ORIGINAL ARTICLES

CARBON DIOXIDE AND HUMIDITY CONTROL IN A HYPERBARIC CHAMBER

Andrew Peacock and Ray Palmer

Introduction

There is a hyperbaric chamber located at the Australian Institute of Marine Science (AIMS) which is 50 kilometres by road south of the coastal city of Townsville in North Queensland. It is a multiplace hyperbaric treatment facility with two locks that can be independently pressurised. The term recompression chamber (RCC) is commonly applied to such a facility as it is used to compress divers as part of a therapeutic regimen[1]. The RCC at AIMS is supported medically by the Intensive Care Unit at the Townsville General Hospital. It was established in 1977 and since then has been used almost exclusively for the treatment of divers with hyperbaric illness. Only nine patients with illnesses unrelated to diving have been treated in the RCC. From the beginning of 1986 to the time of writing, sixty-nine divers had undergone therapeutic recompressions for cerebral arterial gas embolism (CAGE) and/or decompression sickness (DCS). Of these, twenty-four had required retrieval to the AIMS RCC using the Drager Duocom, a transportable two-man RCC, which was operated out of Townsville by the National Safety Council of Australia (Victorian Division).

As part of its requirement to meet the therapeutic needs of critically-ill patients with either cerebral arterial gas embolism or decompression sickness, the operators of a recompression chamber must be able to:

1. Measure and maintain the levels of oxygen and carbon dioxide.
2. Measure and maintain at tolerable levels humidity within the RCC.

It is important to measure the performance of a RCC with regard to these requirements. However such performance testing has not been carried out on the RCC at AIMS. This study was carried out to assess the performance of the carbon dioxide elimination, humidity control and oxygen make-up systems which can be fitted to the RCC at AIMS. The study was conducted without personnel inside the RCC.

The AIMS RCC has two compartments, an air lock or outer chamber (volume = 3,250 dm^3) and a treatment or main chamber (volume = 7,600 dm^3). The compartments are separated by a pressure locking door. Five trials were conducted, a carbon dioxide absorption trial in each chamber, a carbon dioxide-humidity trial in each chamber and an oxygen make-up trial in the main chamber.

All pressures are given as bars absolute. Although not strictly a SI unit, this unit has been used because of the ease of conversion from water depth to bar. Each 10 msw increment in depth equals an increase in pressure of 1 bar (1 bar = 1 atmosphere).

