Compressed Gases Safety Program

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Office of Environmental Health & Safety

TEXAS A&M UNIVERSITY GALVESTON CAMPUS.

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Introduction and Purpose

Texas A&M University at Galveston continually strives to provide a learning, teaching, and research environment free from recognized hazards. The University requires the safe handling, use, and storage of compressed gas cylinders to protect employees and students from potential physical and health hazards associated with using compressed gases in laboratories or other locations that are part of the University.

Scope and Application

Texas A&M University at Galveston wants to ensure employees who handle compressed gases understand the health and physical hazards of the compressed gas cylinders, the contents, proper handling, use, storage, and emergency procedures. To accomplish this, the Environmental Health and Safety Office (EHS) will ensure compliance with TAMUS Policy 24.01 and 24.01.01 and State Executive Order GWB 95-8.

Compressed gas cylinders can present a variety of hazards due to their pressure and/or contents. This program covers requirements which must be followed for the use of all compressed gases. In addition to the standardly required work practices for inert gases, flammable and toxic gases as defined in TAMU Lab Safety Manual section 3.1 requires the installation and maintenance of gas cabinets approved by the TAMUG EHS office. Additional controls and work practices including, but not limited to, gas monitors, emergency shutoffs, proper equipment design, leak testing procedures, and the use of air supplying respirators for certain highly toxic gases may be required. MSDS sheets must be kept at the location or easily accessible from http://hazard.com/

This program applies to the storage, use, and handling of gases in pressurized portable containers and gas systems. The primary focus of this program is on single gas uses and systems. Additional requirements may be applied to:

- Use of multiple gases in a single control area or building
- Large compressed gas facilities, storage areas, or use areas

All permanent installations of compressed gases must follow the TAMUG lab commissioning process and all toxic and flammable compressed gas cylinders must include the installation and maintenance of a gas cabinet approved by the TAMUG EHS office. All use of portable flammable compressed gas systems must be approved by the TAMUG lab commissioning process. Approved uses of flammable compressed gases will be identified at the point of use by EHS in evaluating regulatory compliance during inspections. Point-of-use identification will include approved gases and concentrations, quantity, and date of approval.

The TAMUG Lab Safety Officer will review permit requests for consistency with all applicable codes, standards and local adopted specifications, including but not limited to the following codes. Any non-conformance to these codes requirements must be justified and approved by the TAMUG Lab Safety Officer as the "authority having jurisdiction" (AHJ).

- International Fire Code 2003 Edition
- National Fire Protection Association (NFPA) 45 - Fire Protection for Laboratories Using Chemicals
- National Fire Protection Association (NFPA) 55 - Compressed Gases and Cryogenic Fluids Code
- National Fire Protection Association (NFPA) 72 - National Fire Alarm and Signaling Code
- National Fire Protection Association (NFPA) 13 - Standard for the Installation of Sprinkler Systems
- National Fire Protection Association (NFPA) 101 - Life Safety Code
- National Fire Protection Association (NFPA) 2 - Hydrogen Technologies Code

Responsibilities

Department Heads

Department Heads are responsible for establishing and implementing department information and training programs for their respective areas. Delegation of this responsibility to the Principle Investigator (PI), laboratory supervisor or manager, Compliance Officer, and/or safety committee is acceptable. It is the responsibility of the Department Head or designee to:

- Understand the processes and hazards in the work area;
- Ensure that University policies are enforced and safe work practices are followed; and
- To provide for and acquire adequate instruction in the use and maintenance of compressed gas cylinders for employees.

Environmental Health & Safety (EHS)

- Ensures that University policies and procedures are enforced and safe work practices are used.
- Provides gas system planning guidance related to new construction and renovation.
- Assists, advises, and provides training as necessary.
- Reviews and approves procedures for all controlled, highly toxic, or hazardous gases.
- Assists, advises, and instructs University employees in the care and handling of compressed gas cylinders and gas systems.

Compliance Officers

calls for the University to be a model of quality in environmental health and safety. Compliance Officers are critical links in the development of this level of quality. Compliance Officers undergo special training and can be a crucial step in maintaining compliance to EHS programs. They:

- Assist and review compressed gas storage and installation to ensure safe work practices are used.
- Coordinate activities between compressed gas uses and the EHS department.

TAMUG Employees

- Perform all work with compressed gases in accordance with TAMUG procedures and prudent safe work practices.
- Obtain required training to safely work in the laboratory area.

Training Requirements and Competency Assessment

Each TAMUG employee (including faculty, staff, researchers, and part-time employees) who physically transports and makes connections to compressed gas systems for use at TAMUG must complete compressed gas safety training approved by EHS. Lab specific training is considered adequate for connecting tubing and adjusting flows at valves for pressures less than 30 psig. EHS provides a web-based training program through Train Traq that includes a component that requires each participant to demonstrate competency in the handling and use of compressed gases. TAMUG faculty members sponsoring graduate students, visiting researchers, or other personnel not identified above as qualified licensed contractors will follow this policy. Other training programs may be acceptable and credit can be given by EHS for other training programs after verifying equivalency. Please contact the EHS office for more information at EHS@TAMUG.edu.

The training program mentorship will be provided by EHS or a Lab PI and will include operational training on specific compressed gas cylinder hazards on campus.

Employees will require refresher training under any of the following conditions:

- Changes in the workplace rendering previous training obsolete.
- Changes in the types of cylinder systems or equipment used that would render previous training obsolete.
- Observation of unsafe work practices and/or violations of safety rules involving the use of compressed gas cylinders or equipment, or observed behavior indicating that the employee has not retained the required training and retraining may be recommended.

Personal Protective Equipment

- Safety Glasses: Use especially when connecting and disconnecting gas regulators and lines.

- Foot Protection: Use closed toed shoes when moving or transporting cylinders.
- Gloves and Clothing: To protect against frostbite, corrosives, and pinch points.
- Face protection: A face shield shall be worn when there are additional hazards to the face.

Labeling Requirements

Compressed gas cylinders shall be legibly marked for the purpose of identifying the gas content with either the chemical or the trade name of the gas. Such marking shall be by means of stenciling, stamping, or labeling, and shall not be readily removable. Whenever practical, the marking shall be located on the shoulder of the cylinder (OSHA Standard 29 CFR 1910.253 (b) (1) (ii)).

- A durable label should be provided that cannot be removed from the compressed gas cylinder.
- Compressed gas cylinders that do not clearly identify its contents by name should not be accepted for use.
- Color-coding is not a reliable means of identification; cylinder colors vary from supplier to supplier, and labels on caps have no identification value because many caps are interchangeable.
- Tags should be attached to the gas cylinders on which the names of the users and dates of use can be entered.
- If the labeling on the gas cylinder becomes unclear or defaced so that the contents cannot be identified, the cylinder should be marked “contents unknown” and the manufacturer must be contacted regarding appropriate procedures for removal.

Proper Storage of Compressed Gas Cylinders

All compressed gas cylinders must be properly stored in compliance with OSHA, and NFPA code requirements. Cylinders internal pressure can reach over 2,000 psi. In the event of a container breach, the cylinder becomes a projectile hazard.

Signage required at compressed gas cylinder storage locations may include any of the following. Specific requirements will be identified by the TAMUG Lab Safety Officer.

The following precautions must be taken for the storage of compressed gas cylinders.

