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SAFE INSTALLATION AND OPERATION OF PSA AND MEMBRANE OXYGEN AND NITROGEN GENERATORS

FOURTH EDITION

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PREFACE

As part of a program of harmonization of industry standards, the Compressed Gas Association (CGA) has published CGA P-8.1, *Safe Installation and Operation of PSA and Membrane Oxygen and Nitrogen Generators*, jointly produced by members of the International Harmonization Council.

This publication is intended as an international harmonized standard for the worldwide use and application of all members of the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Each association's technical content is identical, except for regional regulatory requirements and minor changes in formatting and spelling.

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NOTE—Technical changes from the previous edition are underlined.

NOTE—No technical information has been changed from the 2016 edition. This reaffirmed edition may include minor editorial changes.

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1 Introduction

Oxygen and nitrogen generators that use pressure swing adsorption (PSA) and membrane technologies, like many present-day processes, have some degree of potential hazards that must be recognized and addressed. Common hazards associated with these generators are the asphyxiant properties of oxygen-deficient atmospheres and the ability of oxygen-enriched atmospheres to accelerate combustion. Other hazards include noise, electricity, rotating equipment, and gases under pressure.

Oxygen and nitrogen generator technology is not static. Because a wide variety of plant process cycles, equipment, and operating conditions are in use, this publication includes some generalized statements and recommendations with which there may be diversity of opinion or practice. Users of this publication should recognize that it is presented with the understanding that it cannot take the place of sound engineering judgment, training, and experience. It does not constitute, and should not be construed to be, a code of rules or regulations.

2 Scope and purpose

2.1 Scope

This publication is a guide that applies to safety in the location, installation, operation, and maintenance of certain oxygen and nitrogen generators. Included are systems using PSA and membranes for nitrogen production, PSA and vacuum swing adsorption (VSA) for oxygen production, and catalyst-based oxygen removal systems for nitrogen purification. For systems using cryogenic technologies for the production of nitrogen, oxygen, or both, see CGA P-8, *Safe Practices Guide for Cryogenic Air Separation Plants* [1].¹

Emphasis has been placed on equipment and operational features that are unique to these system processes. Limited coverage has been given to plant equipment such as air compressors used in other industrial applications and for which safe practices in design, installation, and use have already been established elsewhere. While important supplemental equipment such as in-plant transfer piping is included, liquid backup for pipelines and cylinder filling facilities that are an adjunct to some oxygen and nitrogen generators are not covered. Also, coverage is not extended to equipment such as product transmission piping outside the generator boundaries.

While many references have been cited in this publication that give information relating to air separation plants, related equipment, and their products, the reference section is not intended to be all inclusive. Not all federal, state, provincial, territorial, or local requirements, regulations, and ordinances are listed. Further, as this publication is not intended as a universal safe practices manual for specific design and safety features, it is important to refer to the operating manuals of the equipment supplier.

2.2 Purpose

This publication is intended to serve the interest of all who may be associated with oxygen and nitrogen generator installation and operations.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Asphyxiation

To become unconscious or die from a lack of oxygen.

3.2.2 Cryogenic liquid

Refrigerated liquefied gas having a boiling point colder than -130°F (-90°C) at atmospheric pressure.

NOTE—Oxygen, nitrogen, and hydrogen can be supplied in cryogenic liquid form.

3.2.3 Deoxo system

Catalytic-based system used with nitrogen generators to achieve a lower oxygen level than typically can be produced solely by the generator.

3.2.4 Double block and bleed

Piping/valving system used when two or more systems or parts of a system are required to be completely isolated from each other.

NOTE—It generally consists of two line-size blocking valves and a small bleed valve located between the blocking valves. The bleed valve vents any leakage from either blocking valve. When isolation is required, the blocking valves are closed and the bleed valve is opened.

3.2.5 Fail-safe

When a failure of a component of the system occurs, the resulting situation does not present a safety concern.

NOTE—One example is an isolation valve closing when the generator air or power supply fails.