Carbon dioxide absorption trials

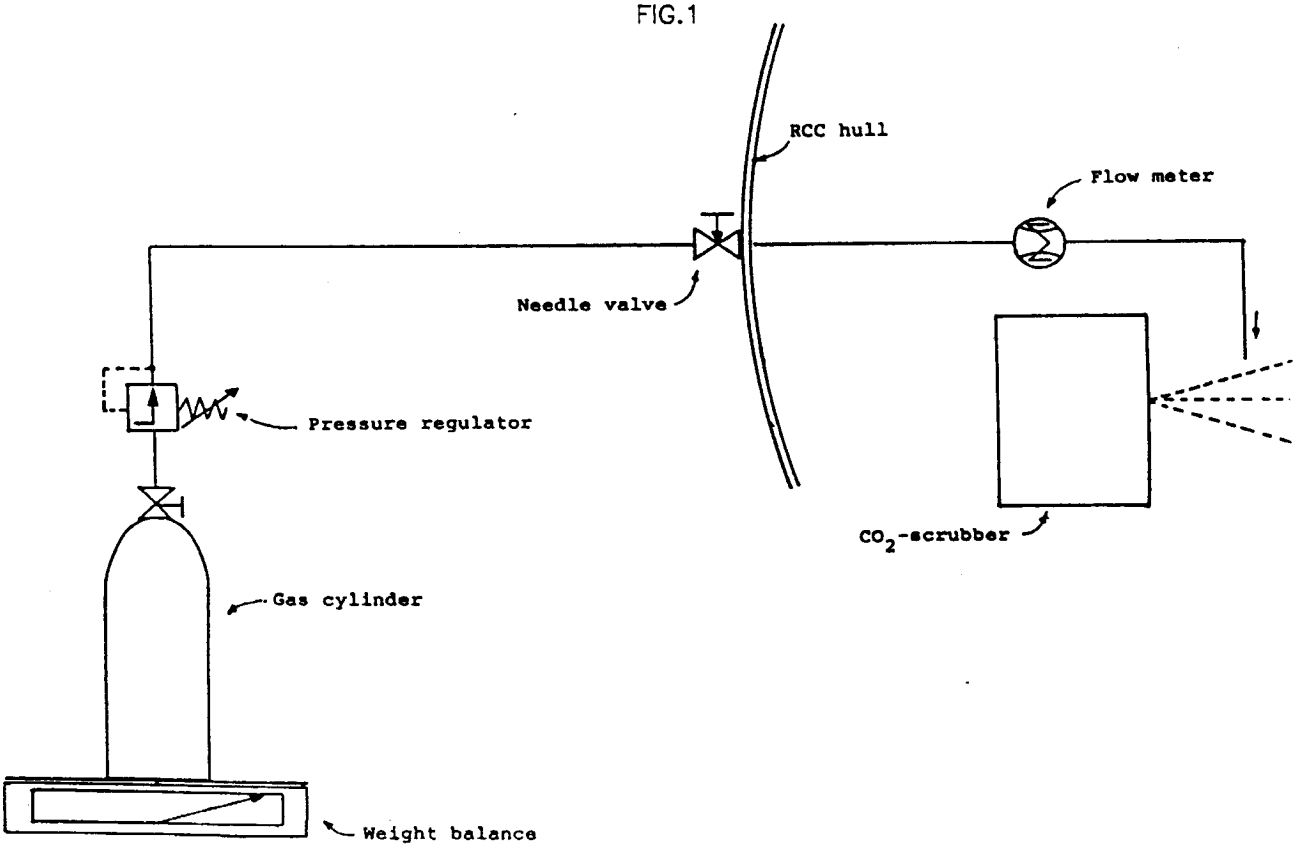
Carbon dioxide is normally present in the atmosphere in a concentration of 0.03 to 0.04% volume of dry air. Carbon dioxide is a product of metabolism which can have toxic effects. The production of carbon dioxide can vary from 200 ml carbon dioxide STPD/min for an individual at rest to 6000 ml carbon dioxide STPD/min during extreme work.

Hypercapnia is an abnormal elevation of carbon dioxide levels in the body. The patho-physiological changes associated with hypercapnia are called carbon dioxide toxicity. Two situations in the enclosed environment of a hyperbaric chamber can lead to carbon dioxide toxicity in the chamber occupants, inadequate ventilation of the RCC where flushing is required to remove carbon dioxide or failure of a carbon dioxide absorber system[1]. An increase in the partial pressure of carbon dioxide (PCO_2) in a RCC is much more likely when the chamber occupants are active and producing large amounts of carbon dioxide.

Observable responses to raised ambient carbon dioxide levels begin with increases in the depth and rate of respiration at between 10 and 20 millibars[1]. The maximum permissible concentration (MPC) of carbon dioxide varies with exposure-time. Given that therapeutic recompressions take several hours, the appropriate MPC for PCO_2 for hyperbaric treatment exposures in a RCC is 10 millibars. It follows that the level of carbon dioxide should be maintained at less than 10 millibars[2]. Using a molecular weight of 44 for carbon dioxide and knowing that under standard conditions one mole of gas occupies 22.4 litres, carbon dioxide production rates in litres per minute can be translated to production rates in grams per minute (g carbon dioxide/min). A therapeutic RCC must be able to remove the carbon dioxide products of 3 moderately exercising individuals (a patient convulsing and 2 attendants). That is a carbon dioxide production rate of approximately 5.3 to 5.9 g carbon dioxide/min (900 ml carbon dioxide STPD/min to 1,000 ml carbon dioxide STPD/min). The situation described above would represent an extreme load on the carbon dioxide removal system for the main chamber of a RCC. During a therapeutic recompression in the main chamber the outer chamber may be required to transfer a person from outside the RCC into the main chamber. Consequently a carbon dioxide production rate of approximately 3.0 g carbon dioxide/min would represent an extreme test of the carbon dioxide removal capability of the outer chamber.

