Chapter 6.13
Safety and Health Requirements for Ground-Based Breathing Gases and Breathing Gas Systems

1. Applicability of this chapter

You are required to follow this chapter if you design, build, operate, oversee, maintain, or modify a ground-based breathing gas system.

2. Definition of a breathing gas systems

A breathing gas includes breathing air (CGA-G7.1), breathing oxygen (MIL-PRF-27210G), oxygen-enriched breathing air such as nitrox or heliox (NASA SD-B-0023-A), and any other breathing gas approved as required by this chapter for human breathing. A breathing gas system is a hardware assembly that provides a breathing gas to a human. The breathing gas system may contain gas and liquid pumps, gas compressors, piping, filters, analysis equipment, tanks and pressure vessels, regulators, valves and safety devices, connectors, soft-goods, lubricants, heating, cooling and mixing equipment, gauges, and other hardware.

3. Surface cleanliness requirements for breathing gas systems

To ensure surface cleanliness in breathing gas systems, you shall:

a. Clean breathing gas systems to national consensus standards. Paragraph 12 references several of these national consensus standards. The cleanliness level shall be determined by the user organization and an appropriate oxygen hazards review organization, committee, or similar recognized oxygen system design expert.

b. Have an operational readiness inspection (ORI), use readiness review (URR), or TRR approve the determined breathing gas cleanliness level(s) before use.

c. Clean soft good components, such as neoprene rubber hoses used at or below 0.689 MPa (100 psig) and other nonmetallic materials, to Level 100 or 300 per JPR 5322.1, “Contamination Control Program Requirements Manual.” There is no nonvolatile residue (NVR) requirement for soft goods. More stringent cleanliness levels may be required for breathing gas systems depending upon the system hazard assessment and cleanliness requirements for flight hardware attached to these systems.

d. During normal and routine operations, install and monitor inlet filters and other in-line filters as required by design and operation to maintain system cleanliness. Maintain system cleanliness during nonroutine operations such as unscheduled maintenance, system modifications, and repairs. To maintain system surface cleanliness, you shall establish the following protocols:

    1. Wear approved gloves when internal surfaces are exposed.

2. Take care to minimize exposure time to maintain both the particulate and NVR cleanliness levels.
3. Use only approved clean materials, protective films, and caps or plugs.
4. Use only approved lubricants, soft goods, sealants, valve seats, and alloys. Apply lubricants sparingly.
5. Use only approved wipes and solvents.

e. Establish a process to verify, periodically, cleanliness to ensure that surface cleanliness is maintained for the life of the system. The user organization shall:

1. Maintain the surface cleanliness level and document procedures for periodically evaluating system cleanliness. The procedures must determine and establish the frequency of these evaluations as necessary.
2. Do this evaluation, including particulate matter determination and NVR, or other suitable film or non-particulate matter determination, such as total organic carbon, as is agreed necessary.

4. Breathing gas chemical purity requirements

To establish and maintain the breathing gas chemical purity, also referred to as the breathing gas chemical composition or breathing gas specification, you shall follow these requirements:

a. A JSC medical doctor shall approve the breathing gas purity requirements for breathing gas systems.

b. Breathing gases prepared by mixing or blending shall have established written procedures and sampling methods to assure breathing gas purity and homogeneity.

c. Analyze and approve all JSC supply breathing gases to meet the breathing gas chemical purity requirements before the breathing gas is inhaled or used. The table below lists minimum sampling requirements to establish gas purity. The following source testing requirements are intended to ensure that all gases used for breathing on site at JSC are analyzed by JSC-approved personnel and meet the gas purity requirements before breathing the gas.

For . . .	***You shall . . .***
Large compressed gas bottles (compressed gas cylinders containing ≥ 4247.53 liters (150 ft^3) of gas at maximum allowable operating pressure (MAWP), also commonly referred to as K-Bottles)	Test all large compressed gas bottles used for breathing before use on site at JSC individually as approved by the Space Medicine Division, SD, and inspected and certified as approved by the Safety and Test Operations Division, NS.

For . . .	*You shall . . .*
Small compressed gas bottles (compressed gas cylinders containing < 4247.53 liters (150 ft^3) of gas at MAWP, commonly referred to as SCUBA cylinders, SCBA cylinders, small emergency cylinders, etc.)	Due to their small size, as a minimum all SCBAs and small emergency breathing gas bottles shall have either the gas fill source analyzed as approved by the Space Medicine Division (SD) and the Safety and Test Operations Division (NS) before use, or each individual bottle may be tested similarly to the large compressed gas bottle requirement listed above.
Cryogenic-supplied aviator's breathing oxygen (ABO)	A member of the Safety and Test Operations Division (NS) or a delegate of the U.S. government, as approved by NS, shall inspect all cryogenic-supplied ABO.
Compressed air systems	All on-site compressed air systems gas purity requirements shall be approved by the Space Medicine Division (SD) and the Safety and Test Operations Division (NS) prior to operations. Normally, as a minimum, a fail-safe, in-line calibrated carbon monoxide system is required that complies with 29 CFR 1910.134.

5. Labeling and certification

For proper labeling and certification of pressure systems, you shall:

a. Identify use-point outlets by displaying a sign, tag, or label that reads "Compressed Gas for Breathing Purposes" or a similar statement that clearly indicates the contents of the breathing gas.

b. Have new breathing gas systems certified. Breathing gas systems that have been modified in design, have undergone a major maintenance overhaul, or have been contaminated and subsequently decontaminated and re-cleaned shall be recertified. Certification or recertification is required before the breathing gas systems may be used.

c. Operate breathing gas systems to be certified or recertified without breathing the gas, and take a gas purity sample once after 24 hours and once following 48 hours. If the samples, when analyzed, meet the applicable specification, and if the user organization documents that the requirements of sections 9 and 10 are established, the breathing gas system is certified or recertified.

