13.12 Program Evaluation.

13.12.1* Periodic drills shall be conducted at various times and locations.

13.12.2 The drills shall be critiqued for plan effectiveness and to identify opportunities for improvement.

13.12.3 Identified opportunities for improvement shall be incorporated into the security plan.

13.12.4 The security plan shall be evaluated at least annually.

13.12.5 The evaluation of the security management plan shall include a review of laws, regulations, and standards applicable to the security program.

Chapter 14 Hyperbaric Facilities

14.1* Scope. The scope of this chapter shall be as specified in 1.1.12.

14.1.1 Applicability.

14.1.1.1 This chapter shall apply to new facilities.

Δ **14.1.1.2** The following sections of this chapter shall apply to both new and existing facilities:

(1) 14.2.4.1.1 (excluding subsections)
(2) 14.2.4.1.1.1
(3) 14.2.4.1.2
(4) 14.2.4.1.3 (excluding subsections)
(5) 14.2.4.1.3.3
(6) 14.2.4.4 (and subsections)
(7) 14.2.5.4
(8) 14.2.6.1.4
(9) 14.2.6.1.5
(10) 14.2.6.1.7
(11) 14.3.4.3.5 (and subsections)
(12) 14.2.8.1
(13) 14.2.8.2 (and subsections)
(14) 14.2.9.3.1 through 14.2.9.3.4
(15) 14.2.9.3.8 (and subsection)
(16) 14.2.9.3.14.4
(17) 14.2.9.3.15.5
(18) 14.2.9.3.16 (and subsections)
(19) 14.2.9.4.1.3
(20) 14.2.9.6 (and subsections)
(21) 14.2.10.3 through 14.2.10.6.3 (and subsections)
(22) 14.2.11.2.5
(23) 14.3.1 (and subsections)
(24) 14.3.2.1.1 through 14.3.2.1.5
(25) 14.3.2.4 through 14.3.2.6 (and subsection)
(26) 14.3.3 and 14.3.4 (and subsections)

14.1.1.3 This chapter shall also apply to the altered, renovated, or modernized portion of an existing system or individual component.

14.1.1.4 Existing construction or equipment shall be permitted to be continued in use when such use does not constitute a distinct hazard to life.

14.1.2 Classification of Chambers.

14.1.2.1 General. Chambers shall be classified according to occupancy in order to establish appropriate minimum essentials in construction and operation.

14.1.2.2 Occupancy. Hyperbaric chambers shall be classified according to the following criteria:

(1) Class A — Human, multiple occupancy
(2) Class B — Human, single occupancy
(3) Class C — Animal, no human occupancy

14.1.3 Category.

14.1.3.1 Category 1 Hyperbaric Care.

14.1.3.1.1 Where interruption or failure of medical gas supply is likely to cause major injury or death of patients, staff, or visitors, the medical gas system shall be Category 1 for use in this chapter.

14.1.3.1.2 Where interruption or failure of electrical service is likely to cause major injury or death of patients, staff, or visitors, the electrical service shall be Category 1 for use in this chapter.

14.1.3.2 Category 2 Hyperbaric Care.

14.1.3.2.1 Where interruption or failure of medical gas supply is likely to cause minor injury of patients, staff, or visitors, the medical gas system shall be considered Category 2 for use in this chapter.

14.1.3.2.2 Where interruption or failure of electrical service is likely to cause minor injury of patients, staff, or visitors, the electrical service shall be Category 2 for use in this chapter.

14.1.3.3 Category 3 Hyperbaric Care.

14.1.3.3.1 Where interruption or failure of medical gas supply is not likely to cause injury to patients, staff, or visitors, the medical gas system shall be considered Category 3 for use in this chapter.

14.1.3.3.2 Where interruption or failure of electrical service is not likely to cause injury to patients, staff, or visitors, the electrical service shall be Category 3 for use in this chapter.

14.1.3.4 Category 4 Hyperbaric Care. (Reserved)

14.1.4 Applicable Code. Hyperbaric facilities that are conducting any form of treatment and are not located in a designated health care facility, including residential occupancies, shall comply with the requirements of the applicable code.

14.2 Construction and Equipment.

14.2.1 Housing for Hyperbaric Facilities.

14.2.1.1 For Class A chambers located inside a building, the chamber(s) and all ancillary service equipment shall be protected by 2-hour fire-resistant-rated construction.

14.2.1.1.1* Freestanding, dedicated buildings containing only a Class A chamber(s) and ancillary service equipment shall not be required to be protected by 2-hour fire-resistant-rated construction.

14.2.1.1.2 Class B and C chambers located inside a building shall not be required to be protected by 2-hour fire-resistant-rated construction.

14.2.1.1.3 Trailer or vehicle-mounted facilities shall be permitted without a 2-hour fire-resistant-rated perimeter.

14.2.1.1.4 When trailer or vehicle-mounted facilities are located contiguous to a health care facility or another structure, a

2-hour fire-resistant-rated barrier shall be placed between the facility and the contiguous structure.

14.2.1.1.5 Where building exterior walls form part of the facility boundary, that portion of the facility boundary shall not require 2-hour fire-resistant-rated construction.

14.2.1.1.6* If there are connecting doors through such common walls of contiguity, they shall be at least B-label, 1½-hour fire doors.

14.2.1.1.7 When used for hyperbaric procedures, the room or rooms housing the Class A or Class B chambers shall be for the exclusive use of the hyperbaric operation.

14.2.1.1.8 Service equipment (e.g., compressors) shall be permitted to be located in multi-use spaces meeting the requirements of 14.2.1.1.

14.2.1.1.9 The supporting foundation for any chamber shall be designed to support the chamber.

14.2.1.1.9.1 If on-site hydrostatic testing will be performed, the chamber supporting foundation shall be designed to support an additional water weight.

14.2.1.2* The room housing a Class A or Class B chamber and any ancillary equipment rooms shall be provided protection by one of the following systems:

(1)* A hydraulically calculated automatic wet pipe sprinkler system meeting the requirements of NFPA 13
(2) An automatic water mist fire protection system installed in accordance with NFPA 750
(3)* A clean agent fire protection system in accordance with NFPA 2001

14.2.1.2.1 Class A or Class B chambers not contiguous to a health care facility and located in a mobile vehicle-mounted facility shall not be required to be protected as specified in 14.2.1.2.

14.2.1.2.2 The room housing a Class A, Class B, or Class C chamber shall contain a minimum of one 2-A:10B:C portable fire extinguisher.

14.2.1.3 Hyperbaric Piping Requirements.

14.2.1.3.1* Except where otherwise required by this chapter, piping systems dedicated to the hyperbaric chamber shall meet the requirements of ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*, for hyperbaric facility piping systems.

14.2.1.3.2 Shutoff valves accessible to facility personnel shall be provided for piping specified in 14.2.1.3.1 at the point of entry to the room housing the chamber(s).

14.2.1.3.3* Gas supplies from cylinders and portable containers shall include particulate filters to protect downstream components in the piping system.

14.2.1.4 Hyperbaric Medical Oxygen System Requirements.

14.2.1.4.1 Where medical oxygen systems are installed for hyperbaric use, the hyperbaric area(s) or facility shall be treated as a separate zone.

14.2.1.4.2 The requirements of Chapter 5 shall apply to the medical oxygen system for hyperbaric use, from the source of supply to the first in-line valve located downstream of the zone valve(s).

Δ **14.2.1.4.3** The requirements of ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*, shall apply to the medical oxygen system for hyperbaric use, starting immediately downstream of the first in-line valve located after the zone valve(s).

14.2.1.4.4 Hyperbaric oxygen systems for Category 1, Category 2, and Category 3 hyperbaric care connected directly to a hospital's oxygen system shall comply with Section 5.1, as applicable, except as noted in 14.2.1.4.4.1.

14.2.1.4.4.1 Central Supply Systems. Oxygen systems shall comply with 5.1.3.5, as applicable, except as follows:

(1) An emergency oxygen supply connection (EOSC) shall not be required for the hyperbaric oxygen system.
(2) An in-building emergency reserve (IBER) shall not be required for the hyperbaric oxygen system.

14.2.1.4.5 Hyperbaric stand-alone oxygen systems for Category 1 and Category 2 hyperbaric care shall comply with Section 5.1, as applicable, except as noted in 14.2.1.4.5.1.

14.2.1.4.5.1 Central Supply Systems. Oxygen systems shall comply with 5.1.3.5, as applicable, except as follows:

(1) An EOSC shall not be required for the hyperbaric oxygen system.
(2) An IBER shall not be required for the hyperbaric oxygen system.

14.2.1.4.6 Warning Systems.

14.2.1.4.6.1 Oxygen systems shall comply with 5.1.9, as applicable, except that warning systems shall be permitted to be a single master/area alarm panel.

14.2.1.4.6.2 The alarm panel shall be located in the room housing the chamber(s) to allow for easy audio and visual monitoring by the chamber operator.

14.2.1.4.7 Hyperbaric stand-alone oxygen systems for Category 3 hyperbaric care shall comply with Section 5.2, as applicable, except as noted in 14.2.1.4.7.1.

14.2.1.4.7.1 Central Supply Systems. Oxygen systems shall comply with 5.1.3.5, as applicable, except as follows:

(1) If the operating oxygen supply consists of high-pressure cylinders designed with a primary and secondary source, no reserve supply shall be required.
(2) If the operating oxygen supply consists of liquid containers designed with a primary and secondary source, a reserve with a minimum supply of 15 minutes shall be required.
(3) If the operating oxygen supply consists of a bulk primary, a reserve with a minimum supply of 15 minutes shall be required.
(4) An EOSC shall not be required for the hyperbaric oxygen system.
(5) An IBER shall not be required for the hyperbaric oxygen system.

14.2.1.5 Hyperbaric Medical Air System Requirements.

14.2.1.5.1 Where medical air systems are installed for hyperbaric use, the hyperbaric area(s) or facility shall be treated as a separate zone.

14.2.1.5.2 Chapter 5 requirements shall apply to the medical air system for hyperbaric use, from the source of supply to the first in-line valve located downstream of the zone valve(s).

Δ **14.2.1.5.3** ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*, requirements shall apply to the medical air system for hyperbaric use, starting immediately downstream of the first in-line valve located after the zone valve(s).

14.2.1.5.4 Where a medical air system is installed for hyperbaric treatments, it shall comply with the requirements for the appropriate level as determined in 14.2.1.5.4.1 through 14.2.1.5.4.7.

14.2.1.5.4.1 Hyperbaric medical air systems for Category 1, Category 2, and Category 3 hyperbaric care connected directly to a hospital's medical air system shall comply with Section 5.2, as applicable.

14.2.1.5.4.2 Reserved.

14.2.1.5.4.3 Hyperbaric stand-alone medical air systems for Category 1 and Category 2 hyperbaric care shall comply with Section 5.2, as applicable.

14.2.1.5.4.4 Reserved.

14.2.1.5.4.5 Medical air systems for Category 1 and Category 2 hyperbaric care shall comply with Section 5.2, as applicable, except that warning systems shall be permitted to be a single master/area alarm panel.

14.2.1.5.4.6 Hyperbaric stand-alone medical systems for Category 3 hyperbaric care shall comply with Section 5.2, as applicable, except as noted in 14.2.1.5.4.7.

14.2.1.5.4.7 Medical air systems shall comply with Section 5.2 as applicable, except as follows:

(1) Area and master alarms shall not be required for Category 3 hyperbaric care.
(2) A gas cylinder header per Section 5.2 with sufficient cylinder connections to provide for at least an average day's supply with the appropriate number of connections being determined after consideration of delivery schedule, proximity of the facility to alternate supplies, and the facility's emergency plan shall be permitted.
(3) A medical air cylinder directly connected to a Class B or Class C chamber and used to provide air to that chamber shall be permitted to be in the same room as the chamber.
(4) Where a cylinder is used as described in 14.2.1.5.4.7(3), the cylinder shall be considered to be "in use" and shall not be counted when determining the total volume of medical gas outside a storage area in Section 11.3.

14.2.1.6 Storage and Handling of Medical Gases. Storage and handling of medical gases shall meet the applicable requirements of Chapter 5 and Chapter 11.

14.2.2 Fabrication of the Hyperbaric Chamber.

14.2.2.1* Chambers for human occupancy and their supporting systems shall be designed and fabricated to meet the requirements of ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*, by personnel qualified to fabricate vessels under such codes.

N **14.2.2.1.1*** The primary pressure relief device on a chamber shall be capable of preventing any increase in pressure above the design pressure.

N **14.2.2.1.2*** A means to provide secondary pressure relief capable of preventing pressure exceeding 200 percent of the design pressure shall be provided.

14.2.2.1.3 Piping systems for hyperbaric facilities shall be required to meet only the requirements of this chapter and Section 4, "Piping Systems," of ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*.

Δ **14.2.2.1.4** Piping installed in concealed locations in the building that houses the hyperbaric facility, such as inside building walls or above false ceilings, shall use only those joining procedures permitted by Chapter 5.

14.2.2.2 The chamber shall be stamped in accordance with ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*.

14.2.2.3 Class C chambers shall be designed, fabricated, and stamped to meet Division 1 or Division 2 code requirements of Section VIII of the ASME *Boiler and Pressure Vessel Code*.

14.2.2.4* The viewports for Class C chambers shall be designed, fabricated, and marked to meet Section 2 of ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*.

14.2.2.5 The floor of a Class A chamber shall be designed to support equipment and personnel necessary for the operation of the chamber according to its expected purpose.

14.2.2.5.1 The floor of Class A chambers shall be noncombustible.

14.2.2.5.2 If a bilge is installed, access to the bilge shall be provided for cleaning purposes.

14.2.2.5.3 If the interior floor of a Class A chamber consists of removable floor (deck) plates, the plates shall be mechanically secured and electrically bonded to the chamber to ensure a positive electrical ground and to prevent movement of the plate, which could cause injury to personnel.

14.2.2.6 The interior surface of Class A chambers shall be unfinished or treated with a paint/coating in accordance with 14.2.2.6.1.

Δ **14.2.2.6.1*** Interior paint/coating shall meet the performance criteria of NFPA *101*, Class A interior finish, when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or UL 723, *Test for Surface Burning Characteristics of Building Materials*.

14.2.2.6.2* One additional application of paint shall be permitted, provided total paint thickness does not exceed $\frac{1}{28}$ in. (0.9 mm).

14.2.2.6.3 If the interior of a Class A chamber is treated (painted), the cure procedure and minimum duration for each layer of paint/coating to off-gas shall be in accordance with the manufacturer's application instructions.

14.2.2.6.4* If sound-deadening materials are employed within a hyperbaric chamber, they shall be limited-combustible materials.

14.2.2.7* Viewing ports, access ports for piping and wiring or monitoring, and related leads shall be installed during initial fabrication of the chamber.

14.2.2.7.1 Access ports in Class A chambers, access ports for monitoring, and other electrical circuits shall be housed in enclosures that are weatherproof, both inside and outside the chamber, for protection in the event of sprinkler activation.

Δ **14.2.2.7.2** Viewports and penetrator plates shall be designed and fabricated according to ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*.

14.2.3 Illumination.

14.2.3.1 Sources of illumination mounted outside the pressure chamber and arranged to shine through chamber ports or through chamber penetrators designed for fiber-optic or similar lighting shall meet the following requirements:

(1) Lighting fixtures used in conjunction with viewports shall be designed so that temperature ratings for the viewport material given in ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*, are not exceeded.
(2) Gasket material shall be of a type that allows the movement of thermal expansion and shall be selected for the temperatures, pressures, and composition of gases involved.
(3) Gaskets or O-rings shall be confined to grooves or enclosures, which will prevent their being blown out or squeezed from the enclosures or compression flanges.

14.2.3.2 Emergency lighting for the interior of the chamber shall be provided.

14.2.4 Chamber Ventilation.

14.2.4.1 Ventilation of Class A Chambers.

14.2.4.1.1 The minimum ventilation rate for a Class A chamber shall be 0.085 m^3/min (3 ft^3/min) of air per chamber occupant who is not using a breathing-mask overboard dump system that exhausts exhaled gases.

14.2.4.1.1.1 The minimum threshold rate shall be 0.085 m^3/min (3 ft^3/min).

14.2.4.1.1.2 Provision shall be made for ventilation during nonpressurization of Class A chambers as well as during pressurization.

14.2.4.1.2* Ventilation shall not be required when saturation operations are conducted in the chamber, provided that carbon dioxide removal and odor control are accomplished and that the monitoring requirements of 14.2.10.4.3 and 14.2.10.5 are met.

Δ **14.2.4.1.3*** Individual breathing apparatus for use by each occupant shall be available inside a Class A chamber in the event that the chamber atmosphere is fouled by combustion or otherwise.