1. Cylinders must be stored in a dry, cool, well-ventilated, secure area.
2. All cylinders whether empty or full must be stored upright and secured by chains, straps or in racks to prevent them from falling.
3. Segregated cylinders by contents. For example, flammable gases must be stored separately from oxidizing gases by a distance of 20 feet or a 5 foot high, one-hour fire-rated wall.
4. Prevent smoking or open flames in oxidizer or flammable gas storage areas.
5. Do not expose cylinders to corrosive materials such as corrosive gas or other combustible materials.
6. Segregate full and empty cylinders, use "first in first out" inventory control method.
7. Store cylinders away from heavily traveled areas and emergency exits.
8. Provide adequate access for cylinder handling and material handling carts.
9. Visually inspect stored cylinders on a routine basis, look for indication of leakage or problems.
10. All cylinder storage areas, outside or inside, shall be protected from extreme heat and cold and from access by unauthorized personnel. Prevent indoor or outdoor temperatures from exceeding 125 °F or 52 °C.

Securing Compressed Gases Cylinders

Cylinders must be secured in one or more of the following ways:

- By a noncombustible, two-point restraint system (e.g., chains) that secures the cylinder. Nesting of cylinders is <u>not</u> an approved method to secure cylinders. Individual cylinders can use a bracket or saddle to support the cylinder.

- By a noncombustible rack, framework, cabinet, approved strapping device, secured cylinder cart, or other substantial assembly that prevents the cylinder from falling.

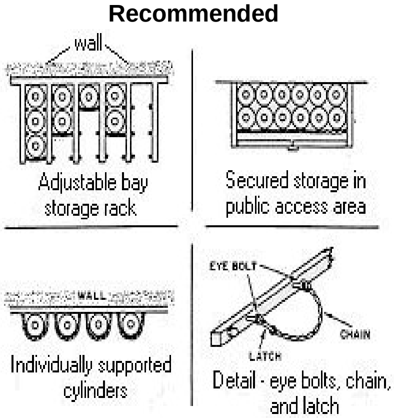
- Straps must surround the cylinder approximately ½ to 1/3 the height of the cylinder measured from the floor.

- Gas cylinders must be secured to prevent falling due to accidental contact or vibration.

- Compressed gas cylinders must be protected from sources of heat while stored in a well-protected, well-ventilated, and dry location away from highly combustible materials.

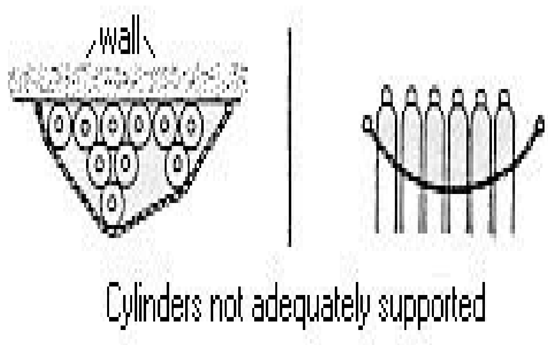
METHODS OF SECURING CYLINDERS

Recommended



Recommended

Not Recommended



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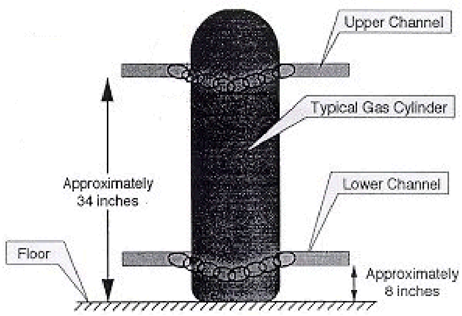
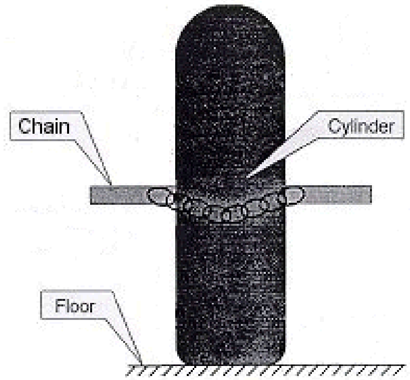




Proper Handling of Compressed Gas Cylinders

Compressed gas cylinders should be handled only by those familiar with the hazards and who can demonstrate safety precautions working with cylinders. Cylinders are heavy and awkward to move and improper handling can result in sprain, strain, falls, bruised, or broken bones. Other hazards such as fire, explosion, chemical burns, poison, and cold burns could occur due to mishandling. Eye protection and substantial footwear should always be used when transporting compressed gas cylinders. Always push cylinder carts, never pull.

The following precautions must be taken when handling compressed gas cylinders.

- Wear the appropriate personal protective equipment when handling cylinders.
- Cylinders must always be transported on wheeled cylinder carts with retaining straps or chains.
- Do not roll or drag a cylinder over a few feet necessary to position the cylinder.
- Compressed gas cylinders must be transported with protective caps in place. Do not lift the cylinder by the protective cap.
- Avoid dropping the cylinder; do not tamper with pressure-relief devices or remove any product label or shipping hazard labels.
- Don't try to catch a falling cylinder.
- Do not allow grease or oil to come in contact with oxygen cylinder valves, regulators, gauges or fittings; an explosion or fire can result. Oxygen cylinders and apparatus must be handled with clean hands and tools.
- Open cylinder valve slowly, directed away from your face.
- Do not attempt to refill compressed gas cylinders; this is only to be done by qualified manufacturer of compressed gases.

Proper Use of Compressed Gas Cylinders

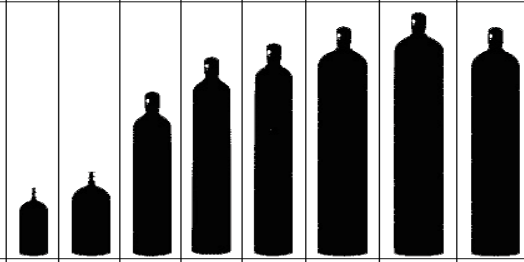
Take the following precautions to prevent injuries caused by the improper use of compressed gases.

- Know and understand the gases associated with the equipment being used.
- Use regulators approved for the specific gas.
- Do not mix gases in a cylinder.
- Do not permit cylinders to become part of an electrical circuit.
- Use non-sparking tools (brass) when working with flammable/explosive materials.
- Prevent sparks and flames from contacting cylinders.
- Never strike an arc on a cylinder. Never introduce another product into the cylinder.
- Do not discharge the contents from any gas cylinder directly towards any person.
- Do not force cylinder valves connections that do not fit.
- Open cylinder valve slowly and carefully after the cylinder has been connected to the process. Use check valves to prevent reverse flow into the cylinder.
- Close the cylinder valve and release all pressure from the downstream equipment. Disconnect the cylinder anytime there an extended non-use period is expected. Cap the cylinder when not in use.
- Follow storage and handling requirements.
- Never use a compressed gas in any confined space.
- Never work alone when using compressed gas.
- Never use compressed gas to dust off clothing. This could cause injury to the eyes or body and create a fire hazard. Clothing can become chemically saturated and burst into flames if touched by an ignition source such as a spark or cigarette.

If the cylinder's valve does not operate properly, do not attempt to force the valve to turn. The cylinder should be returned to the vendor. Employees must not attempt to repair cylinders or cylinder valves or to force stuck or frozen cylinder valves.

Cylinder Size

High Pressure Cylinders



Size	R	RR	Q	LD	S	K	T	KHP
Height (In)	14	17	32	43	47	51	55	51
Weight (Lbs)	11	24	46	58	61	113	139	188
Nominal Volume (CU FT)	20	40	80	122	150	244	330	N/A

Use a returnable cylinder for lecture bottles or small sizes gas cylinders when hazardous gas sources are needed in small volumes While the initial purchase cost per cubic foot may be lower when hazardous gases are purchased in full sized cylinders the overall cost of experimental setup which may require local ventilation, gas cabinets, stainless steel piping and purging systems may offset the apparent saving from buying hazardous gases in full sized cylinders	

Tubing and Piping Connections

Hazardous gases must be dispensed using systems that are properly cleaned and compatible with the gas in use. “Burst pressure” of tubing and piping must be twice the maximum pressure on the second stage regulator. Exceptions to this requirement may be made for short sections of tubing when it and the compressed gas cylinder are completely enclosed in a fume hood and low pressures and flow rates are used.

