Hyperbaric Chamber Safety

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NFPA® 99

Health Care Facilities Code

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Tentative Interim Amendments (TIAs) to 10.2.3.6(5) and 11.5.1.1 were issued on August 14, 2014. For further information on tentative interim amendments, see Section 5 of the Regulations Governing the Development of NFPA Standards, available at http://www.nfpa.org/regs

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Origin and Development of NFPA 99

The idea for this document grew as the number of documents under the original NFPA Committee on Hospitals grew. By the end of 1980, there existed 12 documents on a variety of subjects, 11 directly addressing fire-related problems in and about health care facilities. These documents covered health care emergency preparedness, inhalation anesthetics, respiratory therapy, laboratories in health-related institutions, hyperbaric facilities, hypobaric facilities, inhalation anesthetics in ambulatory care facilities, home use of respiratory therapy, medical–surgical vacuum systems in hospitals, essential electrical systems for health care facilities, safe use of electricity in patient care areas of health care facilities, and safe use of high-frequency electricity in health care facilities.

A history on the documents that covered these topics can be found in the "Origin and Development of NFPA 99" in the 1984 edition of NFPA 99.

What was then the Health Care Facilities Correlating Committee reviewed the matter beginning in late 1979 and concluded that combining all the documents under its jurisdiction would be beneficial to those who used those documents, for the following reasons:

(1) The referenced documents were being revised independently of each other. Combining all the individual documents into one document would place all of them on the same revision cycle.
(2) It would place in one unit many documents that referenced each other.
(3) It would be an easier and more complete reference for the various users of the document (e.g., hospital engineers, medical personnel, designers and architects, and the various types of enforcing authorities).

To learn if this proposal was desired or desirable to users of the individual documents, the Committee issued a request for public comments in the spring of 1981, asking whether purchasers of the individual documents utilized more than one document in the course of their activities and whether combining these individual documents would be beneficial. Seventy-five percent of responses supported such a proposal, with 90 percent of health care facilities and organizations supportive of it. Based on this support, the Correlating Committee proceeded with plans to combine all the documents under its jurisdiction into one document.

In January, 1982, a compilation of the latest edition of each of the 12 individual documents under the jurisdiction of the Correlating Committee was published. It was designated NFPA 99, *Health Care Facilities Code*. The Correlating Committee also entered the document into the revision cycle reporting to the 1983 Fall Meeting for the purpose of formally adopting the document.

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.

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) 14.2.4.3.3 (and subsections)
(7) 14.2.4.4 (and subsections)
(8) 14.2.4.5.3
(9) 14.2.4.5.4 (and subsection)
(10) 14.2.5.1.4 (excluding subsection)
(11) 14.2.5.1.5
(12) 14.2.5.1.7
(13) 14.2.5.5 (and subsection)
(14) 14.2.7.1
(15) 14.2.7.2 (and subsection)
(16) 14.2.8.3 through 14.2.8.3.5
(17) 14.2.8.3.9 (and subsection)
(18) 14.2.8.3.15.4
(19) 14.2.8.3.16.5
(20) 14.2.8.3.17 (and subsections)
(21) 14.2.8.4.1.3
(22) 14.2.8.6 (and subsections)
(23) 14.2.9.3 through 14.2.9.8 (and subsections)
(24) 14.2.10.2.5
(25) 14.3.1 (and subsections)
(26) 14.3.2.1.1 through 14.3.2.1.8
(27) 14.3.2.4 through 14.3.2.6 (and subsection)
(28) 14.3.3 through 14.3.6 (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 of Care.

14.1.3.1 Category 1 Care. Where interruption or failure of medical gas supply is likely to cause major injury or death of patients, staff, or visitors, the level of care shall be considered Category 1 in the requirements for medical gas systems in hyperbaric facilities.

14.1.3.2 Category 2 Care. Where interruption or failure of medical gas supply is likely to cause minor injury of patients, staff, or visitors, the level of care shall be considered Category 2 in the requirements for medical gas systems in hyperbaric facilities.

14.1.3.3 Category 3 Care. Where interruption or failure of medical gas supply is not likely to cause injury to patients, staff, or visitors, the level of care shall be considered Category 3 in the requirements for medical gas systems in hyperbaric facilities.

14.1.3.4 Category 4 Care. (Reserved)

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* A hydraulically calculated automatic wet pipe sprinkler system meeting the requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems*, or an automatic water mist fire protection system installed in accordance with NFPA 750, *Standard on Water Mist Fire Protection Systems*, shall be installed in the room housing a Class A, Class B, or Class C chamber and in any ancillary equipment rooms.

14.2.1.2.1 Class A, Class B, or Class C 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.

14.2.1.3 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 ANSI/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).

14.2.1.4 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).

14.2.1.4.3 The requirements of ANSI/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 General. Where an oxygen system is installed for hyperbaric treatments, it shall comply with the requirements for the appropriate level as determined in 14.2.1.4.4.2 through 14.2.1.4.4.7.

14.2.1.4.4.1 Hyperbaric oxygen systems for Category 1, Category 2, and Category 3 care connected directly to a hospital's oxygen system shall comply with Section 5.1, as applicable, except as noted in 14.2.1.4.4.2.

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

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

14.2.1.4.4.3 Hyperbaric stand-alone oxygen systems for Category 1 and Category 2 care shall comply with Section 5.1, as applicable, except as noted in 14.2.1.4.4.4.

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

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

14.2.1.4.4.5 Warning Systems.

(A) 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.

(B) 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

14.2.1.4.4.6 Hyperbaric stand-alone oxygen systems for Category 3 care shall comply with Section 5.2, as applicable, except as noted in 14.2.1.4.4.7.

14.2.1.4.4.7 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 is 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 is required.
(3) If the operating oxygen supply consists of a bulk primary, a reserve with a minimum supply of 15 minutes is required.
(4) An EOSC is not required for the hyperbaric oxygen system.
(5) An IBER is not required for the hyperbaric oxygen system.

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

14.2.1.6 Hyperbaric Medical Air System Requirements.

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

14.2.1.6.2 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).

14.2.1.6.3 ANSI/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).

14.2.1.6.4 Where a medical air system is installed for hyperbaric treatments, it shall comply with the requirements for the appropriate level as determined in 14.2.1.6.4.1 through 14.2.1.6.4.7.

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

14.2.1.6.4.2 Reserved.

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

14.2.1.6.4.4 Reserved.

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

14.2.1.6.4.6 Hyperbaric stand-alone medical systems for Category 3 care shall comply with Section 5.2, as applicable, except as noted in 14.2.1.6.4.7.

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

(1) Area and master alarms are not required for Category 3 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 is permitted.

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 ANSI/ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*, by personnel qualified to fabricate vessels under such codes.

14.2.2.1.1 Piping systems for hyperbaric facilities shall be required to meet only the requirements of this chapter and section "Piping" of ANSI/ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy.*

14.2.2.1.2 Piping that is installed in concealed locations in the building housing 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 ANSI/ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy.*

14.2.2.3 As a minimum, animal chambers shall be designed, fabricated, and stamped to meet ASME *Boiler and Pressure Vessel Code* Section VIII, Division 1 code requirements.

14.2.2.4 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.

14.2.2.4.1 The floor of Class A chambers shall be noncombustible.

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

14.2.2.4.3 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.

14.2.2.5* The interior surface of Class A chambers shall be unfinished or treated with a paint/coating in accordance with 14.2.2.5.1.

14.2.2.5.1* Interior paint/coating shall meet the performance criteria of NFPA *101*, Class A interior finish, when tested in accordance with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials,* or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials.*

14.2.2.5.2 One additional application of paint shall be permitted, provided total paint thickness does not exceed 1/28 in. (0.9 mm).

14.2.2.5.3 If the interior of a Class A chamber is treated (painted) with a finish described in 14.2.2.5, 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.

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

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

14.2.2.6.1 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.

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

14.2.3 Illumination.

14.2.3.1 Unless designed for chamber use, sources of illumination shall be mounted outside the pressure chamber and arranged to shine through chamber ports or through chamber penetrators designed for fiber-optic or similar lighting.

14.2.3.1.1 Lighting fixtures used in conjunction with viewports shall be designed so that temperature ratings for the viewport material given in ANSI/ASME PVHO-1 are not exceeded.

14.2.3.1.2 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.

14.2.3.1.2.1 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 Lighting permanently installed inside the chamber and portable lighting for temporary use inside the chamber shall meet the requirements of 14.2.8.3.15.

14.2.3.3 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 14.2.9.4.1 and 14.2.9.5 are met.

14.2.4.1.3 Individual breathing apparatus shall be available inside a Class A chamber for each occupant for use 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 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.

14.2.4.1.3.4 In the event of a fire within a chamber, provision shall be made to simultaneously switch all breathing apparatus to an air supply that is independent of the chamber atmosphere.

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 14.2.9.6.

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 14.2.9.6.

14.2.4.2.4.1 The air treatment packages shall include automatic safeguards.

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 14.2.8.2.5 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* Class A chambers that are not used in the capacity of an operating room shall maintain a temperature that is comfortable for the occupants [usually 22°C ±2°C (75°F ±5°F)].

14.2.4.3.3 Whenever the Class A chamber is used as an operating room, it shall be ventilated, and the atmosphere shall be conditioned according to the minimum requirements for temperature in hospital operating rooms.

14.2.4.3.3.1 If inhalation anesthetic agents are being utilized (e.g., halothane, isoflurane, sevoflurane, desflurane), a closed anesthetic system with exhaled gas scavenging and overboard dumping shall be employed.

14.2.4.3.3.2 Flammable inhalation anesthetics (e.g., cyclopropane, ethyl ether, ethylene, and ethyl chloride) shall not be employed.

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

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

14.2.4.3.6 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 14.2.9.4.

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.

14.2.4.5 Emergency Depressurization and Facility Evacuation Capability.

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

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

14.2.4.5.3* A means for respiratory and eye protection from combustion products allowing unrestricted mobility shall be available outside a Class A or Class B chamber for use by personnel in the event the air in the vicinity of the chamber is fouled by smoke or other combustion products.

14.2.4.5.4 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 during the fire training drill required by 14.3.1.4.5.

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14.2.4.5.4.1 The occupants for this training drill shall be permitted to be simulated.

14.2.5 Fire Protection in Class A Chambers.

14.2.5.1 General.

14.2.5.1.1 A fire suppression system consisting of independently supplied and operating handline- and deluge-type water spray systems shall be installed in all Class A chambers.