14.2.4.1.3.1 The breathing mixture supplied to breathing apparatus shall be independent of the chamber atmosphere.

14.2.4.1.3.2 The breathing gas supply shall be designed for simultaneous use of all breathing apparatus.

14.2.4.1.3.3 Breathing apparatus shall function at all pressures that can be encountered in the chamber.

Δ **14.2.4.1.3.4** Provisions shall be made to simultaneously switch all breathing apparatus to an air supply independent of the chamber atmosphere in the event of a fire within the chamber.

14.2.4.2 Sources of Air for Chamber Atmospheres.

14.2.4.2.1* Sources of air for chamber atmospheres shall be such that toxic or flammable gases are not introduced.

14.2.4.2.2 Compressor intakes shall be located away from air contaminated by exhaust from activities of vehicles, internal combustion engines, stationary engines, or building exhaust outlets.

14.2.4.2.3 Air supply for chamber atmosphere shall be monitored as required in 14.2.10.6.

14.2.4.2.4 The use of conventional oil-lubricated compressors shall be permitted, provided that they are fitted with air treatment packages designed to meet the requirements of 14.2.10.6.

14.2.4.2.5 Air compressor installations shall consist of two or more individual compressors with capacities such that required system flow rates can be maintained on a continuous basis with any single compressor out of operation, unless 14.2.9.2.6 is satisfied.

14.2.4.2.5.1 Each compressor shall be supplied from separate electrical branch circuits.

14.2.4.2.6 Air compressor installations that supply medical air to piped gas systems as well as to hyperbaric facilities shall meet the requirements of 5.1.3.6.3 and this chapter.

14.2.4.2.7 Air compressor installations that are used exclusively for hyperbaric facilities shall meet the requirements of this chapter only.

14.2.4.3 Temperature and Humidity Control.

14.2.4.3.1 Warming or cooling of the atmosphere within a Class A chamber shall be permitted by circulating the ambient air within the chamber over or past coils through which a constant flow of warm or cool water or water/glycol mixture is circulated.

14.2.4.3.2 Dehumidification shall be permitted through the use of cold coils.

14.2.4.3.3 Humidification by the use of an air-powered water nebulizer shall be permitted.

14.2.4.3.4 Noncombustible packing and nonflammable lubricant shall be employed on the fan shaft.

14.2.4.4 Ventilation of Class B Chambers.

14.2.4.4.1* The minimum ventilation rate for a Class B chamber shall be 0.0283 m^3/min (1 ft^3/min).

14.2.4.4.2 Class B chambers not designed for 100 percent oxygen environment shall comply with the monitoring requirements of 14.2.10.4.

14.2.4.4.3 For Class B chambers equipped with a breathing apparatus, the breathing apparatus shall function at all pressures that can be encountered in the chamber.

14.2.5 Emergency Depressurization.

14.2.5.1 Class A chambers shall be capable of depressurizing from 3 ATA (304.0 kPa absolute) to ambient pressure in not more than 6 minutes.

14.2.5.2 Class B chambers shall be capable of depressurizing from 3 ATA (304.0 kPa absolute) to ambient pressure in not more than 2 minutes.

14.2.5.3 Class C chambers shall be capable of rapid depressurization.

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14.2.5.4* A risk assessment shall be performed to determine if means for respiratory and eye protection from combustion products allowing unrestricted mobility is required to be available outside all classes of hyperbaric chambers for use by personnel in the event the air in the vicinity of the chamber is fouled by smoke or other combustion products.

14.2.6 Fire Protection in Class A Chambers.

14.2.6.1 General.

14.2.6.1.1 Fire suppression consisting of a primary fire suppression system and a secondary fire suppression system shall be installed in all Class A chambers.

Δ **14.2.6.1.2** Design of fire suppression systems shall be such that failure of components in either the primary or secondary fire suppression system will not render the other system inoperative.

14.2.6.1.3 System design shall be such that activation of the primary fire suppression system automatically causes the following:

(1) An alarm signal shall be transmitted to the facility's central fire alarm system, if present.
(2) Visual and audible indication of activation shall occur at the chamber operator's console.
(3) All ungrounded electrical leads for power and lighting circuits contained inside the chamber shall be disconnected.
(4) Emergency lighting *(see 14.2.3.2)* and communication, where used, shall be activated.

14.2.6.1.3.1 Intrinsically safe circuits, including sound-powered communications, shall be permitted to remain connected when either the primary or secondary fire suppression system is activated.

14.2.6.1.4 A means of communication shall be provided at the chamber operator's control console for notifying the fire department.

14.2.6.1.5* Fire blankets and portable carbon dioxide extinguishers shall not be installed in or carried into the chamber.

14.2.6.1.6 Booster pumps, control circuitry, and other electrical equipment involved in fire suppression system operation shall be powered from a critical branch of the essential electrical system as specified in 14.2.9.2.1.2.

14.2.6.1.7* At least one sign prohibiting the introduction of flammable liquids, gases, and other articles not permitted by this chapter into the chamber shall be posted in the room housing the chamber(s).

14.2.6.1.8 Fire suppression systems shall be permitted to be supplied from the local potable water service.

N **14.2.6.1.9*** Design and performance of primary fire suppression systems shall comply with either 14.2.6.2 or 14.2.6.4.

N **14.2.6.1.10*** Design and performance of secondary fire suppression systems shall comply with either 14.2.6.3 or 14.2.6.5.

14.2.6.2 Deluge System. Where fixed water deluge extinguishing systems serve as primary fire suppression systems in accordance with 14.2.6.1.9, they shall be installed in all chamber compartments that are designed for manned operations.

14.2.6.2.1 In chambers that consist of more than one chamber compartment (lock), the design of the deluge system shall meet the requirements of 14.2.6.2 when the chamber compartments are at different depths (pressures).

14.2.6.2.2 The deluge system in different compartments (locks) shall operate independently or simultaneously.

14.2.6.2.3* Manual activation and deactivation deluge controls shall be located at the operator's console and in each chamber compartment (lock) containing a deluge system.

14.2.6.2.3.1 Controls shall be designed to prevent unintended activation.

14.2.6.2.4 Water shall be delivered from the fixed discharge nozzles as specified in 14.2.6.2.6 within 3 seconds of activation of any affiliated deluge control.

14.2.6.2.5* Average spray density at floor level shall be not less than 81.5 L/min/m^2 (2 gpm/ft^2), with no floor area larger than 1 m^2 (10.76 ft^2) receiving less than 40.75 L/min/m^2 (1 gpm/ft^2).

14.2.6.2.6 Water shall be available in the deluge system to maintain the flow specified in 14.2.6.2.5 simultaneously in each chamber compartment (lock) containing the deluge system for at least 1 minute.

14.2.6.2.6.1 The limit on maximum extinguishment duration shall be governed by the chamber capacity (bilge capacity also, if so equipped) or its drainage system, or both.

Δ **14.2.6.2.7** The deluge system shall have stored pressure to operate for at least 1 minute without electrical power.

14.2.6.2.8 All dedicated storage vessels used to provide the deluge system with water shall be fitted with a suitable water level indicator, with the level displayed at the chamber console.

14.2.6.2.9 Deluge systems using pressurized water vessels shall be designed to prevent the driving gas supply from pressurizing the hyperbaric chamber if all the water is driven out of the water vessel.

N **14.2.6.2.10*** Water storage vessels capable of producing or containing corrosion or other products capable of blocking outlet nozzles shall be equipped with a strainer complying with 14.2.6.2.10.1 through 14.2.6.2.10.3.

N **14.2.6.2.10.1** The strainer shall be located where water exits the vessel into the fire suppression system piping.

N **14.2.6.2.10.2** The strainer shall be capable of opening for inspection and cleaning of the filter device during periodic system maintenance inspections.

N **14.2.6.2.10.3** The strainer mesh or pore size shall be selected to protect deluge nozzles and any inline flow control equipment from blockage or damage and to ensure the filter does not clog between fire suppression system testing intervals specified in 14.3.4.3.5.

14.2.6.3 Handline System. Where handline extinguishing systems serve as secondary fire suppression systems in accordance with 14.2.6.1.10, they shall be installed in all chamber compartments (locks) designed for manned operations.

14.2.6.3.1 At least two handlines shall be strategically located in treatment compartments (locks).

14.2.6.3.2 At least one handline shall be located in each personnel transfer compartment (lock).

14.2.6.3.3 If any chamber compartment (lock) is equipped with a bilge access panel, at least one handline shall reach the bilge area.

14.2.6.3.4 Handlines shall have a 12.7 mm (0.5 in.) minimum internal diameter and shall have a rated operating pressure greater than the highest supply pressure of the supply system.

14.2.6.3.5 Each handline shall be activated by a manual, quick-opening, quarter-turn valve located within the compartment (lock).

14.2.6.3.5.1 A hand-operated spring-return to close valves at the discharge end of handlines shall be permitted.

14.2.6.3.6 Handlines shall be equipped with override valves that are accessible to personnel outside the chamber.

14.2.6.3.7 The water supply for the handline system shall be designed to ensure a 345 kPa (50 psi) minimum water pressure above the maximum chamber pressure.

14.2.6.3.7.1 The system shall be capable of supplying a minimum of 18.9 L/min (5 gpm) simultaneously to each of any two of the handlines at the maximum chamber pressure for a period of not less than 4 minutes.

N **14.2.6.3.8** System design shall be such that activation of the handline system automatically causes the following to occur:

(1) Visual and audible indication of activation shall occur at the chamber operator's console.
(2) All ungrounded electrical leads for power and lighting circuits contained inside the chamber shall be disconnected.
(3) Emergency lighting *(see 14.2.3.2)* and communication, where used, shall be activated.

N **14.2.6.4 Alternative Primary Fire Suppression System.** Where alternative fire suppression systems serve as primary fire suppression systems in accordance with 14.2.6.1.9, they shall be installed in all chamber compartments designed for manned operations.

N **14.2.6.4.1*** The fire suppression system shall be designed to suppress a fire in all areas of the compartment where an occupant could be sitting or lying.

N **14.2.6.4.1.1*** Fire suppression shall be demonstrated by lowering the temperature at the head of the occupant to 50°C (122°F) or lower within 20 seconds of activation.

N **14.2.6.4.1.2** Testing shall be conducted at the maximum operating pressure of the chamber and at surface (i.e., normal) pressure.

N **14.2.6.4.2** The system shall have sufficient capacity to operate for at least 1 minute after activation.

N **14.2.6.4.3** The fire suppression media shall be safe for human exposure.

N **14.2.6.5 Alternative Secondary Fire Suppression System.** Where alternative fire suppression systems serve as secondary fire suppression systems in accordance with 14.2.6.1.10, portable, handheld fire extinguishers shall be available in all chamber compartments designed for manned operations.

N **14.2.6.5.1** At least two portable fire extinguishers shall be strategically located in treatment compartments.

N **14.2.6.5.2** At least one portable fire extinguisher shall be located in each personnel transfer compartment.

N **14.2.6.5.3** Portable fire extinguishers shall be designed to function at the maximum operating pressure of the chamber.

N **14.2.6.5.4** The fire extinguishing media shall be safe for human exposure.

14.2.6.6 Automatic Detection System. Automatic fire detection systems shall not be required.

14.2.6.6.1 Surveillance fire detectors responsive to the radiation from flame shall be employed.

14.2.6.6.1.1 The type and arrangement of detectors shall be such as to respond within 1 second of flame origination.

14.2.6.6.2* The number of detectors employed and their location shall be selected to cover the chamber interior.

14.2.6.6.3 The system shall be powered from the critical branch of the essential electrical system or shall have automatic battery backup.

14.2.6.6.4 If used to automatically activate the deluge system, the requirements for manual activation/deactivation in 14.2.6.2.3 and deluge system response time in 14.2.6.2.4 shall still apply.

14.2.6.6.5 The system shall include self-monitoring functions for fault detection and fault alarms and indications.

14.2.6.6.6 Automatic fire detection equipment, when used, shall meet the applicable requirements in 14.2.9.3.

14.2.7 Pneumatic Controls for Class A Chambers. Class A chambers that utilize pneumatically operated controls that are related to fire suppression system operation, breathing gases, or rapid exhaust valves shall be equipped with a means to operate such controls or intended function in the event that the pneumatic supply fails.

14.2.8 Fire Protection in Class B and Class C Chambers. Class B and Class C chambers shall not be required to comply with 14.2.6.

14.2.8.1* At least one sign prohibiting the introduction of flammable liquids, gases, and other articles not permitted by this chapter into the chamber shall be posted in the room housing the chamber(s).

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14.2.8.2 A means for communication shall be provided within the room housing the chamber(s) for notifying the fire department.

14.2.8.2.1 If the building housing the hyperbaric facility has a central fire alarm system, the communication shall be a pull-station connected to the system.

14.2.8.2.2 Trailer or vehicle-mounted facilities not contiguous to a health care facility shall conform to one of the following:

(1) They shall comply with 14.2.8.2.
(2) They shall have a means for immediately contacting the local fire department.

14.2.9 Electrical Systems.

14.2.9.1 General.

14.2.9.1.1 The requirements of *NFPA 70* or local electrical codes shall apply to electrical wiring and equipment in hyperbaric facilities within the scope of this chapter, except as such rules are modified in 14.2.9.

14.2.9.1.2 All hyperbaric chamber service equipment, switchboards, panels, or control consoles shall be located outside of, and in the vicinity of, the chamber.

14.2.9.1.3 Console or module spaces containing both oxygen piping and electrical equipment shall be either one of the following:

(1) Mechanically or naturally ventilated
(2) Continuously monitored for excessive oxygen concentrations whenever the electrical equipment is energized

14.2.9.1.4 For the fixed electrical installation, none of the following shall be permitted inside the chamber:

(1) Circuit breakers
(2) Line fuses
(3) Motor controllers
(4) Relays
(5) Transformers
(6) Ballasts
(7) Lighting panels
(8) Power panels

14.2.9.1.5 All electrical equipment connected to, or used in conjunction with, hyperbaric patients shall comply with the requirements of Chapter 10 and with the applicable subparagraphs of 14.2.9.3.

14.2.9.1.6 In the event of activation of the room sprinkler system, electrical equipment shall be protected from sprinkler water but shall not be required to remain functional if manual means to control and decompress the chamber are provided.

14.2.9.2 Electrical Service.

14.2.9.2.1* All hyperbaric facilities equipped with any of the following electrically driven feature shall be provided with some means of backup electric power:

(1)* Chamber room emergency lighting, installed per Section 7.9 of NFPA *101*.
(2)* Chamber emergency lighting, whether internally or externally mounted
(3)* Chamber intercommunications
(4)* Alarm systems, including flame detectors
(5)* Chamber fire suppression system equipment and controls
(6)* Electrical controls used for chamber pressurization and ventilation control

14.2.9.2.1.1 Electrical control and alarm system design shall be such that hazardous conditions (e.g., loss of chamber pressure control, deluge activation, spurious alarms) do not occur during power interruption or during power restoration.

14.2.9.2.1.2 Booster pumps in the chamber fire suppression system shall be on separate branch circuits serving no other loads.

14.2.9.2.2 Article 700 of *NFPA 70* shall apply to hyperbaric systems located in facilities other than health care facilities.

14.2.9.2.3 Hyperbaric electrical service for Category 1 or 2 hyperbaric care shall be supplied from two independent sources of electric power.

14.2.9.2.3.1 For hyperbaric facilities using a prime-mover–driven generator set, they shall be designated as the life safety and critical branches and shall meet the requirements of Chapter 6 for hyperbaric systems based in health care facilities.

14.2.9.2.3.2 Electrical equipment associated with life-support functions of hyperbaric facilities shall be connected to the critical branch of the essential electrical system, which requires that such equipment shall have electrical power restored within 10 seconds of interruption of normal power.

14.2.9.2.4 Electric motor–driven compressors and auxiliary electrical equipment normally located outside the chamber and used for chamber atmospheric control shall be connected to the equipment system *(see Chapter 6)* or the life safety and critical branches *(see Article 700 of NFPA 70)* as applicable.

14.2.9.2.5 Electric motor–driven compressors and auxiliary electrical equipment shall be arranged for delayed-automatic or manual connection to the alternate power source so as to prevent excessive current draw on the system during restarting.

14.2.9.2.6 Where reserve air tanks or a nonelectric compressor(s) is provided to maintain ventilation airflow within the chamber and supply air for chamber pressurization, the compressor(s) and auxiliary equipment shall not be required to have an alternate power source.

14.2.9.3* Wiring and Equipment Inside Class A Chambers. The general rules of 14.2.9.3.1 through 14.2.9.3.16.5 shall be satisfied in the use of electrical devices and equipment. These requirements are intended to protect against the elevated fire risks known to exist in a pressurized air environment and shall not be construed as classifying the chamber interior as a Class I (as defined in Article 500 of *NFPA 70*) hazardous location.

14.2.9.3.1 Equipment or equipment components installed in, or used in, the chamber shall not present an explosion or implosion hazard under the conditions of hyperbaric use.

14.2.9.3.2 All equipment shall be rated, or tested and documented, for intended hyperbaric conditions prior to use.

Δ **14.2.9.3.3** Only electrical equipment necessary for safe operation of the chamber, required patient care, and patient entertainment provided by the facility shall be permitted in the chamber.

