

Australian Standard™

Work in compressed air and hyperbaric facilities

Part 2: Hyperbaric oxygen facilities



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This Australian Standard was prepared by Committee SF-046, Non-diving Work in Compressed Air and Hyperbaric Treatment Facilities. It was approved on behalf of the Council of Standards Australia on 29 March 2002 and published on 24 April 2002.

The following interests are represented on Committee SF-046:

Australian and New Zealand Hyperbaric Medicine Group
Australian and New Zealand College of Anaesthetists
Australian Industry Group
Australian Medical Association
Hyperbaric Engineering Industry Forum
Hyperbaric Technicians and Nurses Association
Institution of Engineers Australia
South Pacific Underwater Medicine Society
WorkCover New South Wales

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This Standard was issued in draft form for comment as DR 00249.



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Part 2: Hyperbaric oxygen facilities

First published as AS 4774.2—2002.

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Published by Standards Australia International Ltd
GPO Box 5420, Sydney, NSW 2001, Australia

ISBN 0 7337 4464 8

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PREFACE

This Standard was prepared by Standards Australia Committee SF-046, Non-diving Work in Compressed Air and Hyperbaric Treatment Facilities, in response to a request from the Hyperbaric Technicians and Nurses Association (HTNA).

This Standard was prepared using the Hyperbaric Oxygen Therapy Facilities Industry Guidelines (HOTFIG) as a basis. HOTFIG was prepared by participants in the hyperbaric oxygen therapy industry during the period of 1995 to 1998. HOTFIG was a consensus document prepared by a committee with membership from the HTNA, Australian and New Zealand Hyperbaric Medicine Group and operators and suppliers of hyperbaric chambers.* A wider review group provided comment on HOTFIG drafts at various stages.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendices. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

* The Undersea and Hyperbaric Medicine Society (UHMS) *Guidelines for Clinical Multiplace Hyperbaric Facilities* was used as a basis for HOTFIG.

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Australian Standard

Work in compressed air and hyperbaric facilities

Part 2: Hyperbaric oxygen facilities

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements and recommendations for the design, construction, operation and maintenance of pressure vessels used for human occupancy other than those used in conjunction with, and support of, underwater diving operations.

Minimum training requirements for hyperbaric attendants, chamber operators and technical officers are included in appendices.

NOTES:

- 1 Both monoplace and multiplace hyperbaric chambers are covered.
- 2 This Standard does not address hypobaric chambers.
- 3 Facilities such as sporting domes and medical or industrial clean rooms which operate at very low increased pressures are excluded from the scope of this Standard.

1.2 OBJECTIVE

The objective of this Standard is to provide designers, manufacturers, operators and maintainers of hyperbaric oxygen facilities other than those used in conjunction with, and support of, underwater diving operations, with requirements and recommendations so that safe hyperbaric exposures of all persons involved in the operation of such facilities may be conducted.

1.3 REFERENCED DOCUMENTS

A list of referenced and other related publications is provided in Appendix A.

1.4 DEFINITIONS

For the purposes of this Standard the definitions below apply.

1.4.1 Air environment

A pressurized environment having an oxygen concentration not exceeding 23.5% oxygen by volume.

1.4.2 Chamber operator

The person responsible for operating the controls of a hyperbaric chamber.

1.4.3 Competent person

A person who has acquired through training, qualifications or experience, or a combination of these, the knowledge and skills enabling that person to safely perform a specific task.

1.4.4 Control panel

The place from where the operations of the hyperbaric chamber are controlled and monitored.

1.4.5 Hyperbaric chamber

A pressure vessel designed for human occupancy for use in the treatment of illness or injury by the use of oxygen, or combinations of oxygen and other gas mixtures, breathed at greater than atmospheric pressure.

1.4.6 Monoplace chamber

A stand-alone, single compartment hyperbaric chamber designed for occupancy by one person without an attendant.

1.4.7 Multiple lock chamber

A hyperbaric chamber with more than one compartment. Allows entrance or exit whilst the treatment compartment remains under pressure.

1.4.8 Multiplace chamber

A hyperbaric chamber designed for occupancy by more than one person at a time.

1.4.9 Oxygen-enriched environment

An environment having an oxygen concentration exceeding 23.5% oxygen by volume.

1.4.10 Patient

Anyone undergoing hyperbaric oxygen therapy for elective, medical or investigational exposure.