The RCC at AIMS has two means by which the operators can reduce the carbon dioxide concentration gen-

FIG.1



erated by the occupants. In each of the main and outer chambers there is an electrically powered carbon dioxide scrubber which uses a blower to force chamber gas through a cannister containing a granulated carbon dioxide absorbing agent (Sodasorb).

The chamber operator of the RCC at AIMS can also remove carbon dioxide by ventilating the chamber with air. This is done while maintaining the chamber ambient pressure constant. Ventilation is performed by opening both the pressurisation and the exhaust valves at the same time. There should be no requirement for this if the carbon dioxide scrubber system is working efficiently.

AIM OF THE STUDY

To evaluate the performance of the carbon dioxide absorbing systems in the main and outer chambers of the RCC.

METHODS

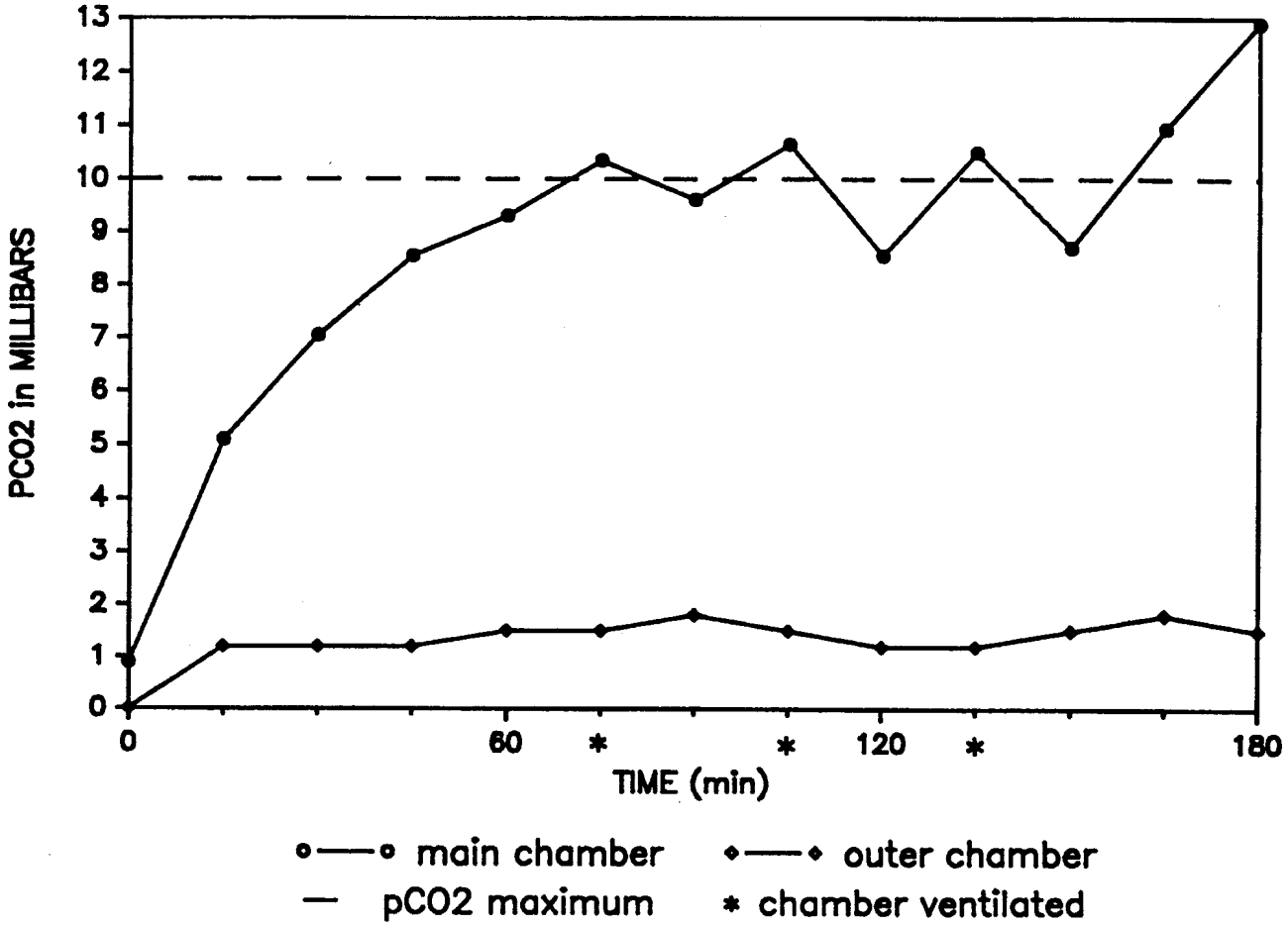
Two separate trials were conducted, one in each of the chambers. In each trial, carbon dioxide was added to the RCC environment at a known rate, using the equipment as shown in Figure 1. The carbon dioxide-scrubber outlet flow was used to distribute the carbon dioxide around the RCC. A cylinder of carbon dioxide was connected through a pressure regulator (adjusted to give a line pressure of 8.0 bar) and a needle valve to the chamber via a flexible hose. The rate at which carbon dioxide was added to the RCC was monitored by placing the cylinder on an electronic weight balance (Digi Model 430) (weight loss/time = rate of addition of carbon dioxide in grams). The weight balance was calibrated using standard weights prior to use. The scale was in 5 gram increments.