N **14.2.9.3.3.1** Fixed patient entertainment equipment shall be permitted where installed by the manufacturer.

N **14.2.9.3.3.2*** Portable patient entertainment equipment shall be permitted where approved by the manufacturer or hyperbaric safety coordinator.

Δ **14.2.9.3.4** Only portable equipment necessary for logistical, operational, and patient-care support shall be permitted in the chamber.

14.2.9.3.5 Wires and Cables. Wires and cables used inside the chamber shall be resistant to the spread of fire by complying with 14.2.9.3.5.1 or shall be contained within equipment described in 14.2.9.3.5.2.

Δ **14.2.9.3.5.1** Wires and cables shall comply with the spread of fire requirements of "UL Flame Exposure, Vertical Tray Flame Test" in UL 1685, *Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables*, or shall exhibit damage (char length) not to exceed 1.5 m (4 ft 11 in.) when performing the CSA "Vertical Flame Test — Cables in Cable Trays," as described in CSA C22.2 No. 0.3, *Test Methods for Electrical Wires and Cables*.

14.2.9.3.5.2 Wires and cables that form an integral part of electrical equipment approved or listed specifically for use inside hyperbaric chambers, including patient leads, shall not be required to comply with the requirements of 14.2.9.3.5.1.

14.2.9.3.6 Wiring Methods.

14.2.9.3.6.1 Fixed wiring shall be installed in conduit using the following components and be watertight after installation:

(1) Threaded metal joints
(2) Fittings
(3) Boxes
(4) Enclosures

14.2.9.3.6.2 A continuous ground shall be maintained between all conductive surfaces enclosing electrical circuits and the chamber hull using approved grounding means unless prohibited by 14.2.9.3.6.3.

N **14.2.9.3.6.3** Grounding to the chamber hull shall be prohibited where electrical circuits require an independent ground.

Δ **14.2.9.3.6.4** All threaded conduit shall be threaded with an NPT standard conduit cutting die that provides a 0.75 in. taper per 1 ft or the equivalent tapered metric thread in accordance with ISO 724, *ISO general-purpose metric screw threads — Basic dimensions*.

14.2.9.3.6.5 All threaded conduit shall be made wrench-tight to prevent sparking when fault current flows through the conduit system.

14.2.9.3.6.6 Wiring classified as intrinsically safe for any group location and installed in accordance with Article 504 of *NFPA 70* shall be permitted.

14.2.9.3.6.7 Threaded, liquidtight flexible metal conduit installed in accordance with Article 350 of *NFPA 70* shall be permitted when protected from damage by physical barriers such as equipment panels.

14.2.9.3.7 Drainage. Means of draining fixed conduit and fixed equipment enclosures shall be provided at points where fluids can collect.

14.2.9.3.8 Flexible Electrical Cords. Flexible cords used to connect portable utilization equipment to the fixed electrical supply circuit shall meet all the following requirements:

(1) They shall be of a type approved for extra-hard use in accordance with Table 400.4 of *NFPA 70*.
(2) Electrically conductive casings of all portable equipment for use inside the chamber shall be grounded.
(3) They shall meet the requirements of 501.140 of *NFPA 70*.

14.2.9.3.8.1 The normal cord supplied with the portable utilization equipment shall be permitted when the portable device is rated at less than 2 A and the cord is positioned out of traffic and protected from physical abuse.

14.2.9.3.9* Receptacles Installed Inside the Chamber.

14.2.9.3.9.1 Receptacles shall be waterproof.

14.2.9.3.9.2 Receptacles shall be of the type providing for connection to the grounding conductor of the flexible cord.

14.2.9.3.9.3 Receptacles shall be capable of conducting ungrounded power between each isolated external power circuit meeting the requirements of 14.2.9.4.2 and the device inside the chamber.

14.2.9.3.9.4 The design of the receptacle shall be such that sparks cannot be discharged into the chamber environment when the plug is inserted or withdrawn under electrical load.

14.2.9.3.9.5 One of the following shall be satisfied to protect against inadvertent withdrawal of the plug under electrical load:

(1) The receptacle–plug combination shall be of a locking type.
(2) The receptacle shall carry a label warning against unplugging under load, and the power cord shall not present a trip hazard for personnel moving in the chamber.

14.2.9.3.10 Switches. Switches in the fixed wiring installation shall be waterproof.

14.2.9.3.10.1* Switch make and break contacts shall be housed in the electrical enclosure so that no sparks from arcing contacts can reach the chamber environment.

14.2.9.3.11* Temperature. No electrical equipment installed or used in the chamber shall have an operating surface temperature in excess of 85°C (185°F).

14.2.9.3.12 Exposed Live Electrical Parts. No exposed live electrical parts shall be permitted, except as specified in 14.2.9.3.12.1 and 14.2.9.3.12.2.

14.2.9.3.12.1 Exposed live electrical parts that are intrinsically safe shall be permitted.

14.2.9.3.12.2 Exposed live electrical parts that constitute patient monitoring leads, which are part of electromedical equipment, shall be permitted, provided that they meet the requirements of 14.2.9.3.16.

Δ **14.2.9.3.13* Motors.** Motors located in the chamber that are not a component of medical equipment shall meet one of the following requirements:

(1) They shall comply with 501.125(A)(1) of *NFPA 70*.
(2) They shall be totally enclosed in accordance with 501.125(A)(2) or 501.125(A)(3) of *NFPA 70*.
(3) They shall comply with all of the following:
    (a) The motor shall be of the brushless, dc type with no flammable lubricants.
    (b) Any internal control circuitry attached to the motor shall be potted in an oxygen-compatible compound to prevent exposure to the chamber atmosphere.
    (c) No powered switches shall be permitted inside the chamber.

14.2.9.3.14* Lighting.

14.2.9.3.14.1 Lighting installed or used inside the chamber shall be of a type that is not damaged by exposure to 1½ times the maximum allowable working pressure (MAWP).

14.2.9.3.14.2 Permanently installed fixtures shall meet the following requirements:

(1) They shall be rated and approved for Class I (Division 1 or 2) classified areas.
(2) They shall have lens guards installed.
(3) They shall be located away from areas where they would experience physical damage from the normal movement of people and equipment.

14.2.9.3.14.3 Ballasts and other energy storage components that are part of the lighting circuit shall be installed outside the chamber in accordance with 14.2.9.1.4.

14.2.9.3.14.4 Portable fixtures intended for spot illumination shall be shatterproof or protected from physical damage.

14.2.9.3.15 Low-Voltage, Low-Power Equipment. The requirements of 14.2.9.3.15.1 through 14.2.9.3.15.5 shall apply to sensors and signaling, alarm, communications, and remote-control equipment installed or used in the chamber for operation of the chamber.

14.2.9.3.15.1* Equipment shall be isolated from main power by one of the following means:

(1) Design of the power supply circuit
(2) Opto-isolation
(3) Other electronic isolation means

14.2.9.3.15.2 Circuits such as headset cables, sensor leads, and so forth, not enclosed as required in 14.2.9.3.6, shall meet one of the following requirements:

(1) They shall be part of approved intrinsically safe equipment.
(2) They shall be limited by circuit design to not more than 28 V and 0.5 A under normal or circuit-fault conditions.

14.2.9.3.15.3 Chamber speakers shall be of a design in which the electrical circuitry and wiring is completely enclosed.

14.2.9.3.15.4 The electrical rating of chamber speakers shall not exceed 28 V rms and 25 W.

14.2.9.3.15.5 Battery-operated, portable intercom headset units shall meet the requirements of 14.2.9.3.16.4 for battery-operated devices.

14.2.9.3.16 Portable Patient Care–Related Electrical Appliances.

14.2.9.3.16.1 The appliance shall be designed, constructed, inspected, and maintained in accordance with Chapter 10.

14.2.9.3.16.2 The electrical and mechanical integrity of the appliance shall be verified and documented through an ongoing maintenance program as required in Chapter 10.

14.2.9.3.16.3 Appliances that utilize oxygen shall not allow oxygen accumulation in the electrical portions of the equipment under normal and abnormal conditions.

14.2.9.3.16.4 Battery-Operated Devices. Battery-operated devices shall meet the following requirements:

(1) Batteries shall be fully enclosed and secured within the equipment enclosure.
(2) Batteries shall not be damaged by the maximum chamber pressure to which they are exposed.
(3) Batteries shall be of a sealed type that does not off-gas during normal use.
(4) Batteries or battery-operated equipment shall not undergo charging while located in the chamber.
(5) Batteries shall not be changed on in-chamber equipment while the chamber is in use.
(6) The equipment electrical rating shall not exceed 12 V and 48 W.

14.2.9.3.16.5 Cord-Connected Devices. Cord-connected devices shall meet the following requirements:

(1) All portable, cord-connected equipment shall have an on/off power switch.
(2) The equipment electrical rating shall not exceed 120 V and 2 A, unless the electrical portions of the equipment are inert-gas purged.
(3) The plug of cord-connected devices shall not be used to interrupt power to the device.

14.2.9.3.17* Gas Purging. Gas purging of AC and DC equipment used inside the chamber shall be permitted using inert gas or air.

14.2.9.4 Grounding and Ground-Fault Protection.

14.2.9.4.1 All chamber hulls shall be grounded to an electrical ground or grounding system that meets the requirements of Part III of Article 250 of *NFPA 70*.

14.2.9.4.1.1 Grounding conductors shall be secured as required by Part III of Article 250 of *NFPA 70*.

14.2.9.4.1.2 The material, size, and installation of the grounding conductor shall meet the requirements of Part VI of Article 250 of *NFPA 70* for equipment grounding conductors.

Δ **14.2.9.4.1.3** The resistance between the grounded chamber and electrical supply system ground shall not exceed 1 ohm.

14.2.9.4.2 All ac electrical power circuits located within the chamber shall be supplied from an ungrounded electrical system.

14.2.9.4.2.1 The circuits specified in 14.2.9.4.2 shall meet the requirements of 517.160(A) and 517.160(B) of *NFPA 70*.

14.2.9.4.2.2 Branch circuits shall not exceed 125 V or 15 A.

14.2.9.4.3 Wiring located both inside and outside the chamber, that serves line level circuits and equipment located inside the chamber, shall meet the grounding and bonding requirements of 501.30 of *NFPA 70*.

14.2.9.5 Wiring Outside the Chamber. Those electrical components that must remain functional for the safe termination of chamber operations following activation of the room sprinkler system shall be enclosed in waterproof housing.

14.2.9.5.1 All associated conduits shall meet the following requirements:

(1) They shall be waterproof.
(2) They shall meet the requirements of *NFPA 70*.
(3) They shall be equipped with approved drains.

14.2.9.5.2* All other electrical devices outside the chamber shall meet the requirements of *NFPA 70*.

14.2.9.6 Additional Wiring and Equipment Requirements Inside Class B and Class C Chambers. The requirements in 14.2.9.6 shall apply to Class C chambers pressurized with oxygen and to Class B chambers whether they are pressurized with oxygen or with air.

14.2.9.6.1 Electrical equipment inside chambers shall be restricted to communications functions and patient physiological monitoring leads.

14.2.9.6.1.1* Each circuit shall be designed to limit the electrical energy to wire leads into the chamber under normal or fault conditions to not more than 28 V and 4.0 W. This requirement shall not exclude more stringent requirements imposed by other codes governing electromedical apparatus.

14.2.9.6.1.2 Communications wires shall be protected from physical damage and from coming into contact with flammable materials in the chamber by barriers or conduit.

14.2.9.6.1.3 Patient monitoring leads shall be part of approved electromedical apparatus meeting the requirements in 14.2.9.3.16.

14.2.9.6.2 Lighting inside the chamber shall be supplied from external sources.

14.2.9.6.3 No materials shall be permitted in a chamber whose temperature exceeds 50°C (122°F), nor shall any electrical circuit inside a chamber operate at a temperature exceeding 50°C (122°F).

N **14.2.9.6.4** Equipment not specified by 14.2.9.6 shall be permitted in the chamber, with the approval of the hyperbaric medical director and the hyperbaric safety coordinator, if any of the following conditions exists:

(1) The equipment is intrinsically safe.
(2) The equipment is compliant with Class 1 requirements specified in Article 500 of *NFPA 70*.
(3) The equipment meets all of the following conditions:
   (a) The batteries and circuitry are sealed or isolated from the chamber environment.
   (b) The equipment has a maximum voltage of 3 volts and a power requirement of 4 W.
   (c) The equipment contains no volatile lubricants or hydrocarbons.

14.2.10 Communications and Monitoring.

14.2.10.1 General.

14.2.10.1.1 Electrical monitoring equipment used inside the chamber shall comply with the applicable requirements of 14.2.9.

14.2.10.1.2 Detectors, sensors, transducers, and communications equipment located inside the chamber shall meet the requirements of 14.2.9.3.15 for Class A chambers and 14.2.9.6 for Class B chambers.

14.2.10.1.3 Wiring methods in the chamber shall meet the applicable requirements in 14.2.9.3.

14.2.10.1.4 The following equipment shall be installed outside the chamber or shall meet the requirements of 14.2.9.3.15:

(1) Control equipment
(2) Power amplifiers
(3) Output transformers
(4) Monitors associated with communications and monitoring equipment

14.2.10.2* Intercommunications.

14.2.10.2.1* An intercommunications system shall connect all personnel compartments (locks) and the chamber operator's control console.

14.2.10.2.2* Closed-circuit television monitoring of the chamber interior shall be employed for chamber operators who do not have direct visual contact with the chamber interior from their normal operating location.

14.2.10.2.3 Oxygen mask microphones shall be intrinsically safe at the maximum proposed pressure and 95 ± 5 percent oxygen.

14.2.10.3 Combustible Gas Detection.

14.2.10.3.1 The chamber atmosphere shall be continuously monitored for combustible gas concentrations whenever any volatile agents are used in the chamber.

14.2.10.3.1.1 The monitor shall be set to provide audible and visual alarms at 10 percent lower explosive limit (LEL) for the particular gas used.

14.2.10.4 Oxygen Monitoring.

N **14.2.10.4.1** Where required, oxygen monitors shall be equipped with audible and visual alarms.

N **14.2.10.4.2** Where required, oxygen monitors shall have a sample response time of no more than 30 seconds at all treatment levels.

14.2.10.4.3 Oxygen levels shall be continuously monitored in any chamber in which nitrogen is added to the chamber or to reduce the volumetric concentration of oxygen in the atmosphere.

14.2.10.4.4* Oxygen levels shall be continuously monitored in Class A chambers when breathing mixtures containing greater than 21 percent oxygen by volume are being breathed by patients or attendants, when any flammable agents are present in the chamber, or when both conditions exist.

14.2.10.4.4.1 Audible and visual alarms shall indicate volumetric oxygen concentrations greater than 23.5 percent range for Class A chambers.

14.2.10.4.4.2* At least one sample port shall be equipped with a removable extension to allow for spot-checking of any location within the chamber.

14.2.10.5 Carbon Dioxide Monitoring. The chamber atmosphere shall be monitored for carbon dioxide levels during saturation operations whenever ventilation is not used.

14.2.10.6* Chamber Gas Supply Monitoring. p.214

14.2.10.6.1* As a minimum, the air supplied from compressors to all classes of chambers shall meet the requirements for CGA Grade E with the added requirement that condensed hydrocarbons and particulates shall be less than 0.1 mg/m^3.

14.2.10.6.2 When air cylinders are used to provide breathing air in chambers, the breathing air shall be medical air USP.

14.2.10.6.3 When cylinders are used to provide oxygen in chambers, the gas shall be oxygen USP.

14.2.11 Other Equipment and Fixtures.

14.2.11.1 All furniture permanently installed in the hyperbaric chamber shall be grounded.

14.2.11.2* Exhaust from all classes of chambers shall be piped outside of the building.

14.2.11.2.1 Each Class B and Class C chamber shall have an independent exhaust line.

14.2.11.2.2 The point of exhaust shall not create a hazard.

14.2.11.2.3 The point of exhaust shall not allow reentry of gases into the building.

14.2.11.2.4 The point of exhaust shall be protected by the provision of a minimum of 0.3 cm (0.12 in.) mesh screen and situated to prevent the intrusion of rain, snow, or airborne debris.

14.2.11.2.5* The point of exhaust shall be identified as an oxygen exhaust by a sign prohibiting smoking or open flame and the sign shall include a pictograph indicating "no smoking" and "no open flame — flame" in accordance with NFPA 170.

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14.3 Administration and Maintenance.

14.3.1 General.

14.3.1.1 Purpose. Section 14.3 contains requirements for administration and maintenance that shall be followed as an adjunct to physical precautions specified in Section 14.2.

14.3.1.2* Recognition of Hazards. The nature and recognition of hyperbaric hazards are outlined in Annex B of this document and shall be reviewed by the hyperbaric safety coordinator.

