

- 19.3.3 Reserved.
 19.3.4 Reserved.
 19.3.5 Reserved.
 19.3.6 Reserved.
 19.3.7 Reserved.

19.3.8 **Electrical Equipment Requirements.** Electrical equipment used in the home for health care shall conform to such requirements of Chapter 8 as applicable.

19.3.9 **Gas Equipment Requirements.** Gas equipment used in the home for health care shall conform to such requirements of Chapter 9 as applicable.

Chapter 20 Hyperbaric Facilities

20.1 Applicability.

20.1.1 This chapter shall apply to new facilities.

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

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

20.1.4* **Scope.** The scope of this chapter shall be as specified in 1.1.20.

20.1.5 Classification of Chambers.

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

20.1.5.2* **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

20.1.6 **Nature of Hazards.** See Section B.7.

20.2 Construction and Equipment.

20.2.1 Housing for Hyperbaric Facilities.

20.2.1.1 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.

20.2.1.1.1* Free-standing, 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.

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

20.2.1.1.3 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.

20.2.1.1.4 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.

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

20.2.1.1.6 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.

20.2.1.1.7 Service equipment (e.g., compressors) shall be permitted to be located in multi-use spaces meeting the requirements of 20.2.1.1.

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

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

20.2.1.2 A hydraulically calculated automatic wet pipe sprinkler system meeting the requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be installed in the room housing a Class A chamber and in any ancillary equipment rooms.

20.2.1.2.1 Class A 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 20.2.1.2.

20.2.1.2.2* Chamber room sprinkler heads shall be an approved type equipped with fusible elements.

20.2.1.2.3 The element temperature ratings shall be as low as possible, consistent with the requirements against false operation in NFPA 13.

20.2.1.3 The room or rooms housing Class B and Class C chambers shall be afforded sprinkler protection in accordance with 20.2.1.2.

20.2.1.3.1 Chambers not contiguous to a health care facility, and located in a mobile vehicle-mounted facility shall not be required to have sprinkler protection as specified in 20.2.1.2.

20.2.1.4 Nonflammable gases shall be permitted to be piped into the hyperbaric facility.

20.2.1.4.1 Shutoff valves accessible to facility personnel shall be provided for such piping at the point of entry to the room housing the chamber.

20.2.1.4.2 Storage and handling of nonflammable gases shall meet the applicable requirements of Chapter 5, Gas and Vacuum Systems, of this document and NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*.

20.2.2 Fabrication of the Hyperbaric Chamber.

20.2.2.1* 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.

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

20.2.2.3 As a minimum, animal chambers shall be designed, fabricated, and stamped to meet ANSI/ASME Section VIII, Division 1 code requirements.

20.2.2.4 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.

20.2.2.4.1 The floor of Class A chambers shall be noncombustible.

20.2.2.4.2 If the procedures to be carried out in the Class A hyperbaric chamber require antistatic flooring, the flooring shall be installed in accordance with the provisions of 13.4.1.

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

20.2.2.4.4 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.

20.2.2.5 The interior of Class A chambers shall be unfinished or treated with a finish that is one of the following:

- (1) Inorganic-zinc-based
- (2) High-quality epoxy
- (3) Flame resistant

20.2.2.5.1 If the interior of a Class A chamber is treated (painted) with a finish listed in 20.2.2.5, the cure procedure and minimum duration for each coat of finish to off-gas shall be in accordance with the manufacturer's application instructions and material safety data sheets.

20.2.2.5.2* If sound-deadening materials are employed within a hyperbaric chamber, they shall be flame resistant as defined in Chapter 3.

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

20.2.2.6.1 Access ports in Class A chambers, 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.

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

20.2.3 Illumination.

20.2.3.1 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 fiberoptic or similar lighting.

20.2.3.1.1 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.

20.2.3.1.2 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.

20.2.3.1.2.1 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.

20.2.3.2 Lighting permanently installed inside the chamber and portable lighting for temporary use inside the chamber shall meet the requirements of 20.2.7.3.15.

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

20.2.4 Chamber Ventilation.

20.2.4.1 Ventilation of Class A Chambers.

20.2.4.1.1 The minimum ventilation rate for a Class A chamber shall be 0.085 actual m³ (3 actual ft³) per minute of air per chamber occupant who is not using a breathing-mask overboard dump system that exhausts exhaled gases.

20.2.4.1.1.1 The minimum threshold rate shall be 0.085 actual m³ (3 actual ft³) per minute.

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

20.2.4.1.2* 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 20.2.8.4.1 and 20.2.8.5 are met.

20.2.4.1.3 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.

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

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

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

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

20.2.4.2 Sources of Air for Chamber Atmospheres.

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

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

20.2.4.2.3 Air supply for chamber atmosphere shall be monitored as required in 20.2.8.6.

20.2.4.2.4 The use of conventional oil-lubricated compressors shall be permitted provided they are fitted with air treatment packages designed to produce medical air, and they meet the monitoring requirements of 20.2.8.6.

20.2.4.2.4.1 The air treatment packages shall include automatic safeguards.

20.2.4.2.5 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 20.2.7.2.4 is satisfied.

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

20.2.4.2.6 Air compressor installations that supply medical air to piped gas systems as well as to hyperbaric facilities shall

meet the requirements of 5.1.3.5.3 in Chapter 5 and the requirements of this chapter.

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

20.2.4.3 Temperature and Humidity Control.

20.2.4.3.1 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.

20.2.4.3.2* 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 $22^{\circ}\pm 2^{\circ}\text{C}$ ($75^{\circ}\pm 5^{\circ}\text{F}$)].

20.2.4.3.3 Whenever the Class A chamber is used as an operating room, it shall be ventilated and the air supply thereto shall be conditioned according to the minimum requirements for temperature for hospital operating rooms as specified in 13.4.1.