- Use "hard" piping (such as copper and stainless steel tubing) whenever possible (as opposed to flexible or plastic tubing). Never use cast iron pipe or fittings.
- Teflon tape should never be used on cylinder connections or tube-fitting connections. Use Teflon tape only on pipe threads where the seal is made at the threads. All other

connections have metal to metal face seals or gasket seals.

- When flexible tubing must be used, select tubing compatible with the chemical and pressure properties of the gas being used in the system. Do not use flexible tubing for highly toxic gases. Flexible tubing should only be used within "line of sight." Do not run flexible tubing through walls, ceiling spaces, doorways, or other non-visible pathways if chafing is likely to occur.
- Always clamp flexible tubing connections. Use a clamp approved for the maximum allowable pressure that the connection is subject to. Never use wire, which may cut the flexible tubing.
- Most flexible tubing deteriorates with age or exposure to chemicals or UV light. Replace old flexible tubing before it deteriorates.
- Always leak-check tubing or piping connections when using hazardous gases.
- Secure and support tubing or piping to keep it in place and to prevent "whipping" if a connection fails under pressure.
- Appropriately rated flexible lines are suitable for manifold/cylinder connections.

Regulators

Regulators reduce high pressure gas on a cylinder or process line to a lower usable level. Regulators provide additional safety measures by preventing fire/explosions, chemical or cold burns, poisoning and system over-pressurization.

Safety considerations include materials of construction to ensure chemical compatibility, and never use any regulator for gases other than those for which it is intended.

Care must be taken when using left-handed treaded connectors. Do not force connected or over tighten a connection. Check the bolt for hash marks indicating a left-handed treaded connection.

Valves on Compressed Gas Cylinders

Most compressed gas cylinders require the installation of at least one valve. This valve allows the cylinder to contain gases and allows gas to be filled into or emptied from the cylinder.
The cylinder valve is the most vulnerable part of the compressed gas cylinder. Leaks can also occur at the regulator, cylinder stem and at the hose connection.

Types of Valves Check valves are mechanical valves that permit gases and liquids to flow in only one direction, preventing process flow from reversing. Common types of valves include check, ball, disk, butterfly, gate, diaphragm, needle, and solenoid. Valves can be made of plastic, stainless steel or other material. Valves serve unique requirements so it is important to select the specific type of valve for your operation.

Precautions to consider while using valves are:

- Open valves slowly to control pressure surges and heat of compression.
- Inspect the valve for damage and foreign materials before connecting to the cylinder.
- Never use a damaged valve where integrity may have been affected. Discontinue using a valve that operates abnormally, i.e., becomes noisy or progressively harder to operate.
- Never tamper with regulatory or attempt to tighten or loosen the valve into or out of the cylinder.
- Never use an automatic operator, adapter, wrenches, or other tools to obtain a mechanical advantage on hand wheel-operated valves without reviewing all safety requirements.
- Never lubricate valves or their connections.
- Never drag, lift, or move a cylinder using the valve or the hand wheel as a handle.
- Use the cylinder valve to regulate flow or pressure.
- Never move cylinders without the transport cap installed.

Restrictive Flow Orifices (RFOs)

Restrictive Flow Orifices are installed in the cylinder valve outlet and provides significant safety benefits for uses of hazardous gases including pyrophoric gases like silane. Consult the EH&S Office for additional information on RFOs.

Rupture Disk

A rupture disk is a non-reclosing pressure relief device that protects a pressure vessel like a compressed gas cylinder from over pressurization or potentially damaging vacuum conditions. A rupture disc (also known as a bursting disc), is designed to provide a leak-tight seal within a pipe or vessel, until the internal pressure rises to a predetermined level. At that point the rupture disc bursts preventing damage to the equipment from overpressure.

Vacuum Pumps

Hydrocarbon based vacuum pump oil is incompatible with strongly oxidizing and many reactive gases. New vacuum pumps that have inert lubricants such as DuPont Krytox and never contained oil-based lubricants must be used with oxidizing and reactive gases.

Vacuum pumps must be securely vented to a fume hood or other approved exhaust system with tubing that is compatible with the gases used. Exhaust lines must be as short as feasible. Vented enclosures may be required for vacuum pumps depending on the toxicity of the gases used.

Specific Requirements of Compressed Gas Cylinders

Read the label on the cylinder and identify the contents before using. If the label is illegible or missing, return the cylinder to the supplier. Don't rely on stenciling or the color of the cylinder. Do not use a cylinder with unidentified contents. All cylinders must be permanently labeled as to their contents and if they are full or empty (example - an empty cylinder may be marked “MT”).

Empty cylinders must also be separated from full cylinders. Know the hazards of the contents and follow appropriate safe use practices for the material inside. Refer to the specific Safety Data Sheet (SDS) for additional information.

Gases that have poor warning properties such as colorless, odorless, tasteless, non-irritating, odor threshold near the toxic level, or used in enclosed areas must be reviewed for exposure hazards. General or mechanical ventilation, personal badges, hand held monitors or sensors, room monitors, and/or environmental monitors should be considered. Delivery systems must be designed with auto shut-offs.

Types of Compressed Gases

The types of compressed gas can be divided into four categories, each with unique characteristics.

Liquefied Gas can become liquid at normal temperatures when they are inside a cylinder under pressure. When gas is removed from the cylinder, enough liquid evaporates to replace it, keeping the pressure in the cylinder constant. Common examples include anhydrous ammonia, chlorine, propane, nitrous oxide, and carbon dioxide.

Non-Liquefied Gas is also a compressed, pressurized or permanent gas. These gases do not become liquid when they area compressed at normal temperatures or even very high pressures. Common examples are oxygen, nitrogen, helium, and argon.

Dissolved Gas can also be compressed. A common example of dissolved gas is acetylene. Care should be taken when using acetylene or welding. Consult your supervisor before using acetylene.

Flammable and Toxic Compressed Gases

For the purposes of TAMU Lab safety Manual, "Compressed Gases," and this program, the following definitions apply:

Flammable Gas: A gas that, at ambient temperatures and pressures, forms a flammable mixture with air at a concentration of less than thirteen (13) percent by volume; or forms a range of flammable mixtures with air wider than twelve (12) percent by volume.

Toxic Gas: A gas that is a gas at room temperature; and has a median lethal dose (LD(50)) of more than 50 mg, but less than 500 per kg of body weight when administered orally to albino rats weighing between 200 and 300 grams each; has an LD(50) of more than 200 mg/kg, but less than 1,000 mg/kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each; or has a median lethal concentration (LC(50)) in air of more than 200 PPM, but less than 2,000 PPM by volume or less when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

Highly Toxic Gas: A gas that is a gas at room temperature; and has a median lethal dose (LD(50)) of 50 mg or less per kg of body weight when administered orally to albino rats weighing between 200 and 300 grams each; has a LD(50) of 200 mg/kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each; or has a median lethal concentration (LC(50)) in air of 200 PPM by volume or less when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

Permanent installations of compressed gases must follow the Lab Commissioning process and all toxic and flammable compressed gas cylinders must include the installation and maintenance of a gas cabinet approved by the TAMUG EHS office.