The needle valve was used to adjust the rate of carbon dioxide addition. This could be monitored by observation of a CIG flow meter placed inside the RCC. The carbon dioxide passed through this before being released from flexible tubing positioned above the carbon dioxide scrubber outlet. The needle valve was continually adjusted to maintain a carbon dioxide addition rate of: between 5.3 and 5.9 g carbon dioxide/min for the main chamber trial and 3.0 g carbon dioxide/min for the outer chamber trial.

The actual carbon dioxide addition rates were main chamber 5.94 g carbon dioxide/min and outer chamber 2.92 g carbon dioxide/min

With the carbon dioxide scrubber operating in the RCC compartment being tested, carbon dioxide was added to the compartment for 180 minutes while the internal compartment pressure was maintained at 6 bars absolute. This pressure was chosen because this is the greatest pressure used to treat dysbaric illness[2,3]. The PCO_2 was measured every 15 minutes during this period, by withdrawing gas from the RCC, and using an Infrared carbon dioxide analyser (GasTech Model RI-411). This analyser was precalibrated

FIG.2
CARBON DIOXIDE ABSORPTION TRIAL
BOTH CHAMBERS



according to standard operating manual procedures. The analyser provided a continuous digital display of instantaneous carbon dioxide concentration to the nearest 50 ppm. Its output (ppm) was converted to millibars (ppm carbon dioxide/1000 x Pamb).

RESULTS

The PCO_2 data were corrected for the actual carbon dioxide addition rates (main chamber trial 6/5.94, outer chamber trial 3/2.92) and are listed in Table 1 and displayed in Figure 2.

DISCUSSION

Although the carbon dioxide addition rates used for the trials reflected moderate exercise only, the duration of these exposures makes the trials an extreme test of the RCC's carbon dioxide absorption system as this level of exercise would not be maintained for over 180 minutes.

The data show a marked difference between the capabilities of the carbon dioxide absorbing systems in each compartment of the RCC. While the PCO_2 in the outer chamber remained at a level significantly less than 10 millibars for the duration of the trial, the PCO_2 in the main chamber reached this accepted upper limit between 60 and 75 minutes.