SAFETY COORDINATOR RESPONSIBILITIES

14.3.1.3 Responsibility.

14.3.1.3.1* Personnel responsible for the hyperbaric facility, and those responsible for licensing, accrediting, or approving institutions or other facilities in which hyperbaric installations are employed, shall establish and enforce programs to fulfill the provisions of this chapter.

14.3.1.3.2* For each hyperbaric facility, a hyperbaric safety coordinator shall be designated as responsible for all hyperbaric equipment and the operational safety requirements of this chapter.

14.3.1.3.2.1 The hyperbaric safety coordinator shall develop operation and maintenance procedures for the hyperbaric facility with facility management personnel and the hyperbaric physician(s).

14.3.1.3.2.2 The hyperbaric safety coordinator shall make recommendations for departmental safety policies and procedures.

14.3.1.3.2.3 The hyperbaric safety coordinator shall have the authority to restrict or remove any potentially hazardous supply or equipment items from the chamber.

14.3.1.3.3* By virtue of its responsibility for the professional conduct of members of the medical staff of the health care facility, the organized medical staff shall adopt and enforce regulations with respect to the use of hyperbaric facilities located in health care facilities.

14.3.1.3.3.1 The hyperbaric safety coordinator shall participate in the enforcement of the regulations required by 14.3.1.3.3.

14.3.1.3.4* The hyperbaric safety coordinator shall ensure that electrical, monitoring, life-support, fire protection, and ventilating arrangements in the hyperbaric chamber are inspected and tested as part of the routine maintenance program of the facility.

14.3.1.4 Rules and Regulations.

14.3.1.4.1* General. The administrative, technical, and professional staffs shall jointly develop policies for management of the hyperbaric facility.

N **14.3.1.4.1.1** The hyperbaric safety coordinator shall participate in the development of the policies required by 14.3.1.4.1.

14.3.1.4.1.2 Upon adoption, the management policies shall be available in the facility.

14.3.1.4.2 The physician in charge of hyperbaric medicine and the hyperbaric safety coordinator shall jointly develop the minimum staff qualifications, experience, and complement based on the following:

(1) Number and type of hyperbaric chambers in use
(2) Maximum treatment capacity
(3) Type of hyperbaric therapy normally provided

14.3.1.4.3 All personnel, including those involved in maintenance and repair of the hyperbaric facility, shall be trained on the purpose, application, operation, and limitations of emergency equipment.

14.3.1.4.4 When an inspection, test, or maintenance procedure of the fire suppression system results in the system being placed out of service, a protocol shall be followed that notifies appropriate personnel and agencies of the planned or emergency impairment.

14.3.1.4.5 A sign indicating the fire suppression system is out of service shall be conspicuously placed on the operating console until the fire suppression system is restored to service.

14.3.1.4.6* During chamber operations with an occupant(s) in a chamber, the operator shall be physically present and shall maintain visual or audible contact with the control panel or the chamber occupant(s).

14.3.1.5 Emergency Procedures.

14.3.1.5.1 Emergency procedures specific to the hyperbaric facility shall be established.

14.3.1.5.2* All personnel shall be trained in emergency procedures.

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14.3.1.5.3 Personnel shall be trained to control the chamber and decompress occupants when all powered equipment has been rendered inoperative.

14.3.1.5.4* Emergency procedures and fire training drills shall be conducted at least annually and documented by the hyperbaric safety coordinator.

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14.3.1.5.4.1 The time required to evacuate all persons from a hyperbaric area with a full complement of chamber occupants all at treatment pressure shall be measured annually.

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14.3.1.5.4.2 The occupants for the timed evacuation drill shall be permitted to be simulated.

14.3.1.6 General.

14.3.1.6.1 Potential Ignition Sources.

14.3.1.6.1.1* The following shall be prohibited from inside the chamber and the immediate vicinity outside the chamber:

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(1) Smoking
(2) Open flames
(3) Hot objects

14.3.1.6.1.2 The following shall be prohibited from inside the chamber:

(1) Personal warming devices (e.g., therapeutic chemical heating pads, hand warmers, pocket warmers)
(2) Personal electrically powered devices (e.g., laptops, electronic tablets, cell phones, pagers)
(3) Sparking toys
(4) Personal entertainment devices

14.3.1.6.1.3* Prior to each hyperbaric treatment, a pretreatment safety check to identify and remove prohibited items shall be performed and documented by a qualified person.

14.3.1.6.2 Flammable Gases and Liquids.

14.3.1.6.2.1 Flammable agents, including devices such as laboratory burners employing bottled or natural gas and cigarette lighters, shall be prohibited inside the chamber and from the proximity of the compressor intake.

14.3.1.6.2.2 For Class A chambers, flammable agents used for patient care, such as alcohol swabs, parenteral alcohol-based pharmaceuticals, and topical creams, shall be permitted in the chamber if the following conditions are met:

(1) Such use is approved by the hyperbaric safety coordinator or other authority having jurisdiction.
(2)* The quantities of such agents are limited so that they are incapable of releasing sufficient flammable vapor into the chamber atmosphere to exceed the LEL for the material.
(3) A safety factor is included to account for the localized concentrations, stratification, and the absence of ventilation.
(4) The oxygen monitoring requirement of 14.2.10.4.4 is observed.

14.3.1.6.2.3 Flammable liquids, gases, or vapors shall not be permitted inside any Class B chamber.

14.3.1.6.3* Personnel.

14.3.1.6.3.1 Antistatic procedures, as directed by the hyperbaric safety coordinator, shall be employed whenever atmospheres containing more than 23.5 percent oxygen by volume are used.

14.3.1.6.3.2 In Class A and Class B chambers with atmospheres containing more than 23.5 percent oxygen by volume, electrical grounding of the patient shall be ensured by the provision of a high-impedance conductive pathway in contact with the patient's skin.

patient ground

14.3.1.6.3.3 Shoes having ferrous nails that make contact with the floor shall not be permitted to be worn in Class A chambers.

14.3.1.6.4* Textiles.

14.3.1.6.4.1 Except where permitted in 14.3.1.6.4.3, silk, wool, or synthetic textile materials, or any combination thereof, shall be prohibited in Class A or Class B chambers.

14.3.1.6.4.2* Garments permitted inside of chambers shall be as follows:

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(1) Garments fabricated of 100 percent cotton or a blend of cotton and polyester fabric shall be permitted in Class A chambers.
(2) Garments fabricated of 100 percent cotton, or a blend of cotton and polyester fabric containing no more than 50 percent polyester, shall be permitted in Class B chambers.

Δ **14.3.1.6.4.3*** The hyperbaric physician in charge, with the concurrence of the hyperbaric safety coordinator, shall be permitted to use materials that are prohibited or not specifically permitted by this chapter.

14.3.1.6.4.4* Approval by the hyperbaric physician in charge and the hyperbaric safety coordinator to use prohibited items shall be stated in writing for all prohibited items employed.

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14.3.1.6.4.5 Upholstered Furniture.

(A) Upholstered furniture (fixed or portable) shall be resistant to smoldering (or cigarette) ignition in accordance with one of the following:

(1) The components of the upholstered furniture shall meet the requirements for Class 1 when tested in accordance with NFPA 260.
(2) Mocked-up composites of the upholstered furniture shall have a char length not exceeding 38 mm (1½ in.) when tested in accordance with NFPA 261.

(B) Upholstered furniture shall have limited rates of heat release when tested in accordance with ASTM E1537, *Standard Test Method for Fire Testing of Upholstered Furniture*, or with California Technical Bulletin 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*, as follows:

(1) The peak rate of heat release for the single upholstered furniture item shall not exceed 80 kW.
(2) The total heat released by the single upholstered furniture item during the first 10 minutes of the test shall not exceed 25 MJ.

14.3.1.6.4.6 Mattresses.

(A) Mattress components shall have a char length not exceeding 2 in. (51 mm) when tested in accordance with 16 CFR 1632, "Standard for the Flammability of Mattresses and Mattress Pads (FF 4-72)," or NFPA 260.

(B) Mattresses shall have limited rates of heat release when tested in accordance with ASTM E1590, *Standard Test Method for Fire Testing of Mattresses*, or California Technical Bulletin 129, *Flammability Test Procedure for Mattresses for Use in Public Buildings*, as follows:

(1) The peak rate of heat release for the mattress shall not exceed 100 kW.

A. Flammable? B. Inflammable? C. Non-Flammable?

(2) The total heat released by the mattress during the first 10 minutes of the test shall not exceed 25 MJ.

14.3.1.6.4.7 Fill materials contained within upholstered furniture and mattresses shall comply with the open flame test in Section A-1 of the 2000 edition of California Technical Bulletin 117, *Requirements, Test Procedure and Apparatus for Testing the Flame Retardance of Resilient Filling Materials Used in Upholstered Furniture.*

14.3.1.6.4.8 For materials with fire-retardant coatings, the material shall be maintained in accordance with the manufacturer's instructions to retain the fire-retardant properties.

14.3.1.6.4.9 Exposed foamed plastic materials shall be prohibited.

14.3.1.6.5 The use of flammable hair sprays, hair oils, and skin oils shall be prohibited for all chamber occupants/patients as well as personnel.

14.3.1.6.5.1 Whenever possible, patients shall be stripped of all clothing, particularly if it is contaminated by dirt, grease, or solvents, and then reclothed. *(See A.14.3.1.6.4.)*

14.3.1.6.5.2 All cosmetics, lotions, and oils shall be removed from the patient's body and hair.

14.3.1.6.6 All other fabrics used in the chamber, such as sheets, pillow cases, and blankets, shall conform to 14.3.1.6.4.1 and 14.3.1.6.4.2.

14.3.1.6.7 Drapes used within the chamber shall meet the flame propagation performance criteria contained in Test 1 or Test 2, as appropriate, of NFPA 701.

Linen

14.3.1.6.8 Clothing worn by patients in Class A or Class B chambers and personnel in Class A chambers shall, prior to each treatment, conform to the following:

(1) They shall be issued by the hyperbaric facility or specifically approved by the hyperbaric safety coordinator for hyperbaric use.
(2) They shall be uncontaminated.
(3) They shall be devoid of prohibited articles prior to chamber pressurization.

14.3.1.6.9* Paper brought into the chamber shall be stored in a closed metal container.

14.3.2 Equipment.

14.3.2.1 All equipment used in the hyperbaric chamber shall comply with Section 14.2, including the following:

(1) All electrical and mechanical equipment necessary for the operation and maintenance of the hyperbaric facility
(2) Any medical devices and instruments used in the facility

14.3.2.1.1 Use of unapproved equipment shall be prohibited.

14.3.2.1.2 The following devices shall not be operated in the hyperbaric chamber unless approved for such use by the hyperbaric safety coordinator and medical director of hyperbaric medicine:

(1) Portable x-ray devices
(2) Electrocautery equipment
(3) High-energy devices

14.3.2.1.3 Photographic equipment employing the following shall not remain in the chamber when the chamber is pressurized:

(1) Photoflash
(2) Flood lamps

14.3.2.1.4 The use of Class 1 or Class 2 lasers as defined by ANSI Z136.3, *American National Standard for Safe Use of Lasers in Health Care*, shall be permitted.

14.3.2.1.5 Equipment known to be, or suspected of being, defective shall not be introduced into any hyperbaric chamber or used in conjunction with the operation of such chamber until repaired, tested, and accepted by qualified personnel and approved by the hyperbaric safety coordinator. *(See 14.3.1.3.2.)*

14.3.2.2* The following shall be all-metal to the extent possible:

(1) Oxygen containers
(2) Valves
(3) Fittings
(4) Interconnecting equipment

14.3.2.3 The following shall be compatible with oxygen under service conditions:

(1) Valve seats
(2) Gaskets
(3) Hose
(4) Lubricants

14.3.2.4 Equipment used inside the chamber requiring lubrication shall be lubricated with oxygen-compatible material.

14.3.2.4.1 Factory-sealed antifriction bearings shall be permitted to be used with standard hydrocarbon lubricants in Class A chambers that do not employ atmospheres of increased oxygen concentration.

14.3.2.5* Equipment made of the following shall be prohibited from the chamber interior:

(1) Cerium
(2) Magnesium
(3) Magnesium alloys

14.3.2.6* In the event that radiation equipment is introduced into a hyperbaric chamber, hydrocarbon detectors shall be installed.

14.3.2.6.1 In the event that flammable gases are detected in excess of 1000 ppm, radiation equipment shall not be operated until the chamber atmosphere is cleared.

14.3.3 Handling of Gases.

14.3.3.1 The institution's administrative personnel shall develop policies for safe handling of gases in the hyperbaric facility. *(See 14.3.1.6.2.)*

14.3.3.2 Oxygen and other gases shall not be introduced into the chamber in the liquid state.

14.3.3.3 Flammable gases shall not be used or stored in the chamber or in the hyperbaric facility.

14.3.3.4* Pressurized containers of gas shall be permitted to be introduced into the hyperbaric chamber, provided that the container and its contents are approved for such use by the hyperbaric safety coordinator.

relic code

n/a for class B

14.3.4 Inspection, Testing, and Maintenance.

14.3.4.1 General.

14.3.4.1.1 The hyperbaric safety coordinator shall ensure that all valves, regulators, meters, and similar equipment used in the hyperbaric chamber are compensated for use under hyperbaric conditions and tested as part of the routine maintenance program of the facility.

14.3.4.1.1.1 Pressure relief valves shall be tested and calibrated as part of the routine maintenance program of the facility.

N **14.3.4.1.1.2** Where employed, a rupture disc shall be inspected periodically and replaced at intervals specified by the chamber manufacturer.

14.3.4.1.2 The hyperbaric safety coordinator shall ensure that all gas outlets are labeled or stenciled in accordance with CGA C-7, *Guide to Classification and Labeling of Compressed Gases.*

14.3.4.1.3 The requirements set forth in Section 5.1 and NFPA 55 concerning the storage, location, and special precautions required for medical gases shall be followed.

14.3.4.1.4 Storage areas for hazardous materials shall not be located in the room housing the hyperbaric chamber. *(See 14.2.1.)*

14.3.4.1.4.1 Flammable gases, except as provided in 14.3.1.6.2.2(1), shall not be used or stored in the hyperbaric room.

14.3.4.1.5 All replacement parts and components shall conform to original design specification.

14.3.4.1.6* Air from compressors shall be sampled at least every 6 months and after major repair or modification of the compressor(s).

14.3.4.2 Maintenance Logs.

14.3.4.2.1 Installation, repairs, and modifications of equipment related to a chamber shall be evaluated by engineering personnel, tested under pressure, and approved by the hyperbaric safety coordinator.

14.3.4.2.1.1 Logs of all tests shall be maintained.

14.3.4.2.2 Operating equipment logs shall be maintained by engineering personnel.

14.3.4.2.2.1 Operating equipment logs shall be signed before chamber operation by the person in charge. *(See A.14.3.1.3.2.)*

14.3.4.2.3 Operating equipment logs shall not be taken inside the chamber.

14.3.4.3 Fire Protection Equipment for Class A Hyperbaric Chambers.

14.3.4.3.1 Electrical switches, valves, and electrical monitoring equipment associated with fire protection shall be visually inspected before each chamber pressurization.

14.3.4.3.1.1 Where provided, water level indicators shall be visually inspected before each chamber pressurization.

14.3.4.3.1.2 Where provided, air pressure gauges shall be visually inspected before each chamber pressurization.

14.3.4.3.2 Fire detection equipment, if installed, shall be tested each week.

14.3.4.3.2.1 Testing shall include activation of trouble circuits and signals.

14.3.4.3.3 Full testing, including discharge of extinguishing media, shall be conducted annually.

14.3.4.3.4 Inspection, testing, and maintenance of the water storage tanks for Class A chambers shall be in accordance with applicable sections of Chapter 9 of NFPA 25.

14.3.4.3.5* Fire extinguishing systems shall be functionally tested at least semiannually as follows:

(1) For deluge systems, in accordance with the requirements of 14.2.6.2.4 and 14.2.6.2.6
(2) For handline systems, in accordance with the requirements of 14.2.6.3.7.1

14.3.4.3.5.1 Following the test, all valves shall be placed in their baseline position.

14.3.4.3.5.2 If a bypass system is used, it shall not remain in the test mode after completion of the test.

14.3.4.3.5.3 During initial construction, or whenever changes are made to the installed deluge system that will affect the spray pattern, testing of spray coverage to demonstrate conformance to the requirements of 14.2.6.2.5 shall be performed at surface pressure and at maximum operating pressure.

Δ **14.3.4.3.5.4** A detailed record of the test results shall be maintained and a copy sent to the hyperbaric safety coordinator.

14.3.4.3.5.5 Inspection, testing, and maintenance of hyperbaric fire suppression systems shall be performed by a qualified person.