During the permit review process the Campus Lab Safety Officer will specify installation requirements to include, but not limited to the following:

1) Gas cabinets are required for all toxic and flammable compressed gas installations.
2) Piping requirements such as those listed below:

Compressed gas piping, regulators, and flow control equipment must be:

- Compatible with the chemical and physical properties of gas;
- Capable of withstanding gas supply pressures;
- Installed and operated by trained and qualified persons familiar with the specific hazards of the gases in use;
- Grounded to minimize sparks due to static discharge when using flammable gas;
- Provided with a means for safely purging the system and devices to prevent backflow of gases or liquids into the gas storage cylinders when using

hygroscopic corrosive gases, such as anhydrous hydrogen chloride; and

- Leak tested upon installation and monthly thereafter around valve and regulator connections, and fittings.

All compressed gas cylinders must be fitted with a protective valve cap or guard while in storage unless the cylinder is not designed to accept a cap or guard. All cylinders must be secured in the upright position to prevent them from falling. If the use of small non-refillable cylinders is unavoidable (lecture bottles), they should be secured in a device, cage, or box designed for cylinders 18" or smaller.

Toxic gases (such as carbon monoxide and hydrogen sulfide) should be stored and used in a chemical fume hood. If this is not feasible, the area of use should be equipped with a detection system specific to the toxic gas or inhalation hazard.

Portable flammable compressed gas systems must be approved either through the CPMG permitting process or through the use of the prior approval form identified in the *TAMUG Chemical Hygiene Program*.

Approved uses of flammable compressed gases will be identified at the point of use by EH&S or CPMG in evaluating regulatory compliance during inspections. Point-of-use identification will include approved gases and concentrations, quantity, and date of approval. A notice similar to that identified below will be placed at the point of use (hood, gas cabinet, or other permanent

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. Special hand/arm protection includes the use of cryogenic gloves; these gloves should be loose fitted and are designed to protect human tissue from cold burns.

Personal protective equipment includes a full face shield, full foot cover and clothing that prevent the absorption of liquids such as think sweater, jackets and pants with cuffs for transferring cryogenic fluids.

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.

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.

Any space where cryogenic fluids may accumulate (consider leakage into enclosed equipment) must be vented or protected by overpressure relief devices. Tremendous pressures can result 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.

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.

Dewar Safety

See Appendix B on Dewar Safety

Inerts, Oxidizers, Pyropheric or Toxic Compressed Gas Cylinders

Consult the Safety Data Sheet for all gases. Some gases are pyrophoric (phosphine) corrosive (hydrogen chloride), toxic (ethylene oxide), anesthetic (nitrous oxide), or highly reactive (anhydrous ammonia). Call EH&S at 480-965-1823 if you are unsure how to control the dangerous properties of a particular compressed gas.

Inerts - Inerts such as Nitrogen is a gas that makes up about 78% of the air we breathe. Nitrogen is a dry, inert, colorless and odorless gas; it is nonflammable and noncorrosive. Even with these somewhat minor hazard characteristics, inert gases cause numerous emergency incidents each year. Care must be taken to prevent oxygen deficient atmosphere, equipment that used Nitrogen or other inerts should use mechanical ventilation or exhaust monitoring to prevent asphyxiation.

- Carbon Dioxide must be treated with caution. If left to leak into closed space, these gases may displace oxygen and create a risk of asphyxiation.

Oxidizers

- Oxidizing gases such as compressed oxygen or nitrous oxide, while not combustible themselves, will cause many materials to burn violently. Never use grease, solvents, or other flammable material on an oxygen valve, regulator, or piping.
- Anesthetic gas may causes loss of sensation with or without the loss of consciousness and the storage handling and use of these type materials must follow these requirements.

Flammables

- Flammable gases such as propane, hydrogen, and acetylene always have a red label. However, the color of the cylinder itself is not a good indicator of flammability as different distributors may use different colored cylinders for the same gas. Check the label for flammability.
- The flammable range of a gas, including all concentrations in air between the Lower Flammable Limit (LFL) and the Upper Flammable Limit (UFL) needs to be recognized. For example, the flammable range for hydrogen is an LFL = 4% and an UFL = 75%.
- The auto-ignition temperature is the minimum temperature that gas and its vapors can spontaneously ignite in air. Examples include Silane or Diborane.
- Flammable gas must be segregated from oxidizers.

Pyrophoric - Hazardous gas (arsine, silane, phosgene, diborane, etc.) cylinders should be stored in a suitable exhausted location. If a hazardous gas cylinder develops a leak, evacuate and restrict area access.

Toxic - gas use may require the use to toxic gas monitoring, handling, storage and emergency procedures as well as additional facility considerations. A Process Hazard Assessment must be completed before a toxic gas can be used. Specific operating procedures must be developed and reviewed annually per the Chemical Hygiene Plan. Contact EH&S if you plan to use these gases.

Reporting Requirements - Maintain constant awareness of and respect for compressed gas cylinders and equipment. Comply with all applicable TAMUG safety procedures and compliance with all applicable TAMUG EHS rules are mandatory.

- Report all suspected leaks immediately. If the material in the tank is highly toxic or flammable and you suspect a leak, evacuate everyone out of the area and report it to the appropriate person in your department.
- Employees shall report any safety concerns to their supervisor or EHS.
- Accidents must be reported and any injury must follow TAMUG injury reporting requirements.
- Representatives of the EHS Office, including EHS Compliance Officers and Compressed Gas Safety Training mentors are available to observe work practices and may periodically audit work practices. If unsafe work practices are observed, they will communicate their observations to affected employees and assist with preventing unsafe work from continuing.

Compressed Gas Cylinder Emergencies

- Emergencies involving compressed gases are unlikely, provided the recommendations are followed for their correct storage, handling, and use. When problems do arise they are usually due to:
    - fire threatening the cylinder;
    - toxic or inert gas leaks; or
    - unplanned chemical or other reaction.
- Most leaks occur at the valve and valve stem fitted on the top of the cylinder. Leakage here is frequently due to dirt in the connection, or damaged connections or washers where required. Such leaks are easily rectified. Attempt to tighten the connection.
- If cylinders are involved in any type of an emergency, and it's safe to do so, isolate the gas outdoors and away from sparks and heat. In any event all defective cylinders should be clearly labeled and returned to the supplier.

Appendix A

Definitions

Anesthetic gas - A gas that may cause loss of sensation with or without the loss of consciousness.

CGA – Compressed Gas Association

Corrosive Gas - A gas that can cause visible destruction of, or irreversible alterations in, living tissue (e.g., skin, eyes, or respiratory system) by chemical action.

Cryogenic Liquids – Gases condensed to liquid form at extremely low temperatures. Example: Liquid Nitrogen is –196 °Celsius (–320 °Fahrenheit). The term “cryogenics” applies to all temperatures less than –150 °C (–238 °F).

Compressed Gas -

(i) A gas or mixture of gases in a container, having an absolute pressure exceeding 40 psi at 70 ^{0}F (21.1^{0}C) or

(ii) A gas or mixture of gases in a container, having an absolute pressure exceeding 104 psi at 130 ^{0}F (54.4^{0}C) regardless of the pressure at 70 ^{0}F (21.1 ^{0}C) or

(iii) A liquid having a vapor pressure exceeding 40 psi at 100 ^{0}F (37.8 ^{0}C) as determined by ASTM D-323-72.

Corrosive or Corrosive Material - As defined by the Department of Transportation (DOT), a corrosive material is a liquid or solid that causes visible destruction or irreversible alterations in human skin tissue at the site of contact or in the cases of leakage from its packaging, a liquid that has a severe corrosion rate on steel

DOT - U.S. Department of Transportation.

Flammable gas - A gas that can be ignited in air.

Flammable - A chemical that falls into one of the following categories:

(i) Aerosol, flammable: Means an aerosol that, when tested by the method described in 18 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening

(ii) Gas - flammable:

(A)) A gas that at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less or

(B) A gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12 percent by volume, regardless of the lower limit.

Flammable Gas: A gas that, at ambient temperatures and pressures, forms a flammable mixture with air at a concentration of less than thirteen (13)

percent by volume; or forms a range of flammable mixtures with air wider than twelve (12) percent by volume.

