NIST National Institute of Standards and Technology • U.S. Department of Commerce

COMPRESSED GAS SAFETY

NIST S 7101.61
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1. PURPOSE

The purpose of this program is to establish requirements to minimize the potential hazards associated with compressed gases in cylinders, vessels, and systems.

2. BACKGROUND

a. NIST P 7100.00 articulates NIST's commitment to making occupational safety and health an integral core value and vital part of the NIST culture, in part by complying with applicable laws, regulations, and other promulgated safety and health requirements.

b. The content of this suborder was derived primarily from applicable Compressed Gas Association (CGA P-1) and National Fire Protection Association (NFPA) Codes/Standards (NFPA 45, NFPA 55, NFPA 70, and NFPA 704). The hazard definitions and numeric ratings in this suborder are based on NFPA definitions. These are similar to the definitions published in the 1994 version of Occupational Safety and Health Administration (OSHA) standard 29 CFR 1910.1200 – *Hazard Communication*.

c. Compressed gases are subject to the requirements of NIST S 7101.59: *Chemical Hazard Communication* and NIST S 7101.60: *Chemical Management*.

d. This suborder supersedes the NIST *Health and Safety Instruction No. 5 – Compressed Gas Cylinders*.

3. APPLICABILITY

a. The provisions of this suborder apply to all NIST employees and covered associates[2] whose work activities involve use or storage of compressed gases.

[1] The revision history for this document can be found in Appendix A.
[2] See NIST O 7101.00: Occupational Safety and Health Management System.

b. Site-specific Engineering and Administrative controls that are not practical at non-NIST sites do not apply as long as equally protective local controls and practices, consistent with applicable standards, are implemented by the host entity. Equivalency shall be determined by the OU in consultation with OSHE, as warranted.

4. REFERENCES[3]

a. Compressed Gas Association (CGA) Pamphlet C-6, Standards for Visual Inspection of Steel Compressed Gas Cylinders.

b. CGA Pamphlet C-7, Guide to Preparation of Precautionary Labeling and Marking of Compressed Gas Containers.

c. CGA Pamphlet C-8, Standard for Requalification of DOT-3HT, CTC-3HT, and TC-3HTM Seamless Steel Cylinders.

d. CGA Pamphlet P-1, Safe Handling of Compressed Gases in Containers.

e. CGA Pamphlet P-19, Recommended Hazard Ratings for Compressed Gases.

f. CGA Pamphlet P-20, Standard for Classification of Toxic Gas Mixtures.

g. CGA Pamphlet S-1.1, Pressure Relief Device Standards Part 1 – Cylinders for Compressed Gases.

h. CGA Pamphlet S-1.2, Pressure Relief Device Standards Part 2 – Portable Containers for Compressed Gases.

i. Industrial Ventilation, a Manual of Recommended Practice, American Conference of Governmental Industrial Hygienists (ACGIH).

j. International Organization for Standardization (ISO) Standard 10156, Gas Cylinders – Gases and Gas Mixtures – Determination of Fire Potential and Oxidizing Ability

k. ISO 10298, Determination of Toxicity of a Gas or Gas Mixture.

l. NFPA 45, Fire Protection for Laboratories Using Chemicals.

m. NFPA 50A, Gaseous Hydrogen Systems at Consumer Sites.

[3] Where no date is specified, the most recent version applies.

n. NFPA 51, Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes.

o. NFPA 51B, Cutting and Welding Processes.

p. NFPA 55, Compressed and Liquefied Gases in Portable Containers.

q. NFPA 70, National Electric Code (NEC)

r. NFPA 72, Installation, Maintenance, and Use of Protective Signaling Systems.

s. NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.

t. NFPA 704, Identification of the Fire Hazards of Materials.

u. Odor Thresholds for Chemicals with Established Occupational Health Standards, American Industrial Hygiene Association.

v. OSHA Standard 29 CFR §1910.101, Compressed Gases (general requirements).

w. OSHA Standard 29 CFR §1910.307, Hazardous (Classified) Locations

x. Pocket Guide to Chemical Hazards, DHHS (NIOSH), Pub. No. 90-117, National Institute of Occupational Safety and Health LBNL/PUB-3122, Maintenance Program Guidelines for Programmatic Equipment.

y. Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH.

5. APPLICABLE NIST DIRECTIVES

a. NIST S 7101.20: *Work and Worker Authorization (Based on Hazard Review)*

b. NIST S 7101.21: *Personal Protective Equipment (PPE)*

c. NIST S 7101.22: *Hazard Signage*

d. NIST S 7101.23: *Safety Education and Training*

e. NIST S 7101.58: *Respiratory Protection*

f. NIST S 7101.59: *Chemical Hazard Communication*

g. NIST S 7101.60: *Chemical Management*

h. NIST P 7400.00: *Fire and Life Safety*

i. NIST S 7401.02: *Inspection, Testing, and Maintenance of Fire Protection and Life Safety Systems*

6. REQUIREMENTS

a. General Requirements for the Use of Compressed Gases[4]

(1) Area Signage where Highly Toxic Gases are Present

(a) All entrances to areas containing cylinders, vessels, or systems containing highly toxic gases or gases with an NFPA 704 health hazard rating of 4 shall be marked with a "DANGER" sign in accordance with NIST S 7101.20: Hazard Signage. See examples in Figure 1.