20.2.4.3.3.1 If inhalation anesthetic agents are being utilized (e.g., nitrous oxide, methoxyflurane, halothane), a closed anesthetic system with exhaled-gas scavenging and overboard dumping shall be employed.

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

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

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

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

20.2.4.4 Ventilation of Class B Chambers.

20.2.4.4.1* The minimum ventilation rate for a Class B chamber shall be $0.0283\text{ m}^3/\text{min}$ ($1\text{ actual ft}^3/\text{min}$).

20.2.4.4.2 Class B chambers not designed for 100 percent oxygen environment shall comply with the monitoring requirements of 20.2.8.4.

20.2.4.5 Emergency Depressurization and Facility Evacuation Capability.

20.2.4.5.1 Class A chambers shall be capable of depressurizing from 3 ATA (304.0 kPa) to ambient pressure in no more than 6 minutes.

20.2.4.5.2 Class B chambers shall be capable of depressurizing from 3 ATA (304.0 kPa) to ambient pressure in no more than 2 minutes.

20.2.4.5.3* A source of breathable gas allowing unrestricted mobility shall be available outside a Class A or B chamber for use by personnel in the event that the air in the vicinity of the chamber is fouled by smoke or other combustion products of fire.

20.2.5 Fire Protection in Class A Chambers.

20.2.5.1 General Requirements.

20.2.5.1.1 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.

20.2.5.1.2 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.

20.2.5.1.3 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* 20.2.5.3) and communication, where used, shall be activated.

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

20.2.5.1.4* 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.

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

- (1) Comply with 20.2.5.1.4
- (2) Have a means for immediately contacting the local fire department.

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

20.2.5.1.6 Booster pumps, control circuitry, and other electrical equipment involved in fire suppression system operation shall be powered from a critical branch of the emergency electrical system as specified in 20.2.7.2.2.1.

20.2.5.1.7 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).

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

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

20.2.5.2.1 In chambers that consist of more than one chamber compartment (lock), the design of the deluge system shall meet the requirements of 20.2.5.2 when the chamber compartments are at different depths (pressures).

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

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

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

20.2.5.2.4.1 Controls shall be designed to prevent unintended activation.

20.2.5.2.5 Water shall be delivered from the fixed discharge nozzles as specified in 20.2.5.2.7 within 3 seconds of activation of any affiliated deluge control.

20.2.5.2.6* Average spray density at floor level shall be not less than 81.5 L/min/m² (2 gpm/ft²) with no floor area larger than 1 m² (10.76 ft²) receiving less than 40.75 L/min/m² (1 gpm/ft²).

20.2.5.2.7 There shall be water available in the deluge system to maintain the flow specified in 20.2.5.2.6 simultaneously in each chamber compartment (lock) containing the deluge system for 1 minute.

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

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

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

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

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

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

20.2.5.3.4 Handlines shall have a 1.27 cm (0.5 in.) minimum internal diameter and shall have a rated working pressure greater than the highest supply pressure of the supply system.

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

20.2.5.3.5.1 Hand-operated, spring-return to close valves at the discharge end of handlines shall be permitted.

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

20.2.5.3.7 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.

20.2.5.3.7.1 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.

20.2.5.4 Automatic Detection System Requirements. Automatic fire detection systems shall not be required.

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

20.2.5.4.1.1 Type and arrangement of detectors shall be such as to respond within 1 second of flame origination.

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

20.2.5.4.3 The system shall be powered from the critical branch of the emergency electrical system or shall have automatic battery back-up.

20.2.5.4.4 If used to automatically activate the deluge system, the requirements for manual activation/deactivation in 20.2.5.2.4 and deluge system response time in 20.2.5.2.5 shall still apply.

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

20.2.5.4.6 Automatic fire detection equipment, when used, shall meet the applicable requirements in 20.2.7.3.

20.2.5.5* Testing Requirements. The deluge and handline systems shall be functionally tested at least semiannually per 20.2.5.2.7 for deluge systems and 20.2.5.3.7 for handline systems. Following the test, all valves shall be placed in their baseline position.

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

20.2.5.5.2 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 20.2.5.2.6 shall be performed at surface pressure, and at maximum operating pressure. The requirements of 20.2.5.2.6 shall be satisfied under both conditions.

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

20.2.6 Fire Protection in Class B and Class C Chambers. Class B and Class C chambers shall not be required to comply with 20.2.5.

20.2.6.1 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).

20.2.6.2 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.

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

- (1) Comply with 20.2.6.2
- (2) Have a means for immediately contacting the local fire department

20.2.7 Electrical Systems.

20.2.7.1 General.

20.2.7.1.1 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 20.2.7.

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

20.2.7.1.3 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

20.2.7.1.4 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

20.2.7.1.4.1* If motors are to be located in the chamber, they shall meet the requirements of 20.2.7.3.14.

20.2.7.1.5 All electrical equipment connected to or used in conjunction with hyperbaric patients shall comply with the requirements of Chapter 8, Electrical Equipment, and with the applicable paragraphs of 20.2.7.3.

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

20.2.7.2 Electrical Service.

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

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

20.2.7.2.1.2 For hyperbaric facilities using a prime-mover-driven generator set, it shall be designated as the "emergency system" and shall meet the requirements of Chapter 4 of this standard for hyperbaric systems based in health care facilities.

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

20.2.7.2.2 Electrical equipment associated with life support functions of hyperbaric facilities shall be connected to the critical branch of the emergency system; that is, such equipment shall have electrical power restored within 10 seconds of interruption of normal power. Such equipment 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 number of chamber room lights (either overhead or local) to ensure continued safe operation of the facility during a normal power outage

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

20.2.7.2.3 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 4*) or the emergency system (*see NFPA 70, National Electrical Code, Article 700*), as applicable.

20.2.7.2.4 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.

20.2.7.2.5 When reserve air tanks or non-electric compressor(s) to maintain pressure and ventilation airflow within the chamber and supply air for the chamber pressurization are provided, the compressor(s) and auxiliary equipment shall not be required to have an alternate source of power.