(iii) Liquid, flammable: Any liquid having a flashpoint below 100 ^{o}F (37.7 ^{0}C), except any mixture having components with flashpoints of 100 ^{o}F (37.7 ^{0}C) or higher, the total of which make up 99 percent or more of the total volume of the mixture.

(iv) Solid, flammable: A solid, other than a blasting agent or explosive as defined in § 1910.109 (a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard. A chemical must be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.

Flammable limits - The concentration of flammable vapor in air, oxygen, or other oxidants that will propagate flame upon contact when provided with a source of ignition. The lower explosive limit (LEL) is the concentration below which a flame will not propagate; the upper explosive limit (UEL) is the concentration above which a flame will not propagate. A change in temperature or pressure may vary the flammable limits.

Flashpoint - The minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite when tested as follows:

(i) Tagliabue Closed Tester (See American National Standard Method of Test for Flash Point by Tag Closed Tester, Z11.24-1979 (ASTM D 56-79))-for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100 ^{0}F (37.8 ^{0}C), that do not contain suspended solids and do not have a tendency to form a surface film under test or

(ii) Pensky-Martens Closed Tester (see American National Standard Method of Test for Flash Point by Pensky-Martens Closed Tester, Z11.7-1979 (ASTM D 93-79))-for liquids with a viscosity equal to or greater than 45 SUS at 100 ^{0}F (37.8

^{0}C), or that contain suspended solids, or that have a tendency to form a surface film under test or

(iii) Setaflash Closed Tester (see American National Standard Method for Test for Flash Point by Setaflash Closed Tester (ASTM D 3278-78)).

Organic peroxides, which undergo auto accelerating thermal decomposition, are excluded from any of the flashpoint determination methods specified above.

Hazardous Gas - A gas that is included in one or more of the following hazard categories: corrosive, flammable, health hazard, oxidizer, pyrophoric, reactive, or toxic.

Health Hazard - Any chemical for which there is at least one scientific study that shows it may cause acute or chronic health symptoms. This includes chemicals which are carcinogens, toxic or highly toxic, irritants, corrosives, sensitizers, or chemicals that effect target organs including the lungs, kidneys, nervous system, pulmonary system, reproductive system, skin, and/or eyes.
Highly Toxic Gas: A gas that is a gas at room temperature; and has a median lethal dose (LD(50)) of 50 mg or less per kg of body weight when administered orally to albino rats weighing between 200 and 300 grams each; has a LD(50) of 200 mg/kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each; or has a medium lethal concentration (LC(50)) in air of 200 PPM by volume or less when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

Ignition Source - Anything that provides heat, sparks, or flame sufficient to cause combustion/explosion.

Inerts – Gases that do not readily reactive with other elements; forming few or no chemical compounds.

Incompatible - Materials which could cause dangerous reactions from direct contact with one another.

Laboratory – A laboratory is defined as a facility or room where the use of potentially hazardous chemicals, biological agents, or sources of energy (i.e. lasers, high voltage, radiation, etc.) are used for scientific experimentation, research, or education.

LEL – (Lower Explosive Limit) LEL is the lowest concentration of a gas or vapor in the air that can produce ignition or explosion.

Mass Flow Controller- (MFC) is a device used to measure and control the flow of gases.

SDS – (Safety Data Sheet) Written or printed material about a chemical that specifies its hazards, safe use and other information. It is prepared by the chemical manufacturer, and is required by federal law.

Mechanical Exhaust – Mechanical exhaust systems use a powered device, such as a motor-driven fan or air/street venturi tube, for exhausting contaminants from a workplace, vessel, or enclosure.

NFPA - National Fire Protection Association.

OSHA – (Occupational Safety and Health Administration of the U.S. Department of Labor)

OSHA - is a federal agency with safety and health enforcement authority for most of U.S. industry and business.

Oxidizer - Department of Transportation defines oxidizer or oxidizing material as a substance that yields oxygen readily to stimulate the combustion (oxidation) of organic matter. Chlorate (ClO_3), permanganate (MnO_4) and nitrate (NO_3) compounds are examples of oxidizers.

Oxidizing gas - A gas that initiates or promotes combustion in materials, either by catching fire itself or by potentially causing a fire through the release of oxygen or other gases.

Oxygen deficiency - A condition that occurs when a breathable atmosphere contains less than 19.5% oxygen. Note: Normal air contains 20.8% oxygen.

Physical hazard - A chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, an explosive, a flammable, an organic peroxide, an oxidizer, a pyrophoric, an unstable (reactive), or a water-reactive.

Pyrophoric gases - Gases that may spontaneously ignite in air at or below 54 ºC (130 ºF). Specific gases may not ignite in all circumstances or may explosively decompose.

Restrictive Flow Orifice (RFO) — A safety device placed in the outlet of a cylinder valve that is intended to limit the release rate of a hazardous gas to a maximum specified range in the event of the inadvertent opening of the valve, or failure of the system downstream of the valve outlet.

STP – In chemistry, Standard Temperature and Pressure or STP is defined as 0 °C (32 °F) and 1 atmosphere of pressure (101.325 kPa or 29.92 inches of mercury).

Toxic gas – A gas that is poisonous or capable of causing injury or death, especially by chemical means. As defined in EHS 122: Compressed Gases a **Toxic Gas** is a gas that is a gas at room temperature; and has a median lethal dose (LD(50)) of more than 50 mg, but less than 500 per kg of body weight when administered orally to albino rats weighing between 200 and 300 grams each; has a LD(50) of more than 200 mg/kg, but less than 1,000 mg/kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each; or has a medium lethal concentration (LC(50)) in air of more than 200 PPM, but less than 2,000 PPM by volume or less when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

UEL - Upper Explosive Limit - The highest concentration of a gas or vapor in air that can produce ignition or explosion.

Unstable (Reactive) – An unstable or reactive chemical can go through vigorous polymerization, decomposition or condensation. This process occurs when the chemical undergoes shock or changes in pressure or temperature.

Water reactive - A chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

Appendix B

General Guidelines for Flammable Gases

The volume of flammable gas in a lab, room or location is restricted by University guidelines and International Fire Codes. EHS should be contacted regarding any questions or for additional guidance.

The volume of flammable gas shall be kept to the minimum necessary for the work being done. Just in time delivery should be used where possible.

The maximum internal volume (water volume) of all cylinders in each of the listed classifications, in use in the laboratory work area or single fire area, shall comply with the following based on internal cylinder volume at 70 °F (21 °C).

For a laboratory work area of 500 ft^2 or less, the internal cylinder volume equals 6.0 ft^3 or approximately three (3) "K" (9.25 inch diameter, 60 inch height) sized cylinders.

For a laboratory work area greater than 500 ft^2 , the internal cylinder volume is 0.012 ft^3 per ft^2 lab work area, but not to exceed the maximum cubic feet of gas from the chart below (approximately five (5) "K" sized cylinders for flammable gas except hydrogen – see Section 4).

Material	Storage	Use-Closed	Use-Open System
	Cubic Feet	Cubic Feet	Cubic Feet
Oxidizing Gas	1,500	1,500	NA
Flammable Gas	1,000	1,000	NA
Pyrophoric Gas	50	10	NA

The maximum quantity of lecture bottles in a single fire area should not exceed 20. ASU strongly discourages the use of any non- returnable, non-refillable compressed gas cylinders (lecture bottles).

Flammable gasses should be separated by 20 ft. (6.1 m) from all pyrophoric, oxidizing and corrosive gases except as follows:

The 20 ft distance shall be reduced without limit when separated by a barrier of noncombustible materials at least 5 ft (1.5 m) high that has a fire resistance rating of at least 30 minutes.