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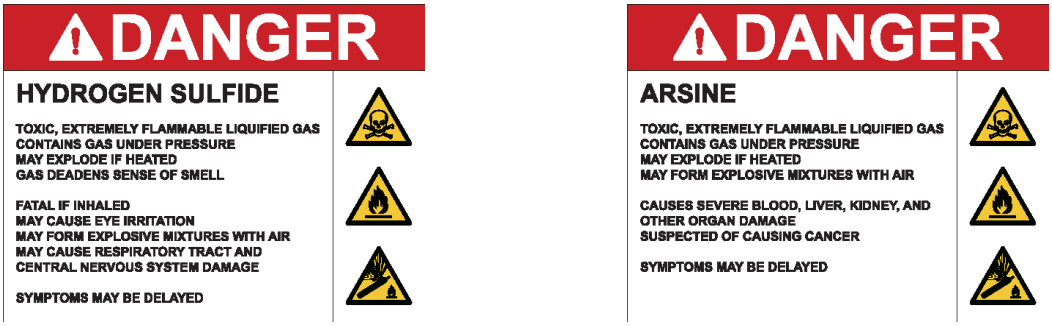

Figure 1: Specific Hazard Signs for Areas Containing Highly Toxic Gases

(2) Area Signage where Compressed Gases are Present

[4] Apart from hazard signage, consideration of the chemical hazards associated with the use of specific gases is covered separately in NIST S 7101.60: Chemical Management.

(a) If smoking is not already prohibited in and near areas containing compressed gases, signs shall be posted in such areas stating that smoking is prohibited within 25 ft (7.6 m) of the storage or use area perimeter.[5] See an example in Figure 2.

Figure 2: Smoking Prohibited Sign

(3) Ventilation of Compressed Gases

(a) If compressed gases are introduced into laboratory fume hoods, steps must be taken to ensure that there is no backflow from the fume hood into the surrounding space.

(b) Local and general exhaust systems used to exhaust hazardous gases shall be constructed of materials that are compatible with the gases to be exhausted.

(c) Incompatible gases shall be exhausted using separate ventilation systems.

(d) Ventilation systems that will handle flammable gases at concentrations of 10 percent of their Lower Explosive Limit or greater must be explosion-proof and have non-sparking exhaust fans.

(e) Vacuum pumps, high-pressure systems, and pressure-relief devices protecting equipment to be attached to compressed gas cylinders, vessels, or systems containing flammable, toxic, or otherwise hazardous gases should be vented directly outdoors or through an exhaust hood discharging away from windows and doors, and no less than 50 feet (ft) (15 meters (m)) from intakes of air-handling systems, air-conditioning equipment, and air compressors. If these requirements cannot be met, or their intent can be met using a different approach, the applicable hazard review must identify alternative controls that provide an equivalent level of safety.

[5] Smoking is prohibited in NIST buildings and within 25 ft of building entrances and air intakes.

(4) Gas Detection Systems for Toxic and Highly Toxic Compressed Gases

(a) A continuous gas detection system shall be provided for the indoor storage or use of all toxic or highly toxic compressed gases in cylinders, vessels, or systems, except for toxic gases that have physiological warning properties at a level below the OSHA Permissible Exposure Limit (PEL) or ACGIH Threshold Limit Value (TLV), whichever is lower.[6]

i. A continuous gas detection system may also be appropriate for other hazardous gases, including flammables, pyrophorics, oxidizers, and corrosives, particularly in cases where there are special hazards (for example, as in the case of continuous operations that are unattended). This shall be decided on a case-by-case basis during the applicable hazard review.

(b) The gas-detection system shall detect the presence of gas at or below the ACGIH TLV, OSHA PEL, or ceiling limit of the gas, whichever is lowest, at all of the following locations:

i. In the room or indoor area in which the gas is used (the point of use);

ii. At the location of the source container, cylinder, or tank used for delivery of the gas to the point of use;

iii. In the room or area in which the gas is stored; and

iv. At the point of discharge of the exhaust system from gas cabinets, exhausted enclosures, and gas rooms, if the point of discharge is not outside the building.

(c) The gas detection system shall detect the presence of the gas at one-half of the Immediately Dangerous to Life and Health (IDLH) level or less at the discharge from any exhaust or waste gas treatment system that is present.

(d) The gas-detection system shall initiate a local alarm that is both audible and visible.

(e) All personnel who may be in the area of a local alarm shall be trained in the recognition of the alarms and in the appropriate response in the case of an alarm.

[6] Contact OSHE at x5375, Option 3 to determine if this requirement applies to a specific compressed gas.

(f) Gas detection systems shall be required to transmit a signal to a constantly attended monitoring station for any location that contains two or more compressed gas cylinders of toxic or highly toxic gas. The attending organization shall develop response protocols for each different alarm.

(g) Activation of the gas detection system at a location where compressed gas is hooked up to a system shall automatically shut off the flow of the compressed gas related to the system being monitored.

i. An automatic shutdown shall not be required for chemical reactors used to produce toxic or highly toxic gases when those reactors are operated at pressures less than 103.4 kPa[7] (15 psig), constantly attended, and have readily accessible, emergency-shutoff valves.

(h) Newly installed and modified existing combustible gas detectors, oxygen depletion sensors, and toxic gas detectors shall be commissioned in accordance with NFPA 3, *Recommended Practice for Commissioning of Fire Protection and Life Safety Systems*, 2015 edition.

Refer to NIST S 7401.02: *Inspection, Testing, and Maintenance of Fire Protection and Life Safety Systems* for additional information.

(i) Combustible gas detectors, oxygen depletion sensors, and toxic gas detectors shall be commissioned, inspected, tested, and maintained in accordance with:

i. NFPA 72, *National Fire Alarm and Signaling Code*, 2013 edition; and

ii. Manufacturer instructions.

Refer to NIST S 7401.02: *Inspection, Testing, and Maintenance of Fire Protection and Life Safety Systems* for additional information.

[7] Pressure measurements are “gauge pressure”, the pressure relative to ambient atmospheric pressure.

(5) Personal Protective Equipment

(a) Personal protective equipment (PPE), including respiratory protection as applicable, shall be used when working with compressed gases, as required by the applicable hazard review.[8]

(6) Eyewashes and Showers

(a) An eyewash station and/or safety shower shall be provided in each area where corrosive gases are used. Refer to NIST S 7101.60: *Chemical Management* for additional information.

b. Compressed Gas Cylinders

(1) Purchasing Compressed Gas Cylinders

(a) The smallest volumes and numbers of compressed gas cylinders needed to conduct the work effectively shall be purchased.