At 75 minutes it was decided to ventilate the main chamber in an attempt to decrease the PCO_2. The first ventilation involved exchanging approximately 10 m^3 of air (over 90 seconds) and it decreased the PCO_2 from 10.35 millibars to 7.8 millibars at the end of that 90 seconds. However within 15 minutes the PCO_2 had increased to 9.6 millibars and then again exceeded the 10 millibar exposure limit. The chamber was subsequently ventilated at 105 minutes and again at 135 minutes (approximately 38 m^3 and 29 m^3 of air respectively). These ventilation periods also proved ineffective in decreasing the PCO_2 appreciably for any length of time.

In contrast, the performance of the carbon dioxide scrubber in the outer chamber is certainly adequate.

The performance of the main chamber carbon dioxide scrubber is unacceptable. In the latter stages of the trial, despite repeated chamber ventilation the PCO_2 continues to

TABLE 1

CARBON DIOXIDE ABSORPTION TRIAL

MAIN AND OUTER CHAMBERS

CARBON DIOXIDE LEVELS IN MILLIBARS

Time (minutes)	Main Chamber	Outer Chamber
0	0.90	0
15	5.10	1.20
30	7.05	1.20
45	8.55	1.20
60	9.30	1.50
75	10.35*	1.50
90	9.60	1.80
105	10.65*	1.50
120	8.55	1.20
135	10.50*	1.20
150	8.70	1.50
165	10.95	1.80
180	12.90	1.50

* Chamber ventilated

CO_2 addition rates

Main chamber 6/5.94 gCO2/min
Outer chamber 3/2.92 gCO_2/min

rise steeply (Figure 2). This indicates that the Sodasorb granules are no longer efficiently absorbing carbon dioxide, i.e. their capacity has been exceeded. During a recompression where there is such extreme carbon dioxide production they would therefore need to be replaced regularly. Fresh Sodasorb can be transferred to the main chamber via the outer chamber. Continuous ventilation of the chamber will be needed when replacing the carbon dioxide absorbent. This places a demand on the high pressure air supply to the chamber and hinders communication between the RCC operator and occupants because of the associated noise.

The basic problem was that the air flow rate of the carbon dioxide scrubber unit in the main chamber was too low. The cause of this has since been found to be a faulty electrical terminal connected to the carbon dioxide scrubber.

Carbon Dioxide and Humidity Trials

Humidity is of importance in a RCC primarily because of the narrowed humidity and thermal comfort zone that exists under hyperbaric conditions for the patient and the in-chamber attendant(s)[3]. Humidity is a particular problem in the RCC at AIMS where ambient relative humidity during the summer months (in the non-airconditioned building containing the RCC) often remains close to 100%. This makes a therapeutic recompression in the RCC very uncomfortable.

A high level of water vapour pressure in the air reduces the effectiveness of the sweating mechanism for cooling the body by evaporation. This results in increased sweating which will increase the often already dehydrated state of the patient suffering from DCS. A high level of humidity places a thermoregulatory stress on the body which is undesirable for both the patient and the attendants in the RCC.

Desirable relative humidity within the confines of a RCC being used for hyperbaric oxygen therapy is in the range 50% to 75%[3].

One approach for humidity control in a RCC is to use a moisture absorbent (desiccant) such as silica gel which can be regenerated. This can be used in a scrubber system equivalent to those used for removal of carbon dioxide and often may be contained in the same container. The RCC at AIMS has no such scrubber system in operation. Instead, to keep relative humidity within the chamber at a reasonable level, the chamber operator intermittently ventilates (or flushes) the RCC with air from the high pressure air bank which contains less water vapour than the chamber air. In the summer months this may need to be done as often as once every 5 to 10 minutes. Although it is not difficult to ventilate the chamber, the necessity to monitor the humidity within the RCC constantly and ventilate the chamber places extra demands on the chamber operator. Equally as important is the observation that the process of ventilating the RCC produces a level of noise (> 90 dB) within the chamber which can be disconcerting to both the patient and the in-chamber attendant(s), especially when ventilation is occurring frequently. Also the noise from ventilation makes any communication between chamber occupants and the RCC operator difficult.