20.2.7.2.6 Electrical control and alarm systems 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.

20.2.7.3* **Wiring and Equipment Inside Class A Chambers.** The following general rules shall be satisfied in the use of electrical devices and equipment. The requirements under 20.2.7.3 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.

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

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

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

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

20.2.7.3.5 Where conformance with Class I, Division 1 requirements is specified in 20.2.7.3.7, conformance with Class I, Division 2 requirements is permitted to be substituted.

20.2.7.3.6 **Conductor Insulation.** All conductors inside the chamber shall be insulated with a material classified as flame resistant as defined in Chapter 3.

20.2.7.3.6.1 Insulation classified as flame retardant shall not be required on conductors that form an integral part of electrical equipment approved for use inside the chamber, including patient leads.

20.2.7.3.6.2 Insulation shall not be required on ground conductors inside of a conduit.

20.2.7.3.7 Wiring Methods.

20.2.7.3.7.1 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

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

20.2.7.3.7.3 All threaded conduit shall be threaded with an NPT standard conduit cutting die that provides a 1.9 cm taper per 0.3 m (0.75 in. taper per ft).

20.2.7.3.7.4 All threaded conduit shall be made wrenchtight to prevent sparking when fault current flows through the conduit system.

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

20.2.7.3.7.6 Threaded, liquidtight flexible metal conduit installed in accordance with Article 351 of NFPA 70, *National Electrical Code*, shall be permitted when protected from damage by physical barriers such as equipment panels.

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

20.2.7.3.9 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) Be of a type approved for extra-hard utilization in accordance with Table 400.4 of NFPA 70, *National Electrical Code*
- (2) Include a ground conductor
- (3) Meet the requirements of Article 501.11 of NFPA 70, *National Electrical Code*

20.2.7.3.9.1 The normal cord supplied with the device 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.

20.2.7.3.10* Receptacles Installed Inside the Chamber.

20.2.7.3.10.1 Receptacles shall be waterproof.

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

20.2.7.3.10.3 Receptacles shall be supplied from isolated power circuits meeting the requirements of 20.2.7.4.2.

20.2.7.3.10.4 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.

20.2.7.3.10.5 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.

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

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

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

20.2.7.3.13 Exposed Live Electrical Parts. There shall be no exposed live electrical parts.

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

20.2.7.3.13.2 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 20.2.7.3.17.

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

- (1) Article 501.8(A)(1) of NFPA 70, *National Electrical Code*, for the chamber pressure and oxygen concentration
- (2) Be of the totally enclosed types meeting Article 501.8(A)(2) or 501.8(A)(3) of NFPA 70, *National Electrical Code*.

20.2.7.3.15* Lighting. Lighting installed or used inside the chamber shall be rated for a pressure of 1½ times the chamber working pressure. Permanently installed fixtures shall meet the following requirements:

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

20.2.7.3.15.1 Ballasts and other energy storage components that are part of the lighting circuit shall be installed outside the chamber in accordance with 20.2.7.1.4.

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

20.2.7.3.16 Low-Voltage, Low-Power Equipment. The requirements of 20.2.7.3.16 shall apply to sensors, signaling, alarm, communication, and remote control equipment installed or used in the chamber for operation of the chamber.

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

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

20.2.7.3.16.2 Circuits such as headset cables, sensor leads, and so forth, not enclosed as required in 20.2.7.3.7, shall meet one of the following requirements:

- (1) Be part of approved intrinsically safe equipment
- (2) Be limited by circuit design to no more than 28 V and 0.5 A under normal or circuit fault conditions

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

20.2.7.3.16.4 Electrical rating of chamber speakers shall not exceed 28 V rms and 25 W.

20.2.7.3.16.5 Battery-operated, portable intercom headset units shall meet the requirements of 20.2.7.3.17.5 for battery-operated devices.

20.2.7.3.17* Portable Patient Care-Related Electrical Appliances.

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

20.2.7.3.17.2 The electrical and mechanical integrity of the appliance shall be verified and documented through an ongoing maintenance program as required in Chapter 8.

20.2.7.3.17.3 The appliance shall conform to the requirements of 20.2.7.3.1 and 20.2.7.3.12.

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

20.2.7.3.17.5 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 they are exposed to.
- (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.

20.2.7.3.17.6 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.

20.2.7.4 Grounding and Ground Fault Protection.

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

20.2.7.4.1.1 Grounding conductors shall be secured as required by Article 250, Section III, Grounding Conductor Connections, of NFPA 70, *National Electrical Code*.

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

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

20.2.7.4.2 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.

20.2.7.4.2.1 Such circuits shall meet the requirements of Article 517.160, Isolated Power Systems, and 517.160(B), Line Isolation Monitor, of NFPA 70, *National Electrical Code*. Branch circuits shall not exceed 125 V or 15 A.

20.2.7.4.3 Wiring located both inside and outside the chamber, which serves line level circuits and equipment located inside the chamber, shall meet the grounding and bonding requirements of Article 501.16 of NFPA 70, *National Electrical Code*.

20.2.7.5 Wiring Outside the Chamber.

20.2.7.5.1 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.

20.2.7.5.1.1 All associated conduits shall meet the following requirements:

- (1) Be waterproof
- (2) Meet the requirements of NFPA 70, *National Electrical Code*
- (3) Be equipped with approved drains

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

20.2.7.6 Additional Wiring and Equipment Requirements inside Class B Chambers. The requirements in 20.2.7.6 shall apply to Class B chambers whether they are pressurized with oxygen or with air.

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

20.2.7.6.1.1 Circuits shall be designed to limit the electrical energy to wire leads into the chamber under normal or fault conditions to no more than 28 V and 0.5 W.

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

20.2.7.6.1.3 Patient monitoring leads shall be part of approved electromedical apparatus meeting the requirements in 20.2.7.3.17.