14.3.4.4 Electrical Safeguards.

14.3.4.4.1 All electrical circuits shall be tested in accordance with the routine maintenance program of the facility.

14.3.4.4.1.1 Electrical circuit tests shall include the following:

(1) Ground-fault check to verify that no conductors are grounded to the chamber
(2) Test of normal functioning *(see 14.2.9.2.3.2)*

14.3.4.4.1.2 In the event of fire, all nonessential electrical equipment within the chamber shall be de-energized before extinguishing the fire. Unplug TV, EKG and TCOM monitors, Phone

(A) Smoldering, burning electrical equipment shall be de-energized before extinguishing a localized fire involving only the equipment. *(See 14.2.6.)*

14.3.4.5 Furniture and Grounding.

14.3.4.5.1 Conductive devices on furniture and equipment shall be inspected to ensure that they are free of wax, lint, or other extraneous material that could insulate them and defeat the conductive properties.

14.3.4.5.2* Casters or furniture leg tips shall not be capable of impact sparking.

14.3.4.5.3 Casters shall not be lubricated with oils or other flammable materials.

14.3.4.5.4 Lubricants shall be oxygen compatible.

14.3.4.5.5 Wheelchairs and gurneys with bearings lubricated and sealed by the manufacturer shall be permitted in Class A chambers where conditions prescribed in 14.2.10.4 are met.

14.3.4.6* Electrostatic Safeguards.

14.3.4.6.1 Conductive accessories shall meet conductivity and antistatic requirements.

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14.3.4.6.2* Patient ground shall be verified in Class B chambers prior to each chamber operation.

patient ground

14.3.4.6.3* Patient ground shall be verified in Class A chambers prior to chamber operation whenever atmospheres containing more than 23.5 percent oxygen by volume are used.

chamber ground

14.3.4.6.4 Chamber ground shall be verified to be in accordance with 14.2.9.4.1.3 for Class A and Class B chambers as part of the preventive maintenance program of the facility.

14.3.4.6.5* Materials containing rubber shall be inspected as part of the routine maintenance program of the facility, especially at points of kinking.

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14.3.4.7* Housekeeping. A housekeeping program shall be implemented, whether or not the facility is in regular use.

14.3.4.7.1 The persons assigned to the task of housekeeping shall be trained in the following:

(1) Potential damage to the equipment from cleaning procedures
(2) Potential personal injury
(3) Specific cleaning procedures
(4) Equipment not to be cleaned

Chapter 15 Dental Gas and Vacuum Systems

15.1 Applicability. This chapter shall apply to dental health care facilities that qualify to install dental gas and vacuum piping systems.

N **15.1.1** Category 1 dental piped gas and piped vacuum system requirements shall be applied in facilities where general anesthesia and deep sedation is performed, as defined in 3.3.70.1 and 3.3.70.2.

15.1.2 Category 2 dental piped gas and piped vacuum system requirements shall be applied in facilities where only moderate and minimal sedation is performed, as defined in 3.3.70.3 and 3.3.70.4.

15.1.3 Category 3 dental piped gas and piped vacuum system requirements shall be applied in facilities where minimal or no sedation is performed, as defined in 3.3.70.4.

15.1.4 A single facility shall be permitted to include dental gas and vacuum systems for more than one category of dental piped gas and vacuum systems.

15.1.5 An existing system that is not in strict compliance with the requirements of this code shall be permitted to continue in use unless the authority having jurisdiction has determined that such use constitutes a distinct hazard to life.

N **15.1.6** This chapter shall apply to new health care facilities as specified by Section 1.3 unless otherwise specified by 15.1.7, 15.1.8, or 15.1.9.

15.1.7 The requirements for Category 1 dental gas and vacuum systems for the operation, management, and maintenance of gas and vacuum piping systems shall apply to both new and existing facilities within the scope of this chapter and in accordance with 5.1.1.5.

Δ **15.1.8** The following sections of this chapter shall apply to the operation, management, and maintenance of Category 2 dental gas and vacuum systems in both new and existing facilities:

(1) 15.1.5
(2) Section 15.2
(3) 15.4.2.4.3
(4) 15.4.2.4.6
(5) 15.4.2.4.12
(6) 15.4.2.5.14
(7) 15.4.2.6.4
(8) 15.4.2.9

15.1.9 The following sections of this chapter shall apply to the operation, management, and maintenance of Category 3 dental gas and vacuum systems in both new and existing facilities:

(1) 15.1.5
(2) Section 15.2
(3) 15.5.8

15.1.10 Where the term *responsible facility authority* is used, that entity shall follow the requirements of 5.1.14.1.

15.2 Nature of Hazards of Gas and Vacuum Systems. Potential fire and explosion hazards associated with positive-pressure dental gas systems and vacuum systems shall be considered in the design, installation, testing, operation, and maintenance of these systems.

15.3 Category 1 Dental Gas and Vacuum Systems.

15.3.1 General. Facilities that perform deep sedation and general anesthesia associated with dental treatment shall meet the requirements for Category 1 dental gas and vacuum systems.

15.3.2 Category 1 Medical Gas Systems (Dental).

15.3.2.1 Medical Gas and Vacuum Sources.

15.3.2.1.1 Central Supply System Identification and Labeling. Category 1 systems shall comply with 5.1.3.1.

15.3.2.1.2 Central Supply Operations. Category 1 systems shall comply with 5.1.3.2.

15.3.2.1.3 Central Supply System Locations. Category 1 systems shall comply with 5.1.3.3.

15.3.2.1.4 Central Supply Systems. Category 1 systems shall comply with 5.1.3.5.

15.3.2.1.5 Medical Air Supply Systems. Category 1 systems shall comply with 5.1.3.6, except as follows:

(1) Medical air compressors, dryers, aftercoolers, filters, and regulators shall be permitted to be simplex.
(2) The facility staff shall develop an emergency plan to deal with the loss of medical air.

15.3.2.1.6 Oxygen Supply Systems Using Concentrators. Oxygen supply systems using concentrators shall be permitted to consist of two sources, one of which being a cylinder header with sufficient cylinder connections for an average day's supply.

ing job classification, uniforms, carrying of firearms, reporting times, watch tours, hours of coverage, and other duties to be assigned. Instructions should be lawful and protect the safety of the security officer and those they encounter. Reviews of post orders should be conducted regularly with facility management and security officers. Post orders should be updated regularly and at least annually. A procedure should be established to inform security officers of changes in post orders.

A.13.12.1 The effectiveness of the security plan is tested by performing drills. Drills should be conducted on all work schedules, so that all personnel are familiar with the plan. Practicing the plan helps personnel react as needed during a security incident.

A.14.1 Chapter 14 does not apply to respiratory therapy employing oxygen-enriched atmospheres at ambient pressures. *(See Chapter 11.)*

A.14.2.1.1.1 For guidance on minimum construction requirements, depending on occupancy classification, see NFPA *101*.

A.14.2.1.1.6 Characteristics of building construction housing hyperbaric chambers and ancillary facilities are no less important to safety from fire hazards than are the characteristics of the hyperbaric chambers themselves. It is conceivable that a fire emergency occurring immediately outside a chamber, given sufficient fuel, could seriously endanger the life or lives of those inside the chamber. Since the service facilities, such as compressors, cooling equipment, reserve air supply, oxygen, and so forth, will, in all probability, be within the same building, these facilities will also need protection while in themselves supplying life-maintaining service to those inside.

A.14.2.1.2 In addition to the functions of building protection, the chamber room sprinkler system should be designed to ensure a degree of protection to chamber operators who likely will not be able to immediately evacuate the premises in the event of a fire.

A.14.2.1.2(1) Where the area to be covered is small (six sprinklers or less), 9.7.1.2 of NFPA *101* permits fire sprinkler systems required to be installed in accordance with NFPA 13 to be supplied from the local domestic water system, provided that the local domestic water system has sufficient pressure and flow capacity.

A.14.2.1.2(3) When selecting a clean agent fire protection system, careful consideration should be given to the selection of agent based on permissible exposure levels.

A.14.2.1.3.1 Hyperbaric chamber systems often require piping materials, pressure ratings, and joining techniques that are not permitted by Chapter 5 of this code.

N **A.14.2.1.3.3** This requirement is meant to protect regulators and other components from particles in the piping system. Many pressure regulators incorporate a particulate filter meeting this requirement. If filtration is added, the particulate filter should be in accordance with CGA E-7, *Standard for Medical Gas Pressure Regulators, Flowmeters, and Orifice Flow Selectors.*

A.14.2.2.1 Other chapters in this code contain many requirements that could appear to relate to hyperbaric facilities but could be inappropriate. The requirements of other chapters in this code should be applied to hyperbaric facilities only where specifically invoked by this chapter.

N **A.14.2.2.1.1** The primary pressure relief device is intended to overcome the pressurization supply system. Hyperbaric chamber volume and maximum flow of the pressurization supply system determine the sizing of the primary relief device.

N **A.14.2.2.1.2** In the event of fire inside the hyperbaric chamber, a rapid rise in pressure might overwhelm the capability of the primary pressure relief device. The means of secondary pressure relief is intended to prevent catastrophic failure of the hyperbaric chamber in this scenario.

A.14.2.2.4 A definition for the term *viewport* can be found in ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*.

A.14.2.2.6.1 In past editions of this code, "high quality epoxy" was specified as interior finish in these chambers, without a specific fire performance. Although not the only option, this type of material offers suitable physical properties. The interior finish of a Class A chamber should be smooth, impermeable, durable, provide corrosion resistance, and be compatible with infection control procedures.

A.14.2.2.6.2 One common hazard of paint fires in ships is related to welding or burning operations on one side of a metal bulkhead that heats the metal to a point where the paint on the opposite side ignites. Most paints are not flammable when installed as thin layers over a substantial heat sink, such as the thick steel walls of a hyperbaric chamber, unless the walls are heated first. The same paints, when ground into a powder or installed over a very thin metal substrate, can burn readily. The paint selected for use in the interior walls of a hyperbaric chamber should be selected both for suitability to the requirements of the application and for its combustibility properties. The hazard of a fire increases as the amount of heat sink is reduced. Therefore, combustion is easier to achieve when paint is applied over thin materials and when there are multiple layers of paint. On thin section materials that are easily heated, care should be exercised in selecting the flammability characteristics of the paint and the amount of paint applied.

A.14.2.2.6.4 Many commercial sound-deadening materials that might be nonflammable are porous and will absorb water from activation of the fire-suppression system and retain odor. Metallic panels that contain a large quantity of small holes or are made of wire mesh and are installed about 2.5 cm (1 in.) away from the chamber wall can be used to form an acoustic baffle. These panels should be made from corrosive-resistant materials, such as stainless steel or aluminum, and are permitted to be painted in accordance with 14.2.2.6.3.

A.14.2.2.7 Prudent design considerations suggest that at least 50 percent excess pass-through capacity be provided, for future use, given the difficulty of adding pass-throughs to the chamber after it is constructed and tested.

A.14.2.4.1.2 Experience and practice can dictate the need for a threshold ventilation rate in excess of the minimum specified for sanitary reasons. It is recommended that consideration be given, if necessary, to the use of odor filters in the chamber circulation system as a means of keeping sanitary ventilation rate requirements to a minimum.

N **A.14.2.4.1.3** The intent of this requirement is to allow options for chamber occupants. A risk assessment should be conducted to determine the breathing apparatus appropriate to the environment and identify the potential hazards.

A.14.2.4.2.1 If intakes are located where it could be possible for maintenance to be conducted in the immediate vicinity, a warning sign should be posted.

A.14.2.4.4.1 Ventilation is permitted to be provided by closed- or open-circuit systems.

smoke hoods class B pg 128

A.14.2.5.4 The risk assessment should be documented. When performing a risk assessment, consider using available internal resources (e.g., safety officer, risk management, public safety). Risk assessments should include, but not be limited to, the following factors:

(1) The time required to evacuate to a safe area (as required by 14.3.1.5.4.1)
(2) Building and room architecture (e.g., egress versus defend-in-place architecture)
(3) Accessible means of egress
(4) Room layout, number, and configuration of the chambers
(5) Possible need for slow decompression or decompression stops
(6) Response time of internal and external emergency responders

A.14.2.6.1.5 Experience has shown that fire blankets, portable carbon dioxide extinguishers, and other methodology intended to "snuff out" fires by excluding air are not effective in controlling fires in oxygen-enriched atmospheres. Valuable time can be lost in attempting to use such devices.

N **A.14.2.6.1.7** The required signage should be visible to the patients preparing to go into the hyperbaric chamber. The intent of this requirement is to remind patients of prohibited items before they enter. Best practice is to use signage in multiple zones of control. Locating signage in the chamber waiting area, visible to patients and their family members or caregivers, should be considered. Placing one or more posters in the patient changing area should also be considered. Additionally, if the chamber has a separate entry compartment, placing a sign near the entry compartment should be considered.

N **A.14.2.6.1.9** The intent of 14.2.6.2 is to prescribe specific design features and performance requirements for a water deluge fire suppression system. The intent of 14.2.6.4 is to allow alternative design features and alternative suppression media if the fire suppression system is demonstrated to be effective.

N **A.14.2.6.1.10** The intent of 14.2.6.5 is to allow portable fire extinguishers and alternative extinguishing media.

A.14.2.6.2.3 More than one control station could be required in a compartment (lock), depending on its size.

A.14.2.6.2.5 Experience has shown that, when water is discharged through conventional sprinkler heads into a hyperbaric atmosphere, the spray angle is reduced because of increased resistance to water droplet movement in the denser atmosphere. This is so, even though the water pressure differential is maintained above chamber pressure. Therefore, it is necessary to compensate by increasing the number of sprinkler heads. It is recommended that spray coverage tests be conducted at maximum chamber pressure.

Some chamber configurations, such as small-diameter horizontal cylinders, could have a very tiny floor, or even no floor at all. For horizontal cylinder chambers and spherical chambers, the term *floor level* should be taken to mean the level at ¼ diameter below the chamber centerline or actual floor level, whichever yields the larger floor area.

N **A.14.2.6.2.10** Carbon steel water storage vessels are likely to produce rust. Stainless steel and epoxy-lined vessels, and vessels with polymer-based bladders, might not need strainers. However, a strainer might be prudent in areas with hard water.

N **A.14.2.6.4.1** Fire suppression performance requires a hot test on a simulated burning occupant in a fire under hyperbaric conditions. At commencement of testing, the chamber environmental oxygen level should be at least 23.5 percent. The test is typically performed using a clothed manikin surrounded by materials specifically permitted in this code, including clothing, mattresses, pillows, cushions, and blankets.

N **A.14.2.6.4.1.1** The system should preferably be able to extinguish the fire within 40 seconds of activation. The system should prevent the subsequent rise of temperature elsewhere in the chamber.

A.14.2.6.6.2 Additional detectors are recommended to avoid "blind" areas if the chamber contains compartmentation.

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N **A.14.2.8.1** The required signage should be visible to the patients preparing to go into the hyperbaric chamber. The intent of this requirement is to remind patients of prohibited items before they enter. Best practice is to use signage in multiple zones of control. Locating signage in the chamber waiting area, visible to patients and their family members or caregivers, should be considered. Placing one or more posters in the patient changing area should also be considered.

A.14.2.9.2.1 A backup generator or backup power system for the hyperbaric facility might not be necessary, but certain electrically driven features of hyperbaric facilities should have some type of backup. This could be addressed with a single backup power system or with multiple, smaller power sources. The source for such backup power and emergency lighting can be battery supplied.

A.14.2.9.2.1(1) Chamber room emergency lighting should be provided and does not require a unique type of emergency lighting because it is a hyperbaric facility.

A.14.2.9.2.1(2) Chamber emergency lighting requirements vary. For chambers with a large acrylic window, found in most Class B chambers, the room emergency lighting is sufficient to meet this requirement. For chambers made primarily of steel, with a small window(s), lighting dedicated to the chamber interior might be necessary. In this case, at least on light should be provided with backup power.

A.14.2.9.2.1(3) Chamber intercommunication power requirements vary. The duration of backup power for communications depends on the type of hyperbaric treatments performed but should not have to exceed the duration of a hyperbaric treatment conducted in the facility.

A.14.2.9.2.1(4) Class A chambers might employ flame detectors. If employed, these detectors should have backup power. Flame detectors are typically not employed in Class B chambers.

A.14.2.9.2.1(5) Class A chambers are required to have a fire suppression system. All electrical controls related to activation and performance of the fire suppression system should have backup power. Fire suppression systems are not typically employed in Class B chambers.

A.14.2.9.2.1(6) Some Class A and Class B chambers employ electrical controls as part of the pressurization and ventilation system of the chamber. These controls should have backup power.

A.14.2.9.3 This subsection contains requirements for the safe use of electrical equipment in the hyperbaric, oxygen-enriched environment of the Class A chamber.

N **A.14.2.9.3.3.2** Portable patient entertainment equipment does not include personal entertainment devices prohibited by 14.3.1.6.1.2.

A.14.2.9.3.9 It should be recognized that interruption of any powered circuit, even of very low voltage, could produce a spark sufficient to ignite a flammable agent.

A.14.2.9.3.10.1 It is recommended that all control switching functions inside the chamber be accomplished using intrinsically safe circuits that control power and control circuits located outside of the chamber.