The 20 ft distance shall be reduced to 5 ft where one of the gases is enclosed in a gas cabinet or without limit where both gases are enclosed in gas cabinets.

Cylinders without pressure-relief devices shall be stored separately from flammable and pyrophoric gases with pressure-relief devices.

The following are requirements for outdoor storage of flammable gas:

The cylinders should not be stored within 10 ft of windows, doors, or other openings nor shall they be stored within 50 ft of ventilation intakes.

Storage areas shall be kept clear of dry vegetation and combustible materials for a minimum distance of 15 ft.

Cylinders stored outside shall not be placed on the ground (earth) or on surfaces where water can accumulate.

Storage areas shall be provided with physical protection from vehicle damage.

Storage areas shall be permitted to be covered with canopies of noncombustible construction.

All compressed gas cylinders shall be stored in an upright position.

All flammable gas cylinders, full or empty, shall be handled in the same manner. Store empty cylinders separately from full cylinders.

Compressed flammable gas cylinders, whether full or partially full, shall not be exposed to or heated by devices that could raise the temperatures above 125 °F (52 °C).

Always use non-sparking tools on compressed gas cylinders.

Static-producing equipment located in flammable gas areas shall be grounded.

Signs should be posted in areas containing flammable gases communicating that smoking or the use of open flame, or both, is prohibited within 25 ft of the storage or use area perimeter.

Compressed flammable gas cylinders should not be placed where they could become a part of an electrical circuit.
Compressed flammable gas cylinders shall not be exposed to dampness, salt, corrosive chemicals or fumes that could damage the cylinders or valve-protective caps.

Leaking, damaged, or corroded compressed flammable gas cylinders should be removed from service.

Hydrogen

Hydrogen gas has several unique properties that make it potentially dangerous. It has an extremely wide flammability range (LEL 4%, UEL 74.5%) that makes it easier to ignite than most flammable gases. Unlike most other gases, hydrogen's temperature increases during expansion. Many hydrogen fires result from the self-ignition of sudden hydrogen release through rupture disks and pressure relief valves.

Observe the following guidelines for hydrogen use and storage:

Limit the number of hydrogen cylinders to approximately 400 ft^3 or two (2) "K" type cylinders in a laboratory or single fire area.

Adequate ventilation should be provided and maintained throughout the area where hydrogen cylinders are in use.

Open the cylinder valve slowly. If a cylinder valve is opened too quickly, the static charge generated by the escaping gas may cause it to ignite.

Hydrogen embrittlement can weaken carbon steel, therefore cast iron pipes and fittings should not be used.

Piping, tubing, fittings, gaskets, and thread sealants should be suitable for hydrogen service at the pressures and temperatures involved. Refer to American Society of Mechanical Engineers Code for Process Piping, ASME B31.3.

For gaseous hydrogen service, joints in piping and tubing should be made by welding or brazing or by use of flanged, threaded, socket, slip, or compression fittings. Brazing materials should have a melting point above 1000 °F (538 °C).

Provide 20 ft of separation from Class I, II and IIIA flammable liquids, oxidizing gases and readily combustible materials.

Locate the cylinders 25 ft from open flames and other sources of ignition.

Hydrogen burns with an invisible flame. Caution should therefore be exercised when approaching a suspected hydrogen flame.

Provide 50 ft of separation from other flammable gas storage.

Acetylene

Acetylene is flammable gas with a normal explosive range with air of 2.3 to 80% acetylene. Special cylinders used for acetylene contain a porous material and acetone, in which the gas dissolves and becomes practically stable. The porous filler absorbs the acetone and eliminates large voids in which decomposition might occur. Because of its tendency to break down and release energy, acetylene is highly reactive and is widely used in chemical processes. The temperature of the oxyacetylene flame, 5400 to 6300 °F (3000 to 3500 °C), is the highest for any commercially practical mixture of gases.

The minimum autoignition temperature for acetylene-air mixtures is about 571 °F (300 °C). The presence of catalytic impurities such as rust, scale, silica gel, charcoal, or potassium hydroxide can lower the ignition temperature substantially. The presence of copper, silver, or mercury acetylides combined with light shock can result in ignition or decomposition of acetylene at room temperatures.

Observe the following guidelines for acetylene use and storage:

- Do not handle cylinders roughly, subject cylinders to hydrostatic test, or take any other action that can create large voids in the mineral filler.
- Provide separate storage locations for acetylene and oxygen or chlorine cylinders. A gas-tight non-combustible partition will serve to separate a storage area for this purpose.
- Store and use cylinders in an upright position to prevent loss of acetone.
- Do not withdraw acetylene from a cylinder or manifold at a rate in excess of one-seventh of the total cylinder capacity per hour. Provide additional cylinders if needed to supply higher demand without exceeding this rate.
- Use a pressure regulator at the discharge of an individual cylinder or manifold to reduce the gas pressure to 15 psi (105 kPa) or less.
- Keep acetylene cylinder valves closed when gas is not being used, and open the valves only 1-1⁄2 turns when in use.
- Use wrought-iron or steel pipe and steel or malleable-iron fittings. Welded joints are preferable because of the reduced probability of leakage. Alloys containing more than 67% copper should not be used for piping, valves, or fittings (with the exception of a torch tip, which is pure copper).

Liquefied Petroleum Gas (LPG)

Although Liquefied Petroleum Gases (LPG) are transported and stored as liquids, they are gases at atmospheric pressures and normal temperatures. They are as hazardous as other combustible gases, with the added danger that they are heavier than air, tend to remain in low places for a somewhat longer period, and have little or no natural odor.

The discharge from tank relief valves, if ignited, can create a large torch fire. The intense, radiated heat may seriously expose buildings and contents. If ignition is delayed, the discharge from tank relief valves may travel hundreds of feet and settle in low-lying areas or enter below grade building openings. If the gas enters a building, ignition may result in an explosion. Once ignited, the resulting flashback to the tank may involve other structures and contents.

Observe the following guidelines for LPG use and storage:

Containers of LPG should be stored outside of buildings at least 10 ft. from any doorway or other opening with the following exceptions:

- For temporary demonstration purposes, a container with a maximum water capacity of 12 pounds (5 pounds of LPG) may be used.
- For hand torches or similar appliances, a container with a maximum water capacity of 2.5 pounds (1 pound of LPG) may be used.

Cylinders should not be filled past their rated capacity. The weight limit is usually specified on the cylinder. If it has been overfilled, the pressure relief valve may release propane as the cylinder warms. Overfilling can lead to flash fires and explosions.

All cylinders having a propane capacity of 4 pounds through 40 pounds fabricated after 1998 must be equipped with an overfill prevention device (OPD) as a secondary means of protecting against overfilling (the primary means is to determine the fill limit by weight). Cylinders equipped with OPD’s will have a triple-notched valve hand wheel with the letters “OPD.”

Used cylinders must be retrofitted with UL listed OPD’s when being re-qualified under DOT regulations. Affected cylinders cannot be filled unless they are equipped with UL listed OPD’s.

Cylinders should be kept away from heat sources, as the heat can build up pressure inside the cylinder and may cause the pressure relief valve to release propane.

The cylinders should be kept in a secure upright position with the valves closed and the thread caps secured when they are transported, stored, or used.

When disconnecting cylinders, whether full or empty, first close the shut- off valve, then disconnect the cylinder and snugly seal the valve with a plug, cap, or approved quick-closing coupling.

Never use propane from a cylinder without a regulator (except for forklift cylinders). Protect the regulator connector from scratches and dents. Ensure the regulator vent is clean and pointed downward, and the regulator is protected.

Cylinders that are visibly rusted or damaged shall not be refilled.