The carbon dioxide scrubber used in the RCC functions by causing an air flow over sodalime, an alkali metal hydroxide reagent (Sodasorb). The chemical reactions involved are as follows[1]:

$$H_2O + \text{carbon dioxide} \rightarrow H_2CO_3$$
$$H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$$
$$Na_2CO_3 + Ca(OH)_2 \rightarrow 2NaOH + CaCO_3$$

These reactions produce one molecule of water for each molecule of carbon dioxide removed. Hence they contribute significantly to an increase in the humidity of the

TABLE 2

CARBON DIOXIDE HUMIDITY TRIAL

MAIN CHAMBER CARBON DIOXIDE LEVELS IN MILLIBARS

WITH AND WITHOUT DESICCANT

Time (minutes)	No desiccant	With desiccant
0	1.20	1.20
5	1.80	3.75
10	2.70	5.70
15	5.10	8.10
20	6.30	9.90
25	7.20	11.40
30	8.10	12.45
35	8.55	
40	9.15	
45	9.60	
50	10.20	
55	10.50	
60	10.80	

TABLE 3

CARBON DIOXIDE HUMIDITY TRIAL

HUMIDITY IN THE MAIN CHAMBER WITH AND WITHOUT DESICCANT

(Expressed as percent relative humidity)

Time (minutes)	No desiccant	With desiccant
0	58.0	54.0
5	63.0	55.0
10	67.5	54.0
15	71.0	52.0
20	74.0	50.0
25	77.0	49.0
30	79.0	48.0
35	81.5	
40	83.0	
45	85.0	
50	86.5	
55	88.0	
60	89.5	

CO_2 addition rates

No desiccant 5.5/5.50 gC02/min
with desiccant 5.5/5.67 gCO_2/min

RCC environment that occurs during a therapeutic recompression. It follows that the carbon dioxide scrubber system can be used to test the humidity control system of the RCC.

AIM OF STUDY

To evaluate the performance of a desiccant granule humidity control system in the main and outer chambers of the RCC.