14.2.5.1.2 Design of the fire suppression system shall be such that failure of components in either the handline or deluge system will not render the other system inoperative.

14.2.5.1.3 System design shall be such that activation of either the handline or the deluge system shall automatically cause the following:

(1) Visual and aural 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 14.2.3.3)* and communication, where used, shall be activated.

14.2.5.1.3.1 Intrinsically safe circuits, including sound-powered communications, shall be permitted to remain connected when either the handline or the deluge system is activated.

14.2.5.1.4* A fire alarm signaling device shall be provided at the chamber operator's control console for signaling the emergency fire/rescue network of the institution containing the hyperbaric facility.

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

(1) They shall comply with 14.2.5.1.4.
(2) They shall have a means for immediately contacting the local fire department.

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

14.2.5.1.6 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 14.2.8.2.2.2.

14.2.5.1.7 Signs prohibiting the introduction of flammable liquids, gases, and other articles not permitted by this chapter into the chamber shall be posted at the chamber entrance(s).

14.2.5.1.8 The fire suppression system shall be permitted to be supplied from the local potable water service.

14.2.5.2 Deluge System. A fixed water deluge extinguishing system shall be installed in all chamber compartments that are designed for manned operations.

14.2.5.2.1 In chambers that consist of more than one chamber compartment (lock), the design of the deluge system shall meet the requirements of 14.2.5.2 when the chamber compartments are at different depths (pressures).

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

14.2.5.2.3 Fixed deluge systems shall not be required in chamber compartments that are used strictly as personnel transfer compartments (locks) and for no other purposes.

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

14.2.5.2.4.1 Controls shall be designed to prevent unintended activation.

14.2.5.2.5 Water shall be delivered from the fixed discharge nozzles as specified in 14.2.5.2.7 within 3 seconds of activation of any affiliated deluge control.

14.2.5.2.6* 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).

14.2.5.2.7 Water shall be available in the deluge system to maintain the flow specified in 14.2.5.2.6 simultaneously in each chamber compartment (lock) containing the deluge system for 1 minute.

14.2.5.2.7.1 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.

14.2.5.2.8 The deluge system shall have stored pressure to operate for at least 15 seconds without electrical branch power.

14.2.5.3 Handline System. A handline extinguishing system shall be installed in all chamber compartments (locks).

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

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

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

14.2.5.3.4 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.

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

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

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

14.2.5.3.7 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.

14.2.5.3.7.1 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.

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

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

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

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

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

14.2.5.4.4 If used to automatically activate the deluge system, the requirements for manual activation/deactivation in 14.2.5.2.4 and deluge system response time in 14.2.5.2.5 shall still apply.

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

14.2.5.4.6 Automatic fire detection equipment, when used, shall meet the applicable requirements in 14.2.8.3.

14.2.5.5* Testing. The deluge and handline systems shall be functionally tested at least semiannually per 14.2.5.2.7 for deluge systems and 14.2.5.3.7 for handline systems.

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

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

14.2.5.5.3 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 14.2.5.2.6 shall be performed at surface pressure and at maximum operating pressure.

14.2.5.5.3.1 The requirements of 14.2.5.2.6 shall be satisfied under both surface pressure and maximum operating pressure.

14.2.5.5.4 A detailed record of the test results shall be maintained and a copy sent to the hyperbaric facility safety director.

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

14.2.6 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.

14.2.7 Fire Protection in Class B and Class C Chambers. Class B and Class C chambers shall not be required to comply with 14.2.5.

14.2.7.1 Signs prohibiting the introduction of flammable liquids, gases, and other articles not permitted by this chapter into the chamber shall be posted at the chamber entrance(s).

14.2.7.2 A fire alarm signaling device shall be provided within the room housing the chamber(s) for signaling the emergency fire/rescue network of the institution containing the hyperbaric facility.

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

(1) They shall comply with 14.2.7.2.
(2) They shall have a means for immediately contacting the local fire department.

14.2.8 Electrical Systems.

14.2.8.1 General.

14.2.8.1.1 The requirements of *NFPA 70, National Electrical Code,* 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 14.2.8.

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

14.2.8.1.3 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

14.2.8.1.4 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

14.2.8.1.4.1* If motors are to be located in the chamber, they shall meet the requirements of 14.2.8.3.14.

14.2.8.1.5 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 14.2.8.3.

14.2.8.1.6 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.

14.2.8.2 Electrical Service.

14.2.8.2.1 All hyperbaric facilities shall contain an electrical service that is supplied from two independent sources of electric power.

14.2.8.2.1.1 All hyperbaric facilities for human occupancies shall contain an electrical service that is supplied from two independent sources of electric power.

14.2.8.2.1.2 For hyperbaric facilities using a prime-mover-driven generator set, it 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.

14.2.8.2.1.3 Article 700 of *NFPA 70, National Electrical Code,* shall apply to hyperbaric systems located in facilities other than health care facilities.

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

14.2.8.2.2.1 The equipment specified in 14.2.8.2.2 shall include, but is not limited to, the following:

(1) Electrical power outlets located within the chamber
(2) Chamber emergency lighting, whether internally or externally mounted
(3) Chamber intercommunications
(4) Alarm systems, including fire detectors
(5) Chamber fire suppression system equipment and controls
(6) Other electrical controls used for chamber pressurization and ventilation control
(7) A sufficient number of chamber room lights (either overhead or local) to ensure continued safe operation of the facility during a normal power outage

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

14.2.8.2.3 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 NFPA 70, National Electrical Code, Article 700)*, as applicable.

14.2.8.2.4 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.

14.2.8.2.5 When 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 source of power.

14.2.8.2.6 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.

14.2.8.3* Wiring and Equipment Inside Class A Chambers. The general rules of 14.2.8.3.1 through 14.2.8.3.17.6 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 *NFPA 70, National Electrical Code*, Article 500) hazardous location.

14.2.8.3.1 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.

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

14.2.8.3.3 Only the electrical equipment necessary for the safe operation of the chamber and for required patient care shall be permitted in the chamber.

14.2.8.3.4 Only portable equipment necessary for the logistical and operational support shall be permitted in the chamber during manned pressurization.

14.2.8.3.5 Where conformance with Class I, Division 1 requirements is specified in 14.2.8.3.7, conformance with Class I, Division 2 requirements shall be permitted to be substituted.

14.2.8.3.6 Wires and Cables. Wires and cables used inside the chamber shall be resistant to the spread of fire by complying with 14.2.8.3.6.1 or shall be contained within equipment described in 14.2.8.3.6.2.

14.2.8.3.6.1 Wires and cables shall comply with the spread of fire requirements of "UL Flame Exposure, Vertical Tray Flame Test" in UL 1685, *Standard for 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-M, *Test Methods for Electrical Wires and Cables*.

14.2.8.3.6.2 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 14.2.8.3.6.1.

14.2.8.3.7 Wiring Methods.

14.2.8.3.7.1 Fixed wiring shall be installed in threaded RMC or IMC conduit utilizing the following waterproof components:

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

14.2.8.3.7.2 A continuous ground shall be maintained between all conductive surfaces enclosing electrical circuits and the chamber hull using approved grounding means.

14.2.8.3.7.3 All threaded conduit shall be threaded with an NPT standard conduit cutting die that provides a 19 mm taper per 0.3 m (0.75 in. taper per 1 ft).

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

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

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

14.2.8.3.8 Drainage. Means of draining fixed conduit and fixed equipment enclosures shall be provided.

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

(1) They shall be of a type approved for extra-hard utilization in accordance with Table 400.4 of *NFPA 70, National Electrical Code*.
(2) They shall include a ground conductor.
(3) They shall meet the requirements of 501.140 of *NFPA 70, National Electrical Code*.

14.2.8.3.9.1 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.

14.2.8.3.10* Receptacles Installed Inside the Chamber.

14.2.8.3.10.1 Receptacles shall be waterproof.

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

14.2.8.3.10.3 Receptacles shall be supplied from isolated power circuits meeting the requirements of 14.2.8.4.2.

14.2.8.3.10.4 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.

14.2.8.3.10.5 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.

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

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

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

14.2.8.3.13 Exposed Live Electrical Parts. No exposed live electrical parts shall be permitted, except as specified in 14.2.8.3.13.1 and 14.2.8.3.13.2.

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

14.2.8.3.13.2 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 14.2.8.3.17.

14.2.8.3.14 Motors. Motors shall meet one of the following requirements:

(1) They shall comply with 501.125(A)(1) of *NFPA 70, National Electrical Code,* for the chamber pressure and oxygen concentration.
(2) They shall be of the totally enclosed types meeting 501.125(A)(2) or 501.125(A)(3) of *NFPA 70, National Electrical Code.*

14.2.8.3.15* Lighting.

14.2.8.3.15.1 Lighting installed or used inside the chamber shall be rated for a pressure of 1½ times the chamber operating pressure.

14.2.8.3.15.2 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.

14.2.8.3.15.3 Ballasts and other energy storage components that are part of the lighting circuit shall be installed outside the chamber in accordance with 14.2.8.1.4.

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

14.2.8.3.16 Low-Voltage, Low-Power Equipment. The requirements of 14.2.8.3.16.1 through 14.2.8.3.16.5 shall apply to sensors and signaling, alarm, communications, and remote-control equipment installed or used in the chamber for operation of the chamber.

14.2.8.3.16.1* 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

14.2.8.3.16.2 Circuits such as headset cables, sensor leads, and so forth, not enclosed as required in 14.2.8.3.7, 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.

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

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

14.2.8.3.16.5 Battery-operated, portable intercom headset units shall meet the requirements of 14.2.8.3.17.5 for battery-operated devices.

14.2.8.3.17* Portable Patient Care–Related Electrical Appliances.

14.2.8.3.17.1 The appliance shall be designed and constructed in accordance with Chapter 10.

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

14.2.8.3.17.3 The appliance shall conform to the requirements of 14.2.8.3.1 and 14.2.8.3.12.

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

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

know what heading this falls under..Class A (14.2.8.3)

(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.
(7) Lithium and lithium ion batteries shall be prohibited in the chamber during chamber operations, unless the product has been accepted or listed for use in hyperbaric conditions by the manufacturer or a nationally recognized testing agency.

14.2.8.3.17.6 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.