A.14.2.9.3.11 It is the intention of 14.2.9.3.11 that equipment used in the chamber be incapable of igniting, by heating, any material or fabric that could come into contact with the surface of the equipment.

A.14.2.9.3.13 It is recommended that electric motors not be located inside the chamber. This recommendation is not intended to apply to a motor that is within a piece of portable medical equipment.

A.14.2.9.3.14 It is strongly recommended that high-intensity local task lighting be accomplished using through-hull fiber-optic lights. Many high-intensity lights will not meet the temperature requirements specified in 14.2.9.3.11.

A.14.2.9.3.15.1 The requirement for isolation from main supply in 14.2.9.3.15.1 is not the same as the requirement in 14.2.9.4.2 that circuits supplying power to portable utilization equipment inside the chamber be isolated, monitored, and alarmed.

It is recommended that intrinsically safe sensors and controls be used whenever possible.

A.14.2.9.3.16 These requirements are only the minimum requirements for electrical safety. There are many other safety concerns that should be addressed on a case-by-case basis. Meeting the requirements of 14.2.9.3.16 does not indicate that proper device performance will occur in the hyperbaric environment and that the device will be safe for use with patients.

A.14.2.9.3.17 The intent of this section is to mitigate the risks of fire when an electrical device is placed inside the chamber and put under pressure.

The requirements of this section are not intended for things such as approved wristwatches and similar approved small battery-powered devices. See B.14.5 for additional information on inert gas or air purging.

A.14.2.9.5.2 It is necessary that these circuits be protected from exposure to water from the room sprinkler system protecting the chamber housing in the event of a fire in the vicinity of the chamber while it is in operation.

A.14.2.9.6.1.1 Limiting current using a suitable current sensing device (e.g., a rapid acting fuse or circuit breaker, located outside the chamber) would provide appropriate protection and prevent circuits from exceeding the 4.0 W power limit.

A.14.2.10.2 Intercommunications equipment is mandatory for safe operation of a hyperbaric facility.

A.14.2.10.2.1 It is recommended that multiple-compartment (lock) Class A chambers be equipped with multiple channel systems and that, in addition, a sound-powered telephone or surveillance microphone be furnished.

A.14.2.10.2.2 It is recommended that information about the status of an anesthetized or otherwise monitored patient be transmitted to the inside chamber attendants via the intercommunications system. As an alternative, the monitor indicators can be placed adjacent to a chamber viewport (or viewports) for direct observation by inside personnel.

A.14.2.10.4.4 Oxygen levels in Class A chambers should be sampled from at least two sample ports at disparate locations in the chamber, and the chamber should be equipped with an oxygen monitor for each sample port.

Chamber atmospheres are typically not homogenous. Oxygen can accumulate in pools or pockets around patients with levels that are dangerously high. A single oxygen sample port inside the chamber might not be sufficient to detect increased oxygen levels in another area of the chamber. In this case, a serious increase of oxygen, well above the allowed level of 23.5 percent, can go undetected. Providing at least two sample ports allows for better assessment of the oxygen levels inside the chamber. The size of the vessel should be factored into determining how many ports are necessary.

A dedicated oxygen analyzer on each line prevents false readings from two or more sample lines feeding into one oxygen sensor.

For example, one sample line might come from an area of 21 percent, and the other line might come from an area of 50 percent or more. When both lines come together, they will mix and give a false low oxygen reading. Having a dedicated oxygen monitor for each sample line will avoid this unsafe situation.

A.14.2.10.4.4.2 The ability to spot check for oxygen leaks and oxygen pooling is essential for the safe management of oxygen levels. If the minimum 30-second response time is not compromised, the extension or "snooping wand" can remain connected for easy use.

A.14.2.10.6 The purity of the various gas supplies should be ensured. A purity statement for any cryogenic or high-pressure cylinder gas should be supplied by the vendor. Gas cylinder purity statements should be cross-referenced, where possible, with the delivered gas.

For additional verification, some facilities have installed sampling ports for monitoring oxygen and other gases.

A.14.2.10.6.1 CGA Grade E permits quantities of hydrocarbons and water in air. In piping systems where air and oxygen might be used interchangeably, hydrocarbon buildup can occur and increase the risk of fire when oxygen is used. There is also a concern about pneumatic components being fouled and functionally impaired by hydrocarbons or water from compressed air. Ideally, there should be no condensed hydrocarbons in an oxygen system and no liquid water in pneumatic control systems.

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A.14.2.11.2 Exhaust piping extending from the building can create a lightning risk. Lightning protection should be considered.

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A.14.2.11.2.5 The facility should consider bilingual signage that is appropriate to the location. The hyperbaric safety coordinator should be aware of any work performed on the roof near exhaust vent.

See Figure A.14.2.11.2.5 for examples of the pictographs required by NFPA 170.

A.14.3.1.2 The hazards involved in the use of hyperbaric facilities can be mitigated successfully only when all of the areas of hazard are fully recognized by all personnel and when the physical protection provided is complete and is augmented by attention to detail by all personnel of administration and maintenance having any responsibility for the functioning of the hyperbaric facility. Since Section 14.3 is expected to be used as a text by those responsible for the mitigation of hazards of hyperbaric facilities, the requirements set forth are frequently accompanied by explanatory text.

N **A.14.3.1.3.1** It is incumbent upon the personnel responsible for the hyperbaric facility to insist that rules and regulations with respect to practices and conduct in hyperbaric facilities — including qualifications and training of hyperbaric personnel — be adopted by the medical or administrative staff of the institution, and that regulations for inspection and maintenance are in use by the administrative, maintenance, and ancillary (and, in hospitals, nursing and other professional) personnel.

Personnel responsible for the hyperbaric facility should adopt or correlate regulations and standard operating procedures to ensure that both the physical qualities and the operating maintenance methods pertaining to hyperbaric facilities meet the safety standards in accordance with Chapter 14. The controls adopted should cover the conduct of personnel in and around hyperbaric facilities and the apparel and footwear allowed. They should also cover periodic inspection of static-dissipating materials and of all electrical equipment, including the testing of ground contact indicators.

Δ **A.14.3.1.3.2** The complexity of hyperbaric chambers necessitates that at least one person be designated as hyperbaric safety coordinator. Regardless of the terminology used for this designee, the intent is for someone to manage the operational responsibilities of this chapter. This requirement can be met by creating a hyperbaric safety coordinator job description for the designee or by merely assigning the additional responsibilities to someone with another job description. In either case, a hyperbaric safety coordinator designation document should be created and signed by a person responsible for the hyperbaric facility.

Because of variations in the management structure of hyperbaric facilities, this designation could be made by a variety of people including the hyperbaric medical director, the hyperbaric department manager/director, hospital administration, or a management company responsible for the hyperbaric facility. It is not the intent of this requirement for the designation to be made by an authority having jurisdiction (e.g., fire marshal, health department inspector).

The hyperbaric safety coordinator does not have to be present during all chamber operations but should be accessible to the hyperbaric physicians and staff and, where unavailable, have a process in place to manage safety decisions based on the responsibilities referenced below. The designee should have firsthand knowledge of the hyperbaric equipment, personnel, training, operating procedures, and maintenance procedures in their facility. Due to a conflict of responsibility, the designee should not be the hyperbaric medical director.

Safety, operational, and maintenance criteria of other organizations have been published (e.g., in Undersea & Hyperbaric Medical Society Safety Committee documents and Compressed Gas Association pamphlets) and should be reviewed by the hyperbaric safety coordinator. The hyperbaric safety coordinator should also serve on the health care facility safety committee.

Hyperbaric safety coordinator responsibilities can be found in the following paragraphs:

(1) 14.2.9.6.4
(2) 14.3.1.2

Outside Chamber Exhaust Sign

No Open Flame — Flame 	Circular field Red circle and slash Black image White background	The identification of areas in which open flame is prohibited	The identification of areas, such as combustible storage areas, gas stations, and hazardous areas
No Smoking 	Circular field Red circle and slash Black image White background	The identification of areas in which smoking is prohibited	The identification of areas, such as those for flammable liquid storage, where smoking could lead to fire or explosion

FIGURE A.14.2.11.2.5 Fire Safety Symbols from NFPA 170.

(3) 14.3.1.3.2, including 14.3.1.3.2.1 through 14.3.1.3.2.3
(4) 14.3.1.3.3.1
(5) 14.3.1.3.4
(6) 14.3.1.4.1.1
(7) 14.3.1.4.2
(8) 14.3.1.5.4
(9) 14.3.1.6.2.2
(10) 14.3.1.6.3.1
(11) 14.3.1.6.4.3
(12) 14.3.1.6.4.4
(13) 14.3.2.1.2
(14) 14.3.2.1.5
(15) 14.3.3.4
(16) 14.3.4.1.1 and 14.3.4.1.2
(17) 14.3.4.2.1
(18) 14.3.4.3.5.4

A.14.3.1.3.3 It is recommended that training of hyperbaric chamber personnel be closely monitored, following the guidelines and publications of the Undersea & Hyperbaric Medical Society, the Baromedical Nurses Association, and the National Board of Diving and Hyperbaric Medical Technology.

A.14.3.1.3.4 In the case of a hyperbaric facility located in a hospital, hospital licensing and other approval bodies, in meeting their responsibilities to the public, should include in their inspections not only compliance with requirements for physical installations in hyperbaric facilities, but also compliance with the requirements set forth in Section 14.3.

A.14.3.1.4.1 It is recommended that all personnel, including trainees and those involved in the operation and maintenance of hyperbaric facilities, and including professional personnel and (in the case of hospitals) others involved in the direct care of patients undergoing hyperbaric therapy, be familiar with Chapter 14. Personnel concerned should maintain proficiency in the matters of life and fire safety by periodic review of Chapter 14, as well as any other pertinent material.

Positive measures are necessary to acquaint all personnel with the rules and regulations established and to ensure enforcement. Training and discipline are necessary.

A.14.3.1.4.6 The complexity of hyperbaric chambers is such that one person should be designated chamber operator, such as a person in a position of responsible authority. Before starting a hyperbaric operation, this person should record, in an appropriate log, the purpose of the operation or test, the duties of all personnel involved, and a statement that he or she is satisfied with the condition of all equipment. Exceptions should be itemized in the statement.

A.14.3.1.5.2 All full- and part-time personnel should receive training in emergency management appropriate to their job descriptions.

A.14.3.1.5.4 A calm reaction (without panic) to an emergency situation can be expected only if the recommendations are familiar to and rehearsed by all concerned.

A suggested outline for emergency action in the case of fire is contained in B.14.2.

A.14.3.1.6.1.1 Oxygen-filled chambers dump oxygen into the room each time the door is opened at the end of a treatment. Oxygen could also be dumped into the room by the chamber pressure relief device. Air-filled chambers could leak oxygen into the room from the breathing gas piping. This oxygen enrichment lowers the ignition temperature of combustible materials. Therefore, extra caution should be used in the area around the chamber as well as inside the chamber.

A.14.3.1.6.1.3 Precautions should be in place for monitoring items used to prepare a patient or staff member for entry into the hyperbaric chamber to prevent the entry of prohibited items into the hyperbaric chamber.

In addition to monitoring prohibited items, the following items should be verified:

(1) Patient identity
(2) Pretreatment orders
(3) Appropriate safety measures
(4) Appropriate staffing
(5) Appropriate textiles
(6) Patient grounding

A.14.3.1.6.2.2(2) Allowable quantities complying with 14.3.1.6.2.2(2) can be determined from the chamber volume, flammable agent vapor density, and lower explosive limit (LEL). Experience has shown that increased pressure has little effect on LEL for a given flammable gas and oxygen concentration. A safety factor of 10 is recommended. Flammable liquids should be confined to nonbreakable, nonspill containers.

Sample Determination. An example of limiting quantity of flammable agent substance:

Isopropyl alcohol (2-propanol)

LEL = 2%/vol. (irrespective of chamber pressure)

Vapor density = 2.1 relative to air

Liquid density = 786 g/L (49.1 lb/ft^3)

Air density = 0.075 lb/ft^3 (1.2 kg/m^3) at STP

The limiting case occurs at the lowest ambient pressure, that is, 1 atmosphere:

$$\begin{aligned}\text{Alcohol vapor density at LEL} &= 0.02 \times 2.1 \times 0.075\\ &= 0.00315 \text{ lb/ft}^3 \text{ (0.05 kg/m}^3\text{)}\\ &= 1.43 \text{ g/ft}^3 \text{ (0.05 kg/m}^3\text{)}\end{aligned}$$

For a relatively small 500 ft^3 (14.2 m^3) chamber, this implies:

1.43 × 500 = 715 g (1.58 lb) alcohol vapor at LEL

Using a safety factor of 10 to account for uneven vapor concentrations gives 71.5 g = 91 mL (3 oz) alcohol.

One could conclude that even 90 mL (3 oz) of alcohol is more than would be needed for almost any medical procedure. The preceding calculation also does not account for the mitigating effect of ventilation.

Many "inert" halogenated compounds have been found to act explosively in the presence of metals, even under normal atmospheric conditions, despite the fact that the halogen compound itself does not ignite in oxygen or, in the case of solids such as polytetrafluoroethylene, is self-extinguishing. Apparently these materials are strong oxidizers, whether gases, liquids (solvents, greases), or solids (electrical insulation, fabric, or coatings). Some halogenated hydrocarbons that will not burn in the presence of low-pressure oxygen will ignite and continue to burn in high-pressure oxygen. Customarily, Class A

chambers maintain internal oxygen concentration that does not exceed 23.5 percent.

Parts of Chapter 14 deal with the elements required to be incorporated into the structure of the chamber to reduce the possibility of electrostatic spark discharges, which are a possible cause of ignition in hyperbaric atmospheres. The elimination of static charges is dependent on the vigilance of administrative activities in materials, purchase, maintenance supervision, and periodic inspection and testing. It cannot be emphasized too strongly that an incomplete chain of precautions generally will increase the electrostatic hazard. For example, conductive flooring can contribute to the hazard unless all personnel wear conductive shoes, all objects in the room are electrically continuous with the floor, and humidity is maintained.

The limitations in 14.3.1.6.2.2 on the use in the chamber of alcohol and other agents that emit flammable vapors should be strictly observed, and such restrictions should be prominently posted.

A.14.3.1.6.3 The number of occupants of the chamber should be kept to the minimum number necessary to carry out the procedure.

A.14.3.1.6.4 It is recommended that all chamber personnel should wear garments of the overall or jumpsuit type that completely cover all skin areas to the extent possible and that are as tight-fitting as possible. It can be impractical to clothe some patients (depending upon their disease or the site of any surgery) in such garments. Hospital gowns can be employed in such a case.

linen

A.14.3.1.6.4.2 Selection of textiles for the hyperbaric chamber should be based on a variety of factors, including comfort, lint production, ignition temperature, static-producing properties, and fuel load of the material. The amount of polyester in a cotton/polyester blend will likely have an effect on all of these factors.

Historically, all synthetic fabrics were prohibited from the chamber. Previous editions of this code allowed an "antistatic blend of cotton and polyester" because of one specific fabric — a blend of cotton and polyester with steel fibers to make it conductive. This blended fabric was intended for surgical scrubs, but its conductive properties made it a good choice for hyperbaric garments. The polyester in the fabric was acceptable because the conductive properties of the fabric actually afforded some protection from static production that cotton fabric did not. This particular fabric is no longer made. Selection of textiles has always been about balancing various safety concerns; primarily fire-resistance and static production. For further guidance on selecting appropriate textiles, see A.14.3.1.6.4.3.

Δ **A.14.3.1.6.4.3** The intent of this requirement is to allow for exceptions, where appropriate. The risk assessment process below is a tool to guide the decision. Although the process was designed for textiles and wound dressings, it could be used to assess any material. In addition to exceptions, this risk assessment should be used to develop a "use" list (i.e., locally approved items) and a "do not use" list (i.e., locally prohibited items). Documentation should include the "use" and "do not use" lists as well as a worksheet for each item identifying the reference material used and rationale for continuing or not continuing at each decision step in the process.

The textiles definitions and risk assessment process for hyperbaric wound dressings are as follows:

Combustion. A chemical process of oxidation that occurs at a rate fast enough to produce heat in the form of either a glow or flame.

Flammable. A combustible (solid, liquid, or gas) that is capable of easily being ignited and rapidly consumed by fire.

Flash Point. The minimum temperature at which a liquid or a solid emits vapor sufficient to form an ignitible mixture with oxygen under specified environmental conditions.

Ignition Temperature. The minimum temperature required to initiate or cause self-sustaining combustion under specified environmental conditions.

Lower Explosive Limit (LEL) or Lower Flammable Limit (LFL). The minimum concentration of fuel vapor (percent by volume) over which combustion will occur on contact with an ignition source.