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

20.2.7.6.3 No electrical circuit in a Class B chamber shall operate at a temperature exceeding 60°C (140°F).

20.2.8 Communications and Monitoring.

20.2.8.1 General.

20.2.8.1.1 Detectors, sensors, transducers, and communications equipment located inside the chamber shall meet the requirements of 20.2.7.3.16.

20.2.8.1.2 Wiring methods in the chamber shall meet the applicable requirements in 20.2.7.3.

20.2.8.1.3 The following equipment shall be installed outside the chamber or shall meet the requirements of 20.2.7.3.16:

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

20.2.8.2* Intercommunications.

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

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

20.2.8.3 Combustible Gas Detection.

20.2.8.3.1 The chamber atmosphere shall be continuously monitored for combustible gas concentrations whenever any volatile agents are used in the chamber (*see 20.2.4.3.3.1*).

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

20.2.8.4 Oxygen Monitoring.

20.2.8.4.1 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.

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

20.2.8.4.2 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 and/or any flammable agents are present in the chamber.

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

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

20.2.8.6* Chamber Gas Supply Monitoring. The air supply of Class A and Class B chambers shall be sampled for concentrations of carbon monoxide.

20.2.8.6.1 Air supplied from oil-lubricated compressors capable of contaminating the compressor output due to wear or failure shall be continuously monitored for volatilized hydrocarbons as well as carbon monoxide at a location downstream from the oil filter when the compressors are running.

20.2.8.6.2* As a minimum, the air supplied to Class A chambers shall meet the requirements for CGA Grade D.

20.2.8.6.3 As a minimum, the air supplied to Class B chambers shall meet the requirements for CGA grade D with the additional limit of no condensable hydrocarbons.

20.2.8.7* Electrical monitoring equipment used inside the chamber shall comply with the applicable requirements of 20.2.7.

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

20.2.9 Other Equipment and Fixtures.

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

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

20.2.9.2.1 The point of exhaust shall not create a hazard.

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

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

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

20.2.9.3 The supply piping for all air, oxygen, or other breathing mixtures from certified commercially supplied flasks shall be provided with a particulate filter of at least 10 microns or finer.

20.2.9.3.1 The 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.

20.3 Administration and Maintenance.

20.3.1 General.

20.3.1.1 Purpose. Section 20.3 contains requirements for administration and maintenance that shall be followed as an adjunct to physical precautions specified in Section 20.2.

20.3.1.2* 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.

20.3.1.3 Responsibility.

20.3.1.3.1 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.

20.3.1.3.2* Each hyperbaric facility shall designate an onsite hyperbaric safety director to be in charge of all hyperbaric equipment and the operational safety requirements of this chapter.

20.3.1.3.2.1 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.

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

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

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

20.3.1.3.4* 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.

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

20.3.1.3.5* 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.

20.3.1.4 Rules and Regulations.

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

20.3.1.4.1.1 Upon adoption, policies shall be available in the facility.

20.3.1.4.2 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) The number and type of hyperbaric chambers in use
- (2) Maximum treatment capacity
- (3) The type of hyperbaric therapy normally provided

20.3.1.4.3 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.

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

20.3.1.4.4.1* All personnel shall be trained on emergency procedures.

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

20.3.1.4.5* Emergency procedures and fire training drills shall be conducted at least annually and documented by the safety director.

20.3.1.4.6* 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. 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.

20.3.1.4.7 During chamber operations with 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).

20.3.1.5 General Requirements.

20.3.1.5.1* Potential Ignition Sources.

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

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

20.3.1.5.1.2 The following shall be prohibited from inside the chamber:

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

20.3.1.5.2 Flammable Gases and Liquids.

20.3.1.5.2.1 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.

20.3.1.5.2.2 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 shall be included to account for the localized concentrations, stratification, and the absence of ventilation.
- (4) The oxygen monitoring requirement of 20.2.8.4.2 is observed.

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

20.3.1.5.3* Personnel.

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

20.3.1.5.3.2 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.

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

20.3.1.5.4* Textiles.

20.3.1.5.4.1 Silk, wool, or synthetic textile materials shall not be permitted in Class A or Class B chambers unless the fabric meets the flame resistant requirements of 20.3.1.5.4.5.

20.3.1.5.4.2 Garments fabricated of 100 percent cotton or a blend of cotton and polyester fabric shall be permitted in Class A chambers equipped with fire protection as specified in 20.2.5, and in Class B chambers.

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

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

20.3.1.5.4.4 Physician and safety director approval to use prohibited items shall be stated in writing for all prohibited materials employed (*see A.20.3.1.3.2*).

20.3.1.5.4.5 Where flame resistance is specified, the fabric shall meet the requirements set forth for the small-scale test in NFPA 701, *Standard Methods of Fire Tests for Flame Propagation of Textiles and Films*, in an atmosphere equivalent to the maximum oxygen concentration and pressure proposed for the chamber.

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

20.3.1.5.5.1 Whenever possible, patients shall be stripped of all clothing, particularly if it is contaminated by dirt, grease, or solvents, and then reclothed. (*See A.20.3.1.5.4.*)

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

20.3.1.5.6 All other fabrics used in the chamber such as sheets, drapes, and blankets shall conform to 20.3.1.5.4.1 and 20.3.1.5.4.2.

20.3.1.5.7 Clothing worn by patients in Class A or B chambers and personnel in Class A chambers shall conform to the following:

- (1) Be issued by the hyperbaric facility or specifically approved by the safety director for hyperbaric use
- (2) Be uncontaminated
- (3) Be devoid of prohibited articles prior to chamber pressurization

20.3.2 Equipment.

20.3.2.1 All equipment used in the hyperbaric chamber shall comply with Section 20.2, 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

20.3.2.1.1 Use of unapproved equipment shall be prohibited. (See 20.3.1.5.4.3.)

20.3.2.1.2 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

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

- (1) Photoflash
- (2) Flood lamps

20.3.2.1.4 Lasers shall not be used under any condition.

20.3.2.1.5 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 20.3.1.3.2).