Oxygen

Oxygen is neither combustible nor explosive. However, the intensity of any ordinary fire or explosion increases as the amount of oxygen in the surrounding air increases. Materials, such as grease or oils that produce intense fires with air, burn in an atmosphere of enriched oxygen with explosive violence. Explosions have occurred in oxygen pressure gauges after being tested on common oil-filled gauge testers. Oxygen at atmospheric pressure in a closed system can combine explosively with lubricating oil at temperatures above 340 °F (170 °C).

Observe the following guidelines for oxygen use and storage:

Separate oxygen cylinders from cylinders or manifolds containing flammable gases and other combustible or easily ignited materials such as wood, paper, oil, and grease. Gas-tight fire partitions having at least ½ hour fire resistance rating are suitable as cutoffs. **Note:** This does not apply to properly arranged and safeguarded oxygen and acetylene tanks used for cutting and welding torches.

Do not use oil or grease for lubricating valves, gauge connections, or other parts of the oxygen system.

Use extra-heavy steel or nonferrous pipe and fittings if the oxygen pressure is over 150 psi (1 MPa). For lower pressures, standard-weight pipe and fittings are satisfactory. Cast-iron fittings should not be used.

In medical oxygen gas systems, Type K or L (ASTM B-88) copper tubing may be used. Brazed fittings should be used for 3⁄4-inch (19-mm) and larger tubing. Flared-type tubing fittings may be used in smaller sizes where the fitting is visible in the room.

Use welded joints whenever possible. If threaded joints are necessary, they should be carefully made using litharge and glycerin or proprietary materials compounded for oxygen service. Compounds containing oils should not be used. Gaskets should be entirely of noncombustible materials.

Pyrophoric Gas

Pyrophoric chemicals are those substances that react so rapidly with air and its moisture that the ensuing oxidation and/or hydrolysis lead to ignition. Ignition may be instantaneous or delayed. Spontaneous (instantaneous) ignition or combustion occurs when a substance reaches its ignition temperature without the application of external heat.

An example of a pyrophoric gas is silane. Silane has caused major losses due to fires in ducts, gas cabinets, and supply systems; and explosions in ducts, vacuum pumps, and cross-contaminated cylinders. These incidents have occurred in research facilities. The hazards are pyrophoric fires, explosions, and/or deflagrations, and autoignition of a vapor cloud. All of these conditions can occur depending on leak location, excess flow control and shutdown of the silane gas. Pyrophoric fires are difficult to extinguish. When pyrophoric fires are extinguished, the gas supply must be shut down promptly by interlocks tied into fire protection and/or detection, because resulting pyrophoric gas build up has the potential to create vapor cloud detonation.

Observe the following guidelines when storing or using pyrophoric gas:

Minimally-sized cylinders of pyrophoric gases shall be limited per the above table and kept in approved gas cabinets.

Remote manual shutdown devices for pyrophoric gas flow should be provided outside each gas cabinet or near each gas panel. Automatic shutdown devices for pyrophoric gas flow activated by interlocks tied into fire protection and/or detection should be provided.

Pyrophoric gas flow, purge, and exhaust systems should have redundant controls that prevent pyrophoric gas from igniting or exploding. These controls include excess flow valves, flow orifices, mass flow controller sizing, process bypass line elimination or control, vacuum-pump inert-gas purging, dilution of process effluent with inert gas and ventilation, controlled combustion of process effluent, ventilation monitoring, and automatic gas shutdown.

Order cylinders with the smallest orifice as practicable (0.006 inch and not to exceed 0.010 inch).

Emergency back-up power should be provided for all electrical controls, alarms, and safeguards associated with the storage and process systems.

All process systems components and equipment should be adequately purged using a dedicated inert gas cylinder.

Appendix C Dewar Safety

Dewars usually have nitrogen as its common content. Contact of liquid nitrogen or any very cold gas with the skin or eyes may cause serious freezing (frostbite) injury**.**
Protect hands at all times when working with liquid nitrogen.

Handle Liquid Nitrogen Carefully

The extremely low temperature can freeze human flesh very rapidly. When spilled on a surface the liquid tends to cover it completely and intimately, cooling a large area.
The gas issuing from the liquid is also extremely cold. Delicate tissue, such as that of the eyes, can be damaged by an exposure to the cold gas which would be too brief to affect the skin of the hands or face.

Never allow any unprotected skin to touch objects cooled by liquid nitrogen.
Such objects may stick fast to the skin and tear the flesh when you attempt to free yourself. Use tongs, preferable with insulated handles, to withdraw objects immersed in the liquid, and handle the object carefully.

Protective Clothing

Protect your eyes with face shield or safety goggles (safety glasses without side shields do not give adequate protection). Always wear cryogenic gloves when handling anything that is, or may have been, in immediate contact with liquid nitrogen. The gloves should fit loosely, so that they can be thrown off quickly if liquid should splash into them. When handling liquid in open containers, it is advisable to wear high-top shoes. Trousers (which should be cuffless if possible) should be worn outside the shoes.

Any kind of canvas shoes should be avoided because a liquid nitrogen spill can be taken up by the canvas resulting in a far more severe burn.

Approved Containers for Low-Temperature Liquids Cryogenic containers are specifically designed and made of materials that can withstand the rapid changes and extreme temperature differences encountered in working with liquid nitrogen. Even these special containers should be filled *slowly* to minimize the internal stresses that occur when any material is cooled. Excessive internal stresses can damage the container.

Do not ever cover or plug the entrance opening of any liquid nitrogen dewar. Do not use any stopper or other device that would interfere with venting of gas.

These cryogenic liquid containers are generally designed to operate with little or no internal pressure. Inadequate venting can result in excessive gas pressure which could damage or burst the container. Use only the loose-fitting necktube core supplied or one of the approved accessories for closing the necktube. Check the unit periodically to be sure that venting is not restricted by accumulated ice or frost.

Proper Transfer Equipment

Use a phase separator or special filling funnel to prevent splashing and spilling when transferring liquid nitrogen into or from a dewar. The top of the funnel should be partly covered to reduce splashing. Use only small, easily handled dewars for pouring liquid. For the larger, heavier containers, use a cryogenic liquid withdrawal device to transfer liquid from one container to another. Be sure to follow instructions supplied with the withdrawal device. When liquid cylinders or other large storage containers are used for filling, follow the instructions supplied with those units and their accessories.

Avoid Overfilling Containers

Filling above the bottom of the necktube (or specified maximum level) can result in overflow and spillage of liquid when the necktube core or cover is placed in the opening.

Never use hollow rods or tubes as dipsticks

When a warm tube is inserted into liquid nitrogen, liquid will spout from the bottom of the tube due to gasification and rapid expansion of liquid inside the tube. Wooden or solid metal dipsticks are recommended; avoid using plastics that may become very brittle at cryogenic temperatures which then become prone to shatter like a fragile piece of glass.

Nitrogen gas can cause suffocation without warning. Store and use liquid nitrogen only in a well ventilated place.

- As the liquid evaporates, the resulting gas tends to displace the normal air from the area. In closed areas, excessive amounts of nitrogen gas reduces the concentration of oxygen and can result in asphyxiation. Because nitrogen gas is colorless, odorless and tasteless, it cannot be detected by the human senses and will be breathed as if it were air. Breathing an atmosphere that contains less than 18 percent oxygen can cause dizziness and quickly result in unconsciousness and death.

Note:
The cloudy vapor that appears when liquid nitrogen is exposed to the air is condensed moisture, not the gas itself. The gas actually causing the condensation and freezing is completely invisible.

Never dispose of liquid nitrogen in confined areas or places where others may enter.

Disposal of liquid nitrogen should be done outdoors in a safe place. Pour the liquid slowly on gravel or bare earth where it can evaporate without causing damage. Do not pour the liquid on the pavement.