14.2.8.4 Grounding and Ground-Fault Protection.

14.2.8.4.1 All chamber hulls shall be grounded to an electrical ground or grounding system that meets the requirements of Article 250, Grounding and Bonding, Section III, Grounding Electrode System and Grounding Electrode Conductor, of *NFPA 70, National Electrical Code.*

14.2.8.4.1.1 Grounding conductors shall be secured as required by Article 250, Grounding and Bonding, Section III, Grounding Electrode System and Grounding Electrode Conductor, of *NFPA 70, National Electrical Code.*

14.2.8.4.1.2 The material, size, and installation of the grounding conductor shall meet the requirements of Article 250, Grounding and Bonding, Section VI, Equipment Grounding and Equipment Grounding Conductors, of *NFPA 70, National Electrical Code,* for equipment grounding conductors.

14.2.8.4.1.3 The resistance between the grounded chamber hull and the electrical ground shall not exceed 1 ohm.

monthly chamber check

14.2.8.4.2 In health care facilities, electrical power circuits located within the chamber shall be supplied from an ungrounded electrical system equipped with a line isolation monitor with signal lamps and audible alarms.

14.2.8.4.2.1 The circuits specified in 14.2.8.4.2 shall meet the requirements of 517.160(A) and 517.160(B) of *NFPA 70, National Electrical Code.*

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

see page 99-115 14.3.1.5.3.2 patient ground check

14.2.8.4.3 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, National Electrical Code.*

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

14.2.8.5.1 All associated conduits shall meet the following requirements:

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

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

14.2.8.6 Additional Wiring and Equipment Requirements Inside Class B Chambers. The requirements in 14.2.8.6 shall apply to Class B chambers whether they are pressurized with oxygen or with air.

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

14.2.8.6.1.1* 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.

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

14.2.8.6.1.3 Patient monitoring leads shall be part of approved electromedical apparatus meeting the requirements in 14.2.8.3.17.

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

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

14.2.9 Communications and Monitoring.

14.2.9.1 General.

14.2.9.1.1 Detectors, sensors, transducers, and communications equipment located inside the chamber shall meet the requirements of 14.2.8.3.16.

14.2.9.1.2 Wiring methods in the chamber shall meet the applicable requirements in 14.2.8.3.

14.2.9.1.3 The following equipment shall be installed outside the chamber or shall meet the requirements of 14.2.8.3.16:

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

14.2.9.2* Intercommunications.

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

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

14.2.9.3 Combustible Gas Detection.

14.2.9.3.1 The chamber atmosphere shall be continuously monitored for combustible gas concentrations whenever any volatile agents are used in the chamber. *(See 14.2.4.3.3.1.)*

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

14.2.9.4 Oxygen Monitoring.

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

14.2.9.4.1.1 Oxygen monitors shall be equipped with audible and visual alarms.

14.2.9.4.2 Oxygen levels shall be continuously monitored in Class A chambers when breathing mixtures containing in excess of 21 percent oxygen by volume are being breathed by patients or attendants or any flammable agents are present in the chamber, or when either of these conditions exists.

14.2.9.4.2.1 Audible and visual alarms shall indicate volumetric oxygen concentrations in excess of 23.5 percent.

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

14.2.9.6* Chamber Gas Supply Monitoring.

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

14.2.9.6.2* As a minimum, the air supplied from compressors to Class A chambers shall meet the requirements for CGA Grade E.

14.2.9.6.3 As a minimum, the air supplied from compressors to Class B chambers shall meet the requirements for CGA Grade E with the additional limit of no condensable hydrocarbons.

14.2.9.6.4 When air cylinders are used to provide breathing air in Class A or Class B chambers, the breathing air shall be medical air USP.

14.2.9.6.5 When cylinders are used to provide oxygen in Class A or Class B chambers, the gas shall be oxygen USP.

14.2.9.7 Electrical monitoring equipment used inside the chamber shall comply with the applicable requirements of 14.2.8.

14.2.9.8* 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 Other Equipment and Fixtures.

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

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

14.2.10.2.1 Each Class B chamber shall have an independent exhaust line.

14.2.10.2.2 The point of exhaust shall not create a hazard.

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

14.2.10.2.4 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.

14.2.10.2.5 The point of exhaust shall be identified as an oxygen exhaust by a sign prohibiting smoking or open flame.

14.2.10.3 The supply piping for all air, oxygen, or other breathing mixtures from certified commercially supplied cylinders and portable containers shall be provided with a particulate filter of 66 microns or finer.

14.2.10.3.1 The particulate filter shall meet the construction requirements of ANSI/ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*, and be located as close as practical to the source.

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 safety director.

14.3.1.3 Responsibility.

14.3.1.3.1 Personnel having responsibility 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* Each hyperbaric facility shall designate an on-site hyperbaric safety director to be in charge of all hyperbaric equipment and the operational safety requirements of this chapter.

see pg 99-166 term S.D. not same as M. Dir.

14.3.1.3.2.1 The safety director shall participate with facility management personnel and the hyperbaric physician(s) in developing procedures for operation and maintenance of the hyperbaric facility.

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

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

14.3.1.3.3* The governing board shall be responsible for the care and safety of patients and personnel.

14.3.1.3.4* 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.

14.3.1.3.4.1 The safety director shall participate in the development of these regulations.

14.3.1.3.5* The safety director shall ensure that electrical, monitoring, life-support, 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.

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

14.3.1.4.2 The medical director of hyperbaric medicine and the safety director 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 Emergency procedures specific to the hyperbaric facility shall be established.

14.3.1.4.4.1* All personnel shall be trained in emergency procedures.

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

14.3.1.4.5* Emergency procedures and fire training drills shall be conducted at least annually and documented by the safety director. **refers to pg 99-108 & 99-167**

including a timed egress

14.3.1.4.6 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.

14.3.1.4.7 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.

14.3.1.4.8 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 General.

14.3.1.5.1 Potential Ignition Sources.

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

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

14.3.1.5.1.2 The following shall be prohibited from inside the chamber:

(1) Personal warming devices (e.g., therapeutic chemical heating pads, hand warmers, pocket warmers)
(2) Cell phones and pagers
(3) Sparking toys
(4) Personal entertainment devices

14.3.1.5.2 Flammable Gases and Liquids.

14.3.1.5.2.1 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.

14.3.1.5.2.2 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 safety director 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 14.2.9.4.2 is observed.

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

14.3.1.5.3* Personnel.

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

14.3.1.5.3.2 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.

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

14.3.1.5.4* Textiles.

see pg 99-168

14.3.1.5.4.1 Except where permitted in 14.3.1.5.4.3, silk, wool, or synthetic textile materials, or any combination thereof, shall be prohibited in Class A or Class B chambers.

14.3.1.5.4.2* 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.

14.3.1.5.4.3* The physician or surgeon in charge, with the concurrence of the safety director, shall be permitted to use one of the following prohibited items in the chamber:

(1) Suture material
(2) Alloplastic devices
(3) Bacterial barriers
(4) Surgical dressings
(5) Biological interfaces
(6) Synthetic textiles

14.3.1.5.4.4 Physician and safety director approval to use prohibited items shall be stated in writing for all prohibited materials employed. *(See A.14.3.1.3.2.)*

14.3.1.5.4.5 Upholstered Furniture.

(A) Upholstered furniture (fixed or portable), shall be resistant to a cigarette ignition (i.e., smoldering) 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, *Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture*, ASTM E 1353, *Standard Test Methods for Cigarette Ignition Resistance of Components of Upholstered Furniture*, or California Technical Bulletin 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies.*
(2) Mocked-up composites of the upholstered furniture shall have a char length not exceeding 1½ in. (38 mm) when tested in accordance with NFPA 261, *Standard Method of Test for Determining Resistance of Mock-Up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes*, or ASTM E 1352, *Standard Test Method for Cigarette Ignition Resistance of Mock-Up Upholstered Furniture Assemblies.*

(B) Upholstered furniture shall have limited rates of heat release when tested in accordance with ASTM E 1537, *Standard Test Method for Fire Testing of Upholstered Furniture*, 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.

14.3.1.5.4.6 Mattresses. Mattresses 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); 16 CFR Part 1633, *Standard for the Flammability (Open Flame) of Mattress Sets*; or California Technical Bulletin 129, *Flammability Test Procedure for Mattresses for Use in Public Buildings.* Mattresses shall have limited rates of heat release when tested in accordance with ASTM E 1590, *Standard Test Method for Fire Testing of Mattresses*, as follows:

(1) The peak rate of heat release for the mattress shall not exceed 100 kW. The peak rate of heat release for the mattress shall not exceed 100 kW.
(2) The total heat released by the mattress during the first 10 minutes of the test shall not exceed 25 MJ.

14.3.1.5.4.7 Fill materials shall comply with California Technical Bulletin 117 Requirements, *Test Procedure and Apparatus for Testing the Flame Retardance of Resilient Filling Materials Used in Upholstered Furniture.*

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

14.3.1.5.4.9 Exposed foamed plastic materials shall be prohibited.

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

14.3.1.5.5.1 Whenever possible, patients shall be stripped of all clothing, particularly if it is contaminated by dirt, grease, or solvents, and then reclothed. *(See A.14.3.1.5.4.)*

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

14.3.1.5.6 All other fabrics used in the chamber, such as sheets, pillow cases, and blankets, shall conform to 14.3.1.5.4.1 and 14.3.1.5.4.2.

14.3.1.5.7 Drapes used within the chamber shall meet the flame propagation performance criteria contained in NFPA 701, *Standard Methods of Fire Tests for Flame Propagation of Textiles and Films.*

14.3.1.5.8 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 safety director for hyperbaric use.
(2) They shall be uncontaminated.
(3) They shall be devoid of prohibited articles prior to chamber pressurization.

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. *(See 14.3.1.5.4.3.)*

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

(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 the Safe Use of Lasers in Health Care Facilities,* 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 safety director. *(See 14.3.1.3.2.)*

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

14.3.2.1.7 Containers used for paper storage shall be emptied after each chamber operation.

14.3.2.1.8 Equipment that does not meet the temperature requirements of 500.8(A), 500.8(B), and 500.8(C) of *NFPA 70, National Electrical Code,* shall not be permitted in the chamber.

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 14.3.1.5.2.)*

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 safety director.

14.3.4 Maintenance.

14.3.4.1 General.

14.3.4.1.1 The hyperbaric safety director 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.

14.3.4.1.2 The hyperbaric safety director shall ensure that all gas outlets in the chambers are labeled or stenciled in accordance with CGA C-4, *Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained.*

14.3.4.1.3 The requirements set forth in Section 5.1 and NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, 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 14.3.1.5.2.2(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.