20.3.2.1.6* Paper brought into the chamber shall be stored in a closed metal container. Containers used for paper storage shall be emptied after each chamber operation.

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

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

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

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

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

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

20.3.2.4.1 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.

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

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

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

20.3.2.6.1 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.

20.3.3 Handling of Gases.

20.3.3.1 The institution's administrative personnel shall develop policies for safe handling of gases in the hyperbaric facility (see 20.3.1.5.2 and C.20.1.1.3.2).

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

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

20.3.3.4* 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.

20.3.4 Maintenance.**20.3.4.1 General.**

20.3.4.1.1 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.

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

20.3.4.1.2 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*.

20.3.4.1.3 Before piping systems are initially put into use, it shall be ascertained that the gas delivered at the outlet is shown on the outlet label and that connecting fittings are checked against their labels, in accordance with Sections 5.1 through 5.3.

20.3.4.1.4 The requirements set forth in Section 5.1 concerning the storage, location, and special precautions required for compressed gases shall be followed. Reserve supplies and master alarm signals shall meet the requirements of Section 5.2.

20.3.4.1.5 Storage areas for hazardous materials shall not be located in the room housing the hyperbaric chamber (see 20.2.1).

20.3.4.1.5.1 Flammable gases, except as provided in 20.3.1.5.2.2(1), shall not be used or stored in the hyperbaric room.

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

20.3.4.2 Maintenance Logs.

20.3.4.2.1 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.

20.3.4.2.1.1 Logs of all tests shall be maintained.

20.3.4.2.2 Operating equipment logs shall be maintained by engineering personnel.

20.3.4.2.2.1 Operating equipment logs shall be signed before chamber operation by the person in charge (*see A.20.3.1.3.2*).

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

20.3.5 Electrical Safeguards.

20.3.5.1 Electrical equipment shall be installed and operated in accordance with 20.2.7.

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

20.3.5.1.1.1 Electrical circuit test shall include the following:

- (1) A ground fault check to verify that no conductors are grounded to the chamber
- (2) A test of normal functioning (*see 20.2.7.2.2*)

20.3.5.1.2 In the event of fire, all nonessential electrical equipment within the chamber shall be deenergized before extinguishing the fire.

20.3.5.1.2.1 Smoldering, burning electrical equipment shall be deenergized before extinguishing a localized fire involving only the equipment (*see 20.2.5*).

20.3.6* Electrostatic Safeguards.

20.3.6.1 Administration. (Reserved)

20.3.6.2 Maintenance.

20.3.6.2.1* **Conductive Floors.** See E.6.6.8, Reduction in Electrostatic Hazard, for recommendations on chambers containing conductive floors.

20.3.6.2.2 Furniture Used in the Chamber.

20.3.6.2.2.1* 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.

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

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

20.3.6.2.2.4 Lubricants shall be oxygen compatible and flame resistant.

20.3.6.2.2.5 Wheelchairs and gurneys with bearings lubricated and sealed by the manufacturer shall be permitted in Class A chambers where conditions prescribed in 20.2.8.4 are met.

20.3.6.2.3* **Conductive Accessories.** Conductive accessories shall meet conductivity and antistatic requirements.

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

20.3.6.3 **Fire Protection Equipment.** Electrical switches, valves, and electrical monitoring equipment associated with fire detection and extinguishment shall be visually inspected before each chamber pressurization. Fire detection equipment shall be tested each week and full testing, including discharge of extinguishing media, shall be conducted annually. Testing shall include activation of trouble circuits and signals.

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

20.3.6.4.1 The persons assigned to this task 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

21.3.7 Freestanding Birthing Centers

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21.3.8 **Electrical Equipment Requirements.** Electrical equipment used in freestanding birthing centers shall conform to such requirements of Chapter 8 as applicable.

21.3.9 **Gas Equipment Requirements.** Gas equipment used in freestanding birthing centers shall conform to such requirements of Chapter 9 as applicable.

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.1.1.11.1(3) Although this subsection deals primarily with hazards related to fires and explosions, many of the requirements to protect against fire or explosion, such as those for hood exhaust systems, also serve to protect persons from exposure to nonfire health hazards of these materials.

A.1.1.12 Because no single model of an emergency management plan is feasible for every health care facility, this chapter is intended to provide criteria in 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.1.1.20 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

gases if there is more than one supply system in the single treatment facility.

A.17.3.5.1(3)(c) It is the intent to provide a simple, safe piping system for small facilities. Although the number of use points could be a consideration, it was felt that actual gas use is a more accurate indicator of complexity. Applications involving a storage in excess of 85 m³ (3000 ft³) would have a complexity warranting installation in accordance with the provisions of Level 1 patient gas distribution systems.

Although the principal intent is to provide simple installations for single treatment facilities, numerous applications exist where a remote use point creates essentially a second treatment facility or where the supply system might be shared by another health care professional such as other dentist, podiatrist, oral surgeon, or general medicine practitioner. The addition of another treatment facility requires incremental safety precautions.

A maximum of two single treatment facilities also approximates the limit with which a 85 m³ (3000 ft³) supply system can provide [143 m³ (5000 ft³) when liquid oxygen is used].

It is acknowledged that older user analgesia equipment has offered a nitrous oxide lockout device that requires a minimum of 3 L/min oxygen flow. However, a reasonable percentage of older equipment without this safety feature is in daily use. The storage and piping system is based upon the potential use, either initially or subsequently, of one of the older style analgesia equipment in one of the single treatment facilities. The quantity of 85 m³ (3000 ft³), or 143 m³ (5000 ft³) if liquid oxygen storage, is to be taken as the total combined storage of gases if there is more than one supply system in the single treatment facility.

A.17.3.11 This is in addition to other nursing home requirements listed in Section 17.3.