3.2.6 Hot repairs

Use of a tool of high heat, for example a torch, that can be a safety hazard by itself; repairs made to a device that is in operation; or repairs made in a hazardous area when special safety precautions are necessary before, during, and after the work is performed.

NOTE—All hot repairs require care, safety supervision, and clear procedures. Use of a checklist or safety permit is recommended.

3.2.7 Locked out

Condition where a device cannot be operated without a willful, conscious action to do so.

NOTE—An example is when the electricity is turned off and cannot be regained without removing a protective device such as a padlock from the actuating device. Another example is a valve where the handle is removed and stored securely until such time it is safe to operate the valve.

3.2.8 Membrane

Polymer material that acts like a filter to separate components such as nitrogen from oxygen in air.

3.2.9 Oxygen-deficient atmosphere/Nitrogen-enriched atmosphere

Air in which the oxygen concentration by volume is less than 19.5%.

NOTE—Also known as nitrogen-rich atmosphere.

3.2.10 Oxygen-enriched atmosphere

Air in which the oxygen concentration by volume exceeds 23.5%.

NOTE—Also known as oxygen-rich atmosphere.

3.2.11 Pressure relief device (PRD)

Device designed to protect a vessel or piping from achieving pressures higher or lower (vacuum) than its design to avoid the failure of the pipe or vessel.

NOTE—Because these devices can have significant flow when activated, the discharge should be directed to a safe area.

3.2.12 Pressure swing adsorption (PSA)

Family of generators that separate one gas from another by passing a feed gas through a bed of adsorbent material at one pressure and cleaning the waste product off the adsorbent material at another pressure, hence the term pressure swing.

3.2.13 Safe area

Location where exhaust gases can be discharged safely causing no harm to personnel or property. A safe area is also a place where surrounding materials are compatible with the exhaust gas.

3.2.14 Safety data sheet (SDS)

Document that describes a material and its associated hazards.

NOTE—The government mandates that generator suppliers provide SDSs.

3.2.15 Safety permits

Procedural documents highlighting special safety considerations that are issued to allow work to commence in a specific location.

3.2.16 Vacuum swing adsorption (VSA)

Subset of the PSA family where one of the operating pressures is below atmospheric pressure (vacuum).

4 Health hazards**4.1 General**

The operation of either oxygen or nitrogen generators can subject personnel to oxygen-deficient (asphyxiating) or oxygen-enriched (increased fire risk) atmospheres. Precautions, a basic knowledge of the behavior of these gases, and wearing of personal protective equipment (PPE) can minimize exposure to these hazards. Refer to the generator supplier's safety data sheet (SDS) for specific information on materials handled in oxygen and nitrogen generators.

Oxygen and nitrogen generators have both oxygen-deficient and oxygen-enriched atmosphere hazards as product or venting waste gas. Unlike gas cylinders or liquid oxygen/nitrogen storage that contains finite quantities of oxygen and nitrogen, generators produce a continuous product stream of oxygen and nitrogen. Over time, this results in the significant accumulation of an oxygen-enriched or an oxygen-deficient atmosphere unless adequate ventilation is provided.

4.2 Cryogenic liquid hazards

In many cases, cryogenic liquid stored adjacent to the oxygen and nitrogen generators is used to back up or supplement the generator product supply. The handling of cryogenic liquid can cause unique hazards such as cryogenic burns, frostbite, and respiratory problems, see CGA P-12, *Safe Handling of Cryogenic Liquids*, for details [2].

4.3 Nitrogen hazards

Nitrogen acts as a simple asphyxiant and, if present in sufficient quantity, can reduce the oxygen in the local atmosphere *and can cause death*.

The normal oxygen concentration in air is approximately 21% by volume. Air containing less than 19.5% or more than 23.5% oxygen constitutes a hazardous working environment as defined by Title 29 of the U.S. *Code of Federal Regulations* (29 CFR) 1910.146 [3]. The depletion of the quantity of oxygen in a given volume of air by displacement with an inert gas is a potential hazard to personnel.