1.4.11 Pressure measuring device

A device using any pressure measuring method, including bourdon tube and diaphragm type gauges, and dial or electronic displays.

1.4.12 Shall

Indicates that a statement is mandatory.

1.4.13 Should

Indicates a recommendation.

1.4.14 Single lock chamber

A stand-alone hyperbaric chamber with only one compartment designed for human occupancy.

1.5 RELATIONSHIP WITH LEGISLATION

Attention is drawn to relevant occupational health and safety legislation requiring employers to provide systems of work that are safe and minimize risks to health.

SECTION 2 HYPERBARIC FACILITY

2.1 CHAMBER ROOM

2.1.1 General

It shall be ensured that the floor can support the weight of the pressure vessel and all ancillary equipment, both when moving the chamber into place and under operating conditions. Although hydrostatic pressure testing is performed at the manufacturer's site, there may be circumstances that require hydrostatic testing after the chamber is installed. Therefore, the floor loading should include capacity for the additional weight of the water in the chamber during hydrostatic testing, or the ability to remove the pressure vessel for testing.

The room housing the chamber should be large enough for not only the chamber, but also patient support and staff activities. Chamber placement within the room should ensure adequate space for chamber operations, patient loading, and support equipment. Access to all sides of the chamber may be required.

2.1.2 Access to chamber and controls

If the chamber is placed near a wall, it shall not hamper the controls or viewports of the chamber.

2.1.3 Chamber room fire protection

Fire protection requirements for hyperbaric facilities should be as listed for hyperbaric facilities in NFPA 99. The room should also be equipped with an adequate number of appropriate fire extinguishers.

'NO SMOKING' signs shall be in open view. The director of the facility should enforce a no smoking policy.

An effective fire evacuation plan should be established, displayed, and periodically reviewed. At least annually, fire evacuation procedures should be practiced with various scenarios that include patient egress and evacuation. NFPA 99 may be used for guidance.

2.1.4 Emergency systems

In the event of a fire or a medical emergency in the facility, personnel should be able to call for assistance, and be able to activate the emergency response network without leaving the control panel. Alarm repeaters that indicate problems in key supply areas should be located at the operator console.

The chamber room should be equipped with an emergency lighting system that will automatically activate in the event of a power failure. This should include illumination for the chamber control panel and power for chamber systems and patient monitors.

2.1.5 Patient support considerations

The chamber area should have space allocated for confidential patient examination and evaluation, wound care, medical supplies, patient transport and handling equipment, patient locker rooms, rest room and a waiting area.

2.1.6 Other space considerations

Additional space shall be allocated for equipment storage, gas cylinder storage, clean and soiled utility rooms, air accumulator and compressor housing, administrative space, and equipment maintenance and repair.

2.2 HYPERBARIC TREATMENT CHAMBER

2.2.1 Pressure vessel (chamber)

When selecting the pressure vessel, consideration should be given to the maximum treatment pressure, chamber internal layout and number of chamber compartments, patient treatment capacity, number and size of viewports, number of penetrators, configuration of doors and type of medical lock.

The pressure vessel should be designed, constructed, tested and approved in accordance with AS 1210 with the exceptions of—

- (a) the requirement to comply with ASME PVHO-1;

NOTE: This relates to Clause 3.29 of AS 1210—1997 and is intended to allow the provisions of AS 1210 to be used for hyperbaric treatment chambers.

- (b) the requirements relating to the discharge capacity of pressure relief devices and the fitting of isolating devices in pressure relief systems for which Clause 2.2.6 of this Standard applies; and

NOTE: This relates to Clauses 8.6 and 8.8.4 of AS 1210—1997.

- (c) requirements concerning viewports. Clause 2.2.2 of this Standard should be applied.

The requirements and recommendations relating to pressure vessels contained in this Standard should be applied in addition to those in AS 1210.

Pressure vessels may be constructed in accordance with international equivalents of AS 1210, provided such equivalent Standards are in use in their country of origin for the construction of pressure vessels for human occupancy.

Copies of pressure vessel certification documents should be maintained by the pressure vessel owner indefinitely. If the chamber is sold or transferred, all documentation should be transferred with the pressure vessel.

During chamber design and construction, consideration should be given to equipment, piping, storage shelves and other items (e.g. brackets, hangers, studs) that are to be permanently installed to support chamber operations or treatments. The internal size and layout can be determined from the anticipated number of ambulatory and stretcher patients, which will determine the number of bunks, trolleys or seats to be accommodated. The maximum working pressure of the chamber should be based on the type of treatments to be performed under presently accepted and anticipated treatment protocols.

2.2.2 Viewports (windows)

Chamber viewports should be constructed in accordance with ASME PVHO-1.

The chamber design will dictate the physical size, number and location of viewports that can be installed. Generally, viewports should be located so the patients can be observed and they can view outside. This will assist greatly in reducing the patients confinement anxiety. If possible, viewports should be located on both sides of the chamber and should allow transfer locks to be monitored.

Externally mounted closed circuit television cameras may require an extra viewport. This viewport should be positioned to give the best overall view of patients.

CAUTION: NON-AQUEOUS CLEANING COMPOUNDS AND ULTRAVIOLET RADIATION FROM DIRECT SUNLIGHT OR LIGHTS THAT EMIT ULTRAVIOLET RADIATION, e.g. FLUORESCENT LAMPS, ON ACRYLIC VIEWPORTS CAN CAUSE VIEWPORT DETERIORATION.

2.2.3 Doors

Rectangular doors allow easier access. Round doors, unless carefully designed, will present difficulties for patient and staff entry and exit.

2.2.4 Penetrators

Penetrators for gases or fluids should be separate from penetrators for electrical or communications purposes.

The number, size and location of through-hull penetrations should be determined in the design phase. It is recommended that provisions be made for an abundance of spare penetrators.

NOTES:

- 1 AS 1210 requires that a chamber be hydrostatically retested and reinspected if, after installation, new penetrations are added to the chamber hull. Therefore, it is much less expensive to provide spare hull penetrations in the initial fabrication phase than to add them at a later date.
- 2 Some chambers utilize large openings covered with blanking or penetrator plates. These plates can be drilled or modified to provide additional through hull penetrators without requiring a hydrostatic test of the entire chamber.
- 3 See also Clause 3.1.4 concerning tube sizes and pipe threads for chamber fittings.
- 4 The number of lights per chamber depends upon the size of the compartment.
- 5 The design of penetrators affects whether cleaning of pipe systems in situ can be safely conducted.

2.2.5 Fitting, furniture and fixtures

2.2.5.1 General

Consideration should be given to the combustion characteristics of all fittings, furniture and fixtures fitted to or taken into a chamber. Whether fixed or portable, these should be selected to be as near as practical to non-ignitable and not produce a toxic environment.

For chambers designed to be pressurized with oxygen or be exposed to oxygen-enriched environments, fittings and fixtures shall be oxygen safe.

CAUTION: UNSUITABLE MATERIALS CAN CAUSE FIRES.

NOTES:

- 1 NFPA 53 provides guidance on selection of materials for oxygen-enriched environments.
- 2 See also Clause 3.12.

2.2.5.2 Flooring

The floor plates, if fitted, should be designed to permit cleaning of spaces below floor level. The floor plates should have a non-slip surface, be non-combustible, be electrically grounded and be attached firmly to the chamber so they will not move.

For oxygen-enriched environments, flooring shall be oxygen compatible.

If supply or exhaust openings are under the floor, there shall be appropriately designed baffles or perforations in the floor plates to ensure adequate mixing of chamber air.

2.2.5.3 Paints

The paint system selected for the chamber should provide adequate corrosion protection and be suitable for hyperbaric use. White or light tints are recommended to enhance internal light levels.

After painting the chamber interior, the paint should be fully cured and off-gassing should no longer be detectable before commencing chamber operations with occupants.

NOTE: Paints used for hyperbaric chambers should have low flammability, ignitability and smoke production, be non-toxic and easy to clean, e.g. paints safe for food or drinking water contact.

2.2.6 Pressure relief

There shall be systems in place to prevent overpressurization of any component of the hyperbaric treatment chamber, its plant and plumbing systems.

Pressure vessels other than the hyperbaric treatment chamber shall be protected with pressure relief devices in accordance with AS 1210.

The hyperbaric treatment chamber shall be protected against exceeding its design pressure by a combination of design factors, pressure relief systems, inflow limitation, inflow isolation valves, pressure monitoring and alarms and operational protocols.

For each compartment of the hyperbaric treatment chamber that can be pressurized independently, the pressure relief system shall include at least one safety valve that meets the requirements of AS 1271.

The capacity of each safety valve should meet or exceed the maximum possible inflow to the compartment involved. Where this is difficult to achieve there should be a combination of factors in place, in addition to the safety valve, to prevent overpressurization in all foreseeable circumstances.

Each safety valve shall be set to discharge at a pressure less than or equal to the design pressure of the compartment or pressurizable component it is designed to protect. Oxygen rich gases that are relieved should be ducted away from the facility to a well ventilated area.

A quarter turn isolation valve should be installed between chamber compartments and that compartment's pressure relief valve so that the relief valve can be overridden in the event of malfunction in a situation where depressurization of the chamber might be harmful to occupants. The quarter turn valve handle should be wired in the open position by a frangible (breakable) safety wire. Consideration may be given to having a three way valve to which two relief valves are fitted.

There shall be audible and visual warning to indicate if the pressure in any compartment of the chamber exceeds the working pressure. The audible alarm may be provided by the cracking of the safety valve. The minimum visual warning should be a maximum pressure marking on an analogue primary pressure measuring device.

Regular checks should be performed of the function of all safety valves and any other equipment or procedures designed to protect against overpressurization. The performance and results of such tests should be documented and retained.

2.2.7 Chamber pressure measuring device

Each chamber compartment should be equipped with an independent pressure measuring device which displays chamber pressure. Occupants of all chamber compartments should have the facility to monitor that compartment's pressure.

Pressure measuring devices should be accurate to within 1% over the range to be measured. Pressure measuring devices that measure chamber pressure shall be checked against a calibration device or deadweight tester at least every 3 months or at any time an error is suspected. Other pressure measuring devices should be checked against another pressure measuring device every 3 months and checked against a calibration device or dead weight tested at least every 12 months, or at any time an error is suspected. These tests and results should be recorded.

The system tubing and components shall be cleaned to a suitable standard for the purpose for which they are to be used before being installed.

Any line plumbed from the chamber hull to the pressure measuring device should have a shut off valve near or at the chamber hull. Lines to pressure measuring devices should not supply any other devices.

The inside ports of such lines should be protected with shields to prevent inadvertent blockage which could cause inaccurate pressure indications.

SECTION 3 MULTIPLE CHAMBER OPERATIONAL SYSTEMS

3.1 GENERAL

3.1.1 Systems

The hyperbaric chamber operational systems include the air pressurization system, breathing gas system, environmental conditioning system, communication system, patient monitoring system, lighting system, electrical systems and fire extinguishing system. In addition to these systems, sound attenuation and materials used in and around the chamber need to be addressed as part of the chamber operational parameters. For requirements for oxygen pressurization systems, see Clause 4.2.

Before a chamber is used for patient treatment, a failure mode analysis of all systems shall be conducted.

3.1.2 Contamination

Hyperbaric gas piping systems shall be cleaned adequately for the gas that is to be used in the system in accordance with AS 2896, to remove contamination prior to the initial introduction of respirable gas during commissioning. An ongoing contamination monitoring program should be put in place for the life of the hyperbaric system.

3.1.3 Control panel

Provision shall be made at the control panel for record keeping and summoning emergency assistance.

3.1.4 Pipe threads and tube sizes

Ideally all plumbing systems should be constructed of components selected from a single, consistent system of pipe sizes and thread types, e.g. metric tube with ISO or BSP thread or fractional tube with NPT thread.

In practice, it may be necessary to use other systems to minimize the risks of incompatible connections being made during construction, commissioning or subsequent repair and maintenance activities. Recommended systems for minimizing these risks include—

- (a) clear labelling of systems and components;
- (b) system drawings which identify component types and sizes; and
- (c) use of only one thread/pipe size system for each particular chamber plumbing subsystem, e.g. one type for breathing gas systems, one type for water supply systems.

3.2 AIR PRESSURIZATION SYSTEM

CAUTION: THE FIRE HAZARD FOR HIGH PRESSURE AIR SYSTEMS CAN
APPROACH THAT FOR OXYGEN-RICH SYSTEMS AS THE PRESSURE
INCREASES. CONSIDERATION SHOULD BE GIVEN TO APPLYING THE
PRECAUTIONS TAKEN FOR OXYGEN SYSTEMS TO HIGH PRESSURE AIR
SYSTEMS.

3.2.1 General

This system is used to increase the pressure of the chamber to the desired treatment pressure. Air is compressed and transported through the piping system to air storage flasks or accumulators. When the chamber is pressurized, air is transported from these flasks or accumulators through the piping system into the chamber. The piping, air compressor and storage capacities should provide adequate flow and volume of air to support treatment protocols and conduct emergency operations.

Provision shall be made for controlled release of pressure from inside the chamber in case of incapacitation of staff operating the chamber. No other chamber pressurization operation shall be carried out from inside the chamber.

The most common method of producing pressurized air is to compress ambient air to the desired working pressure. Compressed atmospheric air contains natural trace gases and impurities which vary with proximity to industrial areas, or other sources of transient pollution such as automotive exhaust or helicopter operations. When atmospheric air is compressed during periods of rain or extremely high humidity, the water content of the source air is raised considerably and in-line water separators or dehumidification systems may be required. Water in itself is not considered an impurity, but can affect operation of the air purification system, chamber control systems, and accelerate corrosion in the air storage vessels.

3.2.2 Air purity standards

Air purity standards which assume that air will only be breathed at atmospheric pressure are not sufficiently stringent for unmodified application to the hyperbaric environment. The toxicity of gaseous contaminants is generally proportional to the partial pressure of the gas involved. If air for hyperbaric chamber use is analysed at atmospheric pressure, the allowable concentration of contaminants will be proportionally lower than normally allowed for sea level air by a factor equivalent to the maximum operational pressure of the chamber in atmospheres absolute (ATA), i.e. for a chamber with a working pressure of 203 kPa (3 ATA), environmental air contaminant concentration limits should be set at one-third of those applicable for indoor air.

AS/NZS 2299.1 includes air purity criteria for divers which take the above factors into account and these criteria may be used for assessing the purity of compressed air for chambers.

NOTE: AS/NZS 2299.1 requires air purity to be checked at least every six months.

For medical breathing air used in the chamber (e.g. for ventilators) or to assess contaminants not listed in AS/NZS 2299.1, the conversion principles above may be applied to the air purity criteria in AS 2568 or NOHSC 1003.

3.2.3 Air compressor intake

The compressor intake shall be located where it will not be contaminated by carbon monoxide such as from automobiles, boilers, or diesel exhausts. The compressor intake shall be equipped with a filter that removes solids such as dirt, dust and airborne impurities. The size of the intake piping should be large enough to avoid compressor starvation.

3.2.4 Filtration and monitoring

Appropriate filtration and monitoring shall be used in all cases to deliver air of an acceptable quality as specified in Clause 3.2.2. Consideration shall be given to ongoing maintenance of the system.

NOTE: Special filters may be necessary to remove carbon monoxide.

3.2.5 Air storage system

All air flasks and accumulators shall be marked in accordance with AS 1345.

Air is stored in either high pressure or low pressure air storage flasks or accumulators. These storage flasks or accumulators are used as the receiver necessary to supply sufficient volume to the chamber.

Air flasks or accumulators are manufactured in a variety of sizes and configurations to meet the individual needs and space requirements of the facility. They should be constructed to meet the appropriate Australian Standard such as AS 1210 and may need to be registered with the relevant local authority.

Flasks and accumulators shall be cleaned before installation and regularly tested (see AS 3873 or AS 2030.1 as appropriate).

3.2.6 Air piping systems

3.2.6.1 Piping

All pressure pipes shall be marked in accordance with AS 1345.

The piping system shall—

- (a) be suitable for the temperatures, flows and design pressures throughout the likely operating range;
- (b) contain neither materials or joining/construction methods which could introduce contaminants;
- (c) be corrosion resistant;
- (d) cope with any expansion or contraction associated with temperature or pressure changes; and
- (e) contain appropriately situated non-return valves.

Galvanized, black iron, or steel pipes shall not be used because of corrosion considerations (see AS 2902).

3.2.6.2 Pressurization

Of major importance is the ability to control the pressurization of therapeutic hyperbaric chambers. The following requirements shall apply to the control of pressurization:

- (a) Pressurization shall be able to be started and stopped rapidly.
- (b) The rate of pressurization shall be able to be controlled to an accuracy of 10 kPa/min (0.1 bar/min).
- (c) The maximum rate of pressurization for the entry lock shall be high enough to allow rapid entry to the treatment chamber for patient care personnel.

The pressurization system should be equipped with noise attenuators to prevent uncomfortable noise levels (see AS/NZS 1269.2).

Exhaust gases from the chamber shall be piped to outside the building. If the exhaust gas is oxygen-enriched then the outlet shall be labelled as an oxygen hazard. The exhaust system should be equipped with an appropriate noise reduction device.

The depressurization system, relief valve, pressure measuring device, and sample line penetrators within the chamber should be equipped with a device over the exhaust port to prevent suction injury.

All system components and piping shall be cleaned using an appropriate cleaning procedure prior to installation (see AS 2896).

If a computer or remote pneumatic control system is used to operate the air pressurization system, it should be possible to isolate or inactivate any such system and operate the chamber via manual controls in the event of remote system failure or computer malfunction. Any manual isolation, override or alternative operation valves should be clearly marked and situated at, or be easily accessible from, the control panel.

3.3 BREATHING GAS SYSTEMS

3.3.1 Oxygen supply and exhaust system

3.3.1.1 Oxygen supply

Special hazards are associated with oxygen supply systems due to the ability of oxygen to vigorously support combustion. Very high concentrations of oxygen support violent combustion of many materials, especially organic materials and even metals. Oxygen supply systems should only be designed, installed, operated and maintained by competently trained persons who are familiar with the problems and safety considerations relevant to the aspect of the oxygen supply system with which they are involved.

The oxygen supply system provides breathing oxygen to patients and attendants as required. Oxygen is delivered to the patient inside the chamber through a variety of delivery systems. Oxygen is normally supplied from either a liquid (cryogenic) system or a high pressure gas source.

The gas from a liquid oxygen source is normally at least 99.5% pure oxygen. Liquid oxygen shall not be introduced directly into a hyperbaric chamber. It should be stored and supplied in accordance with AS 1894. Precautions should be taken to prevent impurities building up in liquid oxygen storage facilities as impurity levels can, over time, change both the flammability and breathability of the oxygen.

High pressure oxygen shall be reduced to a pressure of less than 1000 kPa (10 bar), as near as is practicable to the source. High pressure cylinders of oxygen should be of medical grade purity and labelled accordingly. Cylinders shall be stored and handled in accordance with AS 4332.

The oxygen supply may be provided from the main supply or from an independent source. In either case, consideration should be given to the pressure needed for oxygen equipment to function at the elevated pressure inside the chamber. The oxygen supply should be sized to provide a reasonable number of treatments without refilling or replacing the tanks. A standby source should be plumbed into the hyperbaric system as emergency backup to the main supply. To prevent the introduction of contaminants to the oxygen supply system, the oxygen source should be filtered.

Oxygen supply pressures should be displayed continuously at the control panel. The oxygen supply system should be equipped with a shut off valve for emergency isolation. This valve should be located close to the chamber pressure hull and the control panel.

3.3.1.2 Exhaust system

An oxygen dump system shall be used to remove the exhaled gases from the patient breathing device and exhaust them outside the building to a well ventilated area. Care should be taken to site the exhaust well away from air intakes.

The dump system should be designed to limit the amount of negative pressure between the patient and the ambient pressure outside the chamber.

3.3.1.3 Oxygen piping

All oxygen supply lines and equipment shall be in accordance with AS 2896.

Where the pressure in supply systems for hyperbaric facilities is higher than in normal medical gas systems, the pipes shall be labelled to prevent confusion with normal medical gas supplies.

Oxygen and oxygen-enriched supply systems should be designed so they can be dismantled for maintenance and cleaning.

Oxygen piping and manifold systems should be constructed and maintained in accordance with relevant Australian Standards under the supervision of a competently trained person who is thoroughly familiar with problems and safety considerations related to oxygen and oxygen systems.

Material and fabrication considerations for oxygen piping in multiplace treatment chambers are available from ASME PVHO-1 and in the guidelines of the Compressed Gas Association (CGA).

3.3.1.4 *Oxygen system cleanliness*

Piping, manifold systems, valves, fittings and components used in oxygen systems shall be cleaned to the appropriate level for service before installation and whenever contamination exceeds that level. Regular monitoring of contamination should be conducted and recorded.

3.3.2 Gas analysis system

3.3.2.1 *General*

All analysers shall be calibrated in accordance with the manufacturer's instructions. This Standard only includes oxygen and carbon dioxide monitoring, however, when other contaminants to the chamber atmosphere may exist, other gas analysis may be required.

3.3.2.2 *Oxygen levels*

Oxygen levels in the chamber shall be monitored continuously. Oxygen levels in any air environment hyperbaric chamber (nominally 21% oxygen) shall not exceed 23.5% by volume.

The tubing supplying the chamber gas to the analysis systems should be of small bore to shorten the analyser's response time to occurrences such as changing conditions in the chamber environment or the effects of patient breathing devices.

3.3.2.3 *Carbon dioxide levels*

There shall be continuous monitoring of the chamber environment for carbon dioxide levels.

Carbon dioxide levels shall be maintained at a partial pressure of carbon dioxide (PPCO₂) of less than 0.5 kPa (0.005 bar).

3.4 ENVIRONMENTAL CONDITIONING SYSTEM

The chamber shall incorporate temperature and humidity monitoring systems. The design of the chamber shall ensure a comfortable environment is maintained. This may require additional conditioning systems.

The treatment temperature after the chamber pressure has stabilized shall be not greater than 30°C.

The chance of static discharge is reduced if the humidity in the chamber is greater than 65%.

3.5 COMMUNICATION SYSTEM

3.5.1 *Voice*

A communications system shall be provided. The system shall be designed to provide an 'open' microphone inside the chamber so that those at the control panel can continuously monitor all conversations and noises from inside the chamber.

In addition to the main communications system, a secondary emergency system shall be provided.

There should be a provision for private communication between the inside attendant and the outside staff.

3.5.2 Visual

The chamber operator shall have visual access to the chamber interior at all times during chamber operation.

3.6 PATIENT MONITORING SYSTEM

All patient monitoring equipment shall comply with AS/NZS 3000, the appropriate part of the AS/NZS 3200 series and AS/NZS 3551. Clinical patient monitoring equipment, unless designed or modified for chamber use, should be located outside the chamber and the monitoring leads routed through an approved electrical penetrator.

3.7 LIGHTING SYSTEM

Lighting should conform with the requirements for cyanosis observation lighting and set out in AS/NZS 1680.2.5.

One common type of lighting system uses an external light source and an acrylic light pipe passing through the chamber hull. The acrylic rod is installed into the chamber using an internal o-ring design and is threaded into an existing coupling in the chamber hull. Because the light globe is located outside, the heat generated is dissipated outside the chamber. Provision should be made to allow alteration of light intensities.

Some light sources are designed to transmit light directly into the chamber through chamber viewports. This type of lighting is efficient, but sacrifices use of the viewport for observation. External light sources shall be designed to prevent hot particles or radiant heat damaging viewports.

Chamber lighting should be on an uninterruptable power source or an emergency power circuit. In all cases an emergency alternative method of lighting the chamber should be provided.

3.8 ELECTRICAL SYSTEMS

Electrical power requirements in the chamber should be minimized.

Electrical wiring and electrical equipment in hyperbaric chambers shall be in accordance with the requirements in AS/NZS 3000, AS/NZS 3200 and AS/NZS 3551.

All essential electrical equipment and circuits associated with the hyperbaric system shall have a minimum of two independent sources of electrical power such that chamber operations can be completed safely in the event of failure of one.

Portable electronic or electrical systems, e.g. entertainment units, shall be assessed by a competent person for their risk of ignition and ability to support combustion prior to being taken into the chamber.

3.9 FIRE SUPPRESSION SYSTEM

Every effort should be made to avoid all possible ignition sources in hyperbaric chamber design and in use.

All hyperbaric chambers shall be equipped with a suitable fire suppression system. The system may be either automatically or manually activated. NFPA 99 may be used for guidance.

A fire management protocol shall be prepared. The protocol should take into account that, upon activation of the fire suppression system, communications should remain operable, chamber ventilation should cease, and any fan motors should be shut off so as not to fan the flames.

Hand-held hoses should be provided in the chamber compartments in accordance with NFPA 99 or, if a portable fire extinguisher is used in the chamber, it should be of adequate size, contain water and be pressurized with air. Other extinguishers, such as carbon dioxide and halogenated compounds, shall not be used.

Self-contained breathing apparatus (SCBA) should be installed in the room in which the chamber is located to enable chamber staff to safely complete chamber operations in the event of fire or heavy smoke. The apparatus should be suitable for use in a smoke filled environment, and supply at least 30 minutes of air.

Full activation of the fire suppression system shall be conducted at least every six months.

NOTE: Operational experience has demonstrated that maintaining relative humidity greater than 50% is of significant value in reducing the risk of generating of, or ignition from, static electrical spark. This is of particular importance in oxygen-enriched environments.

3.10 SOUND ATTENUATION

Noise levels inside the chamber shall not interfere with normal conversation once the chamber is pressurized.

Noise levels outside the chamber shall be attenuated to ensure the chamber operator can communicate clearly.

3.11 CLOTHING AND TEXTILES

Where oxygen levels are up to 23.5% by volume in the chamber environment, textiles and clothing shall be clean, anti-static, low ignitability and low flammability. 100% cotton is acceptable.

There shall be systems in place that prevent inadvertent entry of other textiles, clothing or prohibited materials.

NOTE: Practices which involve the changing of clothing or use of clothing with no pockets may assist in achieving this level of control.

For oxygen-enriched environments containing greater than 23.5% oxygen, only clothing and textiles suitable for 100% oxygen environments shall be permitted.

3.12 PROHIBITED AND RESTRICTED MATERIALS

NOTE: Certain materials have proven hazardous in the construction and operation of hyperbaric chambers.

3.12.1 General

Each facility shall have procedures for identification of prohibited and restricted materials. Such procedures shall cover prohibitions and restrictions for the hyperbaric facility as well as for the chamber itself.

All materials taken into the chamber shall be approved through the facility's procedures.

3.12.2 Flammable gases, vapours or liquids

Flammable gases, vapours or liquids represent an extreme hazard and shall not be used or stored within the hyperbaric facility or near intakes.

3.12.3 Mercury

Mercury shall be prohibited within the chamber at any time. Mercury is commonly used in thermometers, manometers and in some electrical switching apparatus.

3.12.4 Chemicals, drugs, pharmaceuticals, medical materials and surgical dressings

Certain chemicals, drugs medical materials, wound dressings, pharmaceuticals and other substances used in patient care may present a risk of fire or toxic contamination of the chamber atmosphere. Such substances shall be excluded or used only in accordance with the facility's procedures (see Clause 3.12.1). Cleaning materials containing alcohol should not be used in the hyperbaric facility.

3.12.5 Alloys

Equipment made of magnesium, beryllium, cadmium or their alloys shall not be used.

3.12.6 Oil-based toiletries and cosmetics

These products should not be used by chamber occupants before hyperbaric exposure.

3.12.7 Paper products

The use of paper items such as cups, dishes, food containers, towels, reading materials, or tissues should be kept to a minimum.

S E C T I O N 4 M O N O P L A C E C H A M B E R S

4.1 AIR PRESSURIZED MONOPLACE CHAMBERS

Operational systems for air pressurized monoplace chambers shall comply with the relevant requirements in Section 3.

4.2 OXYGEN PRESSURIZED MONOPLACE CHAMBERS

Operational systems for oxygen pressurized monoplace chambers shall comply with the relevant requirements in Section 3. Monoplace chambers shall only be pressurized with oxygen if they are designed for this.

For chamber pressurization with either oxygen or gas exceeding 23.5% oxygen by volume, the pressurization system shall comply with the requirements in Clauses 3.2.6.2 and the pressurization gas supply system shall comply with the requirements for oxygen supply systems in Clause 3.3.1.1. The oxygen level in the chamber shall be monitored continuously.

4.3 FIRE SUPPRESSION SYSTEM

Monoplace hyperbaric chambers shall be equipped with a suitable fire suppression system in accordance with Clause 3.9.

SECTION 5 PREVENTIVE MAINTENANCE

5.1 SYSTEM MAINTENANCE

Each facility shall establish written procedures for a regular preventive maintenance program for the hyperbaric system and all ancillary equipment that is designed to meet its own particular system requirements. The chamber and its operational systems, the chamber room, and the equipment used in and around the chamber, shall be maintained at the highest operational standards. This should also include the cleanliness of all elements of the interior and exterior systems.

NOTE: An example of a maintenance program is provided in Appendix B.

The maintenance program and all repairs of the system shall be performed by competent personnel, recorded and a record maintained.

All work on oxygen systems should be conducted by a competent person in a suitable, clean environment. Cleaning in situation may not be as effective as disassembly followed by cleaning in a special environment such as a clean room.

5.2 CHAMBER CLEANING

Each facility shall establish written procedures for infection control and chamber cleaning including cleaning for oxygen systems. IEC 60877 or ASTM G93 should be consulted for cleaning methods for oxygen systems.

Cleaning agents shall be suitable for use in the hyperbaric environment.

NOTE: Particular attention should be paid to the selection of cleaning products for pressure-retaining plastics such as viewports and acrylic hulls.

5.3 LUBRICANTS

Only lubricants safe for an oxygen-rich environment shall be used in a hyperbaric chamber. Lubricants should only be applied by persons familiar with the principles of lubricant use in hyperbaric and oxygen systems.