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It is acknowledged that older user analgesia equipment has offered a nitrous oxide lockout device that requires a minimum of 3 L/min oxygen flow. However, a reasonable percentage of older equipment without this safety feature is in daily use. The storage and piping system is based upon the potential use, either initially or subsequently, of one of the older style analgesia equipment in one of the single treatment facilities. The quantity of 85 m³ (3000 ft³), or 143 m³ (5000 ft³) if liquid oxygen storage, is to be taken as the total combined storage of gases if there is more than one supply system in the single treatment facility.

A.18.3.11 This is in addition to other limited care facility requirements listed in Section 18.3.

A.19.1 As part of the current decentralization of health care modalities, traditionally the province of hospitals, patients are being treated at home using electrical and gas appliances that, if used in a health care facility, would come under the purview of this standard.

A.20.1.4 Chapter 20 does not apply to respiratory therapy employing oxygen-enriched atmospheres at ambient pressures. See Chapter 9.

A.20.1.5.2 Chambers designed for animal experimentation but equipped for access of personnel to care for the animals are classified as Class A for the purpose of Chapter 20.

A.20.2.1.1.1 For guidance on minimum construction requirements, depending on occupancy classification, see NFPA 101, *Life Safety Code*.

A.20.2.1.1.5 Characteristics of building construction housing hyperbaric chambers and ancillary facilities are no less important to safety from fire hazards than are the characteristics of the hyperbaric chambers themselves. It is conceivable that a fire emergency occurring immediately outside a chamber, given sufficient fuel, could seriously endanger the life or lives of those inside the chamber. Since the service facilities such as compressors, cooling equipment, reserve air supply, oxygen, and so forth, will in all probability be within the same building, these will also need protection while in themselves supplying life-maintaining service to those inside.

A.20.2.1.2.2 In addition to the functions of building protection, the chamber room sprinkler system should be designed to ensure a degree of protection to chamber operators and occupants who likely will not be able to immediately evacuate the premises in the event of a fire.

A.20.2.2.1 Other chapters in NFPA 99 contain many requirements that could appear to relate to hyperbaric facilities but could be inappropriate. The requirements of other chapters in NFPA 99 should be applied to hyperbaric facilities only where specifically invoked by this chapter.

A.20.2.2.5.2 Many commercial sound-deadening materials that might be flame resistant are porous and will absorb water from activation of the fire-suppression system and retain odor. Metallic panels that contain a large quantity of small holes or are made of wire mesh and are installed about 1 in. (2.5 cm) away from the chamber wall can be used to form an acoustic baffle. These panels should be made from corrosive-resistant materials such as stainless steel or aluminum and can be painted in accordance with 20.2.2.5.1.

A.20.2.2.6 Prudent design considerations suggest that at least 50 percent excess pass-through capacity be provided, for future use, given the difficulty of adding pass-throughs to the chamber after it is constructed and tested.

A.20.2.4.1.2 Experience and practice can dictate the need for a threshold ventilation rate in excess of the minimum specified for sanitary reasons. It is recommended that consideration be given, if necessary, to the use of odor filters in the chamber circulation system as a means of keeping sanitary ventilation rate requirements to a minimum.

A.20.2.4.2.1 If intakes are located where it could be possible for maintenance to be conducted in the immediate vicinity, a warning sign should be posted.

A.20.2.4.3.2 Subsection 13.4.1 specifies a desirable temperature of 20°C (68°F). It is impractical to maintain such a temperature during pressurization, but efforts should be made in the design and operation of thermal control systems to maintain the temperature as close to 22°C (75°F) as possible. The air-handling system of all Class A chambers should be capable of maintaining relative humidity in the range of 50 to 70 percent during stable depth operations.

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

A.20.2.4.4.1 Ventilation can be provided by closed or open circuit systems.

A.20.2.4.5.3 The intent of this requirement is to allow facility staff to evacuate the facility and avoid breathing contaminated air. This requirement can be met using either a self-contained breathing apparatus, smoke hood with integral filter/air supply, or similar technology.

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

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

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

A.20.2.5.1.4 This requirement does not preclude the use of an alarm system affording direct fire department contact.

A.20.2.5.1.5 Experience has shown that fire blankets, portable carbon dioxide extinguishers, and other methodology intended to "snuff out" fires by excluding air are not effective in controlling fires in oxygen-enriched atmospheres. Valuable time can be lost in attempting to use such devices.

A.20.2.5.2.4 More than one control station could be required in a compartment (lock) depending on its size.

A.20.2.5.2.6 Experience has shown that when water is discharged through conventional sprinkler heads into a hyperbaric atmosphere, the spray angle is reduced because of increased resistance to water droplet movement in the denser atmosphere. This is so even though the water pressure differential is maintained above chamber pressure. Therefore, it is necessary to compensate by increasing the number of sprinkler heads. It is recommended that spray coverage tests be conducted at maximum chamber pressure.

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

A.20.2.5.4.2 Additional detectors are recommended to avoid "blind" areas if the chamber contains compartmentation.

A.20.2.5.5 The primary focus for the semiannual test of a water-based extinguishing system is to ensure water flow through the system (i.e., inspector's test). Other vitally important benefits are the activation of water flow devices, alarm appliances, and notification and annunciator systems.

A.20.2.7.1.4.1 It is recommended that system design be such that electric motors not be located inside the chamber.

A.20.2.7.3 This subsection contains requirements for the safe use of electrical equipment in the hyperbaric, oxygen-enriched environment of the Class A chamber.

A.20.2.7.3.10 It should be recognized that interruption of any powered circuit, even of very low voltage, could produce a spark sufficient to ignite a flammable agent.

A.20.2.7.3.11.1 It is recommended that all control switching functions inside the chamber be accomplished using intrinsically safe circuits that control power and control circuits located outside of the chamber.

A.20.2.7.3.12 It is the intention of this paragraph that equipment used in the chamber be incapable of igniting, by heating, any material or fabric that could come into contact with the surface of the equipment.

