

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 I 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 $\frac{1}{8}$ 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 $0.085 \text{ m}^3/\text{min}$ ($3 \text{ ft}^3/\text{min}$) 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 $0.085 \text{ m}^3/\text{min}$ ($3 \text{ ft}^3/\text{min}$).

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 m³/min (1 ft³/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.

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 I 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:

- (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.

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.

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.

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.

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.

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:

- (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 I 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

Chapter 15 Features of Fire Protection

15.1 Applicability.

15.1.1 This chapter shall apply to all new and existing health care facilities.

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

15.2 Construction and Compartmentation. Buildings or structures housing a health care facility shall meet the minimum construction and compartmentation requirements of the applicable code.

15.3 Special Hazard Protection for Flammable Liquids and Gases.

15.3.1 The storage and handling of flammable liquids or gases shall be in accordance with the following applicable standards:

- (1) NFPA 30, *Flammable and Combustible Liquids Code*
- (2) NFPA 54, *National Fuel Gas Code*
- (3) NFPA 58, *Liquefied Petroleum Gas Code* [101:8.7.3.1]
- (4) NFPA 55, *Compressed Gases and Cryogenic Fluids Code*

15.3.2* No storage or handling of flammable liquids or gases shall be permitted in any location where such storage would jeopardize egress from the structure, unless otherwise permitted by 15.3.1. [101:8.7.3.2]

15.13.3.9.2 Procedures shall include alarm actuation, evacuation, and equipment shutdown procedures and provisions for control of emergencies that could occur in the operating room, including specific detailed plans for control operations by an emergency control group within the organization or a public fire department.

15.13.3.9.3 Emergency procedures shall be established for controlling chemical spills.

15.13.3.9.4 Emergency procedures shall be established for extinguishing drapery, clothing, or equipment fires.

15.13.3.10 Orientation and Training.

15.13.3.10.1 New operating room/surgical suite personnel, including physicians and surgeons, shall be taught general safety practices for the area and specific safety practices for the equipment and procedures they will use.

15.13.3.10.2 Continuing safety education and supervision shall be provided, incidents shall be reviewed monthly, and procedures shall be reviewed annually.

15.13.3.10.3 Fire exit drills shall be conducted annually or more frequently as determined by the applicable code.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.1.10 Because no single model of an emergency management plan is feasible for every health care facility, this chapter is intended to provide criteria for the preparation and implementation of an individual plan. The principles involved are universally applicable; the implementation needs to be tailored to the specific facility.

A.1.1.12 During the past 20 years, there has been a widespread interest in the use of oxygen at elevated environmental pressure to increase the partial pressure of oxygen in a patient's tissues in order to treat certain medical conditions or to prepare a patient for surgery. These techniques are also employed widely for the treatment of decompression sickness (e.g., bends, caisson worker's disease) and carbon monoxide poisoning.

Recently, however, the level of knowledge and expertise has increased so dramatically that the codes are in need of updating. By the end of 1988, there were 218 hyperbaric facilities in operation in the United States and Canada. These facilities supported hyperbaric medical treatments for 62,548 patients between 1971 and 1987. As these facilities provide therapy for disorders indicated for treatment, these numbers will continue to increase. As the number of facilities increases, the number of patients treated will also increase.

Such treatment involves placement of the patient, with or without attendants, in a hyperbaric chamber or pressure vessel, the pressure of which is raised above ambient pressure. In the course of the treatment, the patient breathes up to 100 percent oxygen.

In addition to being used for patient care, these chambers also are being employed for research purposes using experimental animals and, in some instances, humans.

The partial pressure of oxygen present in a gaseous mixture is the determinate factor in the amount of available oxygen. This pressure will rise if the volume percentage of oxygen present increases, if the total pressure of a given gas mixture containing oxygen increases, or if both these factors increase. Because the sole purpose of the hyperbaric technique of treatment is to raise the total pressure within the treatment chamber, an increased partial pressure of oxygen always is available during treatment, unless positive means are taken to limit the oxygen content. In addition, the patient is often given an oxygen-enriched atmosphere to breathe.

The need for human diligence in the establishment, operation, and maintenance of hyperbaric facilities is continual. The chief administrator of the facility possessing the hyperbaric chamber is responsible to adopt and enforce appropriate regulations for hyperbaric facilities. In formulating and administering the program, full use should be made of technical personnel highly qualified in hyperbaric chamber operations and safety.

It is essential that personnel having responsibility for the hyperbaric facility establish and enforce appropriate programs to fulfill the provisions of Chapter 14.

Potential hazards can be controlled only when continually recognized and understood by all pertinent personnel.