14.3.4.2 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 safety director.

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.

14.3.5 Electrical Safeguards.

14.3.5.1 Electrical equipment shall be installed and operated in accordance with 14.2.8.

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

14.3.5.1.1.1 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 14.2.8.2.2)*

14.3.5.1.2 In the event of fire, all nonessential electrical equipment within the chamber shall be de-energized before extinguishing the fire.

14.3.5.1.2.1 Smoldering, burning electrical equipment shall be de-energized before extinguishing a localized fire involving only the equipment. *(See 14.2.5.)*

14.3.6* Electrostatic Safeguards.

14.3.6.1 Administration. (Reserved)

14.3.6.2 Maintenance.

14.3.6.2.1 Furniture Used in the Chamber.

14.3.6.2.1.1 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.

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

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

14.3.6.2.1.4 Lubricants shall be oxygen compatible.

14.3.6.2.1.5 Wheelchairs and gurneys with bearings lubricated and sealed by the manufacturer shall be permitted in Class A chambers where conditions prescribed in 14.2.9.4 are met.

14.3.6.2.2 Conductive Accessories. Conductive accessories shall meet conductivity and antistatic requirements.

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

14.3.6.3 Fire Protection Equipment Inside Hyperbaric Chambers.

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

14.3.6.3.2 Fire detection equipment shall be tested each week, and full testing, including discharge of extinguishing media, shall be conducted annually.

14.3.6.3.3 Testing shall include activation of trouble circuits and signals.

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

14.3.6.4.1 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

Provision of security forces in this situation might be provided by a governmental agency or private security forces. However, activation of facility security forces might be required to prevent hordes of curious onlookers from entering facility work areas and interfering with routine facility functioning. Routine visiting privileges and routine visiting hours might need to be suspended in parts of the facility.

A.13.7.1.1 The marketing department of the hospital might be best suited to assist security personnel with media control.

A.13.7.2 Ideally, news media personnel should be provided with a media briefing area or a media staging area, or both, with access to telephone communication and, if possible, an expediter who, though not permitted to act as a spokesperson for news releases, could provide other assistance to such personnel. News media personnel should not be allowed into the health care facility without proper identification. Media representatives should be requested to wear some means of identification for security purposes. Members of the news media should be asked to wear some means of identification, such as a press card, on their outside garments so that they are readily identifiable by security guards controlling access to the facility or certain areas therein.

A.13.8 Crowd control of persons demanding access to care will create additional demands on security. Because of the intense public interest in disaster casualties, news media representatives should be given as much consideration as the situation will allow. To alert off-duty health care staff and to reassure the public, use of broadcast media should be planned.

Where feasible, photo identification or other means to ensure positive identification should be used. Visitor and crowd control create the problem of distinguishing staff from visitors. Such identification should be issued to all facility personnel, including volunteer personnel who might be utilized in disaster functions. Note that care should be taken to ensure that identification cards are recalled whenever personnel terminate association with the health care facility. Clergy also will frequently accompany casualties or arrive later for visitations and require some means of identification.

A.13.9.3 Key cards are preferable to traditional keys because they can be immediately deactivated if lost or not returned by a terminated employee.

Facility keys should not be identified in any manner such that a person finding a lost key could trace it back to the facility. A policy should be established to restrict duplication of keys without written permission. All keys should be marked "DO NOT DUPLICATE" to deter the unauthorized copying of keys.

There should be a log of keys issued to employees and vendors maintained at the facility. A responsible individual should be in charge of issuing keys and maintaining complete, up-to-date records of the disposition of keys, including copies. The records should show the issuance and return of keys, including the name of the person to whom the key was issued, as well as the date and time. Records of key issuance should be secured and kept separate from keys.

Keys should be restricted to those who need them, and extra copies of keys should be kept locked in a secure cabinet with access control.

Procedures should be established for collecting keys from terminated employees, employees on vacation, and vacated tenants. Lost keys should be reported immediately and procedures established for the rekeying or replacement of the affected locks.

A master key system should be designed so that the grandmaster key is the only key that will open every restricted area of the facility. A master key system is used to limit the number of keys carried by personnel requiring access to multiple areas of the building. It is important that such a system not be designed so that the loss of a single key could provide an unauthorized individual unrestricted access to all areas of the building. The sophistication of the master key system should depend upon an assessment of employees' or tenants' needs and the criticality, risk, and sensitivity of restricted areas.

The number of grandmaster keys should be limited to the least number necessary for operation of the health care facility. Master key distribution should be limited to the personnel requiring access to multiple restricted areas. A log should be maintained showing who is in possession of master keys.

A.13.10 Background checks should include criminal record checks, employment histories, and references. This function is typically managed by the human resources department.

A.13.11 The number of guards needed at any given time will depend on the size of the facility, the hours of operation, and the current risk factors. Many states have laws that require background checks and specific training for security personnel, especially armed personnel. It is essential that facilities using security personnel train them in the legal and practical applications of their employment. Training must reflect changes in regulations and the enactment of new laws.

A.13.11.1 Post orders should contain a list of the duties of the security officer and instructions to cover all foreseeable events the security officer can encounter. Post orders should list the name of the facility, the date issued, the effective date, and the purpose. Duties of security personnel should be listed, including 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.14.1.2.2 Chambers designed for animal experimentation but equipped for access of personnel to care for the animals are classified as Class A for the purpose of Chapter 14.

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

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 When the area to be covered is small (six sprinklers or less), 9.7.1.2 of NFPA *101, Life Safety Code*, permits fire sprinkler systems required to be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, to be supplied from the local domestic water system, provided that the local domestic water system has sufficient pressure and flow capacity.

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

A.14.2.2.1 Other chapters in NFPA 99 contain many requirements that could appear to relate to hyperbaric facilities but could be inappropriate. The requirements of other chapters in NFPA 99 should be applied to hyperbaric facilities only where specifically invoked by this chapter.

A.14.2.2.5 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.14.2.2.5.1 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.14.2.2.5.4 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 14.2.2.5.3.

A.14.2.2.6 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.

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.14.2.4.3.2 Efforts should be made in the design and operation of thermal control systems to maintain the temperature as close to 22°C (75°F) as possible. The air-handling system of all Class A chambers should be capable of maintaining relative humidity in the range of 50 percent to 70 percent during stable depth operations.

The thermal control system should be designed to maintain the temperature below 29°C (85°F) during pressurization, if possible, and above 19°C (65°F) during depressurization, if possible.

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

A.14.2.4.5.3 The intent of this requirement is to allow facility staff to evacuate the facility and avoid breathing contaminated air. This requirement is permitted to be met using either a self-contained breathing apparatus, smoke hood with integral filter/air supply, or similar technology.

The number of units available should be adequate to meet facility staffing.

The breathing duration of the personal protection devices should be predicated upon the time necessary for evacuation of the facility.

Facility evacuation time should be determined during fire drills conducted by the hyperbaric facility.

A.14.2.5.1.4 This requirement does not preclude the use of an alarm system affording direct fire department contact.

A.14.2.5.1.5 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.

A.14.2.5.2.4 More than one control station could be required in a compartment (lock), depending on its size.

A.14.2.5.2.6 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.

A.14.2.5.4.2 Additional detectors are recommended to avoid "blind" areas if the chamber contains compartmentation.

A.14.2.5.5 The primary focus for the semiannual test of a water-based extinguishing system is to ensure water flow 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.14.2.8.1.4.1 It is recommended that system design be such that electric motors not be located inside the chamber.

A.14.2.8.3 This subsection contains requirements for the safe use of electrical equipment in the hyperbaric, oxygen-enriched environment of the Class A chamber.

A.14.2.8.3.10 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.14.2.8.3.11.1 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.14.2.8.3.12 It is the intention of 14.2.8.3.12 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.14.2.8.3.15 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 14.2.8.3.15.

A.14.2.8.3.16.1 The requirement for isolation from mains supply in 14.2.8.3.16.1 is not the same as the requirement in 14.2.8.4.2 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.14.2.8.3.17 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 14.2.8.3.17 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.14.2.8.5.2 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.14.2.8.6.1.1 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.14.2.9.2 Intercommunications equipment is mandatory for safe operation of a hyperbaric facility.

A.14.2.9.2.1 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.14.2.9.6 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.14.2.9.6.1 The frequency of such monitoring should depend on the location of the air intake relative to potential sources of contamination.

A.14.2.9.6.2 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.

A.14.2.9.8 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.14.2.10.2 Exhaust piping extending from the building can create a lightning risk. Lightning protection should be considered.

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.

A.14.3.1.3.2 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 run, this person should record, in an appropriate log, the purpose of the run 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.

Safety, operational, and maintenance criteria of other organizations are published, for example, in the Undersea & Hyperbaric Medical Society Safety Committee documents and the Compressed Gas Association pamphlets and should be reviewed by the safety director. The safety director should serve on the health care facility safety committee.

Due to a conflict of responsibility, the same individual should not serve as both medical director and safety director.

The term *safety director* is used for convenience. It is the intent of 14.3.1.3.2 to establish a set of safety responsibilities for the responsible person, regardless of the job title.

A.14.3.1.3.3 It is incumbent upon the governing body 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 the case of a hospital, nursing and other professional) personnel.

In meeting its responsibilities for safe practices in hyperbaric facilities, the administration of the 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 standards set in Chapter 14. The controls adopted should cover the conduct of personnel in and around hyperbaric facilities and the apparel and footwear allowed. They should cover periodic inspection of static-dissipating materials and of all electrical equipment, including testing of ground contact indicators.

A.14.3.1.3.4 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.14.3.1.3.5 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.14.3.1.4.4.1 All full- and part-time personnel should receive training in emergency management appropriate to their job descriptions.

A.14.3.1.4.5 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.14.3.1.5.1.1 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.14.3.1.5.2.2(2) Allowable quantities complying with 14.3.1.5.2.2(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:

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

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

$1.43 \times 500 = 715$ 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 14.3.1.5.2.2 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.14.3.1.5.3 The number of occupants of the chamber should be kept to the minimum number necessary to carry out the procedure.

A.14.3.1.5.4 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.

A.14.3.1.5.4.2 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.14.3.1.5.4.3.

A.14.3.1.5.4.3 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 a flame.

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

Flash Point. The minimum temperature of a liquid or solid at which it gives off 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. They 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 vapors from the product to interact with the chamber environment. Also, gas-permeable materials exposed to hyperbaric oxygen will hold additional oxygen for some period of 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.14.3.1.5.4.3).