When the oxygen content of air is reduced to approximately 15% or 16%, the rate of burning of combustible materials decreases significantly. The flame of ordinary combustible materials including those commonly used as fuel for heat or light is extinguished. This can be the first indication of an oxygen-deficient hazard. Somewhat below this concentration, an individual breathing the atmosphere is mentally incapable of diagnosing the situation as the symptoms of sleepiness, fatigue, lassitude, loss of coordination, errors in judgment, and confusion are masked by a state of euphoria, giving the victim a false sense of security and wellbeing. See Table 1 for other typical symptoms of oxygen-deficient atmospheres.

WARNING: *Exposure to atmospheres containing 8% to 10% or less of oxygen will bring about unconsciousness without warning and so quickly that the individuals cannot help or protect themselves. Lack of sufficient oxygen can cause serious injury or death.*

Table 1—Effects at various oxygen breathing levels

Percent oxygen at sea level (atmospheric pressure = 14.7 psia [1.013 bara])	Effects
20.9	• Normal
19.0	• Some adverse physiological effects occur, but they are unnoticeable.
16.0	• Increased pulse and breathing rate • Impaired thinking and attention • Reduced coordination
14.0	• Abnormal fatigue upon exertion • Emotional upset • Faulty coordination • Poor judgment
12.5	• Very poor judgment and coordination • Impaired respiration that can cause permanent heart damage • Nausea and vomiting
<10.0	• Inability to perform various movements • Loss of consciousness • Convulsions • Death
NOTES 1 Humans vary considerably in their reaction to an oxygen-deficient atmosphere. It is, therefore, <i>not possible to predict exactly how people will react</i>. A general indication of what is liable to happen is given, but it should be understood that individual reactions may be different from those listed. 2 This table is adapted from <u>ANSI/ASSE Z88.2, Practices for Respiratory Protection</u> [4]. 3 These indications are for a healthy average person at rest. Factors such as individual health, for example, being a smoker, degree of physical exertion, and high altitudes can affect these symptoms and the oxygen levels at which they occur.	

Nitrogen produced in generators is often used in areas remote from the generator itself. Therefore, it is important to recognize that accumulation of nitrogen in these use areas can also result in an oxygen-deficient atmosphere. For example, if nitrogen is used for instrument gas, control room atmosphere should be monitored for oxygen content since all pneumatic controllers bleed a certain amount of instrument gas. Nitrogen instrument gas supply lines shall not be labeled as "AIR". A label such as INSTRUMENT GAS is recommended.

It is important to note that the waste gas from oxygen generators contains significantly less than 19.5% oxygen and without appropriate venting can create an oxygen-deficient atmosphere. Waste gas vents should be piped outside the building to safe areas.

CAUTION: *Be aware of the hazards of oxygen-deficient atmospheres.*

Prior to entering confined spaces, enclosed areas, or vessels, a risk assessment shall be completed and documented and all identified safeguards implemented.

Oxygen monitor sensors should be placed in positions most likely to experience an oxygen-deficient atmosphere, and the alarm should be clearly discernible at the point of personnel entry.

If an oxygen-deficient atmosphere is suspected or is known to exist by analysis, do not enter unless it is unavoidable and then only under the following conditions:

- Use the attendant system. Use more than one attendant if required to remove an authorized entrant in any emergency; and
- Provide both the authorized entrant and the attendant(s) with self-contained or air line breathing equipment.

See also CGA P-76, *Hazards of Oxygen-Deficient Atmospheres*, and 29 CFR 1910.146 [5, 3].

4.4 Oxygen hazards

Oxygen concentrations greater than 23.5% create greater fire hazards than normal air. Although it is not flammable, oxygen vigorously accelerates combustion of flammable materials. Materials that do not burn in air, including fire-resistant materials, can burn vigorously in an oxygen-enriched atmosphere. Although a source of ignition energy is always necessary in combination with flammable materials and oxygen, control or elimination of flammables is a precautionary step. Lubricating oils and other hydrocarbon materials can react violently with higher concentrations of oxygen, and the combination shall be avoided.