The purpose of Chapter 14 is to set forth minimum safeguards for the protection of patients or others subject to, and personnel who administer, hyperbaric therapy and experimental procedures. Its purpose is also to offer some guidance for rescue personnel who are not ordinarily involved in hyperbaric chamber operation, but who could become so involved in an emergency.

Requirements cited in 1.1.12 are minimum requirements. Discretion on the part of chamber operators and others might dictate the establishment of more stringent regulations.

A.1.5 Although it is common practice for medical appliances to use metric units on their dials, gauges, and controls, many components of systems within the scope of this document are manufactured and used in the United States and employ non-metric dimensions. Since these dimensions (such as nominal pipe sizes) are not established by the National Fire Protection Association, the Technical Correlating Committee on Health Care Facilities cannot independently change them. Accordingly, this document uses dimensions that are presently in common use by the building trades in the United States. Trade units vary from SI to U.S. customary units, depending on the equipment devices or material.

A.2.1 The documents referenced in this chapter or portions of such documents are referenced within this code and are considered part of the requirements of this document.

Documents referenced in this chapter or portions of such documents are only applicable to the extent called for within other chapters of this code.

Where the requirements of a referenced code or standard differ from the requirements of this code, the requirements of this code govern.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of

such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.3 Code. The decision to designate a standard as a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

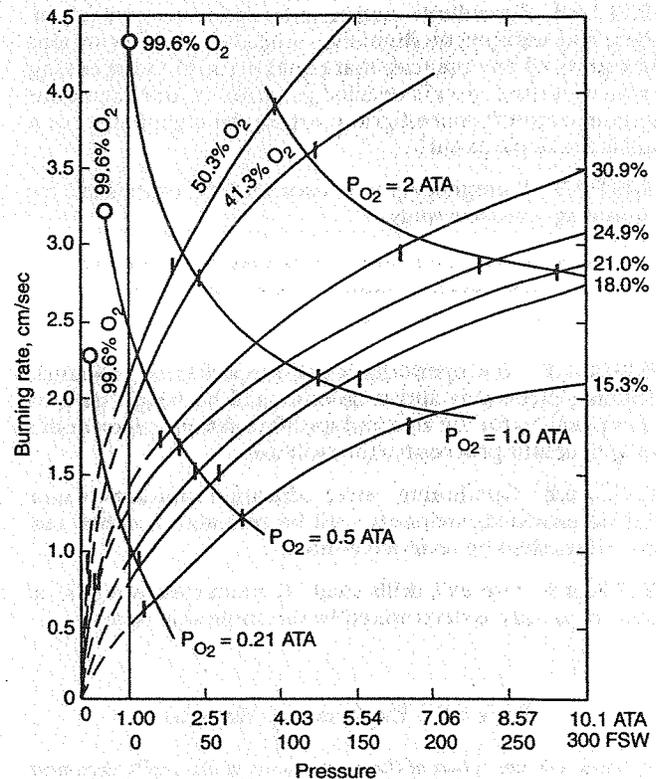
A.3.2.6 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.10 Applicator. In the given sense, an applicator is not an electrode, because it does not use a conductive connection to the patient in order to function. A radio frequency "horn" of a diathermy machine is a typical applicator.

A.3.3.12 Atmosphere. As employed in this code, the term *atmosphere* can refer to the environment within or outside of a hyperbaric facility. When used as a measure of pressure, atmosphere is expressed as a fraction of standard air pressure [101.4 kPa (14.7 psi)]. (See the first column of Table D.1 in NFPA 99B.)

A.3.3.12.2 Atmosphere of Increased Burning Rate. The degree of fire hazard of an oxygen-enriched atmosphere varies with the concentration of oxygen and diluent gas and the total pressure. The definition contained in the current edition of NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*, and in editions of NFPA 56D, *Standard for Hyperbaric Facilities*, prior to 1982 did not necessarily reflect the increased fire hazard of hyperbaric and hypobaric atmospheres.

The definition of *atmosphere of increased burning rate* used in Chapter 14 and in NFPA 99B, *Standard for Hypobaric Facilities*, defines an oxygen-enriched atmosphere with an increased fire hazard as it relates to the increased burning rate of material in the atmosphere. It is based on a 1.2 cm/sec (0.47 in./sec) burning rate (at 23.5 percent oxygen at 1 atmosphere absolute) as described in Figure A.3.3.12.2.



ATA = Atmospheres absolute
FSW = Feet of sea water

FIGURE A.3.3.12.2 Burning Rates of Filter Paper Strips at an Angle of 45 Degrees in N₂-O₂ Mixtures. (Adapted from Figure 4 of "Technical Memorandum UCRI-721, Chamber Fire Safety.")