(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.

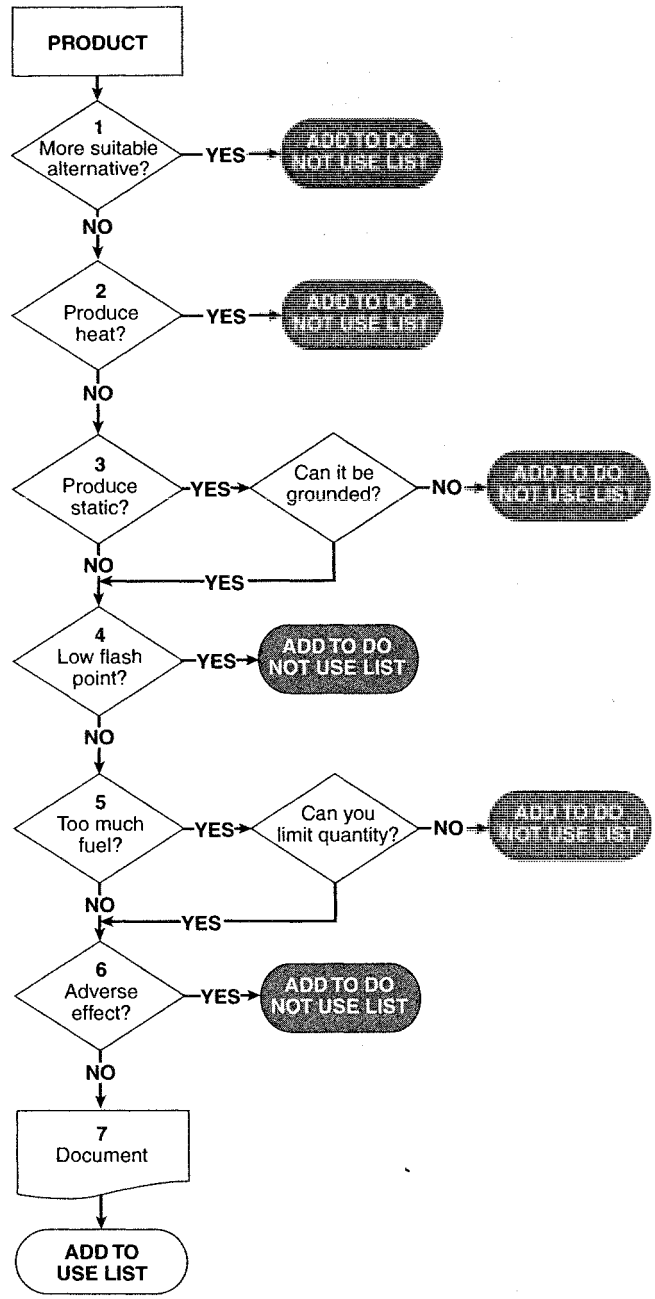

FIGURE A.14.3.1.5.4.3 Risk Assessment Process.

(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 (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 completely eliminated. Use of conductive surfaces and electrical grounding will allow static charge to dissipate. Paragraph 14.2.8.4.1 requires all hyperbaric chambers to be grounded. Paragraph 14.2.10.1 requires any furniture installed inside a chamber to be grounded. Paragraph 14.3.1.5.3.2 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.

(4) Does this dressing have a low ignition temperature/flash point? 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 non-flammable 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 it can be exposed to. Paragraph 14.2.8.3.12 limits electrical equipment inside a Class A (multi-place) chamber to a maximum operating surface temperature of 85°C (185°F). Paragraph 14.2.8.6.3 limits electrical circuits inside a Class B (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 and B chamber and the ignition temperature of material in question. A material will release vapor into the chamber environment as it approaches its flash point temperature. Once a sufficient quantity of vapor is present in the chamber (LEL), it takes very little energy for ignition to occur. Paragraph 14.3.1.5.2.2 sets limits on flammable agents inside Class A (multi-place) chambers. Paragraph 14.3.1.5.2.3 specifically prohibits flammable liquids, gases, and vapors inside Class B (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, therefore, 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 (Sulfamylon®), 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.

A.14.3.2.1.6 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 (Tygon®). Testing for oxygen compatibility is very complicated. Very little data exist, 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.

A.14.3.6 The elimination of static charges is dependent on the vigilance of administrative supervision of materials purchased, maintenance, and periodic inspection and testing.

A.14.3.6.2.1.2 Ferrous metals can cause such sparking, as can magnesium or magnesium alloys, if contact is made with rusted steel.

A.14.3.6.2.3 Materials containing rubber deteriorate rapidly in oxygen-enriched atmospheres.

A.14.3.6.4 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.

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: tri-cresyl 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 13.4.1. See also NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids,* now part of the NFPA *Fire Protection Guide to Hazardous Materials.*

Note that repeated reference to subsection 13.5.1 is made throughout Chapter 14. These references do not imply, and should not be construed to mean, that flammable anesthetics can or should be employed in or around hyperbaric facilities.

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 outergarment, 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 14.2.8, 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 *Boiler and Pressure Vessel Code.*

B.14.1.2.2 The restriction on escape and the impedance to rescue and fire-fighting 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 chamber 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 14.3.1.5.2 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 fire fighting, 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) *Inside Observer:*
  (a) Activate fire suppression system and/or hand-held hoses.
  (b) Advise outside.
  (c) Don breathing air mask.

(2) *Chamber Operator:*
  (a) Activate the fire suppression system, if needed.
  (b) Switch breathing gas to air.
  (c) Decompress the chamber as rapidly as possible.

(3) *Medical Personnel (Outside):*
  (a) Direct operations and assist crew members wherever necessary.
  (b) Provide medical support as required.

(4) *Other Personnel (Outside):*
  (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) *Chamber Operator:*
  (a) Notify the inside observer to stand by for emergency return to normal atmospheric pressure.
  (b) Notify fire department by activating fire signaling device.
  (c) Switch breathing gas to air.
  (d) Don the operator's source of breathable gas.

(2) *Medical Personnel (Outside):*
  (a) Determine whether procedure should be terminated.
  (b) Provide medical support as required.

(3) *Other Personnel (Outside):*
  (a) Stand by with a fire extinguisher.
  (b) Assist in unloading chamber occupants.

B.14.3 Suggested Procedures for Hyperbaric Chamber Operator to Follow in Event of Fire in Class B Chambers.

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

(1) If there is smoke in the area, don the operator's source of breathable gas.
(2) Decompress the chamber. The urgency of decompression should be determined by the location of the fire.
(3) Remove the patient and evacuate to 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.
(3) Stand by with a hand-held 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.

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.

Hyperbaric Medicine Service
Pretreatment Safety Check

During treatment the hyperbaric patient is allowed:
1 gown, 2 sheets, 1 blanket, 1 pillowcase, 1 washcloth, 1 mask, 1 ground strap, 1 water bottle

Prohibited Items

- ☐ All nicotine products: cigarettes, cigars, gum, patch, e-cigs (vapes)
- ☐ Matches, lighters
- ☐ Cell phones, tablets, laptops, headsets
- ☐ All personal clothing
- ☐ All lotions, cosmetics, colognes, perfumes, lipstick, lip balm
- ☐ Dentures, removable dental appliances
- ☐ Hair sprays, hair oils, gels, mousse, grease
- ☐ Food, gum, candy, mints, pills
- ☐ Chemical hair treatment (wait 8 hours after applied)
- ☐ Wigs, hair extensions, hair glue (dread locks must be clean)
- ☐ Hair barrettes, hair bands, hair pins, scrunchy
- ☐ Implanted devices, pumps (must be verified by staff)
- ☐ All jewelry; watches, piercings, rings, (“Diver” watch, Fitbit, iWatch, Oura ring)
- ☐ Nail polish, artificial nails (wait 8 hours after applied)
- ☐ Newspapers, books, magazines, paper
- ☐ Warming devices, hand warmers, Thermacare type products
- ☐ All toys; sparking, dolls, cars, stuffed animals, playing cards, games
- ☐ Transdermal medication patches
- ☐ Velcro, paper, silk
- ☐ Casts and Unna’s boot (wait 8 hours after applied; cover with dry cotton towel)
- ☐ Prosthetics
- ☐ Wound vacuum devices
- ☐ Hearing aids
- ☐ All battery powered devices
- ☐ Cameras, flash photography
- ☐ Lasers, penlights
- ☐ **Any items deemed unsafe by HBO staff**

The Safety Director and Physician will decide on exceptions and or modifications based on medical necessity and risk benefit ratio for the patient. Authorization form must be completed for exceptions.

I have reviewed this list and agree to comply.

Patient Signature	Date/Time
Staff Signature	Date/Time

Staff to confirm:

☐ Patient identity	☐ Safety measures	☐ Textiles
☐ Orders	☐ Staffing	☐ Grounding

Hyperbaric Medicine Service
Authorization Form
Prohibited Materials

Patient Name:

A risk assessment has been discussed and the material(s) are considered medically necessary for this patient.
NFPA 99 14.3.1.6.4.4

√	MATERIAL	DESCRIPTION	MODIFICATION (if any)
√	*Example:* Velcro	Attached to essential material: wrist restraint	Tape over each face of Velcro
√	*Example*: Petroleum or Oil Based Topical or Impregnated Dressing	Petroleum/hydrocarbon off-gassing and readiness to ignite with spark; potential concern	Wrap with dry 100% cotton towel
√	*Example:* Pacemaker or Intrathecal Pump	Brand, Model and Serial # called into manufacturer to determine efficacy under pressure	ECG monitor patient during treatment
√	*Example:* Implanted Cardiac Defibrillator	Theoretical risk of spark ignition through skin upon defibrillation	Cardiology referral to determine deactivation with magnet during treatment
	1.		
	2.		
	3.		
	4.		
	5.		
	6.		
	7.		

HYPERBARIC PHYSICIAN

In my capacity as Attending Hyperbaric Physician, I, (print name) _____authorize the use of the material(s) listed above during hyperbaric oxygen therapy for the following schedule:

☐ Today's treatment(s) only ☐ Initial treatment only ☐ All treatments
☐ Other (specify):_____

_____ _____
Hyperbaric Physician Signature **Date/Time**

SAFETY DIRECTOR

In my capacity as Hyperbaric Safety Director, I, (print name) _____
☐ Concur with the above authorization ☐ Do not concur with the above authorization

_____ _____
Hyperbaric Safety Director Signature **Date/Time**

CARE AND DISINFECTION OF THE CHAMBER AND GURNEY

- Clean the chamber according to the type of cases being treated and as directed by the medical staff.Refer to the list of acceptable cleaners available from SECHRIST INDUSTRIES.
- Wash Stretcher, Pillows. Positioning Pads and Mattress surfaces with approved cleaner or mild dishwashing soap. Refer to the Gurney User Manual for cleaning instructions.