General Risk Assessment Information. This risk assessment process was designed to evaluate wound dressing products for use in a hyperbaric chamber. However, the same decision process can be applied to the evaluation of textiles for hyperbaric use. Wound dressings are commonly used inside hyperbaric chambers and play an important role in infection control and patient outcome. Important safety concerns include production of heat, production of static electricity, production of flammable vapor, ignition temperature, and total fuel load. Many wound dressings employ fabrics and other materials that are gas permeable. It is a common misconception that a gauze bandage will isolate an undesirable product from the chamber environment. Gauze is gas permeable and will allow oxygen from the chamber to interact with the product and allow vapors from the product to interact with the chamber environment. Also, gas permeable materials exposed to hyperbaric oxygen will hold additional oxygen for some time after the exposure. These materials should be kept away from open flames for at least 20 minutes after the hyperbaric treatment.

Risk Assessment Process (see Figure A.14.3.1.6.4.3).

(1) Is there a more suitable alternative to this dressing? The issue of need must first be addressed. There might be a substitute dressing that has already been deemed acceptable for the hyperbaric environment. The wound dressing orders can be changed to the more desirable substitute if there is no negative impact on patient outcome. It might be viable to remove the dressing before the hyperbaric treatment, leave it off during the treatment, and replace it after the treatment. Before making this decision, it is important to remember that some dressings should not be disturbed (e.g., in the case of a new skin graft); some dressings are designed to stay in place for several days; some dressings are very expensive; and it can be detrimental for the wound to remain undressed during the treatment. If there is a suitable alternative to using this dressing, the rest of the decision process can be eliminated.

(2) Does this dressing produce heat in the chamber? Dressings are made from a large variety of materials. The concern is that materials in a dressing can rapidly oxidize and produce heat (i.e., cause an exothermic reaction) when exposed to additional oxygen. For example, air-activated heat patches (commonly used for pain relief)

have been tested in hyperbaric environments. The average operating temperature increased from 48.1°C (119°F) in normobaric air to 121.8°C (251°F) in hyperbaric oxygen. In this circumstance, the patient's skin would be burned, and the heat could ignite combustible material in the chamber. Information on oxygen compatibility can be found in a product material safety data sheet (MSDS).

(3) Does this dressing produce too much static electricity? All common textiles will contribute to static production. Wool and synthetic materials generally contribute more to static production than cotton. Although static charge is constantly accumulating, it will dissipate into the environment when humidity is present. At less than 30 percent relative humidity, static charge can accumulate faster than it can dissipate. At greater than 60 percent relative humidity, static charge is all but eliminated. Use of conductive surfaces and electrical grounding will allow static charge to dissipate. Paragraph 14.2.9.4.1 requires all hyperbaric chambers to be grounded. Paragraph 14.2.11.1 requires any furniture installed inside a chamber to be grounded. Paragraph 14.3.1.6.3.2 requires all occupants of the chamber to be grounded when the oxygen percentage in the chamber is above 23.5 percent. The continuity of electrical grounds should be verified periodically.

grounding

(4) Does this dressing have a low ignition temperature/flash point? ASTM G72/G72M, *Standard Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment*, can be used to determine the autogenous ignition temperatures of products entering a hyperbaric chamber. In 2016, ASTM G72/G72M added a new test for oxygen-enriched environments of less than 300 psi (2068 kPa) of pressure. In all hyperbaric environments, the partial pressure of oxygen is higher than at normal atmospheric conditions. Increasing the partial pressure of oxygen can change the classification of a material from nonflammable to flammable. Many materials are flammable in a 100 percent oxygen environment. Any material used in a hyperbaric chamber should have an ignition temperature higher than the temperature to which it could be exposed. Paragraph 14.2.9.3.11 limits electrical equipment inside a Class A (i.e., multi-place) chamber to a maximum operating surface temperature of 85°C (185°F). Paragraph 14.2.9.6.3 limits electrical circuits inside a Class B (i.e., monoplace) chamber to a maximum operating temperature of 50°C (122°F). As the oxygen percentage increases, it takes less energy to ignite materials. This leads to more conservative decisions in a 100 percent oxygen environment. A greater margin of safety is achieved when there is a greater difference between the temperature limit of the equipment inside a Class A or Class B chamber and the ignition temperature of the material in question. A material will release vapor into the chamber environment as it approaches its flash point temperature. Once sufficient vapor is present in the chamber (i.e., LEL), it takes very little energy for ignition to occur. Paragraph 14.3.1.6.2.2 sets limits on flammable agents inside Class A (i.e., multiplace) chambers. Paragraph 14.3.1.6.2.3 specifically prohibits flammable liquids, gases, and vapors inside Class B (i.e., monoplace) chambers. Information on ignition temperature and flash point in air can be found in a product MSDS.

(5) Is the total fuel load too high? If a fire does occur, the energy produced is a function of the partial pressure of oxygen and the total fuel load. In a hyperbaric environment, the partial pressure of oxygen is higher and contributes to greater energy production. Any dressing product placed inside of a hyperbaric chamber is a combustible material and adds to the fuel load. Therefore, total fuel load inside the chamber should be minimized to only what is necessary.

(6) Is there an adverse effect when this product is used inside the hyperbaric chamber? It has been reported that the antibacterial agent mafenide acetate, in combination with hyperbaric oxygen, has a poorer clinical result than either one by itself. There can be other drug interactions with hyperbaric oxygen that are undesirable. The mechanical effects of pressure change can cause a dressing material to rupture. If the material is capable of venting/equalizing during pressure change, this should not occur.

(7) The hyperbaric facility should maintain a "use" list and a "do not use" list of items that have been evaluated for hyperbaric use. In addition to this list, it is important to keep documentation on file explaining the risk assessment for each item. This will prevent future duplication of effort. It also serves as evidence that due diligence was used.

N **A.14.3.1.6.4.4** Documentation of the exception(s) should include the rationale, any limits, and at least one additional measure to mitigate the hazard(s). The following is an example of such written documentation: "Available chamber-approved clothing is too small for Patient X. To protect patient dignity, we will allow Patient X to wear their own clothing in the chamber for the duration of their course of treatment. The clothing must be made of material allowed by NFPA 99. The clothing will be inspected daily for contraband and cleanliness."

See also A.14.3.1.3.2.

A.14.3.1.6.9 The use of paper should be kept to an absolute minimum in hyperbaric chambers.

A.14.3.2.2 Users should be aware that many items, if ignited in pressurized oxygen-enriched atmospheres, are not self-extinguishing. Iron alloys, aluminum, and stainless steel are, to various degrees, in this category, as well as human skin, muscle, and fat, and plastic tubing such as polyvinyl chloride. Testing for oxygen compatibility is very complicated. Very little data exists, and many standards still have to be determined. Suppliers do not normally have facilities for testing their products in controlled atmospheres, especially high-pressure oxygen. Both static conditions and impact conditions are applicable. Self-ignition temperatures normally are unknown in special atmospheres.

A.14.3.2.5 See A.14.3.2.2.

A.14.3.2.6 Radiation equipment, whether infrared or roentgen ray, can make hyperbaric chambers even more hazardous.

A.14.3.3.4 Quantities of oxygen stored in the chamber should be kept to a minimum.

relic code

A.14.3.4.1.6 The frequency of such monitoring should depend on the location of the air intake relative to potential sources of contamination.

A.14.3.4.3.5 The primary focus for the semiannual test of a water-based extinguishing system is to ensure water flow

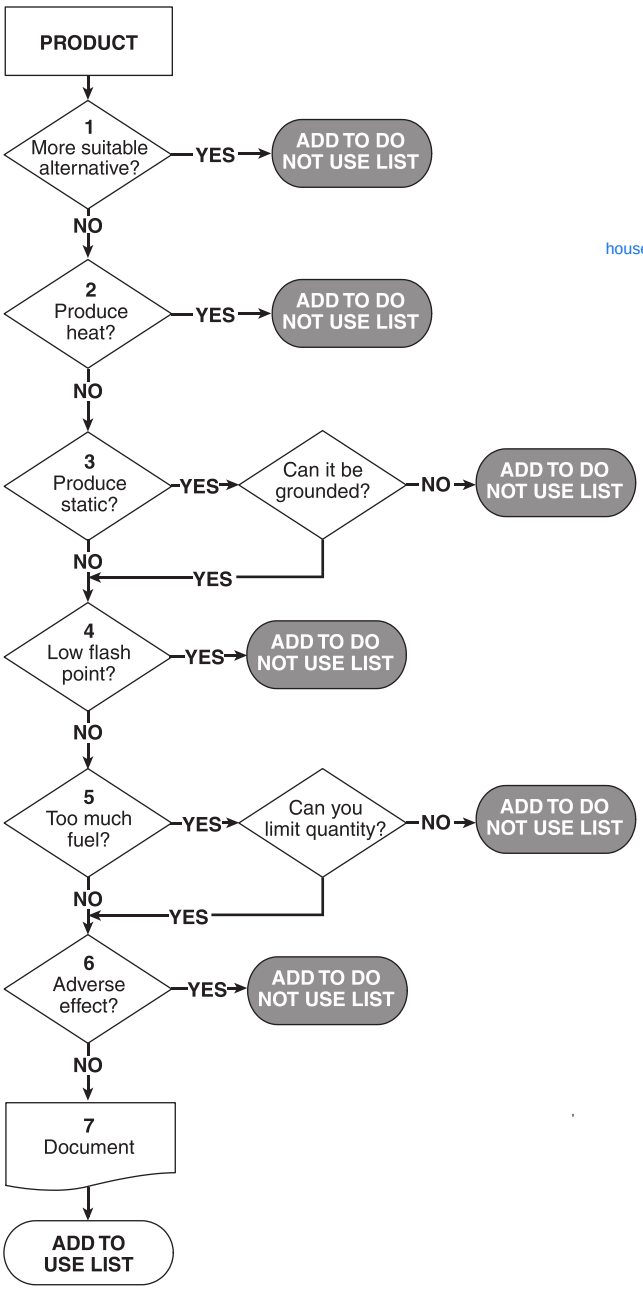

FIGURE A.14.3.1.6.4.3 Risk Assessment Process.

through the system (i.e., inspector's test). Other vitally important benefits are the activation of water flow devices, alarm appliances, and notification and annunciator systems.

A.14.3.4.5.2 Ferrous metals can cause such sparking, as can magnesium or magnesium alloys, if contact is made with rusted steel.

A.14.3.4.6 The elimination of static charges is dependent on the vigilance of administrative supervision of materials purchased, maintenance, and periodic inspection and testing.

grounding

A.14.3.4.6.2 Verification of patient grounding should include actual testing of ground, not just a visual verification. Ideally, the verification will include connecting the patient to the ground pathway and measuring no more than 100,000,000 ohms with a meter. This value comes from NFPA 77.

A.14.3.4.6.3 See A.14.3.4.6.2.

A.14.3.4.6.5 Materials containing rubber deteriorate rapidly in oxygen-enriched atmospheres.

housekeeping

A.14.3.4.7 It is absolutely essential that all areas of, and components associated with, the hyperbaric chamber be kept meticulously free of grease, lint, dirt, and dust.

A.15.3.3.4 Dental air systems are used primarily to drive gas-powered power devices. See Figure A.15.3.3.4 for an illustration of this type of system. Similar applications are found in podiatry and plastic surgery. Examples of these are air used to drive turbine-powered drills and air used to dry teeth and gums. Some dental hand pieces have an internal self-contained air return system, while other hand pieces discharge air into the atmosphere. Some discharge a mixture of air and water. Nitrogen is often piped as an alternative or reserve supply to the compressor system.

Dental compressed air is not used for life-support purposes, such as respirators, intermittent positive-pressure breathing (IPPB) machines, analgesia, anesthesia, and so forth. Air discharged into the oral cavity is incidental and not a primary source of air to sustain life.

A dental compressed air system should not be used to provide power for an air-powered evacuation system without specific attention paid to the discharge of the evacuated gases and liquids. An open discharge of evacuated gases into the general environment of an operatory could compromise the quality of breathing air in the treatment facility. Air discharge should be vented to the outside of the building through a dedicated vent.

An air-powered evacuation system might require significant quantities of air to operate.

Manufacturer's recommendations should be followed regarding proper sizing of the air compressor. Inadequate sizing can result in overheating, premature compressor failures, and inadequate operating pressures and flows.

A.15.3.3.5 A dental vacuum system is not intended for medical–surgical vacuum applications. A wet piping system is designed to accommodate liquid, air–gas, and solids through the service inlet. A dry piping system is designed to accommodate air–gas only through the service inlet, with liquids and solids being trapped before entering the system. *[See Figure A.15.3.3.5(a) through Figure A.15.3.3.5(d).]*

A.15.4.2.4.2 Requirements for the location of these enclosures, including, but not limited to, design and construction, ventilation, and cylinder storage, are located in 5.1.3.3. For additional information on ventilation, see 9.3.6. For additional information on cylinder storage, see Chapter 11.

A.15.4.2.4.7 When the storage/supply enclosure is remote from the single treatment facility, it should be locked for security reasons (i.e., to prevent tampering). Access should only be allowed for authorized staff or fire departments. When the enclosure is within the single treatment facility, it is left to the discretion of facility management as to whether a greater benefit is achieved by immediate access or by higher security. An

B.13 Reserved.

B.14 Additional Information on Chapter 14.

B.14.1 Nature of Hazards.

B.14.1.1 Fire and Explosion.

B.14.1.1.1 The occurrence of a fire requires the presence of combustible or flammable materials, an atmosphere containing oxygen or other oxidizing agent(s), and heat or energy source of ignition.

Note that certain substances such as acetylenic hydrocarbons can propagate flame in the absence of oxygen.

B.14.1.1.2 Under hyperbaric conditions utilizing compressed air, the partial pressure of oxygen is increased. Leakage of oxygen into the atmosphere of the chamber (for example, from improper application of respiratory therapy apparatus) can further increase markedly the oxygen partial pressure.

B.14.1.1.2.1 The flammability or combustibility of materials generally increases as the partial pressure of oxygen increases, even when the percentage of oxygen in the gas mixture remains constant. Materials that are nonflammable or noncombustible under normal atmospheric conditions can become flammable or combustible under such circumstances.

B.14.1.1.3 Sources of Fuel.

B.14.1.1.3.1 Materials that might not ignite in air at atmospheric pressure or require relatively high temperatures for their ignition but that burn vigorously in 100 percent oxygen include, but are not necessarily limited to, the following: tricresyl phosphate (lubricant); certain types of flame-resistant fabrics; silicone rubber; polyvinyl chloride; asbestos-containing paint; glass fiber-sheathed silicone rubber-insulated wire; polyvinyl chloride-insulated asbestos-covered wire and sheet; polyamides; epoxy compounds; and certain asbestos blankets.

Note that flammable lubricants are used widely in equipment designed for conventional use, including shafts, gear boxes, pulleys and casters, and threaded joints, which are coupled and uncoupled.

B.14.1.1.3.2 The flammability of certain volatile liquids and gases containing carbon and hydrogen is well known. Hazards and safeguards for their use in oxygen-enriched atmospheres at ambient pressure are well-documented in the NFPA *Fire Protection Guide to Hazardous Materials* and NFPA 53.

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B.14.1.1.3.3 Human tissues will burn in an atmosphere of 100 percent oxygen. Body oils and fats, as well as hair, will burn readily under such circumstances.

B.14.1.1.3.4 When a conventional loose cotton outer garment, such as scrub suits, dresses, and gowns employed in hospital operating suites, is ignited in an atmosphere of pure oxygen, the garment will become engulfed in flame rapidly and will be totally destroyed within 20 seconds or less.

If such a garment is ignited in a compressed air atmosphere, the flame spread is increased. When oxygen concentration exceeds 23.5 percent at elevated total pressure, flame spread is much more rapid, and at 6 ATA, is comparable to 95 ± 5 percent at 1 ATA. Flame spread in air (21 percent oxygen) is somewhat increased at 6 ATA, but not to the level of 95 ± 5 percent at 1 ATA.

Combustible fabrics have tiny air spaces that become filled with oxygen when exposed to oxygen-enriched environments. Once removed to atmospheric air (e.g., room air outside the chamber), the fabric will burn, if ignited, almost as rapidly as if it were still in the oxygen environment. This hazard will remain until the oxygen trapped in the air spaces in the fabric has had time to diffuse out and be replaced by air.

B.14.1.1.3.5 Oil-based or volatile cosmetics (facial creams, body oils, hair sprays, and the like) constitute a source of fuel that is highly flammable in an oxygen-enriched atmosphere.

B.14.1.1.4 Sources of Ignition.

B.14.1.1.4.1 Sources of ignition that might be encountered in a hyperbaric chamber include, but are not necessarily limited to, the following: defective electrical equipment, including failure of high-voltage components of radiological or monitoring equipment; heated surfaces in broken vacuum tubes or broken lamps used for general illumination, spot illumination, or illumination of diagnostic instruments; the hot-wire cautery or high-frequency electrocautery; open or arcing switches, including motor switches; bare defibrillator paddles; overheated motors; and electrical thermostats.