A.20.2.7.3.15 It is strongly recommended that high-intensity local task lighting be accomplished using through-hull fiber optic lights. Many high-intensity lights will not meet the temperature requirements specified in this subparagraph.

A.20.2.7.3.16.1 The requirement for isolation from mains supply in (1) is not the same as the requirement in 20.2.7.4.2 that circuits supplying power to portable utilization equipment inside the chamber be isolated, monitored, and alarmed.

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

A.20.2.7.3.17 These requirements are only the minimum requirements for electrical safety. There are many other safety concerns that should be addressed on a case-by-case basis. Meeting the requirements of this subparagraph does not indicate that proper device performance will occur in the hyperbaric environment, and that the device will be safe for use with patients.

A.20.2.7.5.2 It is necessary that these circuits be protected from exposure to water from the room sprinkler system protecting the chamber housing in the event of a fire in the vicinity of the chamber while it is in operation.

A.20.2.8.2 Intercommunications equipment is mandatory for safe operation of a hyperbaric facility.

A.20.2.8.2.1 It is recommended that multiple compartment (lock) Class A chambers be equipped with multiple channel systems, and that, in addition, a sound-powered telephone or surveillance microphone be furnished.

A.20.2.8.6 The purity of the various gas supplies should be assured. It is recommended that air be sampled at the air intake location at times when the intake air is likely to have maximum impurities (e.g., when vehicles or stationary engines upwind of the intake are running).

A purity statement for any cryogenic or high pressure cylinder gas should be supplied by the vendor.

Gas cylinder purity statements should be cross referenced, where possible, with the delivered gas.

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

A.20.2.8.6.2 CGA Grade D permits quantities of hydrocarbons and water in air. In piping systems where air and oxygen might be used interchangeably, hydrocarbon buildup can occur and increase the risk of fire when oxygen is used. There is also a concern about pneumatic components being fouled and functionally impaired by hydrocarbons or water from compressed air. Ideally, there should be no condensed hydrocarbons in an oxygen system and no liquid water in pneumatic control systems.

A.20.2.8.7 The frequency of such monitoring should depend on the location of the air intake relative to potential sources of contamination.

A.20.2.8.8 It is recommended that information about the status of an anesthetized or otherwise monitored patient be transmitted to the inside chamber attendants via the intercommunications system. As an alternative, the monitor indicators can be placed adjacent to a chamber viewport (or viewports) for direct observation by inside personnel.

A.20.3.1.2 The hazards involved in the use of hyperbaric facilities can be mitigated successfully only when all of the areas of hazard are fully recognized by all personnel and when the physical protection provided is complete and is augmented by attention to detail by all personnel of administration and maintenance having any responsibility for the functioning of the hyperbaric facility. Since Section 20.3 is expected to be used as a text by those responsible for the mitigation of hazards of hyperbaric facilities, the requirements set forth are frequently accompanied by explanatory text.

A.20.3.1.3.2 The complexity of hyperbaric chambers is such that one person should be designated chamber operator, such as one in a position of responsible authority. Before starting a hyperbaric run, this person should acknowledge, in writing, in an appropriate log, the purpose of the run or test, duties of all personnel involved, and a statement that he or she is satisfied with the condition of all equipment. Exceptions should be itemized in the statement.

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

Due to a conflict of responsibility, the same individual should not serve as both Medical Director and Safety Director.

A.20.3.1.3.3 It is incumbent upon the governing body to insist that rules and regulations with respect to practices and conduct in hyperbaric facilities, including qualifications and training of hyperbaric personnel, be adopted by the medical or administrative staff of the institution, and that regulations for inspection and maintenance are in use by the administrative, maintenance, and ancillary (and in the case of a hospital, nursing and other professional) personnel.

In meeting its responsibilities for safe practices in hyperbaric facilities, the administration of the facility should adopt or correlate regulations and standard operating procedures to ensure that both the physical qualities and the operating maintenance methods pertaining to hyperbaric facilities meet the standards set in Chapter 20. The controls adopted should cover the conduct of personnel in and around hyperbaric facilities and the apparel and footwear allowed. They should cover periodic inspection of static-dissipating materials and of all electrical equipment, including testing of ground contact indicators.

A.20.3.1.3.4 It is recommended that training of hyperbaric chamber personnel be closely monitored, following the guidelines and publications of the Undersea & Hyperbaric Medical Society, Baromedical Nurses Association, and the National Board of Diving and Hyperbaric Medical Technology.

A.20.3.1.3.5 In the case of a hyperbaric facility located in a hospital, hospital licensing and other approval bodies, in meeting their responsibilities to the public, should include in

their inspections not only compliance with requirements for physical installations in hyperbaric facilities, but also compliance with the requirements set forth in Section 20.3.

A.20.3.1.4.1 It is recommended that all personnel, including trainees and those involved in the operation and maintenance of hyperbaric facilities, and including professional personnel and (in the case of hospitals) others involved in the direct care of patients undergoing hyperbaric therapy, be familiar with Chapter 20. Personnel concerned should maintain proficiency in the matters of life and fire safety by periodic review of this chapter, as well as any other pertinent material.

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

A.20.3.1.4.4.1 All full and part-time personnel should receive training in emergency management appropriate to their job description.

A.20.3.1.4.5 A calm reaction (without panic) to an emergency situation can be expected only if the recommendations are familiar to and rehearsed by all concerned.

A.20.3.1.4.6 A suggested outline for emergency action in the case of fire is contained in C.20.2.

A.20.3.1.5.1 The immediate vicinity of the chamber is defined as the area around the chamber from which activation of the flame detector can occur. Flame detectors can be prematurely activated by certain radiation sources.

A.20.3.1.5.2.2(2) Allowable quantities for (2) can be determined from the chamber volume, flammable agent vapor density, and lower explosive limit (LEL). Experience has shown that increased pressure has little effect on LEL for a given flammable gas and oxygen concentration. A safety factor of 10 is recommended. Flammable liquids should be confined to nonbreakable, nonspill containers.