Personnel should not be exposed to an oxygen-enriched atmosphere because of increased risks of fire. As concentrations increase greater than 23.5% oxygen, ease of ignition of clothing increases dramatically. Once ignited by even a relatively weak ignition source such as a spark or cigarette, clothing can burst into flame and burn rapidly. At concentrations greater than approximately 60% oxygen, some clothing and body hair and oil are subject to flash fire that spreads rapidly over the entire exposed surface.

Oxygen generators are often operated inside closed buildings. Consequently, oxygen leakage can result in an oxygen-enriched atmosphere within the building. Areas where it is possible to have this condition shall be well ventilated. Oxygen vents should be piped outside of buildings or to a safe area. Where an oxygen-enriched atmosphere is possible, warning signs shall be posted and precautions shall be taken such as installation of analyzers with alarms, ensuring a minimum number of air changes per hour, implementing special entry procedures, or a combination of these.

Oxygen produced in generators is often used in areas remote from the generator itself. Therefore, it is important to recognize that accumulation of oxygen in these use areas can also result in an oxygen-enriched atmosphere.

It is important to note that the waste gas from nitrogen generators contains significantly greater than 23.5% oxygen and without appropriate venting can create an oxygen-enriched atmosphere. Waste gas should be vented outside the building or to a safe area.

CAUTION: *Be aware of the hazards of oxygen-enriched atmospheres.*

Persons who have been exposed to an oxygen-rich atmosphere should not smoke, use electrical or battery-operated devices, or go near hot spots or sparks until they have changed clothing or properly ventilated their clothes in a normal atmosphere. A ventilation period of not less than 15 minutes with movement of the arms and legs and with coats removed is recommended.

4.5 Protective clothing

Protective clothing and special equipment can serve to reduce fire hazards when working with oxygen, but prevention of the hazard should be the primary objective.

Clothing should have minimum nap. Nap is the raised surface on certain kinds of cloth including, but not limited to, velvet or felt. A number of flame retardant materials are available for work clothing such as NOMEX[®], but they can burn in high-oxygen atmospheres. There is some advantage in these materials as most of them would be self-extinguishing when removed to normal air atmospheres. All clothing should be clean and oil-free. No means of ignition should be carried. Footwear should not have nails or exposed metallic protectors that could cause sparking.

5 General plant considerations

5.1 Site selection

Oxygen and nitrogen generator site selection should begin with a safety evaluation of the proposed location. Frequently, oxygen and nitrogen generators are located in or near other industrial/commercial areas. In all cases, the installation should conform to applicable industrial standards and shall conform to local, state, provincial/territorial, or federal regulations such as the U.S. Occupational Safety and Health Administration (OSHA).

Since air is the raw material for these systems, its quality (type and degree of contamination with foreign materials such as hydrocarbons, acid gases, and particulate matter) is a major concern in selecting a site. Trace quantities of contaminants in the compressed air, particularly oil, heavy hydrocarbons, and acid gases have a direct relationship to the safe operation and performance of oxygen and nitrogen generators. In an industrial/commercial area, some degree of contamination from industrial operations, chemical operations, or both should be expected. In general, the air compressor suction should not be near oxygen or hydrocarbon vent lines. Consult with the generator supplier to determine the acceptable levels of air contamination considered in the equipment design.

Site surveys should be made over a significant area around a proposed location. Attention should be given to the potential future development of the site in addition to the current use. Depending on the surroundings, it may be necessary to investigate sources of air contamination. If the evaluation of atmospheric conditions at the site is deemed unfavorable from a study of air contamination sources such as storage of other chemicals and wind data, then other sites should be considered if adaptive engineering modifications to the plant are not practical. If the investigation does not yield definitive results, more quantitative information should be obtained by monitoring the components in the air at the plant site over an extended period.

Potential fire or explosion hazards from nearby chemical storage or neighboring industrial facilities should be investigated.

Sufficient space should be made available around the generator to allow for safe equipment maintenance and personnel traffic.

With oxygen and nitrogen generators, it is common practice to house the entire generator, or many of the key components, inside existing or new buildings. Storage of combustible materials should be avoided in buildings housing oxygen and nitrogen generators.

Personnel protection such as guard rails, platform gates, and ladder enclosures should be provided to prevent falls from elevated locations.

The generator location should be selected so atmospheric oxygen content between 19.5% and 23.5% exists in all areas frequented by personnel while performing operational and maintenance activities. Consideration shall be given to the location of vents (see 5.8). Additionally, rotating equipment should not be exposed to oxygen-enriched atmospheres since it may have oil-lubricated parts.

Consideration should be given in building ventilation design to accommodate possible accumulation of product or waste gases. Adequate ventilation shall be provided to prevent localized oxygen-deficient or oxygen-rich atmospheres. As a guideline, the building should have a minimum of six air changes per hour.

The location of the oxygen compression equipment (if installed) should be given special consideration for the safety of operating and maintenance personnel. Generally, this equipment and its associated piping should be as isolated as the layout permits to minimize personnel exposure and damage to nearby equipment in case of an incident. This equipment should be readily accessible for maintenance yet removed from the main personnel traffic pattern as far as possible, see CGA G-4.6, *Oxygen Compressor Installation and Operation Guide* [6].

Oxygen compressor fires typically produce high velocity oxygen jets containing molten-metal and metal oxides. Protective barriers should be used to isolate oxygen compression equipment to protect personnel and other equipment in case of a fire, see CGA G-4.6 [6].

Requirements for emergency situations should be anticipated. Emergency lighting, emergency trip stations, safe multiple exit routes, fire protection, alarm systems, and equipment isolation valves are examples of safety features that should be considered for emergency situations.

Other general installation safety items that should be considered are the relative locations of adjacent equipment such as containers of flammable materials (for example, oil), starting panels for oxygen compressors, oxygen gas meters, PRDs, liquid back-up systems, and automatic and manual control valves. Discuss all these issues with the equipment supplier(s).

5.2 Materials of construction

Because the oxygen and nitrogen generators discussed in this publication operate at or about ambient temperature, carbon steel, copper, or both generally are used for interconnecting process piping, vessels, and pipelines. Where ambient conditions fall below -20°F (-29°C), precautions are necessary for the operation of carbon steel vessels and piping. Further, in cases when moisture is present, stainless steel or some other equally suitable metal should be considered. Due to the possibility of causing ignition by the impingement of high velocity particles, oxygen-enriched gas velocity should also be considered in the selection of materials [7]. Discuss all these issues with the generator supplier.

Nonmetallic materials such as gaskets, valve packing, insulation, and lubricants shall be carefully checked to determine if they can be used for a particular application. All factors associated with their use such as temperature, pressure, and oxygen compatibility shall be considered in deciding if a material can be used without decreasing the safety integrity of an oxygen system.

Most nonmetallic materials react with oxygen, some more than others. Since the ignition temperatures are relatively low for nonmetallic materials, consult a qualified engineering source or the equipment supplier before using these materials. The vendor supplying the material may also be contacted for pertinent information.

5.3 Cleaning

An improperly cleaned and dried line in oxygen-enriched service is a hazardous condition. Under certain flow conditions, combustibles can be ignited by the impingement of particulates on metal.

All materials for use in or interconnected with systems should be cleaned before the system is put into service. Mill scale, rust, dirt, weld slag, oils, greases, and other organic materials shall be removed. Fabrication and repair procedures should be controlled to minimize the presence of such contaminants and thereby simplify final cleaning procedures. See CGA G-4.1, *Cleaning Equipment for Oxygen Service* [8]. It is recommended that vendors responsible for cleaning for oxygen service be formally qualified to ensure appropriate procedures, handling, and packaging are used.

5.4 Electrical requirements

Oxygen and nitrogen generators are not considered hazardous for electrical equipment as defined by Article 500 of NFPA 70, *National Electrical Code*®, or CSA C22.1, *Canadian Electrical Code, Part I, Safety Standard for Electrical Installations* [7, 9]. Therefore, unless the generator is located in a classified area, general purpose or weatherproof types of electrical wiring and equipment are acceptable depending on whether the location