Note 1: Check new breathing gas systems initially for mercury contamination as specified in applicable medical and safety requirements. Mercury vapor concentrations shall not exceed 0.005 mg/m^3.

Note 2: Because of the difference in boil-off temperatures between LO_2 and LN_2, Lair systems require strict analysis sampling schedules to preclude a breathing system from becoming nitrogen rich.

6. General requirements

All breathing gas systems shall:

a. Meet the requirements found in other chapters of this handbook that apply. This includes Chapter 10.2, "Safety and health requirements for test, vacuum, or oxygen-enriched facilities," for breathing gas systems in test facilities or those using oxygen-enriched breathing gases.

b. Provide an environment in which a credible single-point failure, loss of or change in utilities, or loss of software command will not injure personnel or damage property.

c. Employ a "buddy system" to monitor the system for safe operations when breathing gases are used.

d. Provide emergency power and other necessary utilities for systems that, if lost, would endanger test personnel or property.

e. Meet the applicable requirements in the following documents:

- NPD 7100.8, "Protection of Human Research Subjects"
- JPD 8080.4, "Exposure to Reduced Atmospheric Pressures"
- National Fire Protection Association Standard 99B, "Standard for Hypobaric Facilities"
- ASTM course book, "Fire Hazards in Oxygen Systems"
- ASTM-MNL-36, "Manual for Safe Use of Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation"
- CGA P39ED1, "Oxygen-Rich Atmospheres"
- OSHA 29 CFR 1910.134, "Respiratory Protection"

7. Safety and quality assurance provisions for breathing gas systems

For safe operations that meet quality requirements, you shall:

a. Have a safety plan that addresses how you make sure your system operations are safe. The plan may be part of an overall facility plan. The Safety and Test Operations Division (NS) shall approve the plan.

b. Prepare and maintain system failure and hazard analyses as described in Chapter 2.4, "Hazard Analysis," of this handbook. This may be part of an overall facility hazard analysis. The hazard analysis shall address all hazards of the system hardware, support equipment, system software, and operations and how the hazards are controlled.

c. Document quality assurance tasks for the system in either the facility operating procedures or a quality assurance plan. Quality assurance tasks may include:

- Calibrating instruments.
- Making sure consumables in life support systems such as breathing air or water meet any standards that apply.
- Inspecting hardware and making sure operations meet requirements.

- Certifying pressure systems if pressurized breathing gases or blends are employed.

8. Operating procedures

For breathing gas systems, the user organization shall develop, document, and approve procedures for system operation, maintenance, preventive maintenance, servicing, and sampling, if such procedures do not exist. The operating procedures shall:

a. Carry out the safety requirements of this chapter and of Chapter 6.9 of this handbook.

b. Outline the processes, ground rules, and personnel for system operation.

c. Outline the process to work with the Safety and Test Operations Division (NS).

The Space Medicine Division (SD) and the Safety and Test Operations Division (NS) approve procedures prepared for JSC on-site breathing gas systems.

9. Training for working with oxygen-enriched breathing gas systems

Your system needs written training and certification requirements for each position. You shall be trained in:

a. Your duties for normal operations and emergencies.

b. Hazards that you face and safety precautions that you need to take.

10. Emergency planning for breathing gas systems

You shall:

a. Have an emergency action plan as described in Chapter 3.8 “Emergency Preparedness,” of this handbook.

b. Conduct emergency drills at least twice a year under the emergency procedures to make sure the team can react to emergencies effectively. A representative of the Safety and Test Operations Division (NS) shall monitor and evaluate your emergency drills. Regular emergency drills are not required for inactive systems.

c. Ensure that all test team members have participated in an emergency drill within 3 months before the test if the system has been inactive.

11. References

You can find more information on breathing gases in:

a. CGA-G7.1, “Commodity Specification for Air”

b. MIL-PRF-27210G, “Oxygen, Aviator’s Breathing, Liquid and Gas”

c. NASA SD-B-0023-A, “Helium/Oxygen Breathing Mixtures”

d. JPR 5322.1, “Contamination Control Requirements Manual”

e. JPR 1710.13, “Design, Inspection, and Certification of Pressure Vessels and Pressurized Systems”

f. NASA-STD-6001, “Flammability, Odor, Off-Gassing and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion”

g. NASA MSC-SP-40M39580B, “Connectors, Electrical, Zero-G, Specifications”

h. NPD 7100.8, “Protection of Human Research Subjects”

i. JPD 8080.4, “Exposure to Reduced Atmospheric Pressures”

j. ASTM Committee G4.05, “Fire Hazards in Oxygen Systems”

k. ASTM-MNL-36, “Manual for Safe Use of Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation”

l. CGA-P39ED1, “Oxygen-Rich Atmospheres”

m. 29 CFR 1910.134, “Respiratory Protection”

n. ASTM-G93-96, “Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen Enriched Environments”

o. IEST-STD-CC1246D, “ Product Cleanliness Levels and Contamination Control Program”

p. MIL-STD-1330, “Standard Practice for Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen and Hydrogen Systems”

q. CGA-G4.4, “Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems”