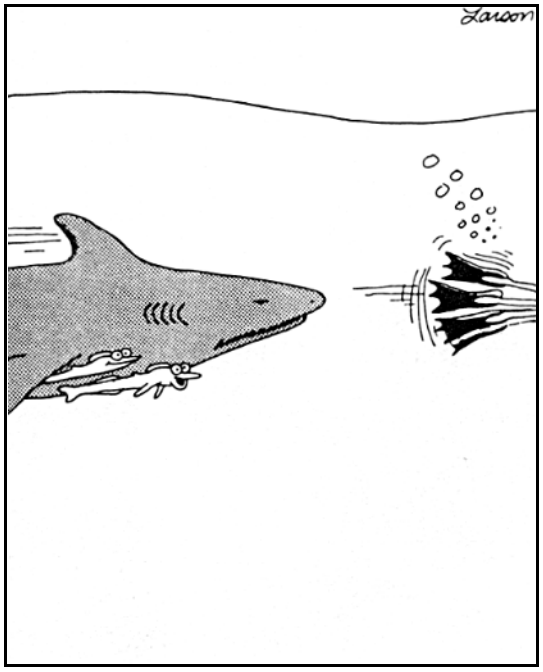
Section 11 — Supervise Chamber Operations



"Wheeeeeeee!"[1]

[1] Copyright © The Far Side, Last Impressions, 2002, Larson. (Stolen and used without permission!)

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1 CHAPTER 1 – COMPRESSION CHAMBERS

INTRODUCTION

ADAS COMPETENCY

Supervise on site chamber operations.

Describe compression chamber operation and use.

Describe potential risks and risk control measures for compression chamber use.

Supervise the use of a twin-lock (two-compartment) compression chamber in a remote location to conduct a therapeutic recompression.

GENERAL

Compression chambers were developed to permit human beings to be subjected to an increased pressure environment. Such chambers are vessels capable of accommodating one or more occupants and of being pressurised so that the environment inside the chamber simulates water depth while the pressure outside the chamber remains at normal pressure (1ATA). Hyperbaric chambers are used in research on the effects of pressure, in the treatment of pressure related conditions, and in the decompression of commercial divers. For example, hyperbaric chambers are used in several situations that occur in diving: surface decompression; omitted decompression; treatment of diving accidents such as gas embolism and decompression sickness; and pressure and oxygen tolerance tests. Terms used interchangeably to denote these chambers include recompression, compression, or hyperbaric chambers (these three terms generally describe chambers used primarily to treat diving casualties), and decompression chambers (a term used to indicate that their primary use is for the surface decompression of divers). Engineers refer to these as PVHO's (Pressure Vessels for Human Occupancy).

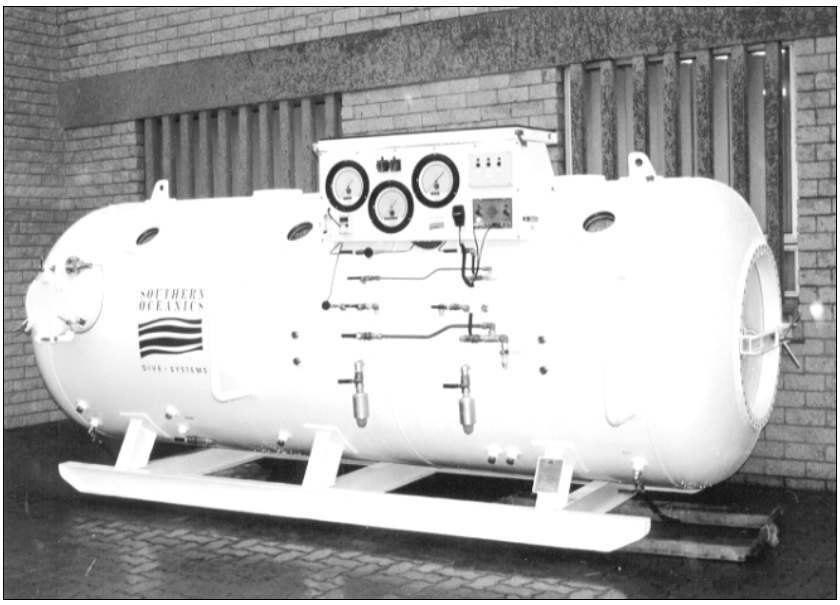

Figure 1: A K1500 Series Deck Decompression Chamber (DDC) (courtesy of The Underwater Centre Fremantle)

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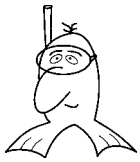
There is a separate qualification for a chamber operator (which is also incorporated into the ADAS Part 3 course). This module does not teach you how to be a chamber operator. It focuses on the responsibilities of a dive supervisor in relation to chamber operation without the direct presence of medical personnel. In this situation, you will need to:



- ✔ understand the compression chamber operation and use
- ✔ know potential risks and risk control measures for compression chamber use
- ✔ supervise the use of a twin-lock (two-compartment) compression chamber in a remote location to conduct a therapeutic recompression or surface decompression (SurD O_2)

CHAMBER OPERATIONS

GENERAL

In order to supervise compression chamber operations, you should be a fully qualified chamber operator. Ideally, you will not operate the chamber yourself and will have a dedicated chamber operator on the dive team.

Although you may not be directly responsible for the chamber operation, you need to:

- ✔ have an understanding of the uses, limitations, layout and functions of compression chambers
- ✔ know the correct preparation of a twin-lock (two-compartment) compression chamber
- ✔ know the correct operation of a twin-lock (two-compartment) compression chamber
- ✔ know how to use therapeutic tables

Specifically, you will need to:

- ✔ ensure that the chamber operator is competent and experienced
- ✔ check the gas supplies
- ✔ ensure availability of other personnel as required, such as a chamber attendant and a diver medical technician (DMT)
- ✔ know treatment options and emergency procedures
- ✔ check that the chamber medical kit is adequate and maintained
- ✔ communicate with medical assistance as necessary
- ✔ manage risk associated with chamber use

Twin lock or two-compartment air chambers are the type required by AS/NZS 2299.1:1999 (Clause 4.1 (a)). They generally have the following features:

- ✔ two compartments
- ✔ two sets of controls
- ✔ two sources of air
- ✔ voice communications

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- ✔ pressure relief valves
- ✔ equalisation valves
- ✔ lights, scrubbers, built in breathing systems (BIBS)

Gas supplies are:

- ✔ main gas, backup gas, oxygen, 50/50
- ✔ backup gas AODC 014
- ✔ two supplies

Chamber fittings include:

- ✔ hull valves or skin valves
- ✔ pressurisation silencer and non return
- ✔ exhausts diffuser to prevent suction
- ✔ depth gauge connections, bypasses
- ✔ BIBS and BIBS dump

Section 4 of AS/NZS 2299.1:1999 gives further detailed guidance on the requirements for compression (recompression) chambers.

In this section we look at the following:

- ✔ checklists
- ✔ pressurisation procedures
- ✔ chamber ventilation
- ✔ oxygen procedures
- ✔ therapeutic tables

CHECKLISTS FOR CHAMBER OPERATION

The procedures for chamber operation are rigorous and detailed. Checklists are an excellent way of ensuring that the procedures are followed correctly and that no steps are missed. They also provide a record of actions taken in the event of an accident or medical investigation.

AS/NZS 2299.1:1999 gives some guidance on chamber operation in Clause 4.3.

CHAMBER SPECIFICATIONS AND MAINTENANCE

AS/NZS 2299.1:1999, Clause 4.2 gives guidance on the design, construction, fitting and services of compression (recompression) chambers.

The chamber specifications should be clearly stated and the limitations of the chamber well understood. Checklists for maintenance should include periodic inspections and maintenance. It is possible for a chamber to deteriorate with wear if not properly maintained, which may affect its working pressure.

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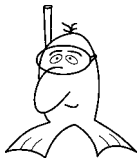
PRE-DIVE CHECKLIST

- ✔ all nominated persons in attendance
- ✔ both locks clean and no unnecessary materials in locks
- ✔ view ports checked and undamaged
- ✔ door seals clean – lubricated and undamaged
- ✔ internal lights working in both locks
- ✔ BIBS clean and fitted (2)
- ✔ all internal valves open
- ✔ check fire extinguisher
- ✔ communications working in both locks
- ✔ all external valves shut
- ✔ both depth gauges read zero
- ✔ check primary air supply
- ✔ check secondary air supply – compressor
- ✔ set primary air supply regulator to 8 bar (800kpa)
- ✔ check oxygen supply – 168 bar
- ✔ set oxygen supply regulator to 8 Bar (800Kpa)
- ✔ test BIBS
- ✔ calibrate the oxygen analyser
- ✔ mobile phone at the chamber
- ✔ patient briefed and waiver signed

Are the following available?



- ✔ protective clothing
- ✔ timers
- ✔ dive torch
- ✔ blankets
- ✔ waste bucket
- ✔ manuals
- ✔ ear muffs
- ✔ urinal
- ✔ tables
- ✔ chamber medical kits

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- ✔ mallet
- ✔ check lists
- ✔ log sheets
- ✔ slate and pencils

To compress:

- ✔ open pressure relief valve no. 18
- ✔ open external depth gauges no. 12 & 13
- ✔ open oxygen analyser valve no. 15
- ✔ open compressor valves no. 3 & 4
- ✔ set oxygen analyser flow meter to 2l per minute
- ✔ calibrate analyser to 20.8%

To decompress:

- ✔ close compression valves no. 3 & 4
- ✔ open exhaust valves no. 5 & 6

To use the BIBS:

- ✔ open oxygen supply valves no. 7 & 8
- ✔ open oxygen overboard dump valves no. 10 & 11
- ✔ monitor the oxygen analyser to ensure the chamber atmosphere does not rise above 24%

POST DIVE SHUT DOWN

- ✔ Patient and attendant O.K.?
- ✔ switch off communications – analyser – lights
- ✔ close all external valves
- ✔ label oxygen and air cylinders with remaining pressure
- ✔ close oxygen and air cylinders
- ✔ back off oxygen and air regulators
- ✔ bleed oxygen and air regulators
- ✔ remove used bibs and bedding and any unneeded materials
- ✔ re-charge oxygen and air banks as necessary
- ✔ wipe out chamber with metis
- ✔ clean BIBS
- ✔ after chamber has dried out and smells fresh, replace BIBS and bedding

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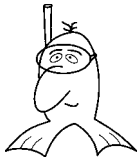
- ✔ close outer door and dog
- ✔ blow chamber down to 2 metres for storage
- ✔ re-isolate air bank

CHAMBER TRANSPORT LIST FOR MOBILE OPERATIONS



- ✔ trailer and tie downs
- ✔ chamber complete with two strong backs
- ✔ 2 x Harris regulators
- ✔ dedicated oxygen hose
- ✔ dedicated air hose
- ✔ 2 x oxygen BIBS
- ✔ 2 x E size air cylinders
- ✔ 1 x E or G oxygen
- ✔ heavy duty battery
- ✔ L.P. compressor
- ✔ compressor to panel air line
- ✔ log books
- ✔ timers
- ✔ operations manual
- ✔ decompression tables
- ✔ 2 x chamber medical kits
- ✔ blankets
- ✔ protective clothing
- ✔ waste bucket
- ✔ urinal
- ✔ mallet
- ✔ toilet paper
- ✔ torch
- ✔ slate and pencils
- ✔ mobile phone

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MEDICAL KIT CHECK LIST

AS/NZS 2299.1:1999 Clause 4.4 gives general guidance on medical equipment. Appendix H gives a listing of a typical medical fit for use with a compression chamber.

PRESSURISATION PROCEDURES

- ✔ The diver and the attendant should enter the chamber together.
- ✔ The diver should remain relaxed and sit in an uncramped position.
- ✔ The attendant closes and gently dogs or holds the inner door shut until pressurised.
- ✔ The attendant pressurises the chamber at a rate of 6 metres a minute, to the depth specified in the appropriate decompression or recompression table.
- ✔ As soon as a seal is obtained on the door, the attendant should release the dogs.

CHAMBER VENTILATION

The following rules assume that circulation of air in the chamber during ventilation is reasonably good.

When no oxygen analyser is available and if using air or overboard elimination BIBS, provide 60 litres per minute of actual volume for each person at rest and 120 litres per minute of Actual Volume for each person not at rest.

> **Note**: Actual Volume is irrespective of chamber volume.

If ventilation must be interrupted for any reason, the time should not exceed 5 minutes in any 30 minute period. When ventilation is resumed, twice the volume of ventilation should be used for the time of interruption and then the basic ventilation rates should be used again.

If intermittent ventilation is chosen, ventilate one minute in every five minutes using five times the normal minute volume – i.e. for patients at rest 60 L x 5 = 300 L in one minute.

When monitoring oxygen levels with an oxygen analyser, intermittent ventilation may be used so that the oxygen concentration in the chamber is maintained between 22 – 23%, with an absolute maximum concentration of 24%.

These rules are not intended to limit ventilation – if air is plentiful, more ventilation then specified will raise the level of personnel comfort as well as further lowering carbon dioxide and oxygen levels.

Continuous ventilation is more efficient and therefore desirable, but may expose personnel in the chamber to excessive noise levels. Ear protectors must be modified with a small hole to prevent ear squeeze, and should be worn to prevent ear damage.

Ventilation of the chamber will ensure that carbon dioxide produced metabolically does not cause the chamber carbon dioxide level to exceed 1.5% at 1 Bar. Sample detector tube analysers, with carbon dioxide tubes can be used inside the chamber to verify the level of carbon dioxide. The STEL (Short Term Exposure Limit) for human exposure is a PCO_2 of 0.03 bar, (3% or 30,000 PPM at 1 Bar Absolute), NOHSC 1003, 1991.

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OXYGEN PROCEDURES

Use oxygen whenever permitted to do so by the tables unless the user is known to be oxygen intolerant.

Any diver under treatment with oxygen should be accompanied by a second person.

Adjust the breathing mask so that it seals tightly around the face.

Make sure that the attendant knows the various symptoms of oxygen poisoning and how to react to each symptom. Remember the symptoms by CON-V-E-N-T-I-D

- ✔ **Convulsion**
- ✔ **Vision** – any abnormality, such as "tunnel vision" (a contraction of the normal field of vision, as if looking through a tube).
- ✔ **Ears** – any abnormal sounds, especially ringing or roaring.
- ✔ **Nausea** – this may be intermittent.
- ✔ **Twitching** – Usually appears first in the lips or other facial muscle. This is the most frequent and clearest warning of oxygen poisoning.
- ✔ **Irritability** – any change in behaviour including anxiety, confusion or unusual fatigue.
- ✔ **Dizziness** – additional symptoms may include difficulty in taking a full breath, an apparent increase in breathing resistance, noticeable clumsiness or lack of co-ordination.

Convulsing divers should be protected from physical harm. If possible, the diver should be kept with head back and chin up until consciousness is regained. Forcing the mouth open to insert a bit block is not necessary. At the first sign of Central Nervous System (CNS) oxygen toxicity, the diver should be taken off oxygen and be allowed to breathe chamber air. Fifteen minutes after all symptoms have subsided, oxygen breathing may be restarted. If CNS oxygen toxicity occurs again, discontinue oxygen breathing and seek specialist advice before proceeding further.

> **Remember**: During an oxygen convulsion, do not alter chamber pressure until the seizure has finished as the patient will normally hold his breath and this could cause lung rupture.

Ventilate the chamber by monitoring oxygen levels with the oxygen analyser or according to the number of persons breathing oxygen.

Remain alert to the increased fire hazard due to oxygen enriched environments and take all precautions to prevent fire.

Oxygen may be applied during routine decompression to a diver alone in the chamber only if:

The chamber has an entrance lock.

The diver is being observed constantly.

The oxygen mask is held to the face by hand. A provision is made to externally switch the breathing supply to air if necessary. Due to the possibility of contamination of the oxygen system, this should only be done in an emergency.

A person other than the chamber operator is immediately available to enter the chamber to assist the diver.

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USING THE OXYGEN ANALYSER

Calibration procedure

Plug the 3.5 mm jack into the bottom of the oxygen sensor; plug the other end of the cable into the "Sensor" input on the analyser.

Expose the oxygen sensor to the calibration gas. Allow the gas to flow past the oxygen sensor for at least 30 seconds. Rotate the calibration knob to desired percentage of oxygen when using air calibrate to 20.8%.

Expose the oxygen sensor to the gas being measured. Allow the gas to flow past the oxygen sensor for at least 30 seconds. Observe the display reading for the percentage of oxygen. Use a flow rate of approximately 2 litres per minute.

In order to get the most accurate measurement, avoid the following:

✔ Do not increase the partial pressure of the oxygen sensor. This will result in an inaccurate measurement.

✔ Keep the oxygen sensor and gas being analysed at ambient temperature. Heat can affect the oxygen sensor's accuracy. For the best results hold the sensor by the fitting.

Oxygen Sensor Pre-Calibration

Because of the difference in oxygen sensors and the Spectrum's ability to work with various oxygen sensors, the analyser may require a one-time adjustment. To check if you should perform the initial adjustment, turn the calibration knob fully counter-clockwise. The analyser should read 16 to 18 percent in air. If not, locate the pre-calibration hole on the front of the analyser. Using a small screwdriver, turn the adjustment until the analyser reads between 16 to 18 percent.

This calibration should only be done on new sensors. Do not repeat this procedure unless a new sensor is used. This may cause the analyser to give false readings.

General Specifications

Power	**:**	Single standard 9V battery.
Oxygen Fuel Cell	**:**	Teladyne R17MED or MSA 406931
Oxygen Sensor range	**:**	0 – 100%
Response Time less than 30 sec	**:**	For 90% of final value.
Operating Temperature Range	**:**	0 degrees to 50 degrees C.
Accuracy within +/- 1% of full scale at constant temperature and pressure	**:**	

Temperature compensation error is +/- 5% of reading over the operating temperature range. Worst case tracking error (within the first hour after a maximum temperature step) is +/- 10% of reading (gas samples must be brought to ambient pressure). Percent readout is only within +/- 1 at a constant pressure (e.g. a 10% increase in pressure will result in 10% increase in reading).

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THERAPEUTIC TREATMENT

INTRODUCTION

This is the name given to the treatment of decompression illness as opposed to preventing it. As in most things, prevention is better than cure. Special tables are provided for therapeutic treatment. The shortest is two hours 15 minutes; the longest 42 hours 55 minutes, and missing a 5-minute stop or ascending too fast can certainly make this treatment necessary.

It can be imagined that to spend nearly 43 hours in a chamber is, at the very least, time consuming. A large amount of back up is required in the form of equipment, operators, attendants and doctors, and in an ordinary chamber physical comfort cannot be expected. One-person chambers, although better than nothing, are not suitable for anything but transporting a patient from site to a large chamber, because it is not possible for an attendant and/or doctor to be in beside the diver. For this reason, single lock chambers are not allowed as work chambers under AS/NZS2299.

THERAPEUTIC TABLES (TREATMENT TABLES)

Tables are known by several different names – for example, Royal Navy 62 (RN 62), United States Navy 6 (USN 6) and Table G1 (AS/NZS 2299.1:1999) are all the same table. Although Table G1 is the name used in the Australian/New Zealand Standard, the common terminology used is the Royal Navy terminology.

The therapeutic table in common use is RN 62/USN 6/Table G1 provided in Appendix G of AS/NZS 2299.1:1999. This appendix in the Standard gives further guidance for recompression therapy and, although an informative appendix, should be adhered to as closely as possible.

These tables are used in HBO Therapy. Duration and depth are calculated bearing in mind CNS and pulmonary oxygen toxicity and the inadvisability of giving the inside attendant DCI. All Hyperbaric Medicine Units have their own, although some are common to all, e.g. Table RN 62/USN 6. Generally, the attendant breathes oxygen during all ascents.

TREATMENT TABLE 5 (RN 61, TABLE F4)

Treatment Table 5 (RN 61/Table F4, AS/NZS 2299.1:1999, p 124) may be used for the following:

- ✔ asymptomatic omitted decompression of rapid ascent from deeper than 6m (20fsw) if the missed decompression is less than 30 minutes
- ✔ current practice in Australia and NZ is typically not to use Treatment Table 5 for any initial DCI patient

PROCEDURES

- ✔ The patient should breathe oxygen during descent if possible.
- ✔ Descent should take between 1 – 2 minutes. The descent time is not included in bottom time.
- ✔ Record lapse time from arrival at 18m on oxygen.
- ✔ Ascend at a continuous bleed rate of.3m/min (1 foot/min). Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.

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- ✔ Halt the chamber if ascent rate cannot be maintained accurately while flushing.
- ✔ If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption.
- ✔ If symptoms arise during recompression on this table, halt the ascent and seek the advice of the AMP. The diver should be returned to 18m pending such advice. The treatment should then proceed as a Table 6.
- ✔ The inside attendant breathes oxygen during the ascent from 9 metres to the surface unless it is a repetitive dive in which case the attendant should breathe oxygen for the final 50 mins.

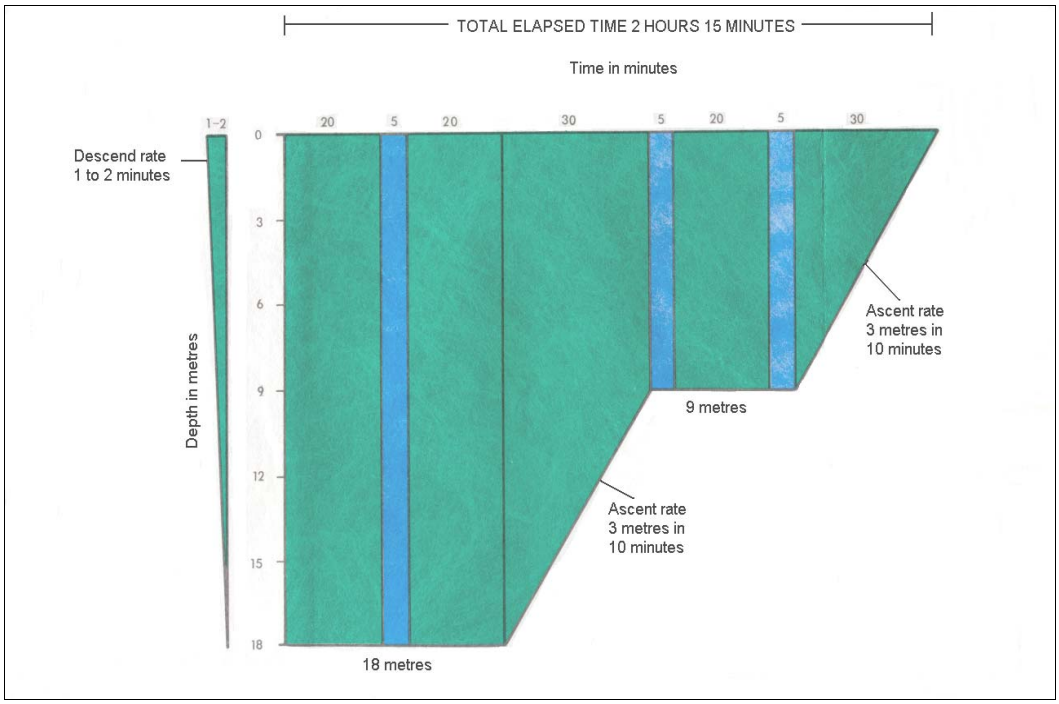

Figure 2: Treatment Table 5 (RN61)

TREATMENT TABLE 6 (RN 62, TABLE G1)

Use of Treatment Table 6 is suggested for:

- ✔ all initial treatments of DCI
- ✔ asymptomatic divers with omitted decompression greater than 30 minutes

This includes treating Arterial Gas Embolism. Arterial gas embolism is treated by initial compression to 18m (60fsw). If symptoms are improved within the first oxygen breathing period, then treatment is continued using Treatment Table 6.

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PROCEDURES

- ✔ The patient should breathe oxygen during descent if possible.
- ✔ Descent should take between 1 – 2 minutes. The descent time is not included in the bottom time.
- ✔ Record lapse time from arrival at 18m on oxygen.
- ✔ Ascend at a continuous bleed rate of.3m/min (1 foot/min). Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
- ✔ Halt the chamber if ascent rate cannot be maintained accurately while flushing.
- ✔ If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption.
- ✔ If symptoms reoccur or new symptoms appear during recompression, halt the ascent and seek the advice of the AMP. The diver should be returned to 18m pending such advice.
- ✔ Table 6 may be extended using one or two 25-minute periods at 18m or an additional 75 mins at 9m or both if relief of symptoms is not complete.
- ✔ The inside attendant breathes oxygen during the last 30 minutes at 9 metres and during the ascent to the surface.
- ✔ If the table is extended more than once the attendant should breathe OXYGEN for the final 90 mins of the treatment. If this is a repetitive exposure for the inside attendant increase his time breathing oxygen by an additional 60 minutes.

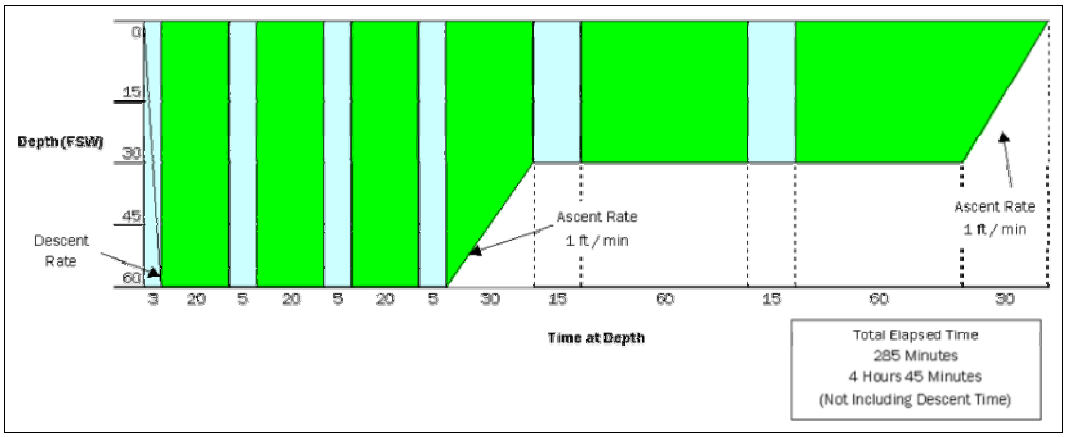

Figure 3: Treatment Table 6 (RN62)

GAS SUPPLIES

You will need at least 8000 litres of oxygen for one patient on table RN 62. This is 1 "G" cylinder. If two patients, you will need 2 "G" cylinders. If using air, you will need seven times as much – i.e. 7 "G" cylinders or a low pressure compressor and an air bank.

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CHAMBER OPERATIONS SUMMARY SHEETS

ASCENT RATES

Air tables Altitude above 1524 m	18m +/- 3m per minute 15m per minute
SUR-D Tables	18m +/- 3m per minute
Table 61 and 62	0.3m per minute (1 ft/min) (3m in 10 mins)
14:90:10	1.4m/min (14m in 10 mins)
Chamber Abort	3m/min
Rapid Ascent	As fast as possible

CHAMBER OPERATIONS

PERSONNEL LIMITATIONS FOLLOWING TREATMENT

- ✔ patient and attendant should remain in the vicinity of the chamber for 4 hours
- ✔ both should have access to an operational chamber for a further 20 hours

TRANSPORTING A DCI PATIENT

- ✔ the patient must be kept flat
- ✔ the patient must remain on 100% oxygen
- ✔ the patient must be accompanied
- ✔ the patient must be transported at a pressure equal to 1 ATA either by a fully pressurised aircraft, low flying helicopter or tup chamber
- ✔ treat for shock
- ✔ treat gently

FLYING AFTER DCI

Do not expose to an altitude greater than 300 metres until cleared by a diving medical specialist

OXYGEN CONVULSION IN A CHAMBER

- ✔ hold chamber pressure steady as convulsing patients often hold their breath
- ✔ remove BIBS or change oxygen BIBS to air
- ✔ protect the patient from injury
- ✔ when convulsion passes wait 15 minutes then replace oxygen BIBS
- ✔ if convulsions re-occur treat as above and then change to an air table

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OMITTED DECOMPRESSION

These omitted decompression procedures are only for divers who are asymptomatic. Divers with symptoms are treated for DCS.

The choice of treatment depends upon:

- ✔ A - chamber availability (within 7 minutes)
- ✔ B - 9 metres and deeper stops not completed
- ✔ C - 9 metre and deeper stops completed

A AND B - CHAMBER AVAILABLE – 9 METRE AND DEEPER STOPS NOT COMPLETED

- ✔ treat with RN Table 61 (USN Table 5) if the omitted decompression is less than 30 minutes
- ✔ treat with RN Table 62 (USN Table 6) if the omitted decompression is more than 30 minutes

A AND C - CHAMBER AVAILABLE – 9 METRE AND DEEPER STOPS COMPLETED

- ✔ return to 12 metres in chamber and complete SUR-D schedule

A - CHAMBER NOT AVAILABLE WITHIN 7 MINUTES

- ✔ the preferred action is to get the diver to a chamber while breathing 100% oxygen
- ✔ return the diver to the next deepest in water stop and repeat this stop, and then complete the schedule
- ✔ if no deeper stop spend the time of the first stop at the next deepest and continue the schedule

VIOLATION OF THE 7 MINUTE SUR-D INTERVAL

Interval more than 7 minutes less than 30 minutes:

- ✔ treat with RN Table 61 (USN Table 5)

Interval exceeds 30 minutes:

- ✔ treat with RN Table 62 (USN Table 6)

SUMMARY OF TREATMENT OPTIONS

Any symptoms - always RN Table 62

Omitted Deco – chamber available – no symptoms

- ✔ 9m and deeper stops NOT completed:
  - ☞ time missed < 30 mins Table 61 (5)
  - ☞ time missed > 30 mins Table 62 (6)
- ✔ 9m and deeper stops completed – SUR-D

SUR-D – chamber available – no symptoms

- ✔ surface interval > 7 mins < 30 mins Table 61 (5)

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- ✔ surface interval > 30 mins Table 62 (6)
- ✔ deco stress (symptoms) in SI
- ✔ if resolved by 12m – continue SUR-D
- ✔ if not resolved – Table 62

Table 62

- ✔ symptoms not resolved
- ✔ extend two 25 min periods @ 18m and/or
- ✔ extend one 75 min period @ 9m

Table 61

- ✔ symptoms – Table 62

Loss of OXYGEN

- ✔ switch to air table – commence @ 12m stop
- ✔ previous oxygen time good time

CHAMBER EMERGENCIES

GENERAL

There are a number of potential risks and risk control measures that need to be applied. You need to:

- ✔ understand the fire risk and apply risk control measures
- ✔ understand other risks and risk control measures applicable to twin-lock (two-compartment) compression chambers
- ✔ ensure appropriate risk control measures are communicated to and followed by all members of the dive team in relation to compression chamber use

AS/NZS 2299.1:1999 has a list of situations for which emergency protocols are recommended (Clause 4.3.5, p 29). Some of these are covered in the following sections.

FIRE – GENERAL PRECAUTIONS

Between the years 1945 and 1981 there were twenty chamber fires reported world wide. Some have been fatal, the occupants dying from asphyxia, noxious gas inhalation or extremely high temperatures. In all cases, the extinguishment systems were primitive or did not exist. Increased flammability of oxygen enriched environments, the problems of extinguishment and escape and the rapid rise in chamber pressure are all special considerations of the hyperbaric environment.

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FIRE SAFETY

The occurrence of fire requires the presence of:

- ✔ combustible or flammable materials (fuel)
- ✔ an atmosphere containing oxygen (oxygen)
- ✔ a heat or energy source (ignition)

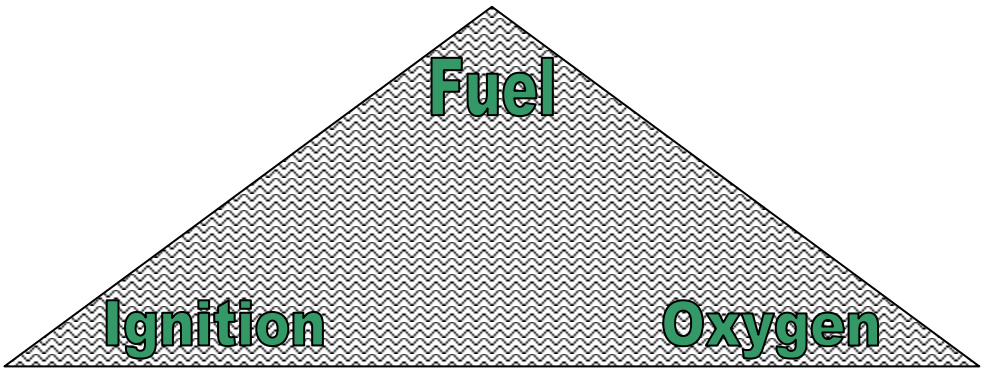

Figure 4: Fire prevention triangle for hyperbaric chambers.

The figure above demonstrates the classic fire triangle. The following outlines the preventative measures associated with the three elements.

OXYGEN

Combustion rates increase rapidly with increased oxygen concentrations. The oxygen level is constantly monitored and maintained below 23% to 25% by continuous ventilation with air for the duration of all compression cycles.

COMBUSTIBLES

Combustible materials are restricted to a minimum essential for patient care. The following are not permitted:

- ✔ cigarettes or tobacco
- ✔ matches or lighters
- ✔ newspapers
- ✔ oil based cosmetics
- ✔ non approved clothing and footwear
- ✔ non approved bedding, mattresses
- ✔ combustible liquids and gases i.e. cyclopropane, ether and alcohol
- ✔ chemical hand warmers

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IGNITION SOURCES

Potential ignition sources have been kept to an absolute minimum and where identified, precautions taken. These are:

- ✔ **Lighting** – sealed from chamber atmosphere to isolate sparks. Heat build up is vented to the atmosphere. External Canti lights are fitted and no wiring enters the chamber.
- ✔ **Communications** – only low voltage inside the chamber (12v) and earth leakage protection is fitted.
- ✔ **Clothing and bedding** should be washed in 5% boracic acid to reduce static electricity or fire retardant overalls worn.
- ✔ **Matches and lighters** are not permitted.
- ✔ **Oil contaminated materials** are not permitted.
- ✔ **Extra high voltage lighting or power** (>24v) is not permitted.

The fire safety rules should not be so rigid as to deny access to essential medical supplies during a crisis. After adequate planning and preparation almost any essential material or equipment can be utilised inside the chamber environment without compromising fire safety.

■ ACTION TO BE TAKEN IN THE EVENT OF A FIRE

FIRE INSIDE THE CHAMBER

The **Inside Attendant** is to:

- ✔ Notify the chamber operator (yell “Fire, fire”)
- ✔ Attack the fire with the internal fire extinguisher
- ✔ All occupants are to don BIBS masks (these will be supplied with air)

The **Outside Attendant** is to:

- ✔ notify the others in the building of fire
- ✔ dial 000 in Australia and 111 in New Zealand and request Ambulance and Fire Brigade
- ✔ standby to evacuate chamber occupants
- ✔ keep onlookers away from the chamber complex
- ✔ activate the external fire hose reel if necessary

The **Chamber Operator** is to:

- ✔ change the oxygen supply to air for the BIBS
- ✔ isolate all oxygen
- ✔ initiate rapid decompression procedures
- ✔ note time and record events
- ✔ keep onlookers away from chamber vicinity
- ✔ standby to evacuate chamber occupants

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- ✔ prepare to recompress occupants as appropriate
- ✔ isolate all chamber power if the cause of the fire is electrical

When the fire is out:

- ✔ initiate abort dive procedures
- ✔ place all occupants on oxygen
- ✔ on surfacing, decide whether occupants can be safely recompressed

> **Note:** The attendant should always be recompressed (see Omitted Decompression)

Transfer all occupants requiring recompression into another compartment as soon as possible. Outside attendant is now the inside attendant. The previous attendant is now treated as a patient.

Recompress in accordance with omitted decompression.

FIRE OUTSIDE THE CHAMBER

If the fire is in the **immediate vicinity** of the chamber, the Chamber Operator is to assess the situation and:

- ✔ inform the chamber occupants that the Rapid Decompression Procedure is about to be initiated
- ✔ change the supply for the BIBS to air
- ✔ initiate rapid decompression procedure
- ✔ note the time and record events
- ✔ standby to evacuate chamber occupants
- ✔ prepare to recompress the occupants as appropriate

If the fire is in the **close proximity** of the chamber complex, the Chamber Operator is to:

- ✔ inform the Inside Attendant that the “Abort Dive Procedure” is to be initiated
- ✔ ensure all occupants are breathing oxygen
- ✔ decompress no faster than 3 metres/minute
- ✔ standby to evacuate chamber occupants
- ✔ prepare to recompress the occupants as deemed appropriate by technical staff in attendance
- ✔ The **Outside Attendant** is to:
  - ☞ dial the emergency number (000 in Australia and 111 in New Zealand) and request Fire Brigade and Ambulance
  - ☞ attack the fire with the hose reel
  - ☞ standby to evacuate the chamber occupants

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Rapid Decompression Procedure

This procedure will be used in the following situations:

- ✔ uncontrolled fire outside (immediate vicinity) the chamber
- ✔ uncontrolled fire inside the chamber
- ✔ fire extinguished but occupants suffering from toxic gas inhalation and not on BIBS

The decision to initiate the rapid decompression procedure will be made by the chamber operator in an attempt to save the lives of the occupants. The following action will be taken:

- ✔ all exhaust valves on the chamber will be opened fully to achieve the maximum decompression rate, this includes the Bilge valves
- ✔ all occupants are to breathe oxygen after surfacing
- ✔ chamber occupants will be recompressed in accordance with Omitted Decompression Procedures

Abort Dive Procedure

This procedure will be used in the following situations:

- ✔ fire outside (close proximity) to the chamber complex
- ✔ fire inside the chamber, extinguished
- ✔ patient or attendant unwell

The decision to initiate the Abort Dive Procedure will be made by the ***Chamber Operator*** in conjunction with the ***Outside Attendant*** and ***Physician***. On the ascent:

- ✔ all chamber occupants are to breathe oxygen
- ✔ decompression is initiated no faster than 3 metres/minute
- ✔ all occupants are to continue oxygen breathing after surfacing

On completion of the ascent a decision will be made regarding recompression requirements for patients and staff.

If recompression is required, the outside attendant becomes the inside attendant. The previous attendant is then treated as a patient. Recompress in accordance with omitted decompression.

■ OTHER RISKS AND RISK CONTROL PROCEDURES

VIEW PORT LEAKS

The view ports are constructed of an acrylic lens sealed by o-rings and held in position by a keep ring and 12 bolts.

If a leak is detected the following action is to be taken:

Inside attendant:

- ✔ inform the technician immediately
- ✔ do not attempt to stop the leak

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✔ remove all small lightweight items from the vicinity

A decision to abort or continue will be made by the technician depending on the circumstances. He will commence the following:

Assess the situation:

✔ inform the inside attendant that the dive is to be aborted

✔ ensure all occupants are breathing oxygen

✔ on surfacing, prepare to recompress the occupants as appropriate

VIEW PORT RUPTURE

THIS IS A LIFE THREATENING SITUATION as the compartment will immediately commence a rapid decompression to sea level. During this "explosive decompression" the following will occur:

✔ visibility will be almost completely obscured

✔ the noise level will be high

✔ all lightweight objects will be drawn to the point of rupture, becoming air borne hazards

In the event of a view port rupture the following action is to be taken by the **Inside Attendant**:

✔ try to remain calm

✔ keep yourself and the patient as far away from the point of rupture as possible and close to the floor

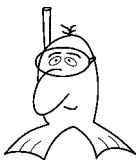
✔ exhale at whistling rate

The **Chamber Operator** will undertake the following actions:

✔ close outlet and airflow valves of the compartment concerned

✔ open inlet valve fully to try and control the rate of decompression

POWER FAILURE



Loss of main power will not affect lighting inside the chamber compartments or power for the communications system as these are supplied from a 12 volt battery pack. A 3.5 KVA Auxiliary generator is available for general lighting back up which can also supply 12 volt power for the chamber lights and communications. When located at the base, the main compressor is electrically driven and supplies a six cylinder storage bank which is piped to the main chamber pressure regulator. This bank has a capacity of 74,880 litres of filtered breathing air. In addition three portable cylinders are piped to the secondary regulator and a petrol driven low pressure compressor, capable of direct connection is available. When using the chamber in a remote location the primary air supply is the portable petrol driven compressor with the three portable gas cylinders as the secondary supply. In both instances a chamber programme must be capable of being completed without the availability of mains power.

DOOR SEAL FAILURE

O-ring seals are fitted to all doors and medical locks. If a leak is detected the following action is taken by the inside attendant:

✔ inform the chamber operator immediately

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- ✔ do not attempt to stop the leak
- ✔ remove all small lightweight items from the immediate vicinity

A decision to continue or to abort will be made by the chamber operator depending on the circumstances.

OMITTED DECOMPRESSION PROCEDURE

Certain emergencies may interrupt or prevent decompression. Machine failure, fire, deterioration of the patient's condition and similar situations constitute such emergencies. Even if the inside attendant shows no signs or symptoms, omitted decompression must be made up, to avert later difficulties.

The following procedure is to be followed:

- ✔ inside attendant must be recompressed as soon as possible, a surface interval of less than 10 minutes is recommended
- ✔ compress to 18 msw with the attendant on oxygen from the surface
- ✔ **note**: the inside attendant is now the patient, so need new inside attendant
- ✔ if no signs and symptoms appear, decompress on Table RN 61
- ✔ if signs and symptoms appear and are not relieved within 45 minutes, decompress on Table RN 62

■ COMPLICATIONS AND SIDE EFFECTS OF HYPERBARIC OXYGEN THERAPY (HBO)

BAROTRAUMA

This most commonly affects the ear on descent in patients who are unable to effectively equalise the pressures in their middle ear cavities with ambient pressure.

Other sites may suffer barotrauma including the respiratory sinuses, lungs (leading to pneumothorax and pneumomediastinum) and carous teeth. Such teeth have exploded in the mouths of the sufferer on ascent!

Gastrointestinal pain and discomfort is another type of barotrauma. These symptoms are generally related to air swallowing at depth and subsequent distension of the gastrointestinal tract on surfacing. They are generally transient and benign but a few extreme cases leading to gastric rupture have been recorded.

OXYGEN TOXICITY

This takes two forms, one CNS (acute) and one Pulmonary (cumulative). CNS toxicity is very rare using current treatment tables but has been reported with pressures as low as 2 ATA. The typical seizure closely resembles grand mal epileptic seizures and may occur without warning or be preceded by a wide variety of prodromata, notably involuntary twitching.

Lung toxicity can occur with exposure to 100% oxygen at less than 1 ATA for prolonged periods, or after about six continuous hours at pressures of about 2 ATA. There is a cumulative effect to some extent and HBO undoubtedly plays some part in the development of lung impairment in severely ill patients who may require significant oxygen support in the intensive care unit between treatments. The initial effects are a feeling of irritation or dull pain retrosternally, perhaps with a dry cough. These symptoms progressively worsen on continuing exposure. This is paralleled by a progressive reduction in vital capacity and diffusion capacity for carbon monoxide.

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These changes all tend to reverse quite quickly on removal from high dose oxygen between treatments. (See section 2.4 for oxygen procedures)

CLAUSTROPHOBIA

This is seldom a problem but may require considerable counselling by the attendant.

REFRACTIVE CHANGES

Myopic patients may experience reversible worsening of visual acuity over a prolonged course of treatment. Although this is reversible, it may take up to two weeks to get back to normal vision.

SUPERVISION IN A REMOTE LOCATION

CHAMBER TEAM

AS/NZS 2299.1:1999 specifies that the chamber is to be supervised by a competent person and at least one assistant.

Generally, the minimum team for conducting any recompression operation consists of the Dive supervisor or chamber operator, and an inside attendant. An outside attendant is desirable and if possible, the Medical Officer (the MO may well be acting as inside attendant).

DIVE SUPERVISOR

The Dive supervisor is in complete charge of the operation and must be familiar with all phases of chamber operation and treatment procedures. The supervisor must ensure that communications, logging and all phases of the treatment are carried out according to prescribed procedures. The diving supervisor may also be the chamber operator if properly qualified.

RECOMPRESSION CHAMBER ATTENDANT

The chamber attendant should be a qualified diver or Diver Medical Technician (DMT) or hyperbaric trained nurse. He or she must be familiar with the diagnosis of diving related injuries and illnesses. The chamber attendant's role is to assist the patient inside the chamber and to care for the patient during treatment.

Responsibilities include:

- ✔ have a valid AS/NZS 2299.1 medical certificate
- ✔ have a valid first aid qualification which includes resuscitation
- ✔ have a valid oxygen administrators certificate
- ✔ operation of all internal valves including the medical lock, under the direction of the chamber operator
- ✔ patient observation and airway management and to communicate these observations to the recompression chamber operator
- ✔ ensure the seals on the Oxygen BIBS
- ✔ to protect the patient in the event of an oxygen convulsion
- ✔ to assist the patient with reassurance and instruction on equalising ears

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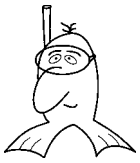
- ✔ to communicate with the chamber operator
- ✔ resuscitate the patient if necessary
- ✔ to check the medical equipment and supplies in the chamber first aid kit prior to compression
- ✔ maintain a clean chamber and transfer body wastes as required
- ✔ ensure hearing protection is worn as necessary during compression and ventilation

During early phases of the treatment, the inside attendant must constantly watch for signs of relief of the patient's symptoms and the use of drugs that will mask changes in the patient's condition must be avoided. Observing these signs is the principal method of diagnosing the patient's sickness, and the depth and time of relief of symptoms is vital in determining the treatment table to be used. The final recommendation as to which treatment regime will be used will be decided by the MO or Dive Supervisor in conjunction with specialist advice. Normal procedure will be to use US Navy table 62 (RN table 6) or US Navy table 6A (RN table 5).

THE CHAMBER OPERATOR

The recompression chamber operator will be a fully trained and competent person, preferably a diver, with adequate knowledge and experience in the operation of a recompression chamber. He or she must hold a current first aid certificate and a DAN Oxygen administrator qualification or equivalent.

Duties include:



- ✔ chamber cleanliness
- ✔ completing the pre-dive and post-dive chamber check lists
- ✔ maintaining and controlling the gas supplies to the chamber (oxygen and air)
- ✔ communicating with the inside personnel
- ✔ operate the recompression chamber in accordance with the compression and decompression standard and decompression tables
- ✔ complete all time keeping, logging all compression and decompression details accurately and in full
- ✔ ensure no dangerous materials are taken into the recompression chamber
- ✔ ensure correct clothing is worn in the recompression chamber
- ✔ ensure the air quality in the chamber by monitoring the analysis and flushing the chamber in accordance with operational procedures
- ✔ compressing and decompressing any additional personnel movements into and out of the chamber before patient treatment is complete
- ✔ operating the medical lock

The chamber operator must give full attention to the task and must not be delegated any other task while a chamber run is in progress. The chamber operator must be located at the chamber console and attend the communication system during the entire duration of the chamber run, from the start of compression until the end of decompression.

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In conducting a recompression treatment, all attending personnel must work as a team for the benefit of the patient. The actual operation of the chamber is dictated by the actual availability of qualified personnel and the circumstances of the casualty being treated.

If the patient has symptoms of serious decompression sickness or arterial gas embolism, the team will require additional personnel. If the treatment is prolonged, a second team may have to relieve the first.

ROUTINE DECOMPRESSION (SURDO_2)

Where divers are well and are undergoing surface decompression on oxygen or other routine decompressions, AS/NZS 2299.1:1999 does not require an attendant to be inside the chamber.

MEDICAL HISTORY AND STATEMENT OF UNDERSTANDING

Each diver should have filled in a medical history and statement of understanding prior to therapeutic recompression treatment. This needs to cover any medical conditions that may affect treatment or their response to treatment.

Anyone entering the chamber needs to understand the risk involved in compression and decompression and the fire risk within the chamber. You should ensure that they are not carrying matches, lighters, chemical hand warmers, cigarettes or any other high fire risk items. Check their recent alcohol, food and drink consumption.

One way of ensuring that these items are covered is to have a form that the patient and anyone else entering the chamber needs to sign.

LIAISING WITH MEDICAL PERSONNEL

In the informative Appendix G of AS/NZS 2299.1:1999, Clause G4 covers recompression therapy for DCI. It states that the advice of a medical practitioner trained in underwater medicine and therapeutic recompression should always be sought when undertaking recompression therapy on site.

This responsibility will rest with the dive supervisor. It is important to communicate calmly and clearly, using appropriate terminology. It is essential to have clear and legible records of events leading up to the decision to undertake recompression therapy. You will need to advise the symptoms, their progress and the therapeutic table used and times and details of therapy.

RECORDS

It is the responsibility of the supervisor to ensure that both routine decompressions and therapeutic recompressions are properly logged. On the following page is an example of a typical form.

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DDC OPERATIONS

SUPERVISOR		**DAY**	
CHAMBER ATTENDANT		**DATE**	
DIVER 1			
DIVER 2		**REG NO**	
DIVER 3			
DIVER 4			
DIVER 5			
DIVER 6			
DIVER 7			
DIVER 8			

BREATHING GAS PRESSURES

		PRE DIVE PRES	*VOLUME*	*LINE PRESSURE*	*POST DIVE*
BREATHING AIR	**MAIN SUPPLY**				
	RESERVE SUPPLY				
MEDICAL OXYGEN	**MAIN SUPPLY**				
	RESERVE SUPPLY				

DIVE PROFILE DETAILS

	DEPTH IN METRES	*ELAPSED TIME*	*REAL TIME*	*ELAPSED TIME*	
				ON O_2 AT	*ON AIR AT*
LEFT SURFACE	**0 m**	**00 : 00**	**:**		
ARRIVED CHAMBER BOTTOM	**m**	**:**	**:**	**:**	**:**
LEFT CHAMBER BOTTOM		**:**	**:**	**:**	**:**
ARRIVED 1ST STOP	**m**	**:**	**:**	**:**	**:**
LEFT 1ST STOP		**:**	**:**	**:**	**:**
ARRIVED 2ND STOP	**m**	**:**	**:**	**:**	**:**
LEFT 2ND STOP		**:**	**:**	**:**	**:**
ARRIVED 3RD STOP	**m**	**:**	**:**	**:**	**:**
LEFT 3RD STOP		**:**	**:**	**:**	**:**
ARRIVED 4TH STOP	**m**	**:**	**:**	**:**	**:**
LEFT 4TH STOP		**:**	**:**	**:**	**:**
ARRIVED SURFACE	**0 m**	**:**	**:**	**:**	**:**

FLUSH THROUGH FOR ONE MINUTE EVERY FOUR MINUTES AND WHEN LEAVING CHAMBER BOTTOM OR STOP

WORK DESCRIPTION AND REMARKS

SUPERVISOR SIGNATURE:	**REPETITIVE GROUP DESIGNATION:**
ATTENDANTS SIGNATURE:	**FLYING RESTRICTIONS:**

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2 CHAPTER 2 – SUMMARY

OPERATIONS

- ✔ AS/NZS 2299.1:1999, Section 4 gives guidance on compression (recompression) chambers including availability of compression chamber, chamber design, construction, fittings and services, chamber operation, medical equipment, transfer under-pressure (TUP), contingency planning for "worst case scenario" chamber operations.
- ✔ General procedures should include checklists, pressurisation procedures, chamber ventilation, oxygen procedures and use of therapeutic.

EMERGENCIES

- ✔ Emergency protocols or procedures are required to cover foreseeable chamber emergencies.
- ✔ Some examples of chamber emergencies are fire, view port leaks or rupture, power failure and door seal failure.
- ✔ Some complications and side effects of HBO include barotrauma, oxygen toxicity, claustrophobia and refractive changes.

SUPERVISION

- ✔ Supervision of therapeutic recompression and surface decompression in a remote location requires a well trained team of at least the dive supervisor or chamber operator and an inside attendant. An outside attendant and medical officer is desirable.
- ✔ Chamber attendant should be a qualified diver or diver medical technician or hyperbaric trained nurse.
- ✔ SurDO_2 does not require an attendant inside the chamber if the diver is well.
- ✔ The dive supervisor is responsible for ensuring proper records of SurDO_2 and therapeutic recompressions are kept.
- ✔ The dive supervisor should seek the advice of an appropriately trained medical practitioner when undertaking recompression therapy on site.

REVISED BY: Active Learning Partners (Bronwen Campbell), Ian A. Milliner, and Paul Bulter **DATE & TIME:** 24-Feb-05 10:38
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ADAS REF: This Section corresponds to Module 6.11, Supervise on site compression chamber operation.