CLEANING OF PAINTED AND ANODIZED SURFACES

- Use the same methods for cleaning as used for the Acrylic Cylinder.

ACCEPTABLE BIOCIDES per ASME PVHO-2-2019

- Bleach, up to 15% aqueous sodium hypochlorite
- Aqueous hydrogen peroxide, 3% to 20%
- Aqueous chlorine dioxide, up to 2%

APPROVED CHAMBER CLEANERS

	DISINFECTANT	MANUFACTURER	EPA REGISTRATIONNUMBER	RECOMMENDED DILUTION WITH WATER	STRENGTH APPROVED FOR USE	APPROVED AT RECOMMENDE DILUTION
**	Virasept	Ecolab Inc.	1677-226	Ready to Use	Ready to use	N/A
flame inhale	Oxycide DailyDisinfectant	Ecolab Inc.	1677-237	1:128-1:64	1:128-1:64	YES
inhale	Neutral DisinfectantCleaner	Ecolab Inc.	47371-129	1:256-2:64	1:256-2:64	YES
flame	Stat III TB	Ecolab Inc.	39967-89-2677	1:128	1:128	YES
flame	LpH-se	Steris Corporation	N/A	1:256	1:256	YES
streak	Sani-Cloth BleachWipe	PDI/Nicepak	9480-8	Equivalent to 1:10 dilution	Ready to use	N/A
streak	Clorox HealthcareBleach Germicidal Cleaner	Clorox Professional Products	67619-12	Ready to Use	Ready to use	N/A
inhale	Quaternary Disinfectant Cleaner	Ecolab Inc.	6836-78	1:256-1:64	1:256 - 1:64 Ready to use	YES
inhale	Quaternary Disinfectant Wipes	Ecolab Inc.	6836-372	Ready to Use	Ready to Use	N/A
mixed SDS	Coverage® Spray HBPLus	Steris Corporation	6836-152	Ready to Use	Ready to use	N/A
	Sani-Cloth® HB Wipe**	PDI/Nicepak	61178-4-9480	Ready to Use	Ready to use	N/A
	Sani-Hypercide Wipe	PDI/Nicepak	9480-16	Ready to Use	Ready to use	N/A
	Sani-Cloth® Plus	PDI/Nicepak	9480-6	Ready to Use	Ready to Use	N/A
	Virex II 256	Diversey	70627-24	1:128	1:128	YES
	Virex Plus	Diversey	6836-349	1:128	1:128	YES
**	Peroxide Multi SurfaceCleaner and Disinfectant RTU	Ecolab Inc.	1677-251	Ready to Use	Ready to Use	N/A
	Vital Oxide	Vital Solutions	82972-1	Ready to Use	Ready to Use	N/A
	Mikrozid Sensitive Wipes Premium	Shulke	88494-4, 88494-2, 88494-2-37549, 74559-3, 67619-25, 70627-77	Ready to Use	Ready to Use	YES
	Asept HB** discontinued	Ecolab Inc	61178 2 1677	Ready to Use	Ready to Use	N/A

***Note: this product has been discontinued by the manufacturer*

Red comments added based on SDS comments or experience with product

Products with bleach will leave streaks and also require to be re-wiped with another approved product.

"Inhale" means there is a inhalation risk when using the product inside the chamber.

"Flame" means the SDS lists flammable properties exist.

As of 2/2023

** NBS Recommends

Hyperbaric Medicine Service

HYPERBARIC FACILITY CLEANING PROCEDURES FOR ENVIRONMENTAL SERVICES STAFF

The following is the list of daily cleaning responsibilities for Environmental Services:
Damp high and low dusting
General spot cleaning of vertical surfaces (walls, cabinet doors)
General disinfecting of countertop surfaces, appliances
Waste removal
Dirty linen removal
Disinfecting of all sinks and toilet with hospital approved disinfectant
Damp mop floor surfaces with hospital approved disinfectant

IMPORTANT ***Hyperbaric chambers operate on 100% oxygen under pressure. Extreme fire risk if mishandled!***
Use caution when cleaning the floor surrounding chambers so not to interfere with it's hoses, cables and exhaust at rear of chamber. Please keep flammable materials and liquids like lighters and alcohol away from chamber. Only products approved by the chamber manufacturer to clean the chamber are allowed otherwise it may damage the acrylic window and paint.

Only the hyperbaric clinical staff will use _____disinfectant on chamber surfaces.

_____ _____
Hyperbaric Medicine Safety Director Date/Phone

_____ _____
Environmental Services Manager Date/Phone

ENVIRONMENTAL SERVICES STAFF *WILL NOT* BE RESPONSIBLE FOR CLEANING THE HYPERBARIC CHAMBERS.
I have read the above instructions and received training on the proper handling and cleaning of the Hyperbaric Medicine Service. I understand I am not to clean the chamber(s).

Date of Training	**Employee Name**	**Signature**

One copy maintained in HBO dept and one copy maintained in E.S.
This documentation is required according to NFPA 99 14.3.6.4

672-011

COMMENTARY

Titanium in a Hyperbaric Oxygen Environment May Pose a Fire Risk

JONAS HINK AND ERIK JANSEN

Monoplace chambers have a 3 ATA max pressure

HINK J, JANSEN E. *Commentary: Titanium in a hyperbaric oxygen environment may pose a fire risk.* Aviat Space Environ Med 2003; 74: 1301–2.

The use of titanium during hyperbaric oxygen therapy may pose a risk of fire. A fresh titanium surface in a high oxygen atmosphere can be a source of ignition. The clinical scenario may be a patient who accidentally breaks his titanium-framed glasses during a hyperbaric oxygen treatment in a monoplace chamber or using an oxygen hood. We recommend some safety precautions to be exercised until consensus standards have been established by the hyperbaric medicine community.

Keywords: safety guidelines.

IT IS WELL KNOWN that hyperbaric chamber operations pose a special fire risk (6). An increased oxygen partial pressure generally increases the flammability of material, and some materials considered non-flammable in normal atmospheric conditions can become flammable in an oxygen-enriched atmosphere such as a hyperbaric air/oxygen environment. Also, the minimum energy required for ignition of combustible materials is lower in a hyperbaric air/oxygen environment than under normal atmospheric conditions (3,5). Therefore, fire-preventing techniques are extremely important when administering hyperbaric oxygen therapy (7).

These preventive measures are aimed at eliminating ignition sources, limiting the combustible materials, and reducing oxygen concentration (6). In the case of monoplace chambers or the use of oxygen hoods, the oxygen fraction is close to 100%, and material selection becomes even more crucial in order to prevent fire. Among the materials used in hyperbaric chambers, metals are normally considered safe (6). However, titanium and its alloys, which are now found in many different consumer products as well as in medical replacement structures, require special attention.

A fresh titanium surface oxidizes instantly when exposed to oxygen, resulting in the formation of a very stable, protective, and strongly adherent oxide film. The oxidation reaction is exothermic, and if the heat given off from the reaction exceeds the rate at which the heat can be conducted away, ignition and burning of the titanium may occur (8). It has been reported that an oxygen partial pressure of 25 ATA (2514 kPa) was required to ignite and burn a fresh titanium surface at room temperature during static conditions (1). However, the results of combustion tests are very configuration-dependent, and such a threshold pressure is not an absolute flammability limit (4). When a test was performed under dynamic flow conditions with pure oxygen streaming past the fresh titanium surface, an oxygen partial pressure of 4.4 ATA (446 kPa) was sufficient to ignite and propagate the reaction (1). In the same study using other configurations, tensile rupture of unalloyed titanium (and hence formation of a fresh titanium surface) in gaseous oxygen at 6.1 ATA (618 kPa) at room temperature was shown to initiate a violent burning reaction. Also, fatigue cracking of a titanium alloy during exposure to gaseous oxygen at 4.4–5.1 ATA (446-515 kPa), at body temperature or less, was shown to induce minute burned spots on the titanium. It was concluded that the use of titanium in oxygen systems should be severely restricted.

In hyperbaric medicine practice, patients are often allowed eyeglasses and jewelry inside the hyperbaric chamber. Due to the growing use of titanium in consumer products, an increasing number of patients can, therefore, be expected to bring titanium items in the form of eyeglasses and jewelry inside the hyperbaric chamber. If these titanium items are only exposed to air in the hyperbaric chamber there is no need for concern, since the studies by Jackson et al. (1) have shown that titanium would not be expected to burn under any pressure when the oxygen concentration is less than 35%. However, if the items are exposed to pure oxygen, which would be the case inside a hyperbaric monoplace chamber or inside an oxygen hood, there is a potential fire hazard, but only if the titanium item breaks and a fresh un-oxidized surface is formed. Although unlikely, it is not impossible that the frames of titanium eyeglasses or a titanium ear-ring might break when manip-

From the The Royal Naval Technical School, Nyholm, Copenhagen, Denmark (J. Hink); and the Hyperbaric Oxygen Treatment Unit, Department of Anaesthesia and Operating Theatre Services, The Centre of Head and Orthopaedics, Copenhagen University Hospital Rigshospitalet, Copenhagen, Denmark (J. Hink and E. Jansen).

This manuscript was received in May 2003; it was revised in July and August 2003. It was accepted for publication in August 2003.

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ulated by the anxious patient during hyperbaric oxygen therapy. Titanium watches and medical replacement structures, on the other hand, are not prone to breakage and would not be likely to pose a problem, since unruptured and hence oxidized titanium will ignite and burn only at temperatures above 1200°C (1).

Hyperbaric oxygen therapy is typically performed at a pressure of 2.5–2.8 ATA (253–284 kPa). Due to the risk of oxygen toxicity, the maximum partial pressure of oxygen in clinical hyperbaric chambers is 3 ATA (304 kPa). This value is more than 30% lower than the lowest oxygen partial pressure at which ignition of or burned spots on the titanium were observed in the study by Jackson et al. (1). However, other alloys or different configurations of the titanium than those used in the tests might have lower threshold values for ignition. Moreover, heat given off from the oxidation of a freshly broken titanium surface might not be sufficient for ignition of the titanium itself, but sufficient for ignition of hair or clothing in near contact with the titanium surface.