This rate can be determined as follows:

$$\frac{23.45}{\sqrt{TP_{atmos}}} \quad [\text{A.3.3.12.2}]$$

where:

TP_{atmos} = total pressure in atmospheres

A.3.3.19.3 Bulk Oxygen System. The oxygen containers can be stationary or movable, and the oxygen can be stored as gas or liquid. The bulk oxygen system terminates at the point where oxygen at service pressure first enters the supply line.

A.3.3.23 Combustible Liquid. See NFPA 30, *Flammable and Combustible Liquids Code*, for further information on flash point test procedures.

A.3.3.24 Combustion. Combustion is not limited to a chemical reaction always involving oxygen. Certain metals, such as calcium and aluminum, will burn in nitrogen; nitrous oxide will support the combustion of phosphorus and carbon; and so on. However, this document deals with the more common process of fuels burning in air.

A.3.3.32 Defend in Place. The concept of the term *defend in place* includes, but is not limited to, elements related to moving building occupants from an area of immediate danger to a safe location in the building and containment of the emergency or dangerous condition.

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

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

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

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

B.14.1.1.4 Sources of Ignition.

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

B.14.1.1.4.2 Sources of ignition that should not be encountered in a hyperbaric facility, but that might be introduced by inept practice, include the following: lighted matches or tobacco, static sparks from improper use of personal attire, electrical wiring not complying with 14.2.8, 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 distracting, 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 pO₂) 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 pO₂).

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.

Annex C Sample Ordinance Adopting NFPA 99

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 The following sample ordinance is provided to assist a jurisdiction in the adoption of this code and is not part of this code.

ORDINANCE NO. _____

An ordinance of the [jurisdiction] adopting the [year] edition of NFPA [document number], [complete document title], and documents listed in Chapter 2 of that [code, standard]; prescribing regulations governing conditions hazardous to life and property from fire or explosion; providing for the issuance of permits and collection of fees; repealing Ordinance No. _____ of the [jurisdiction] and all other ordinances and parts of ordinances in conflict therewith; providing a penalty; providing a severability clause; and providing for publication; and providing an effective date.

BE IT ORDAINED BY THE [governing body] OF THE [jurisdiction]:

SECTION 1 That the [complete document title] and documents adopted by Chapter 2, three (3) copies of which are on file and are open to inspection by the public in the office of the [jurisdiction's keeper of records] of the [jurisdiction], are hereby adopted and incorporated into this ordinance as fully as if set out at length herein, and from the date on which this ordinance shall take effect, the provisions thereof shall be controlling within the limits of the [jurisdiction]. The same are hereby adopted as the [code, standard] of the [jurisdiction] for the purpose of prescribing regulations governing conditions hazardous to life and property from fire or explosion and providing for issuance of permits and collection of fees.

SECTION 2 Any person who shall violate any provision of this code or standard hereby adopted or fail to comply therewith; or who shall violate or fail to comply with any order made thereunder; or who shall build in violation of any detailed

statement of specifications or plans submitted and approved thereunder; or fail to operate in accordance with any certificate or permit issued thereunder; and from which no appeal has been taken; or who shall fail to comply with such an order as affirmed or modified by a court of competent jurisdiction, within the time fixed herein, shall severally for each and every such violation and noncompliance, respectively, be guilty of a misdemeanor, punishable by a fine of not less than \$ _____ nor more than \$ _____ or by imprisonment for not less than _____ days nor more than _____ days or by both such fine and imprisonment. The imposition of one penalty for any violation shall not excuse the violation or permit it to continue; and all such persons shall be required to correct or remedy such violations or defects within a reasonable time; and when not otherwise specified the application of the above penalty shall not be held to prevent the enforced removal of prohibited conditions. Each day that prohibited conditions are maintained shall constitute a separate offense.

SECTION 3 Additions, insertions, and changes — that the [year] edition of NFPA [document number], [complete document title] is amended and changed in the following respects:

List Amendments

SECTION 4 That ordinance No. _____ of [jurisdiction] entitled [fill in the title of the ordinance or ordinances in effect at the present time] and all other ordinances or parts of ordinances in conflict herewith are hereby repealed.

SECTION 5 That if any section, subsection, sentence, clause, or phrase of this ordinance is, for any reason, held to be invalid or unconstitutional, such decision shall not affect the validity or constitutionality of the remaining portions of this ordinance. The [governing body] hereby declares that it would have passed this ordinance, and each section, subsection, clause, or phrase hereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses, and phrases be declared unconstitutional.