(b) Returnable lecture bottles should be purchased whenever possible.

(2) Point-of-Delivery Inspection of Compressed Gas Cylinders

Employees and associates who receive compressed gas cylinders from outside vendors shall conduct point-of-delivery inspections of the cylinders in accordance with the following considerations.[9] Employees and associates who receive compressed gas cylinders from other individuals within NIST are encouraged to conduct such inspections. Any cylinder not meeting these considerations should not be accepted.[10]

(a) Labeling Requirements

i. It shall be verified that the compressed gas cylinder is labeled and that the label contains the following information:

[8] The MSDS/SDS for the chemical product will provide guidance on appropriate PPE. The NIOSH Pocket Guide to Chemical Hazards provides guidance on the selection of proper respiratory protection. Personnel shall consult with OSHE prior to using respiratory protection.

[9] For the purposes of this section, the Storeroom, Logistics Group, Facilities Services Division, Office of Facilities and Property Management in Gaithersburg (hereafter referred to as "Storeroom") is not considered an external vendor.

[10] If a cylinder not meeting these considerations has been accepted, contact OSHE at x5375, Option 3.

(i) Product identifier; and

(ii) Words, pictures, symbols, or combination thereof, which provide at least general information regarding the hazards of the compressed gas, and which, in conjunction with the other information immediately available to employees and associates under NIST S 7101.59: *Chemical Hazard Communication*, will provide employees and associates with the specific information regarding the physical and health hazards of the compressed gas.

(b) Visual Inspection

i. It shall be verified that the compressed gas cylinder is free of visible signs of damage, *e.g.*, cuts, digs, gouges, dents, bulging, corrosion.

(c) Leak Testing

i. It is recommended that compressed gas cylinders containing toxic, highly toxic, corrosive, or flammable gases are leak tested using a hand-held direct-reading thermal conductivity meter (preferred method) or a liquid soap solution or commercially available liquid leak detection solution. If the cylinder cap does not have openings in it, it must be removed before performing the leak test.

(d) Valid Hydrostatic or Ultrasonic Test Date[11]

i. It shall be verified that the compressed gas cylinder has a valid hydrostatic or ultrasonic test date clearly indicated on the cylinder, typically stamped near the shoulder or into the valve guard ring welded to the cylinder, if present. This testing is performed by the vendor or supplier prior to refilling a cylinder.[12]

(i) Most cylinders require a hydrostatic or ultrasonic test every 5 years.

(ii) Certain steel cylinders require testing only once every 10 years. These can be recognized by the five-pointed star stamped after the test date.

[11] Contact OSHE at x5375, Option 3, with questions or concerns.

[12] A cylinder may remain onsite, either in use or in storage, beyond its retest date. Retesting is only required when a cylinder is refilled and then transported in public. Retesting is also appropriate any time a cylinder had been damaged or potentially weakened, such as by being in a fire. [See DOT regulation 49 CFR 180.205(c)].

(3) Transport of Compressed Gas Cylinders

(a) Gas cylinders shall not be dragged, rolled on their sides, slid, or allowed to strike each other forcefully. Cylinders may be moved short distances (5-10 ft) by rolling them on their bottom edges.

(b) When lifting a cylinder with a crane, hoist, or derrick, an appropriate lifting device, such as a cradle or net, shall be used. Cylinders shall not be lifted with magnets or slings.

(c) Cylinders must never be lifted by their valve caps or valve guards.

(d) Cylinders transported by truck shall be fastened securely so that they will not fall or strike each other.

(e) Once delivered to the user, cylinders being moved more than a short distance (5-10 ft) shall only be transported in a cart or vehicle equipped to secure the cylinder in place.

i. Such carts or vehicles shall be inspected for defects prior to use.

ii. Cylinders weighing 11 Kg (25 lb) or less may be hand-carried.

(f) If a cylinder is to be transported in an elevator, the elevator should be unoccupied, and a sign stating, “Gas Cylinder in Transit, Do Not Ride”, or equivalent, should be attached to the gas cylinder cart or the interior of the elevator. An example is shown in Figure 3. Once the gas cylinder has been placed in the elevator and the desired floor selected, the gas cylinder should be met at the selected floor.

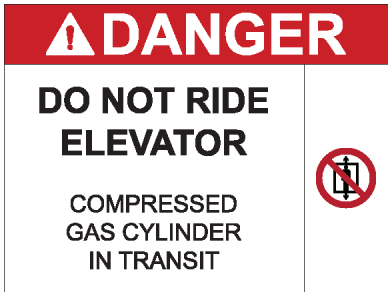

Figure 3: Sign for Transporting Compressed Gas Cylinder in Elevator

i. Special care should be taken in moving compressed gas cylinders onto and off elevators with regard to both the elevator threshold and the opening and closing of the elevator doors.

ii. No one not actually engaged in transporting a compressed gas cylinder on an elevator shall be permitted in the elevator while a cylinder is in transit.

(g) Cylinders shall only be moved or transported with the regulator removed and the valve protection cap properly secured.

i. It is acceptable to move or relocate a cylinder within an individual laboratory space (*i.e.*, a single room) without removing the regulator provided the cylinder is secured and transported on a stable cart.

(4) Storage of Compressed Gas Cylinders

(a) Gas cylinders shall be stored only in indoor and outdoor storage areas that have been determined by a hazard assessment to meet the requirements of applicable regulations, codes, and standards, especially NFPA 45 and 55.[13]

i. Gas cylinders shall not be stored in laboratories [see Section 6b(5)(c), Maximum Number of Cylinders in Use].[14]

(b) Gas cylinders shall be stored in such areas in accordance with the requirements of applicable regulations, codes, and standards, especially NFPA 45 and 55.