B.14.1.1.4.2 Sources of ignition that should not be encountered in a hyperbaric facility, but that might be introduced by inept practice, include the following: lighted matches or tobacco, static sparks from improper use of personal attire, electrical wiring not complying with 14.2.9, cigarette lighters, and any oil-contaminated materials that present a spontaneous heating hazard.

B.14.1.1.4.3 In oxygen-enriched atmospheres, the minimum energy necessary to ignite flammable or combustible materials is reduced in most instances below the energy required in atmospheres of ambient air.

B.14.1.2 Mechanical Hazards.

B.14.1.2.1 General.

B.14.1.2.1.1 A large amount of potential energy is stored in even a small volume of compressed gas. In hyperbaric chambers of moderate or large size, the potential energy of the chamber's compressed atmosphere, if released suddenly, can produce devastating destruction to adjacent structures and personnel, as well as to structures and personnel remote from the site of the chamber. Such sudden release could result from failure of the vessel structure, its parts, or its piping.

B.14.1.2.1.2 A particular hazard can be created if individuals attempt to drill, cut, or weld the vessel in a manner contrary to ASME's *Boiler and Pressure Vessel Code*.

B.14.1.2.2 The restriction on escape and the impedance to rescue and firefighting efforts posed by the chamber create a significant hazard to life in case of fire or other emergency.

B.14.1.2.2.1 A particular hazard exists to chamber personnel in the event of a fire within the structure housing the chamber. Inability to escape from the chamber and loss of services of the chamber operator would pose serious threats to the lives of all occupants of the chamber.

B.14.1.2.2.2 All personnel involved in hyperbaric chamber operation and therapy, including patients and family, have to be made aware of the risks and hazards involved. Fire prevention is essential. Extinguishment of a fire within a Class B cham- ***

****Safest Patient: Grounded, Naked, Skinny, Hairless, & Soaked with water! Anything more is added risk; how much risk is acceptable?

ber is impossible. Extinguishment of a fire within a Class A chamber is only possible utilizing equipment already installed in such a chamber, and then often only by the efforts of the occupants of such a chamber or the chamber operator.

B.14.1.2.3 The necessity for restricting viewing ports to small size limits the vision of chamber operators and other observers, reducing their effectiveness as safety monitors.

B.14.1.2.4 Containers and enclosures can be subjected to collapse or rupture as a consequence of the changing pressures of the hyperbaric chamber. Items containing entrained gas include, but are not necessarily limited to, the following: ampuls, partially filled syringes, stoppered or capped bottles, cuffed endotracheal tubes, and pneumatic cushions employed for breathing masks or aids in positioning patients. The rupture of such containers having combustible or flammable liquids would also constitute a severe fire or explosion hazard.

B.14.1.2.4.1 The sudden collapse of containers from high external pressures will result in adiabatic heating of the contents. Therefore the collapse of a container of flammable liquid would constitute a severe fire or explosion hazard both from heating and from a spill of the liquid. *(See 14.3.1.6.2 and B.14.1.1.3.2.)*

B.14.1.2.5 Other mechanical hazards relate to the malfunction, disruption, or inoperativeness of many standard items when placed in service under pressurized atmospheres. Hazards that might be encountered in this regard are implosion of illuminating lamps and vacuum tubes; overloading of fans driving gas at higher density; and inaccurate operation of standard flowmeters, pressure gauges, and pressure-reducing regulators.

Note that illuminating lamps or vacuum tubes, which implode, or overloaded fans, are sources of ignition.

B.14.1.3 Pathophysiological, Medical, and Other Related Hazards.

B.14.1.3.1 Exposure of pregnant chamber occupants to hyperbaric atmospheres might result in fetal risk.

B.14.1.3.2 Medical hazards that can be encountered routinely include compression problems, nitrogen narcosis, oxygen toxicity, and the direct effects of sudden pressure changes.

B.14.1.3.2.1 Inability to equalize pressure differentials between nasopharynx (nose) and nasal sinuses or the middle ear can result in excruciating pain and might cause rupture of the eardrum or hemorrhage into the ear cavity or nasal sinus.

B.14.1.3.2.2 The breathing of air (78 percent nitrogen) under significant pressures (as by chamber personnel breathing chamber atmosphere) can result in nitrogen narcosis, which resembles alcoholic inebriation. The degree of narcosis is directly related to the amount of pressurization. Nitrogen narcosis results in impairment of mental functions, loss of manual dexterity, and interference with alertness and ability to think clearly and act quickly and intelligently in an emergency.

B.14.1.3.2.3 Oxygen toxicity can develop from breathing oxygen at partial pressures above 0.50 atmospheres absolute for a significant length of time. Oxygen toxicity can affect the lungs (pain in the chest, rapid shallow breathing, coughing), nervous system (impaired consciousness and convulsions), or other tissues and organs, or combinations thereof.

B.14.1.3.2.4 Direct effects of reduction in pressure can include inability to equalize pressures between the nasopharynx and sinuses or middle ear, expansion of gas pockets in the gastrointestinal tract, and expansion of trapped gas in the lungs.

B.14.1.3.2.5 The presence of personnel within the cramped confines of the hyperbaric chamber in close proximity to grounded metallic structures on all sides creates a definite shock hazard if accidental contact is made with a live electrical conductor or a defective piece of electrical equipment. Such accidental contact also could be a source of ignition of flammable or combustible materials. *(See B.14.1.1.4.)*

B.14.1.3.3 Medical hazards that are not ordinarily encountered during hyperbaric oxygen therapy, but that might arise during malfunction, fire, or other emergency conditions, include electric shock and fouling of the atmosphere of the chamber with oxygen, nitrous oxide, carbon dioxide, carbon monoxide, pyrolysis products from overheated materials, or the toxic products of combustion from any fire.

B.14.1.3.3.1 Increased concentrations of carbon dioxide within the chamber, as might result from malfunction of the systems responsible for monitoring or removal thereof, can be toxic under increased pressures.

B.14.1.3.3.2 The development of combustion products or gases evolved from heated nonmetallics within the closed space of the hyperbaric chamber can be extremely toxic to life because of the confining nature of the chamber and the increased hazards of breathing such products under elevated pressure.

Note that extreme pressure rises have accompanied catastrophic fires in confined atmospheres. These pressures have driven hot, toxic gases into the lungs of victims as well as exceeding the structural limits of the vessel in at least one case.

B.14.1.3.4 Physiological hazards include exposure to high noise levels and decompression sickness. Rapid release of pressurized gases can produce shock waves and loss of visibility.

B.14.1.3.4.1 During hyperbaric therapy, and especially during compression, the noise level within the chamber becomes quite high. Such a level can be hazardous because it is distractive, interferes with communication, and can produce permanent sensory-neural deafness.

B.14.1.3.4.2 Decompression sickness (bends, caisson worker's disease) results from the elution into the bloodstream or extravascular tissues of bubbles of inert gas (mainly nitrogen) that becomes dissolved in the blood and tissue fluids while breathing air at elevated pressures for a significant period of time.

Note that rapid decompression of the chamber can occur if the pressure relief valve is damaged from exposure to a fire external to the chamber or from the venting of hot products of combustion from within the chamber.

B.14.1.3.4.3 The use of decompression procedures will prevent immediate escape from the Class A chamber by occupants during emergency situations.

Note that these procedures are not followed if chamber occupants are exposed to a "no-decompression exposure" [compression to less than 2 atmospheres absolute (ATA) air],

or when compressed to 2 ATA or higher pressures and breathing 100 percent oxygen.

B.14.1.3.4.4 The sudden release of gas, whether by rupture of a container or operation of a device such as used in firefighting, will produce noise, possible shock waves, reduced or obscured visibility, and temperature changes. The initial effect might be to cool the air, but resulting pressure rises will cause adiabatic heating.

B.14.1.3.5 In summary, the hazards of fire and related problems in hyperbaric systems are real. By the very nature of the hyperbaric atmosphere, increased partial pressures of oxygen are present routinely. Flammability and combustibility of materials are increased. Ignition energy is lowered. Both immediate escape and ready entry for rescue are impeded. Finally, attendants within the chamber, through effects of the elevated noise level and nitrogen pressure, might be unable to respond to emergencies quickly and accurately.

B.14.2 Suggested Procedures to Follow in Event of Fire in Class A Chambers.

B.14.2.1 Fire Inside Chamber. For fire inside the chamber, the following procedures should be performed:

(1) The actions of the inside observer should be as follows:
   (a) Don breathing air device immediately.
   (b) Activate fire suppression system and/or handheld hoses.
   (c) Advise outside.
(2) The actions of the chamber operator should be as follows:
   (a) Activate the fire suppression system, if needed.
   (b) Switch breathing gas to air.
   (c) Decompress the chamber as rapidly as possible.
   (d) Deactivate all unnecessary electrical equipment.
(3) The actions of the medical personnel (outside) should be as follows:
   (a) Direct operations and assist crew members wherever necessary.
   (b) Provide medical support as required.
(4) The actions of the other personnel (outside) should be as follows:
   (a) Notify the fire department by activating fire signaling device.
   (b) Stand by with a fire extinguisher.
   (c) Assist in unloading chamber occupants.

B.14.2.2 Fire Outside Chamber. For fire outside the chamber, the following procedures should be performed:

(1) The actions of the chamber operator should be as follows:
   (a) Notify the inside observer to stand by for emergency return to normal atmospheric pressure.
   (b) Notify the fire department by activating fire signaling device.
   (c) Switch breathing gas to air.
   (d) Don the operator's breathing device, if applicable.
(2) The actions of the medical personnel (outside) should be as follows:
   (a) Determine whether procedure should be terminated.
   (b) Provide medical support as required.

B.14.3 Suggested Fire Procedures for Facilities with Class B Chambers.

B.14.3.1 For fires within the facility not involving the chamber, the following procedure should be performed:

(1) Don the operator's means for respiratory and eye protection, if applicable *(see 14.2.5.4)*.
(2) Decompress the chamber. The urgency of decompression should be determined by the location of the fire.
(3) Remove the patient and evacuate to a safe area.
(4) Turn off the oxygen zone valve to the chamber room and close any smoke/fire barrier doors. These steps are consistent with the rescue and confine elements of the rescue, alarm, confine, extinguish (R.A.C.E.) procedure. It is assumed that other personnel will evacuate other patients and visitors from the area and activate a fire alarm signaling device (if not already activated).

B.14.3.2 For fire within the chamber, the following procedure should be performed:

(1) Stop oxygen from flowing into the chamber by switching off the chamber (if the chamber is compressed with oxygen) or switching the supply gas of a breathing device from oxygen to air (if the chamber is compressed with air).
(2) Decompress the chamber as rapidly as possible in accordance with the emergency decompression procedures.
(3) Stand by with a handheld fire extinguisher and spray into the chamber (if necessary) when the chamber door is opened.
(4) Remove the patient and evacuate to a safe area.
(5) Turn off the oxygen zone valve to the chamber room and close any smoke/fire barrier doors.

These steps are consistent with the rescue and confine elements of the rescue, alarm, confine, extinguish (R.A.C.E.) procedure. It is assumed that other personnel will evacuate other patients and visitors from the area and activate a fire alarm signaling device (if not already activated). The injured patient should have appropriate medical attention immediately after evacuation to a safe area. Many Class B chambers require oxygen supply pressure to operate a rapid decompression feature. If this is the case, do not turn off the oxygen zone valve or any inline oxygen supply shutoff valve until all patients have been removed from the chamber(s).

B.14.4 See Table B.14.4.

B.14.5 Gas Purging. Inert gas or air purging is a means to mitigate the risk of fire from an electrical device brought into the chamber. The three main objectives to inert gas or air purging are to lower the oxygen level, to purge increased heat from the device and to help prevent dust accumulation inside the device.

Fire research has demonstrated that under normal conditions combustion will not take place when the oxygen level is at 6 percent or less. This is regardless of the treatment pressure and is related to the ratio of oxygen to the inert gas. With an oxygen level of 6 percent and the balancing inert gas level of 94 percent, the high percentage of inert gas will prevent combustion.

A clear policy and procedure should be written for an inert gas purging system. It should include the inert gas parameters for each device and instructions for the proper setup of the system.

Δ Table B.14.4 Pressure Table

Atmosphere Absolute (ATA)	mm Hg	psia	psig	Equivalent Depth in Seawater		mm Hg Oxygen Pressure of Compressed Air	mm Hg Oxygen Pressure of Oxygen-Enriched Air (23.5%)
				ft	m		
1	760	14.7	0	0	0	160	179
1.5	1140	22	7.35	16.5	5.07	240	268
2.0	1520	29.4	14.7	33.1	10.13	320	357
2.5	1900	36.7	22.0	49.7	15.20	400	447
3.0	2280	44.1	29.4	66.2	20.26	480	536
3.5	2660	51.4	36.7	82.7	25.33	560	625
4.0	3040	58.8	44.1	99.2	30.40	640	714
5.0	3800	73.5	58.8	132.3	40.53	800	893

Notes:
(1) The oxygen percentage in the chamber environment, not the oxygen partial pressure, is of principal concern, as concentrations above 23.5 percent oxygen increase the rate of flame spread. Thirty percent oxygen in nitrogen at 1 ATA (228 mm Hg pO_2) increases burning rate. However, 6 percent oxygen in nitrogen will not support combustion, regardless of oxygen partial pressure (at 5 ATA, 6 percent oxygen gives 228 mm Hg pO_2).
(2) The Subcommittee on Hyperbaric and Hypobaric Facilities recommends that one unit of pressure measurement be employed. Since a variety of different units are now in use, and since chamber operators have not settled upon one single unit, the above table includes the five units most commonly employed in chamber practice.

All testing to determine the proper inert gas or air flow should be well documented. At a minimum, approval signatures have to be obtained from the medical director and the hyperbaric safety coordinator. Other signatures should include the department manager and biomedical representatives.

Startup and shutdown checklists should include purge gas parameters with visual checks and verifications of inside devices, purge gas equipment, and alarms.

Where gas purging is used, the following should be considered:

(1) Each electrical device should comply with 14.2.9.3.17. Gas purging is only one element of the essential risk assessment and management that is critical to safely managing any electrical device that is introduced into the chamber. A comprehensive risk assessment with approved safety procedures and mitigation orders needs to be documented and signed by the medical director, hyperbaric safety coordinator and all who are directly involved, prior to the device being used in the chamber.
(2) Each gas purge device should have its own dedicated purging line and flowmeter with each flowmeter clearly labeled identifying the gas used. Splitting a purge line to supply two or more devices can create a disparity of flow between the multiple gas lines depending on the length and resistance of each line. One device might be well protected with high flow and the other device inadequately protected with very little flow. A single line with a single flowmeter will prevent this and will provide a measurable way to verify the correct flow to the device. A gas flowmeter can be mistaken for an oxygen flowmeter.
(3) When using an inert gas, oxygen should be maintained at less than or equal to 6 percent within the electrical compartment(s) of the device at all treatment levels. For initial testing and, to establish the proper inert gas flow, oxygen levels in the electrical compartments of the device should be tested at all treatment pressures.
(4) The manufacturer's safe operating temperature range should be maintained at all treatment levels. Gas purging is useful for purging increased heat from the device. For initial testing and, to establish the proper inert gas flow, temperature levels in the electrical compartments of the device should be tested at all treatment pressures.
(5) Supply pressure for gas purging should be supplied from a regulator system that will maintain the surface pressure over the chamber's treatment pressure, or over-bottom pressure. Maintaining purge gas pressure at all treatment levels can be accomplished by means of a tracking type regulator outside the chamber or by placing the regulator inside the chamber with an adequate supply pressure for all treatment pressures.
(6) An audio and visual alarm system should activate at the operator's console if there is a loss of sufficient pressure to maintain set flowrates to the gas purging system during any pressurization of the chamber. The chamber operator needs to be alerted to a loss of purge gas flow.
(7) Chamber operations should be aborted if there is a loss of sufficient pressure to the gas purging system as noted in (6). Loss of purge gas pressure creates risks to patients and staff.
(8) When using inert gas, oxygen monitoring of the chamber's atmosphere should have a low-level alarm limit set at no lower than 19.5 percent. Normal gas purging is unlikely to lower the oxygen level of the chamber atmosphere during hyperbaric oxygen treatments. However, because inert gas is being introduced into the chamber, an oxygen low-level alarm limit of 19.5 percent should be set.
(9) Electrical devices that are enclosed, such as TV monitors placed in acrylic boxes, should have some means of extinguishing the device with water from the deluge system or the handheld hose. Acrylic boxes/enclosures are sometimes used to make gas purging easier. In the event of a fire or smoke inside this box there should be some means of drenching the device inside with water.
(10) The doors to chambers with gas purging systems using inert gas should be kept open during nonoperational hours. Chambers are made to be airtight. If the chamber doors are closed, (e.g., overnight), and the inert gas is inadvertently left on, the inert gas could potentially accumulate inside the chamber to a dangerous level. This would deplete the oxygen level and create a hazard for anyone entering the chamber.