The NASA Safety Standard for oxygen and oxygen systems (2) states that titanium must not be used with gaseous oxygen at oxygen pressures above 2 ATA (207 kPa). Whether the same safety limits should be implemented in hyperbaric medicine is a relevant and urgent issue. Until further discussions and/or investigations have been performed in order to establish consensus on safety guidelines for titanium in hyperbaric medicine, we recommend the following preventive measures:

1. Breakable titanium and titanium alloy items including eyeglasses and jewelry should not be permitted in a hyperbaric monoplace chamber or in a pure oxygen atmosphere in a multiplace chamber such as an oxygen hood. (This is a very simple safety precaution considering the potential risk.)
2. Titanium and its alloys should not be permitted in oxygen lines and high-pressure systems.

Focus on the above recommended preventive measures should under no circumstances divert the attention from general fire-preventing techniques and more easily ignited and more flammable materials than titanium and titanium alloys.

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Health Devices Alerts Action Item

Accession Number : A7964 Friday, November 3, 2006

Fire Risk from Alcohol-Based Hand Sanitizers Worsens in Oxygen-Enriched Environments

Priority : High Priority

In This Issue: Fire Risk from Alcohol-Based Hand Sanitizers Worsens in Oxygen-Enriched Environments

Antimicrobial Cleansers, Gel [17-783];

Towelettes, Personal, Antiseptic [17-988]

Device: Alcohol-Based Hand Sanitizers *[Consumable]*

Problem: A fire occurred when a nurse in a neonatal intensive care unit placed an alcohol-based sanitizer in her hands and then, while rubbing in the sanitizer, walked toward an oxygen/air proportioner to change a setting on the device. Her hand was still wet with the sanitizer when she reached for the device's control knob. She then felt a shock, heard a "whoosh" sound, and saw the knob immediately catch fire. Other clinicians disconnected the device, extinguished the flames, and cared for the infant nearby. The nurse's hand was burned, but no other injuries were reported.

ECRI believes that a similar incident could occur when any alcohol-based sanitizer is used in an oxygen-enriched environment, which we believe existed in this case. The reported event provides one example of how vapors from such sanitizers can be ignited.

Clinicians often use an alcohol-based hand sanitizer before and after treating patients. The product is placed in one hand, and the clinician rubs both hands together until the product is absorbed into the skin and the resulting vapors dissipate.

ECRI's investigation revealed two key points about the hand sanitizer involved. First, it sometimes required tens of seconds of hand rubbing for vapors to dissipate; until the vapors dissipate, they contribute to the risk of a fire. Second, in our testing, static electric sparks—which are common in certain healthcare settings—sometimes ignited the sanitizer in ordinary air and resulted in flames that lasted for several tens of seconds; these flames became more intense in oxygen-enriched environments.

In hospitals, oxygen-enriched environments often exist. In the reported incident, for example, normal operation of the proportioner sometimes caused oxygen to exit its bleed port, increasing the oxygen concentration around the device. (This particular unit also leaked oxygen around its control-knob shaft, but oxygen-enriched environments exist even when these devices operate as expected.) In an environment with normal oxygen concentration (i.e., 21% oxygen), the electrostatic discharge likely would have ignited the sanitizer on the nurse's hand; the flames would have injured her, but the fire would have spread no further. However, in this incident, the oxygen enrichment surrounding the proportioner enabled the control knob—which would not normally support combustion—to catch fire and continue burning after the nurse withdrew her hand. If the other clinicians had not responded immediately, the fire could have spread quickly.

We concluded that the nurse's movements created a static electric charge that was discharged to the grounded proportioner when the nurse reached for it. Such a discharge typically would not create a hazard, but in this case, the three components necessary for a fire were present: (1) an ignition source—the spark resulting from the discharge, (2) fuel—the hand sanitizer, and (3) oxygen—already present in the air but further concentrated by the proportioner leak and bleed port.

Although it has already been established that alcohol-based sanitizers can ignite in room air, our investigation shows that ignition in oxygen-enriched environments can lead to far more serious fires than those previously reported. Furthermore, it

is important to note that an oxygen-enriched atmosphere can extend a foot or more from any open oxygen source. We believe that these factors heighten the need for cautious, educated use of alcohol-based sanitizers.

Action Needed: ECRI recommends the following, regardless of whether supplemental oxygen is in use:

1. Alert users to the problem and to this report.

2. Direct clinicians to ensure that when they use a hand sanitizer, it has fully evaporated before they touch devices, bed linens, or patients. Once a clinician's hands feel dry and the cooling sensation associated with evaporation disappears, the vapors should be adequately dissipated.

Source: ECRI. Fire risk from alcohol-based hand sanitizers worsens in oxygen-enriched environments [hazard report]. *Health Devices* 2006 Oct;35(10):390.

Comment: This Hazard Report has been adapted for inclusion in *Health Devices Alerts*. The original version of the article is available in the October 2006 issue of ECRI's *Health Devices* journal.

Suggested Distribution: Critical Care, CSR/Materials Management, Emergency/Outpatient Services, Facilities/Building Management, Infection Control, NICU, Nursing, OR/Surgery, Risk Management/Continuous Quality Improvement, Staff Education

smith&nephew

ACTICOAT°
with SILCRYST NANOCRYSTALS

ACTICOAT° 7
with SILCRYST NANOCRYSTALS

HBO & ACTICOAT

As ACTICOAT contains no volatile/combustible components such as petrolatum, etc., it is felt that its use in conjunction with HBO therapy presents minimal safety risks. To test this position we performed tests aimed at determining the safety aspects, as well as, effects of HBO on the efficacy of the dressings.

Study

Samples of ACTICOAT (3 day) were placed in an HBO chamber for 3 consecutive treatments. Samples of ACTICOAT 7 (7 day) were placed in an HBO chamber for 7 consecutive treatments. At the end of the test periods, the samples were tested for efficacy via log reduction assays. Safety was evaluated by noting any adverse events.

Results

The log reduction values were slightly reduced relative to the control samples; however, ACTICOAT still demonstrated bactericidal (log reduction of 3 or greater) activity against clinically relevant pathogens. Also, no adverse events were observed at any time during the study.

Conclusions

Based upon this study, the high pressure/concentration of oxygen to which the dressings were exposed did complex some of the silver ion as Ag_2O (presumably); however, the majority of the silver was not affected. As a result, the effect on the efficacy of the dressings was minor and all of the dressings displayed bactericidal activity. Also, in this study no adverse events were noted suggesting that ACTICOAT contains no volatile/combustible components and is safe for use in conjunction with HBO therapy.

Note

This was not an exhaustive study and should not be used to make a final decision on the issue of HBO and ACTICOAT. This study can be used as a guide, but the final decision will be made by the clinician. This study suggests that the risks to the patients and the efficacy of the dressings are minimal; however, more in depth studies would provide a higher level of certainty.

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Dear Valued Customer,

The use of ConvaTec's AQUACEL® wound dressings* during hyperbaric oxygen therapy

In accordance with ISO 13485:2016 [Medical devices—Quality management systems – Requirements for regulatory purposes published March 1, 2016], ConvaTec applies a risk-based approach to the assessment of the safe and efficacy of wound care products. This same principle has been applied to use of their Hydrofiber®-based AQUACEL® wound dressing, both with and without the addition of ionic silver, in conjunction with Hyperbaric Oxygen Therapy (HBOT).

Three different aspects need to be considered in relation to the potential interaction with a pressurized (up to 3 atmosphere) high oxygen-content (up to 100%) atmosphere:

1. **Fire:** Could the dressing act as an ignition source or unacceptably add to the fuel load?

   AQUACEL® dressings are based on a cellulose fiber which is modified to increase its absorbency. This modification reduces the organic content of the fibre therefore reduces the flammability of the final dressing fabric. The thickest (heaviest) dressings weigh approximately 150 grams per square metre (gsm). AQUACEL dressings are indicated for exuding wounds because they avidly absorb moisture, or for dry wounds where the dressing can be pre-hydrated with saline solution – therefore the moisture content of the dressing is often high (>90%).

   Cellulose fiber in the form of cotton, is the most widely recommended material for HBOT use as patient gowns and bedding. Commercial cotton pillowcase fabrics for example typically weigh between 100 and 150 gsm.

   The largest dressing adds less than 2% to the total cellulose in the chamber (based on $2m^2$ bedsheet, $2m^2$ gown and one $0.5m^2$ pillowcase) and is less flammable. **Therefore the additional fuel load is not unacceptable.**

   Like cotton, AQUACEL dressing fabrics do not generate or store static electricity and are not electrically conductive. The addition of ionic silver does not change any of these properties. **Therefore AQUACEL dressings are not a potential source of ignition.**

2. **Patient Safety:** Could the safety of the dressing change due to reaction during HBOT?

   Like cotton, AQUACEL fibres are very resistant to oxidation (as demonstrated by long term elevated temperature stability studies) and will remain stable during HBOT. Additionally, oxidised cellulose is frequently used in wound care as a haemostat or as a wound dressing (for example in Promogran from Systagenix), therefore is considered safe.

ConvaTec

Ionic silver in AQUACEL Ag dressings is already in its most stable oxidation state therefore will not react under HBOT. This may not be the case for dressings that contain silver in its metallic form (such as Acticoat [from Smith & Nephew], Silvercel [from Systagenix] or Silverlon [from Argentum Medical]).
Therefore the toxicity risk is unchanged and no heating due to chemical changes will occur.

3. **Device Efficacy:** *Will the dressing remain effective - absorbent and antimicrobial?*
Based on the comments above if the fibre is unaffected and there is no change to the amount or form of ionic silver **therefore no change in product performance is anticipated.**

Conclusion

The risk assessment indicates that there are no detrimental interactions between the products listed* and HBOT. The dressings do not add to the risk of fire and do not introduce any new patient safety concerns. There is no identified mechanism by which product performance will be affected.

Use of all the listed products remains subject to clinical judgement and to any local guidelines for hyperbaric oxygen therapy.

D Parsons 10th May 2018

David Parsons PhD, FRSC CChem
Director of Science and Technology
ConvaTec Global Development Centre
Deeside, Wales, United Kingdom

* Dressings covered by this assessment

AQUACEL	AQUACEL Ag Extra
AQUACEL Extra	AQUACEL Ag WSF (ribbon)
AQUACEL WSF (ribbon)	AQUACEL Ag Burn
AQUACEL Burn	AQUACEL Ag Advantage
AQUACEL Ag	AQUACEL Ag Advantage WSF

Monthly Hyperbaric Safety Notice

June 2011 National Baromedical Services, Inc.