(c) Cylinders shall not be stored in the delivery cages at Building 1 in Boulder. All cylinders shall be moved out of these cages as soon as possible after the person that ordered them is notified of their arrival, preferably that same day. Cylinders shall never stay in a cage for more than two days.

(d) Cylinders Stored in Building Loading Docks in Gaithersburg[15]

[13] For assistance in establishing new indoor or outdoor storage areas, or of modifying existing storage areas, contact OSHE at x5375, Option 3.

[14] A request for variance (RFV) may be submitted to the NIST AHJ by a Division Chief (or equivalent) detailing the programmatic need for storing gas cylinders in a laboratory. The NIST AHJ will evaluate the request from a safety and regulatory compliance standpoint and either approve or disapprove it. The NIST AHJ will document its evaluation and provide it to the requesting Division Chief. If the request is approved, the NIST AHJ's evaluation must be appended to appropriate hazard review(s).

[15] A request for waiver (RFW) may be submitted to the Chief Safety Officer by a Division Chief (or equivalent) detailing the programmatic need for exceeding the storage timeframes. In this case, the Storeroom in Gaithersburg

i. Cylinders of normally-stocked gases may be stored in building loading docks for no more than 30 days.

ii. Cylinders of non-stocked (special order) gases may be stored in building loading docks for no more than 90 days.

(e) Cylinders containing liquified flammable gases and flammable gases in solution shall be positioned in the upright position.

i. Cylinders with a water capacity of 5 liters (1.3 gallons) or less shall be permitted to be stored in a horizontal position.

ii. Cylinders designed for use in a horizontal position shall be permitted to be stored in a horizontal position.

(f) Cylinders of flammable gases shall not be stored near highly flammable solids or liquids such as oil, gasoline, flammable solvents, or near combustible waste material, or similar substances. Cylinders of flammable gases, including small cylinders such as lecture bottles, shall not be stored in flammable storage cabinets if flammable or combustible solids or liquids are also present in the cabinet.

(5) Handling and Use of Compressed Gas Cylinders

(a) General Requirements

i. Cylinders shall be secured at all times to prevent them from falling or being knocked over by securing them to a gas cylinder cart, framework, or fixed object by use of a restraint. Restraints shall be used in such a way that they secure each cylinder individually.[16]

(i) Restraints designed for the purpose of restraining cylinders should be used.

(ii) In locations with large numbers of compressed gas cylinders, nesting using a contiguous 3-point contact system may be utilized. For more

and the OU responsible for managing the loading-dock storage area [see Section 9.a(2)] will be included in the safety evaluation of the request.

[16] The best practice for larger cylinders (e.g., 55 inches tall) is to apply one restraint one third of the way up the cylinder and a second restraint two thirds of the way up the cylinder. If only one restraint is available, it should be applied between one half and two thirds of the way up the cylinder.

information, refer to the definition of "nesting" in Section 7 and Appendix A of CGA P-1.

ii. Cylinders containing liquified flammable gases and flammable gases in solution shall be used in the upright position unless they are specifically designed for use in a horizontal position.

iii. Compressed gas cylinders, containers, and tanks shall not be placed where they could become a part of an electrical circuit.

iv. Compressed gas cylinders containing toxic, highly toxic, corrosive, or flammable gases should be leak tested before being put into service using a hand-held direct-reading thermal conductivity meter (preferred method) or a liquid soap solution or commercially available liquid leak detection solution. If the cylinder cap does not have openings in it, it must be removed before performing the leak test.

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

vi. Heating, where provided, shall be by indirect means. Equipment used for heating applications in rooms or areas where flammable gases are stored or used shall be listed and labeled for use in hazardous environments established by the gases present and shall be installed in accordance with the conditions of the listing and the manufacturer's installation instructions.

vii. When not in service, regulators shall be removed and valve protection caps that are not integrated into the cylinder design (and hence technically never removed) properly secured.

viii. One oxygen cylinder and one fuel gas cylinder may be located side-by-side on the same cart for welding and cutting, as long as they are in use or connected for use. When not in use or connected for use, the cylinders must be capped, removed from the cart, and placed in properly segregated storage areas, unless the cart is equipped with a five foot high, half hour rated fire wall located between the two cylinders, in which case the cylinders may remain on the cart even when not in use or connected for use.

ix. Cylinders, even when partially empty, shall never be heated by any device that could raise the surface temperature of the cylinder to above 52° C (125° F).

x. Cylinders should not be emptied to pressures lower than 172 kPa (25 psig) when such pressures could result in contaminants back-flowing into the cylinders and carrying over to when the cylinders are refilled and reused.

xi. Refilling or transfilling of cylinders shall be performed only by personnel who:

(i) Are properly trained and/or qualified to refill or transfill cylinders;

(ii) Have the proper equipment to refill or transfill cylinders;

(iii) Have approved hazard reviews and written operating procedures for refilling or transfilling cylinders; and

(iv) Are familiar with the precautions necessary to avoid the hazards of the product being handled.

xii. If a cylinder is connected to a closed system where there is a possibility of flow reversal, the cylinder shall be shut off and removed from the system while the pressure remaining in the cylinder is still greater than the pressure in the closed system.

(b) Valves and Regulators

i. Cylinder pressure shall be reduced through a regulator mounted to the cylinder-valve outlet or through a manifold.

ii. The cylinder valve shall be closed as soon as the necessary amount of gas has been released. The cylinder valve shall never be left open when the equipment is not in use, including when the cylinder is empty.

iii. The cylinder valve, not the regulator, shall be used for turning gas off when the cylinder is not in use.

iv. Only standard combinations of valves and fittings, as specified in CGA Standard V-1, or equivalent DIN or ISO standards, shall be used.

v. Cylinders that are opened with a valve spindle or stem instead of a hand-wheel shall have a spindle key on the spindle while the cylinder is in service.

vi. If tools are required to open cylinder caps or valves, only wrenches or tools specified by the manufacturer or supplier shall be used; tools shall not be used that could damage the cylinder, cylinder cap, or valve, or result in the valve being unintentionally opened while the cap is in place.

vii. Screwdrivers shall never be used to pry off a stuck cap.

viii. Pliers shall never be used to open a cylinder valve.

(c) Maximum Number of Cylinders in a Laboratory or Work Area

i. Cylinders not "in use" shall not be stored in the laboratory unit[17].

ii. A compressed gas cylinder shall be considered to be "in use" if it is in compliance with one of the following:

(i) Connected through a regulator to deliver gas to a laboratory operation; or

(ii) Connected to a manifold being used to deliver gas to a laboratory operation; or

(iii) A single cylinder secured alongside the cylinder connected through a regulator to deliver gas to a laboratory operation as a reserve cylinder.

(iv) The restriction against keeping cylinders that are not "in use" in a laboratory may not apply to laboratories that handle only chemicals with a hazard rating of 0 or 1 for health, flammability, and instability, as defined in NFPA 704, or in situations where storing a cylinder in a laboratory does not create an additional hazard. See footnote 17 regarding requesting an exception.

iii. Quantities of compressed and liquefied gases in laboratories and work areas shall be in accordance with NFPA 55.[18]

(i) The number of lecture-bottles in use or reserve shall be limited to 25 per lab or work area.

[17] Variances are possible under certain circumstances to increase the maximum number of cylinders in a space. Please contact OSHE for assistance at x5375, option #3.

[18] For assistance in determining quantity limits, contact OSHE at x5375, Option 3

(6) Mechanically Ventilated Enclosures and Gas Cabinets

(a) Lecture bottle-sized cylinders of the following gases located in laboratories shall be kept in continuously mechanically ventilated hoods or other continuously mechanically ventilated enclosures:

i. All gases that have a NFPA 704 health hazard rating of 3 or 4;

ii. All gases that have a NFPA 704 health hazard rating of 2 without physiological warning properties such as odor or irritation; and

iii. Pyrophoric gases.

(b) Compressed gas cylinders that are larger than lecture bottles and contain the following gases shall be kept in approved continuously mechanically ventilated, sprinklered gas cabinets:

i. All gases that have a NFPA 704 health hazard rating of 3 or 4;

ii. All gases that have a NFPA 704 health hazard rating of 2 without physiological warning properties; and

iii. Pyrophoric gases.

(c) Gas cabinets shall be constructed in accordance with NFPA 55.

(d) Gas cabinets shall be tested before they are put into service for any of the following events to ensure that the velocity at the face of the access ports or windows, with the access port or window open, is at least 200 ft per minute (fpm) average, and at least 150 fpm at each single point of measurement:

i. Installation;

ii. Modification; or

iii. Repaired.

(e) Gas cabinets shall be tested annually to ensure they meet the criteria listed in Section 6.b(6)(d).

(f) Gas cabinets shall be used as follows:

i. Gas cabinets shall contain no more than three containers, cylinders, or tanks; and

ii. Incompatible gases shall be stored and used in separate gas cabinets.

(7) Disposition of Empty and No-Longer-Needed Compressed Gas Cylinders

(a) When a cylinder is emptied to a pressure of 172 kPa (25 psig), the following actions shall be taken:

i. The regulator shall be removed;

ii. If the cylinder is designed to take a valve cap, the valve cap shall be installed;

iii. The cylinder shall be marked as empty; and

iv. The cylinder shall be returned to the storage area for pickup.

(b) If the contents of a cylinder are unknown or appropriate DOT labeling is not present on the cylinder, the cylinder shall not be moved from the laboratory. OSHE shall be contacted to assist with the identification of the cylinder contents and to provide guidance on appropriate disposal procedures.

(c) Lecture bottles shall not be abandoned in building loading docks or other storage areas.

(d) Chemical Waste Pick-Up requests shall be submitted to OSHE for pick-up and disposal of empty and no-longer-needed lecture bottles.

c. Compressed Gas Vessel and System Design

(1) System Design

(a) All systems shall be designed and constructed in accordance with the references listed in Section 4 of this suborder.

(b) Supply, piping, valves, connections, *etc.*, must be placed in such a way that they can be inspected and will not release into an occupied area without sufficient ventilation to prevent an oxygen-deficient atmosphere.

(c) If reserve cylinders or back-up supplies are connected, the arrangement shall preclude discharge of reserve cylinders during normal operation of primary supply.

(d) Systems shall be designed to be free of cross-connections that could allow gas to pass from a section of the system where the gas is intended to be present to a section of the system where the gas is not intended to be present.

(e) Tubing

i. Sharp tube bends shall be avoided. Tubing shall not be bent more sharply than recommended by the manufacturer.

ii. Flexible or plastic tubing shall only be used within "line of sight."

iii. Flexible tubing lengths shall be kept as short as possible, shall be protected from mechanical damage, and shall be anchored at the ends to prevent whipping in case of tubing or tube-fitting failure.

iv. Flexible tubing connections shall be secured with clamps approved for the maximum allowable pressure subjected to the connection. Flexible tubing connections shall not be secured with wire.

(f) Valves

i. The number and placement of valves shall be sufficient to facilitate maintenance, and to isolate systems for renovation and in case of emergency.

ii. Continuous access to valves located above ceilings, in utility rooms, or behind equipment shall be maintained.

iii. Valves shall be provided on each line running from a supply line to equipment so the equipment can be isolated for maintenance, repair, or replacement.

iv. Where fuel gas is permitted, a shut-off valve shall be provided immediately adjacent to the safety cabinet or hood or other location where the gas is used.

v. On liquefied-gas systems, all terminal-block (liquid-withdrawal) valves shall:

(i) Be rated above the vapor pressure of the liquid gas at 38 degrees Celsius (°C) (100 degrees Fahrenheit (°F)); or

(ii) Have properly set relief valves permanently installed on the outlet side of each terminal-block valve.

(g) Gauges

i. Gauges subject to pressure surges or cyclic pulses shall be protected by installing a needle valve or orifice for damping.

ii. When large pressure gauges (over 100 mm in face diameter) are used on gas systems with operating pressures over 1.4 MPa (200 psig) or on liquid systems over 140 MPa (20,000 psig), they shall have a special safety-type design including:

(i) Shatterproof faces;

(ii) Solid fronts; and

(iii) Blowout or generously vented cases.

If a large pressure gauge is used that does not have a special safety-type design, operators must be protected by a Lexan safety shield that is securely mounted over the existing gauge face, or the equivalent.

(h) Flammable Gas-Specific Requirements

i. Systems using flammable gases shall be designed to prevent a release in concentrations that are within flammable limits.

(i) Intentional release of any flammable gas indoors, even outside of flammable limits, must have prior approval of the NIST Authority Having Jurisdiction (AHJ). Please contact OSHE to request this approval.

ii. When using flammable gas-air mixtures, a flame arrester shall be utilized to prevent flashback.

iii. When using a flammable gas in the absence of an oxidizer, a flame arrester shall be required if a risk of flashback exists e.g. where air could infiltrate via a leak in a closed system

iv. Backflow prevention or check valves shall be provided where the backflow of a gas could create a hazardous condition, e.g. backflow of air into a closed system via a purge line.

v. Electrical and electronic equipment and wiring that is to be used in gas systems or locations where fire or explosion hazards may exist due to flammable gases must be approved for that use.

(i) The approval shall be from a nationally recognized testing laboratory such as Factory Mutual Insurance Co. (FM Global) or Underwriter's Laboratory (UL).

(ii) The potential hazard shall be categorized by Class and Division in accordance with Occupational Safety and Health Administration (OSHA) regulation 29 CFR 1910.307 and NFPA 70, Article 500.

(a) Class I: Class I locations are those in which flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

(b) Class I, Division 1: A Class I, Division 1 location is a location (1) In which ignitible concentrations of flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors can exist under normal operating conditions.

(c) Class I, Division 2: A Class I, Division 2 location is a location (1) In which volatile flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems or in case of abnormal operation of equipment.

(2) Pipes, Tubing, and Component Materials

(a) Gas pipes, valves, fittings, regulators, and related components must be constructed of materials compatible with the gases to be contained and must be rated for the service. Stainless steel components are preferred in most systems. Where nonmetallic tubing is approved, additional controls may be required.

(b) Pipes and Tubing

i. Nonmetallic tubing shall not be used on flammable, toxic, and/or radioactive gas systems.

ii. Flexible tubing shall not be used for highly toxic gases.

(c) Fittings

i. Brass fittings shall be used with copper or brass tubing.

ii. Stainless-steel fittings shall be used with steel or stainless-steel tubing.

(3) Labeling of Gas Lines Emanating from Enclosures

(a) Each compressed gas line outside of the source gas cabinet or ventilated enclosure must be labeled:

i. At least every 6 m (20 ft) unless the gas line is shorter than 6 m (20 ft) and the gas line and gas source are in sight;

ii. At critical shutoff valves;

iii. At wall, floor, or ceiling penetrations; and

iv. As otherwise necessary to provide clear identification.

(b) Labels must be durable and display the gas name and direction of gas flow.

(c) Piping that may contain more than one type of gas at various times shall be marked to provide clear identification of that fact.

(4) System Testing

(a) Prior to operation, all newly constructed, newly installed, and remodeled compressed gas systems shall be tested per all applicable codes and standards as well as manufacturer specifications.

(b) Prior to operation, all lines and equipment shall be leak tested with an inert gas.

(5) Inspection and Repair

(a) Flexible tubing shall be inspected for aging, deterioration, and damage with a frequency in accordance with the manufacturer's recommendations.

(b) Any tubing showing leaks, burns, wear, or other defects shall be repaired or replaced immediately. The vessel or system shall not be used until the defective part is repaired or replaced.

(6) Deviations from the Requirements of Sections 6c(1)-(5)

(a) When requirements for specialized compressed gas vessels or systems make it impossible to comply with any of the provisions of Sections 6c(1)-(5), measures must be implemented to provide a level of protection equivalent that provided by these provisions.

(b) Any deviations from these provisions shall be identified as part of the applicable hazard review, and the alternative measures implemented documented therein.

(c) Alternative measures may include the following:

i. Ventilated enclosures;

ii. Gas detectors;

iii. Emergency off buttons;

iv. Emergency power;

v. Pneumatic shut-off valves;

vi. Smoke detectors;

vii. Fire sprinklers;

viii. Exhaust scrubbers;

ix. Flow restrictors; and

x. Ventilation alarms.

d. Hazardous Material Release

(1) In the case of an accidental or uncontrolled release, excluding a small amount that may be released during a cylinder exchange, of a hazardous compressed gas, the individual that discovers the release shall warn others in the immediate area, move to a safe location, and report the leak.

(a) In Boulder, the incident shall be reported by dialing 911 for Boulder Fire-Rescue and x7777 for NIST Police.

(b) In Gaithersburg, the incident shall be reported by dialing x2222 for NIST Emergency Services.

(c) Ignition sources in the vicinity of leaking flammable gas should be turned off if it is obvious that this can be done safely.

e. Training

(1) Training provided by OSHE on the Compressed Gas Safety Program and activity-specific training required by applicable hazard reviews shall be assigned and documented, and its completion by affected employees and associates recorded, in accordance with the requirements, roles, and responsibilities of NIST S 7101.23: *Safety Education and Training*. In particular:

(a) Employees and associates who are to engage in activities involving compressed gases shall complete:

i. The training provided by OSHE on the Compressed Gas Safety Program; and

ii. The activity-specific training, provided by their Organizational Units, required by applicable hazard reviews.

(b) The official first-level supervisors of employees and associates who are to engage in activities involving compressed gases shall complete the training provided by OSHE on the Compressed Gas Safety Program.

7. DEFINITIONS

a. Asphyxiant – A material capable of reducing oxygen in a person's body to dangerous levels, most commonly caused by displacing breathable air in an enclosed environment.

b. Ceiling Limit – An occupational exposure limit that should not be exceeded during any part of the working exposure. If instantaneous exposure levels cannot be determined, an average exposure over a 15-minute time period is generally used.

c. Compressed Gas – A material, or mixture of materials, that (1) is a gas at 20°C (68°F) or less at an absolute pressure of 101.325 kPa (14.696 psia) and (2) that has a boiling point of 20°C (68°F) or less at an absolute pressure of 101.325 kPa (14.7 psia) and that is liquefied, non-liquefied, or in solution, except those gases that have no other health or physical hazard properties are not considered to be compressed gases until the pressure in the packaging exceeds an absolute pressure of 280 kPa (40.6 psia) at 20°C (68°F).

d. Compressed Gas Cylinder (Cylinder) – A pressure vessel designed for pressures higher than 276 kPa (40 psia) and having a circular cross-section. It does not include a portable tank, multiunit tank car tank, cargo tank, or tank car.

e. Corrosive Gas – A gas that causes visible destruction of, or irreversible alterations in, materials or living tissue by chemical action at the site of contact.

f. Design Pressure – The maximum pressure at which a vessel or the weakest member of a pressure system has been designed to safely function at the normal operating temperature. Also the maximum setting of a pressure-relief device on a vessel or pressure system.

g. Exception – A condition for which a requirement does not apply because the condition falls outside of the scope or intent of the requirement.

h. Flammable Gas – Any substance that exists in the gaseous state at normal atmospheric temperature and pressure and is capable of being ignited and burned when mixed with the proper proportions of air, oxygen, or other oxidizers.

i. Highly Toxic Gas – A gas that can kill 50 percent of the test subjects (LC_{50}) with a concentration of less than or equal to 200 parts per million (ppm), a gas that has an ACGIH TLV or OSHA PEL of one ppm or less, or a gas designated as a "Poison A" by the DOT and

defined as a poisonous gas of such nature that a very small amount of the gas mixed with air is dangerous to life. Lists of LC_{50} values for toxic gases and vapors are available in ISO 10298. (An NFPA 704 Health Hazard rating of 4 is given to gases having an LC_{50} in air of less than or equal to 1000 ppm.)

j. Hydrostatic Test – A test of the strength and leak-resistance of a compressed gas cylinder by internal pressurization with a test liquid.

k. Immediately Dangerous to Life or Health (IDLH) – Defined by NIOSH as exposure to airborne contaminants that is "likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment."

l. Lecture Bottle – A small compressed gas cylinder up to a size of approximately 5 centimeters in diameter and 33 centimeters tall (2 in. x 13 in.).

m. Nesting – A method of securing flat-bottom cylinders upright in a tight mass using a contiguous three-point contact system whereby all cylinders within a group have a minimum of three points of contact with other cylinders, walls, or bracing (see CGA P-1, Appendix A).

n. Operating Pressure – The maximum pressure at which a vessel or pressure system is intended to be used under normal circumstances. This will generally be 5 percent to 25 percent lower than the design pressure for systems protected by a spring-loaded relief device and approximately 33 percent lower than the design pressure for systems protected by rupture-disk relief devices, depending on the fatigue life of the disc used, the temperature, and load pulsation.

o. Oxidizing Gas – A gas that can initiate or support combustion and can accelerate the combustion of other materials.

p. Oxygen-Deficient Atmosphere – An atmosphere containing less than 19.5 percent oxygen by volume.

q. Permissible Exposure Limit (PEL) –A legally enforceable occupational exposure limit established by OSHA that sets the maximum time-weighted average concentration of an air contaminant that workers may be exposed to over an 8-hour workday of a 40-hour workweek.

r. Pressure Relief Valve – A device designed to open at a predetermined pressure in order to prevent an unsafe rise of internal pressure in a pressure vessel or system.

s. Pyrophoric Gas – A chemical in a gaseous state that will ignite spontaneously in air at a temperature of 54.4°C (130°F) or below.

t. Regulator – A device that controls the release of gas from cylinders or other vessels.

u. Safety Data Sheet (SDS/MSDS) – A document produced by chemical manufacturers or importers in accordance with 29 CFR 1910.1200 to relay chemical, physical, and hazard information about specific substances.

v. Storage Area – A designated area, either indoors or outdoors, where cylinders that are not being used, loaded, or unloaded are stored safely for future use, and to which cylinders that are empty are returned for pickup.

w. Threshold Limit Value (TLV) – A recommended occupational exposure limit established by ACGIH, which is the time-weighted average of a contaminant to which nearly all workers may be repeatedly exposed day after day without adverse health effects.

x. Toxic Gas – A gas with an LC_{50} between 200 ppm to 2,000 ppm, or a gas that has an ACGIH TLV or OSHA PEL between 1 ppm to 50 ppm. Lists of LC_{50} values for toxic gases and vapors are available in ISO 10298. (An NFPA 704 Health Hazard rating of 3 is assigned to gases having LC_{50} air concentrations between 1,000 ppm to 3,000 ppm.)

y. Transfilling – Transfer of compressed gas from one container to another.

z. Variance – Authorization to have an alternative means of providing an equal or greater degree of safety (*i.e.*, equivalency) than that afforded by strict conformance to:

- NIST-adopted codes and standards overseen by the NIST AHJ; or
- NIST-specific requirements originating from AHJ interpretations and implementation of these same adopted codes and/or standards.