Sample Determination. Example of Limiting Quantity of Flammable Agent Substance: Isopropyl alcohol (2-propanol)

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

Vapor density = 2.1 relative to air

Liquid density = 786 g/L

Air density = 0.075 lb/ft³ at STP

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

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

For a relatively small 500 ft³ chamber, this implies:
1.43 × 500 = 715 g alcohol vapor at LEL.

Using a safety factor of 10 to account for uneven vapor concentrations gives 71.5 g = 91 ml alcohol.

One could conclude that even 90 ml of alcohol is more than would be needed for almost any medical procedure. The above calculation also does not account for the mitigating effect of ventilation.

Many "inert" halogenated compounds have been found to act explosively in the presence of metals, even under normal atmospheric conditions, despite the fact that the halogen compound itself does not ignite in oxygen, or, in the case of solids such as polytetrafluoroethylene, is self-extinguishing.

Apparently these materials are strong oxidizers whether as gases, liquids (solvents, greases), or solids (electrical insulation, fabric, or coatings). Some halogenated hydrocarbons that will not burn in the presence of low-pressure oxygen will ignite and continue to burn in high-pressure oxygen. Customarily, Class A chambers maintain internal oxygen concentration that does not exceed 23.5 percent.

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

The limitations on the use in the chamber of alcohol and other agents that emit flammable vapors in 20.3.1.5.2.2 should be strictly observed and such restrictions should be prominently posted.

A.20.3.1.5.3 The number of occupants of the chamber should be kept to the minimum number necessary to carry out the procedure.

A.20.3.1.5.4 It is recommended that all chamber personnel should wear garments of the overall or jumpsuit type, completely covering all skin areas possible, and as tightfitting as possible. It can be impractical to clothe some patients (depending upon their disease or the site of any operation) in such garments. Hospital gowns of flame-resistant textile should be employed in such a case.

A.20.3.2.1.6 The use of paper should be kept to an absolute minimum in hyperbaric chambers.

A.20.3.2.2 Users should be aware that many items if ignited in pressurized oxygen-enriched atmospheres are not self-extinguishing. Iron alloys, aluminum, and stainless steel are, to various degrees, in that category as well as human skin, muscle, and fat, and plastic tubing such as polyvinyl chloride (Tygon®). Testing for oxygen compatibility is very complicated. Very little data exist and many standards still have to be determined. Suppliers do not normally have facilities for testing their products in controlled atmospheres, especially high-pressure oxygen. Both static conditions and impact conditions are applicable. Self-ignition temperatures normally are unknown in special atmospheres.

A.20.3.2.5 See A.20.3.2.2.

A.20.3.2.6 Radiation equipment, whether infrared or roentgen ray, can make hyperbaric chambers even more hazardous.

A.20.3.3.4 Quantities of oxygen stored in the chamber should be kept to a minimum.

A.20.3.6 The elimination of static charges is dependent on the vigilance of administrative supervision of materials purchased, maintenance, and periodic inspection and testing.

A.20.3.6.2.1 The requirements of E.6.6.8 apply.

A.20.3.6.2.2.1 Ferrous metals can cause such sparking, as can magnesium or magnesium alloys if contact is made with rusted steel.

A.20.3.6.2.3 Conductive accessories can include belting, rubber accessories, plastics, covers, and sheeting. For more information see E.6.6.8, Reduction in Electrostatic Hazard, in Annex E.

A.20.3.6.2.4 Materials containing rubber deteriorate rapidly in oxygen-enriched atmospheres.

A.20.3.6.4 It is absolutely essential that all areas of, and components associated with, the hyperbaric chamber be kept meticulously free of grease, lint, dirt, and dust.

Annex B Nature of Hazards

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

B.1 Electrical Systems Hazards. The hazards attendant to the use of electricity include electrical shock, thermal injury, and interruption of power.

B.1.1 Fire and Explosions. Electrical systems can be subject to the occurrence of electrical fires. Grounding systems, over-current protective devices, and other subjects discussed in this standard could be intended for fire prevention as well as other purposes. This aspect of electrical systems is the primary focus of other NFPA standards and will not be emphasized herein.

B.1.2 Shock.

B.1.2.1 General. The major concern in this chapter is electric shock resulting from degradation or some type of failure within normally safe electrical appliances or the facility's electrical distribution system. The defect could be in the wiring, in a component, or the result of deteriorating insulation. The failure could be caused by mechanical abuse or by improper use of the equipment.

Hospital service presents unusually severe environmental stress to equipment, similar to hard industrial use. Appliances are frequently subjected to large mechanical stresses in the course of being transported around the facility. Patients and staff, particularly those in operating rooms, critical care areas, clinical laboratories and some physical therapy areas, are frequently surrounded by exposed, electrically grounded conductive surfaces that increase the risk of serious injury in the event of certain types of electrical failure.

Electricity passing through the body can stimulate excitable tissue, causing pain, involuntary muscle contractions, convulsions, or ventricular fibrillation. Also, electricity can cause tissue necrosis due to heat, chemical imbalance, or arcing. The effect of electricity depends upon the applied voltage, the magnitude of the current, the duration of application, whether the current is direct or alternating, the frequency of the current, and the size and location of the electrodes at which the current enters and leaves the body. The conductivity and dielectric strength of the skin is often a factor in determining the outcome of contact with electrified conductors.

Electrocution resulting from contact with equipment connected to ordinary branch circuit (i.e., less than 250 V at about 60 Hz) is usually a consequence of sustained ventricular fibrillation. When applied directly to the heart, voltages of less than 100 mV rms, 60 Hz can cause sustained ventricular fibrillation and death.

B.1.2.2 Control. Control of electric shock hazard requires the limitation of electric current that might flow in an electric circuit involving the patient's body and is accomplished through a variety of alternative approaches.