Duragesic Patches and Hyperbaric Chambers; Understanding the Effect

Background

A common safety question asked is "Can a medication patch go into the hyperbaric chamber?" The response invariably is, "It depends." The Safety Director is responsible for researching the facts about medical products and briefing the physician and staff of the risks, if any, involving the hyperbaric environment. With the facts gathered, an informed decision weighing the risks and benefits is made. The decision should be documented by the Safety Director with the supporting information to ensure all clinical staff are aware of the decision.

The Issue

Duragesic (Fentanyl) is a transdermal medication administered to opioid-tolerant patients to help manage PERSISTANT moderate to severe chronic pain conditions. The medicated self-adherent patch should remain on the skin for 72 hours.

A concern arises when a patient with this patch is to receive hyperbaric oxygen (HBO) therapy daily. The product manufacturer has provided, upon our request, information from in-vitro studies conducted on the effect HBO had related to the release of Fentanyl following HBO treatment. Both studies demonstrated that a significantly higher ($p<0.05$) release of medication was observed following HBO treatment as compared to the untreated patches.

Bottom Line

Recognizing that a patient may be receiving higher doses from the prescribed Fentanyl patch while undergoing HBO therapy should make one reconsider both this drug and this route. Over-sedating a hyperbaric patient can result in slower respirations that can lead to CO2 retention, which contributes to oxygen toxicity that may result in a seizure. Removing the patch daily prior to HBO therapy is a costly alternative because a fresh patch should be replaced to a different skin site immediately upon removal from the sealed package. Also, removing the patch for the two-hour treatment disrupts the intended continuous administration of the medication in order to maintain a therapeutic blood level for effective pain management.

Attachments

DURAGESIC® (fentanyl transdermal system)

The following information is provided because of your specific unsolicited request and is not intended as an endorsement of any usage not contained in the Prescribing Information. For complete information, please refer to the enclosed full Prescribing Information, including the following sections: **BOXED WARNING(S), INDICATIONS AND USAGE, DOSAGE AND ADMINISTRATION, CONTRAINDICATIONS, WARNINGS AND PRECAUTIONS, and ADVERSE REACTIONS**.

SUMMARY:

DURAGESIC - Use with an Occlusive Dressing

- Patients should be advised that if they experience problems with adhesion of the DURAGESIC® patch, they may tape the edges of the patch with first aid tape. If problems with adhesion persist, patients may overlay the patch with a transparent adhesive film dressing (e.g., Bioclusive™ or Tegaderm™).[1]
- Patients should be advised that if the patch falls off before 72 hours, dispose of it by folding it in half and flushing the patch down the toilet. A new patch may be applied to a different skin site.[1]

DURAGESIC - Material Safety Data Sheet (MSDS)

- Please find enclosed the MSDS for DURAGESIC®.

DURAGESIC - Effect of Hyperbaric Treatment on Duragesic Release

- The authors of an in vitro study on the release of fentanyl following hyperbaric treatment with 100% oxygen noted a trend of an increased release of fentanyl from patches following the first hyperbaric treatment.[2]
- Shirley et al conducted an in vitro study on the release of fentanyl following hyperbaric treatment with 100% oxygen, which was significantly higher ($p<0.05$) than from untreated patches at 37, 39, and 42°C.[3]

DURAGESIC - Stability - Extreme Heat

- A MEDLINE and an internal database literature search (1990 - July 2009) failed to identify any citations relevant to the effects of extreme heat on the stability of DURAGESIC®.
- DURAGESIC® (Matrix formulation) was found to be stable for six months when stored at 40° C / 75% relative humidity or 30° C. Properties of DURAGESIC® were also found to be unaffected in cycling studies from 4° C to 40° C to 4° C over two weeks and from 25° C to -10° C (freeze-thaw) over 24 hours for three days.[4]
- Stability studies have found DURAGESIC® (Reservoir formulation) to have met product specifications when stored at either 30° C (86° F) for 12 months or 40° C (104° F) for 1 week followed by 25° C (77° F) for 12 months. Physical changes begin to occur above 40° C. It is recommended that systems stored beyond the above parameters be discarded.[4]
- Do not store above 77°F (25°C). Apply immediately after removal from individually sealed package. Do not use if the seal is broken.[1]

DURAGESIC - Use with an Occlusive Dressing

DURAGESIC - Effect of Hyperbaric Treatment on Duragesic Release

PUBLISHED LITERATURE

A MEDLINE literature search and a search of an internal database (1992 - August 2009) identified two citations on the effects of hyperbaric treatment on fentanyl release from transdermal fentanyl. The citations are summarized below for your review.

Michniak et al (1996)[2] conducted an in vitro study of the release of fentanyl following hyperbaric treatment with 100% oxygen. Transdermal fentanyl systems (25 mcg/hr) were placed in unoccluded modified Franz diffusion cells at room temperature or 37°C ± 5 °. The transdermal fentanyl system underwent hyperbaric treatment with either 90 minutes of hyperoxia at 2.5 atmospheres or 90 minutes x 3 of hyperoxia every 8 hours. Release profiles were significantly different ($p<0.05$) between temperatures and a trend was noted following the first hyperbaric treatment of an increased release of fentanyl from the patches.

Shirley et al (1997)[3] conducted an in vitro study of the release of fentanyl following hyperbaric treatment with 100% oxygen. Transdermal fentanyl systems (25 mcg/hr) were placed in unoccluded modified Franz diffusion cells at room temperature and release profiles were studied at room temperature, 37, 39, and 42°C and through hairless mouse skin in vitro at 37° C. The transdermal fentanyl system underwent hyperbaric treatment with either 90 minutes of hyperoxia at 2.5 atmospheres or 90 minutes x 3 of hyperoxia every 8 hours. The release from patches receiving hyperbaric treatment were shown to be significantly higher ($p<0.05$) than from untreated patches at 37, 39, and 42°C.

Monthly Hyperbaric Safety Notice

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Five or Ten Minute Air Breaks: Does it Matter?

Background

Intermittent air breathing during hyperbaric oxygen (HBO) therapy has long been recognized as protective against CNS oxygen toxicity, and as a method to reverse its early manifestations. Optimal oxygen-air breathing ratios, however, remain somewhat controversial.

The Issue

Early efforts to determine this ratio did not involve HBO therapy. Rather, they were directed at military and civilian diving operations, as investigators sought to maximally extend oxygen breathing periods. Overall survival was the common endpoint so animals not humans served as subjects! Typically, oxygen pressures ranged from 1.5 – 4.0 ATA. Resulting mortality would, therefore, be likely a mix of pulmonary and CNS toxicity. One aspect of this work indicated that a twenty minute oxygen five minute air breathing ratio was 'totally ineffective'; with researchers believing that five minutes did not allow adequate recovery in the setting of existing toxicity.(1)

It was the U.S. Navy's development of the *'Minimal Recompression-Oxygen Breathing'* treatment tables (Tables 5 and 6) that brought focus on therapeutic dosing and related oxygen-air ratios. (2) As the idea was to prevent rather than recover from toxicity, the navy chose shorter oxygen breathing periods (20 minutes) at the highest oxygen pressure (60 fsw/2.82 ATA) and felt that five minute breaks would be adequate, thereby producing a ratio of 4:1. This ratio was also maintained at the intermediate oxygen pressure (30 fsw/1.9 ATA), where the cycles were 60 minutes oxygen and 15 minutes air.

Subsequent research demonstrated that toxicity could be delayed significantly at 3.0 ATA oxygen if a 10 minute air break was interspersed between 30 minutes of oxygen, a 3:1 ratio.(3)

When the U.S. Air Force established its multiplace hyperbaric center in San Antonio, in 1974, its clinical team sought out a suitable HBO treatment oxygen-air ratio. They were aware of work in Europe and the USA (Dr. George Hart) that demonstrated 2.0 ATA/90 minutes oxygen to be effective for wound healing enhancement, and without scheduled air breaks. The USAF used face masks for oxygen delivery, however, rather than the 100% oxygen-filled monoplace chambers referenced above. They recognized, therefore, that a higher chamber pressure would be necessary as the masks did not fully deliver 100% oxygen. For several reasons they so chose 45 fsw/

2.36 ATA.[4] At this pressure Air Force personnel used the U.S. Navy air break ratio of 20/5 (4:1). Eventually, the USAF switched to hoods for oxygen delivery. Because management of the 20/5 air break delivery sequence was somewhat cumbersome with these hoods they elected to reduce the frequency of air breaks, moving to a 30/10 (3:1) cycle. This ratio '*has withstood the test of time and has become the U.S. standard for multiplace hyperbaric facilities*'.[4]

As the effective oxygen pressure employed is identical regardless of chamber type, this statement can be considered to likewise represent monoplace hyperbaric facilities.

So, the prevailing data indicates that a five minute air break following 30 minutes of oxygen, a 6:1 ratio, has less basic and clinical science support than the 3:1 ratio of 30 oxygen and 10 air.

Bottom Line

Is the distinction between five and ten minutes critical? Possibly not. It is the provision of an air break*, per se*, at pressures in excess of 2.0 ATA, and at 2.0 ATA in a susceptible patient that is most important. So, every patient, regardless of prescribed treatment pressure, should always have an air break capability available to them. The NBS position in all of this is one of caution and optimal patient safety. As the 6:1 (five minute air break) ratio was never tested for effectiveness the 3:1 ratio is recommended.

Clinicians will find that using ten minute air break periods will occasionally cause a treatment to run over the four billable units that Medicare states most treatments are not expected to exceed. Should such a treatment's fifth unit be denied then an appeal that includes an explanation for the fifth unit will invariably be successful.

References:

1. Clark JM, *et al*. **Optimization of Oxygen Tolerance Extension in Rats By Intermittent Exposure.** *J Appl Physiol 2006;100:869-879*
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3. Lambertsen CJ. **Respiratory and Circulator Actions of High Oxygen Pressure.** *In: Goff LG, (ed): Proceedings of the Underwater Physiology Symposium.[Publication No 377] Washington, DC, National Academy of Sciences-National Research Council, 1955,pp25-38*
4. Sheffield PJ. **How the Davis 2.36 ATA Wound Healing Enhancement Treatment Table Was Established**. *UHM 2004;31(2):193-194* ***(650-144)***