before beginning maintenance.

13. General Work Practices - Never use a cylinder that cannot be identified positively. Do not use compressed gas or compressed air to blow away dust or dirt (unless specifically equipped with a 30 psi or less diffuser for this application as used in machine shops). Flying dust and debris, as well as high-pressure air itself, can cause significant injury. When not in use, close cylinder valves. The main cylinder valve should be tightly closed, but needle valves should only be finger tight to avoid ruining the valve and/or valve stem.

14. Emergency Procedures - Leaking cylinders should not be removed from their exhausted enclosures. Actuate remote emergency gas shutoff valve/button, if present. (Installed highly toxic gases, if properly installed, will have flow limiting devices and/or automatic cylinder shutoff valves in place to limit and shutoff the gas supply.) Close the main cylinder valve if a leak is stopped or

slow, hazardous gases are contained in their enclosure, and it is clearly safe to approach. Do not extinguish a flame involving a highly combustible gas until the source of gas has been shut off, otherwise, it can re-ignite, causing an explosion. Cylinders leaking at the cylinder valve should be reported to Public

Safety (this should be reported as a "non-emergency" if the cylinder and gas are contained in an exhausted enclosure). If a hazardous gas is released into an unexhausted enclosure and the gas supply cannot be promptly cutoff, actuate the emergency evacuation procedure in your area and contact Public Safety. This procedure will also be initiated automatically if gas monitors trigger the building evacuation alarm. The Superfund Amendments and Re-authorization Act of 1986 (SARA Title III) states that releases of extremely hazardous substances must be reported to EPA.

Accidental discharge of cylinder contents is to be promptly reported to the Safety Department and area supervisor. Cylinders found to be leaking upon gas delivery should not be accepted from the gas supplier.

Gases for Welding and Cutting

OSHA lists requirements for oxygen-fuel gas welding and cutting in 29 CFR 1910 .253. Cylinder handling precautions, materials of construction, and additional requirements are listed. Persons who will be using acetylene, oxygen, and other fuel gases or those who are designing facilities and equipment for this purpose should review this information. Please see the Personal

Protective Equipment section of this manual for information on eye protection for welding and cutting operations. Be sure that all fuel gases are shut off at the cylinder valve after each use.

Cryogenic Liquids

All cryogenic liquids should be used with caution due to the potential for skin or eye damage due to the low temperature, and the hazards associated with pressure buildups in enclosed piping or containers. Portable containers should only be used where there is sufficient ventilation. Do not place containers in a closet or other enclosed space where there is no ventilation supply to the area. The buildup of inert gas in such an area could generate an oxygen deficient atmosphere.

A full face shield, loose fitting cryogenic handling gloves, apron, and cuff less slacks are the recommended equipment for transferring cryogenic fluids. Special vacuum jacket containers with loose fitting lids should be used to handle small quantities. Vacuum jacketed containers provided by the gas supplier will have overpressure relief devices in place. When plumbing cryogenic liquids, it is very important to include a pressure relief valve between any two-shutoff valves. Also, any space where cryogenic fluids may accumulate (consider leakage into enclosed equipment as well) must be

protected by overpressure relief devices. Tremendous pressures can be obtained in enclosed spaces as the liquid converts to gas. For example, one cubic centimeter of liquid nitrogen will expand to 700 times this volume as it converts (warms) to its gaseous state. Lines carrying liquid should be well insulated. Containers to be filled with cryogenic liquids should be filled slowly to avoid splashing. Cryogenic containers showing evidence of loss of vacuum in their outer jacket (ice buildup on the outside of the container) should not be accepted from the gas supplier. Contact with air (or gases with a higher boiling point) can cause an ice plug in a cryogenic container. Should ice plugs be noted, contact the Safety department to obtain assistance.

Compressed Air Systems & Usage

Use compressed air as a cleaning method only when absolutely necessary. It involves a significant number of hazards not present with other methods.

Authorized uses include:

- Paint spraying pneumatic controls
- Pneumatic tools
- Siphons

Compressed Air Usage

Only machinery that cannot be cleaned in any other way should be cleaned by compressed air. Never use compressed air to clean equipment or parts that are contaminated by toxic materials.

Compressed air used for cleaning machinery or shop areas and/or operated from a hand-held nozzle or similar device must have a nozzle pressure of less than 30 psig, if the nozzle is deadened. This may be accomplished by the use of a pressure-reducing valve in the airline or by the use of air guns designed to reduce or relieve nozzle airline pressure to less than 30 psig. Wear eye protection when you must use compressed air for cleaning. Ensure people working around you are shielded from the air blast and flying chips.

Air Receivers and Compressors

All air receivers or tanks (this does not include compressed gas cylinders, which must not be employed as air receivers) used for the storage of l cubic foot or more of compressed air at a pressure in excess of 50 psig. must be constructed in accordance with the American Society of Mechanical Engineers (ASME) Boilers and Pressure Code.

- All safety valves must be installed and maintained in accordance with the ASME code. Air receivers and tanks are to be installed so that all drains handholds, and personnel access openings are easily accessible, and should be supported

so as to allow sufficient clearance for complete external inspection.

- Each air compressor system must be provided with a connection of the appropriate size for attaching an inspector's test gauge when the system is in service.

- Nothing must obstruct the connection of the inspector's test gauge.

- Provisions must be made for the removal of oil and water from the tanks. Drain valves must be located at the lowest point possible and a draining schedule established to prevent the accumulation of excessive amounts of liquid in the receiver.

- Readily visible pressure gauges must be installed. Spring loaded safety devices with a total relieving capacity sufficient to prevent a rise in pressure of more than l0 percent above the maximum allowable working pressure of the receiver must also be installed.

- At least one safety valve in each system must be set to operate at or below the maximum allowable working pressure.

- Valves must not be installed between the air receiver and any of its safety valves. Daily testing of controlling and safety valves is required.

- All safety appliances such as safety valves, indicating devices, and controlling devices must be constructed, located, and installed so that they cannot readily be made inoperative by any means, including weathering.

- Hoses and lines used in any compressed air system must be rated to meet the maximum operating pressure (both static and transient) of the equipment or apparatus.

- Hoses and lines should be properly assembled; incorrect fittings should be avoided.

- A system should be designed with the least number of bends and the largest diameter feasible.

- Additionally, hoses and lines should be protected from external damage, e.g., heat, abrasion and corrosion. To this end, they should not be placed where they can be trod on, tripped over, or driven over by personnel or equipment.

- Vent pressure relief valves and rupture discs to a safe area, where personnel will not be affected, e.g. toward a wall.