First Aid

If a person seems to become dizzy or loses consciousness while working with liquid nitrogen, move to a well-ventilated area immediately. If breathing has stopped, apply artificial respiration. If breathing is difficult, give oxygen. Call in for an emergency. Keep warm and at rest.

If exposed to liquid or cold gas, restore tissue to normal body temperature 98.6 °F (37 °C) as rapidly as possible, followed by protection of the injured tissue from further damage and infection. Remove or loosen clothing that may constrict blood circulation to the frozen area. Call a physician. Rapid warming of the affected part is best achieved by using water at 108 °F/42 °C). Under no circumstances should the water be over 112 °F/44 °C, nor should the frozen part be rubbed either before or after rewarming. The patient should neither smoke, nor drink alcohol.

Most liquid nitrogen burns are really bad cases of frostbite. This is not to belittle the harm that can come from frostbite, but at the same time, it’s important to keep the dangers associated with liquid nitrogen burns in perspective. Indeed, liquid nitrogen burns could be treated as frostbite.

Handling Liquid Nitrogen Dewars Keep unit upright at all times except when pouring liquid from Dewars specifically designed for that purpose.

Tipping the container or laying it on its side can cause spillage of liquid nitrogen. It may also damage the container and any materials stored in it.

Rough handling can cause serious damage to dewars and refrigerators.

Dropping the container, allowing it to fall over on its side, or subjecting it to sharp impact or severe vibration can result in partial or complete loss of vacuum. To protect the vacuum insulation system, handle containers carefully. Do not "walk", roll or drag these units across a floor. Use a dolly or handcart when moving containers, especially the larger portable refrigerators. Large units are heavy enough to cause personal injury or damage to equipment if proper lifting and handling techniques are not used.

When transporting contents from a liquid nitrogen dewar, maintain adequate ventilation and protect the unit from damage.

Do not place these units in closed vehicles where the nitrogen gas that is continuously vented from unit can accumulate. Prevent spillage of liquids and damage to unit by securing it in the upright position so that it cannot be tipped over. Protect the unit from severe jolting and impact that could cause damage, especially to the vacuum seal.

Keep the unit clean and dry
Do not store it in wet, dirty areas. Moisture, animal waste, chemicals, strong cleaning agents, and other substances which could promote corrosion should be removed promptly. Use water or mild detergent for cleaning and dry the surface thoroughly. Do not use strong alkaline or acid cleaners that could damage the finish and corrode the metal shell.

Appendix D

Gas Monitoring and Detection

Use of flammable and highly toxic compressed gases (as defined in this guideline) that are not considered a closed system, must be used within ventilated enclosures such as a laboratory hood or glove box, or the use of real time gas detection may be required as follows. The use of emission control devices such as burn boxes or scrubbers will be addressed as part of the permit review process or the Prior Approval Process as applicable.

Exception: Acetylene may be used in designated hot work areas approved by the Campus Fire Marshal without the use of real time gas detection. However, whenever mobile units are carried into confined spaces, gas monitoring for flammable gases and oxygen must be conducted as required under the TAMUG Confined Space Entry Program.

Flammable and Highly toxic gases

Gas detection will be installed at the storage location and within the room conveying the flammable gas unless the tubing used to convey the gas from its storage location to the point of use is continuous non-combustible tubing (orbital welds only unless a variance is granted, no fittings), or all fittings are contained within a manifold equipped with local exhaust ventilation, that has been leak checked. Gas detection within the room itself, if required, should be placed at location likely to detect any leakage such as near an air return. Gas detection systems should be set to alarm as follows.

1) Gas release alarm (TLV level for toxic gases and 50% of LEL for flammable gases)- Activate building fire alarm system (at least horns and strobes, but there may be flexibility with smoke fans such as with Biodesign).
2) Gas warning alarm (1/2 of TLV for toxics and 5% of LEL for flammables) – send trouble signal to fire alarm panel and/or TAMUG PD (security company for some leases) to contact lab or EHS on call representative to investigate.
3) Gas monitor trouble alarm (same as number 2 above).

Alarm set points must be communicated to the Campus Lab Safety Officer. As the authority having jurisdiction, additional guidance or higher alarm levels may be approved on a case by case basis.

Oxygen

Normal oxygen levels range between 19.5 and 20.8%. Serious health effects, or death by asphyxiation can occur quickly when oxygen levels are unsafe (below 16%) or fires (above 21%). Liquefied cryogens and inert gases can displace oxygen and create low oxygen levels in confined spaces or poorly ventilated areas. Many sources of liquid cryogens and inert gas exist in teaching and research facilities, including MRI or NMR magnets, cylinders of carbon dioxide, helium, argon and nitrogen, anaerobic incubators, -80^{o}C freezers, and analytical instruments. Cylinder, tank and dewar failures, magnet quenches or sudden releases from pressure relief valves can overwhelm standard ventilation systems. In most research environments, gas volumes are limited and potentially asphyxiating gases quickly dissipate. Air exchange rates in many labs are relatively high (6-15 ACH) further minimizing the risk of low oxygen levels. Cryogen tanks and compressed gas systems are designed as “fail safe,” venting slowly rather than rupturing. All of these features reduce the need for detection equipment. However, rooms or spaces containing inert gas or other sources of oxygen depletion should be evaluated by an industrial hygienist, and if warranted, safeguards to protect users and those potentially entering these spaces added. When this evaluation indicates, an oxygen monitoring device shall be a first measure and installed in indoor locations where compressed gases or cryogenic liquids are stored and dispensed in a manner that could create the potential for the displacement of oxygen that could present an asphyxiation hazard to occupants. At a minimum, the following factors should be used in determining if a device should be installed: manufacturer (e.g., magnet) guidance, volume of gas used, location of gas, device safety features, device failure probability, and air changes/hour in the room/area. In particular, the 2008 NIH DRM notes that both ‘*carbon dioxide manifold room and nitrogen holding rooms must include oxygen level monitoring alarms*’ (section 8, pages 8-80). Additionally, compressed gases or cryogenic liquids shall not be located or dispensed in any indoor location that does not have proper ventilation as determined by an industrial hygienist (sufficient to prevent oxygen levels from falling below 19.5 %).

The installation of the oxygen monitoring device will rely on the manufacturer’s specific requirements and recommendations. Some of these requirements may include, but not be limited to the following:

1) Installing the device close to an area where a leak would most likely occur;
2) Placing the device at the proper height depending on the density of the gas;
3) Ensuring the device’s display is accessible; and
4) Performing a leak test of the oxygen monitoring devises’ sample lines, system components, and fittings.

As per the manufacture’s recommendation, a low oxygen alarm shall be installed along with the monitoring device to alert persons in the surrounding area of a hazardous condition. This monitoring device should also be interlocked with the building automation system (BAS). Where applicable, the device shall also be interlocked with an emergency exhaust fan or ventilation system that is located at the monitored location. An alarm will trigger emergency ventilation of the space. Alarms installed during new construction, or building alteration, should include both visual and audible warnings to notify occupants. The alarm location will be specified during the permit review or Prior Approval Process.

OSHA specifies that a hazardous atmosphere may include one where the oxygen concentration is below 19.5% or above 23.5%. The device alarm and warning levels should be set according to these oxygen concentration levels (a normal atmosphere is composed of approximately 21% oxygen and 79% nitrogen).

MAINTENANCE & USE

Any maintenance or repair on the monitoring device should be only performed by the manufacturer or manufacturer’s representative using manufacturer specific replacement parts. Most oxygen monitoring devices require minimal periodic maintenance. Follow the manufacturer’s recommendations on calibration, maintenance, and sensor replacement.

The installation, testing and maintenance costs for oxygen monitors and associated engineering controls shall be the responsibility of the department or responsibility center using cryogens or asphyxiant gases.