Variances do not exempt a requester from the requirement(s) and its intent.[19]

[19] The codes "establish the minimum requirements to provide a reasonable level of safety, public health and general welfare" to building occupants. The code allows for AHJ discretion in the interpretation of the code and implementation of "policies and procedures to clarify the application of its provisions." The code also allows for more stringent requirements to be implemented to meet the intent of the code and align with the needs of the occupants and occupancies. An individual requesting an equivalency from a more stringent NIST-specific requirement that originates from a general provision or minimum requirement in a code or standard must request a variance.

aa. Waiver – Authorization to have an alternative means of providing an equal or greater degree of safety (i.e. equivalency) than that afforded by strict conformance to the way NIST implements a NIST-specific requirement or regulatory requirement. Waivers do not exempt the requester from a regulatory requirement or NIST requirement, they simply permit a different means of compliance or implementation.[20]

8. ACRONYMS

a. ACGIH – American Conference of Governmental Industrial Hygienists

b. AHJ – Authority Having Jurisdiction

c. CFR – Code of Federal Regulations

d. CGA – Compressed Gas Association

e. CSO – Chief Safety Officer at NIST

f. DOT – Department of Transportation

g. IDLH – Immediately Dangerous to Life and Health

h. ISO – International Organization for Standardization

i. LC_{50} – Lethal Concentration 50 Percent

j. NFPA – National Fire Protection Association

k. NIOSH – National Institute of Occupational Safety and Health

l. OSHA – Occupational Safety and Health Administration

m. OSHE – NIST Office of Safety, Health, and Environment

n. PEL – Permissible Exposure Limit

[20] In some instances, the regulations task the employer with defining methods to implement requirements. For example, OSHA 1910.147(c)(5)(ii)(B) states that "Lockout and tagout devices shall be standardized within the facility in at least one of the following criteria: Color; shape; or size…" In this example, OSHA defers to the employer to establish a policy for lock color, shape, or size. If an individual wants to deviate from the requirements set forth by NIST regarding color, shape, or size of locks used for LOTO, they must request a waiver.

o. RFV – Request for Variance

p. RFW – Request for Waiver

q. TLV – Threshold Limit Value

9. RESPONSIBILITIES

a. OU Directors are responsible for:

(1) Ensuring that the requirements of Section 6 of this suborder are met in their OUs; and

(2) Determining which OU or division in an OU is responsible for managing gas cylinder storage areas shared by multiple OUs.[21]

b. Chief Safety Officer is responsible for:

(1) Approving or disapproving all appeals of requests for variance (RFV) denied by the NIST AHJ; and

(2) Approving or disapproving all requests for waiver (RFW).

c. Division Chiefs are responsible for:

(1) Submitting a RFV, RFW, and exception to the following requirements based on an evaluation of programmatic need:

(a) Section 6b(4)(a)i regarding the storage of compressed gas cylinders in laboratories;

(b) Section 6b(4)(d)i-ii regarding the storage of compressed gas cylinders in loading docks at NIST Gaithersburg, in consultation with the Storeroom; and

(c) Section 6b(5)(c)i regarding reserve cylinders being alongside cylinders in use.

d. NIST AHJ is responsible for:

(1) Making interpretations of the applicable codes/standards, deciding on the approval of equipment and materials, and granting the special permission contemplated in some of

[21] For example, this responsibility could be assigned to the OU that is the heaviest user of gas cylinders in a particular storage area, or to a division in that OU.

the rules, i.e., allowing deviation from specific requirements in the codes/standards or permitting alternative methods where it is assured that equivalent objectives can be achieved by establishing and maintaining effective safety; and

(2) Approving or disapproving RFVs.

e. Storeroom Supervisor is responsible for:

(1) Ensuring that compressed cylinders delivered to the Storeroom by outside vendors are inspected in accordance with the requirements of Section 6b(2) on point-of-delivery inspection of compressed gas cylinders;

(2) Delivering full compressed gas cylinders to building loading docks per customer orders;

(3) Not delivering compressed gas cylinders to building loading docks when storage rack areas are unavailable to secure the cylinders safely;

(4) Ensuring that cylinders of normally-stocked gases stored in building loading docks for more than 30 days are returned to the storeroom;

(5) Ensuring that cylinders of non-stocked (special order) gases stored in building loading docks for more than 90 days are returned to the storeroom and then to the supplier; and

(6) Consulting with the NIST AHJ on the approval or disapproval of variances to the requirements of Section 6b(4)(c)i-ii regarding the storage of compressed gas cylinders in loading docks at NIST Gaithersburg.

10. AUTHORITIES

There are no authorities specific to this suborder.

11. DIRECTIVE OWNER

Chief Safety Officer

12. APPENDICES

a. Revision History

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Appendix A. Revision History

Revision	Date	Effective Date	Description of Change

None	05/27/15	04/01/2016	None – initial document.
1	11/23/2020	TBD	• Changed document dates to match current format. • Corrected typo in section 3.b. • Allowed transporting cylinders on cart with regulator attached within a room • Forbid storing flammable gas cylinders with other flammable materials • Added wording describing when oxygen and fuel gas cylinders could be together on a welding cart • Revised wording about "in use" cylinders to more closely match NFPA 45 and address exceptions • Added requirement to test new gas cabinets • Added requirements for releasing flammable gases indoors • Revised requirements for flame arresters and backflow prevention • Added requirement that electrical equipment be approved for hazardous locations • Added requirement for requesting variances and waivers • Added definitions for variance, waiver, and exception. • Modified Responsibilities Section to include responsibilities for requesting and approving variances and waivers
2	07/09/2021	TBD	Footnote 17 modified to indicate variance and not exception is possible
3	02/14/2022	06/30/2023	Administrative Revision/Correction: Reference to footnote in clause 6.b.(5)(c)ii(iv) corrected from footnote 12 to footnote 17. • NOTE: Effective date was originally TBD due to the COVID-19 pandemic. It was updated on 4/17/23.

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