METHODS

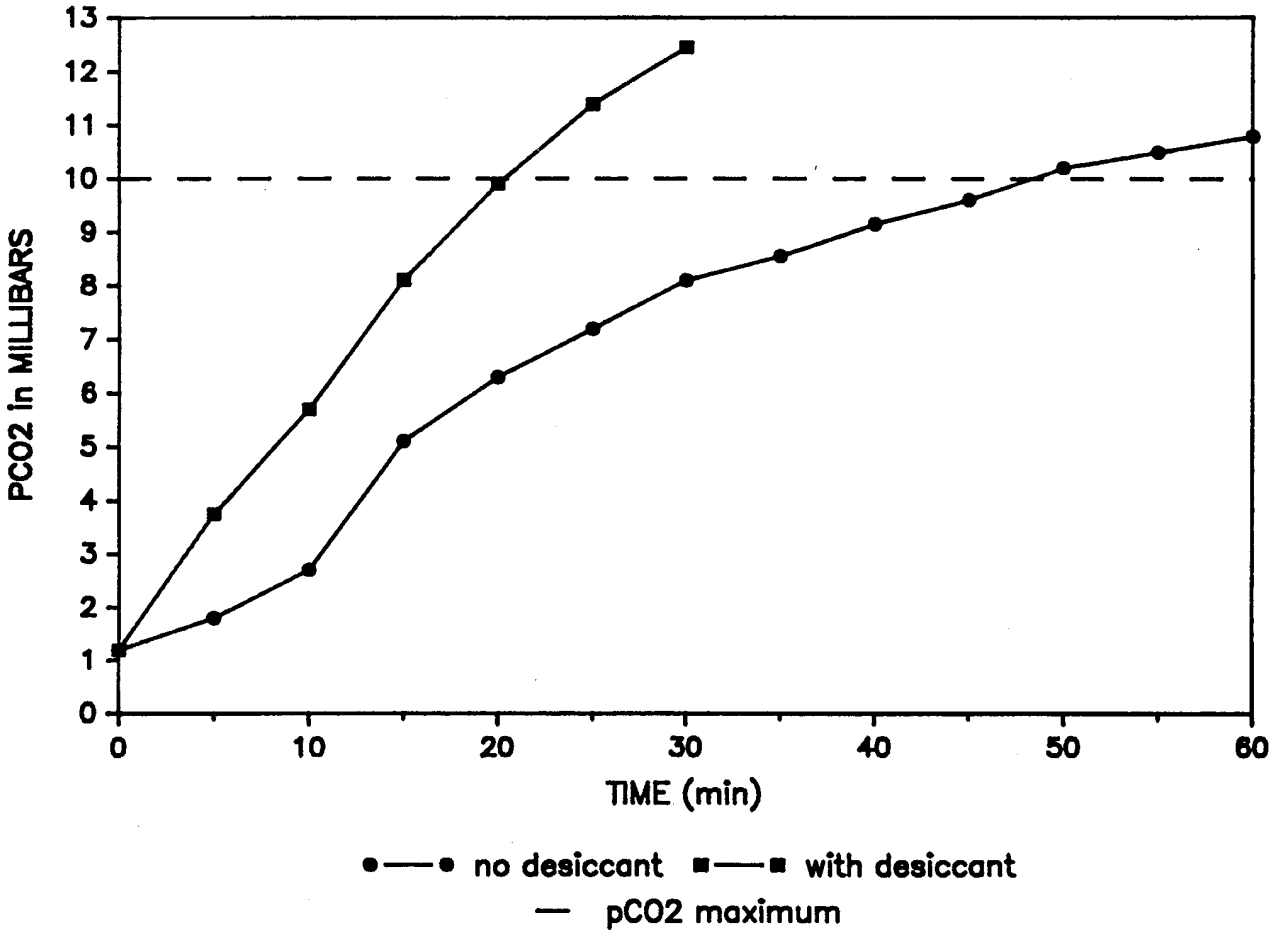
Two separate trials were conducted, one in each chamber of the RCC. In each trial, carbon dioxide was added to the RCC environment at a known rate using the equipment set up as previously described for the carbon dioxide Absorption Trial (Figure 1). The trial was performed in each chamber under two different conditions. First with desiccant granules (silica gel) in a three litre cannister that was fitted to the outlet of the carbon dioxide scrubber in that chamber and then with no desiccant granules. The desiccant granule cannister was specifically designed for the trial by staff in the AIMS workshop.

With the carbon dioxide scrubber operating in the RCC compartment being tested, carbon dioxide was added to the compartment for 1 hour at a rate similar to that used for the carbon dioxide Absorption Trial while the internal ambient compartment pressure was maintained at 6 bars absolute. The carbon dioxide addition rates were as follows:

Main Chamber
No desiccant 5.50 g carbon dioxide/minute
With desiccant 5.67 g carbon dioxide/minute
Outer Chamber
No desiccant 3.00 g carbon dioxide/minute
With desiccant 3.08 g carbon dioxide/minute

The PCO_2 was measured every 5 minutes during this

FIG.3
CARBON DIOXIDE–HUMIDITY TRIAL
MAIN CHAMBER



period using a pre-calibrated Infrared carbon dioxide analyzer (GasTech model RI-411). The relative humidity inside the chamber was measured directly every 5 minutes using a hair hygrometer (Measuretec) which had previously been calibrated. It recorded in one percent graduations. This instrument was mounted inside the chamber so that it could be viewed easily from the outside through one of the chamber portholes.

RESULTS

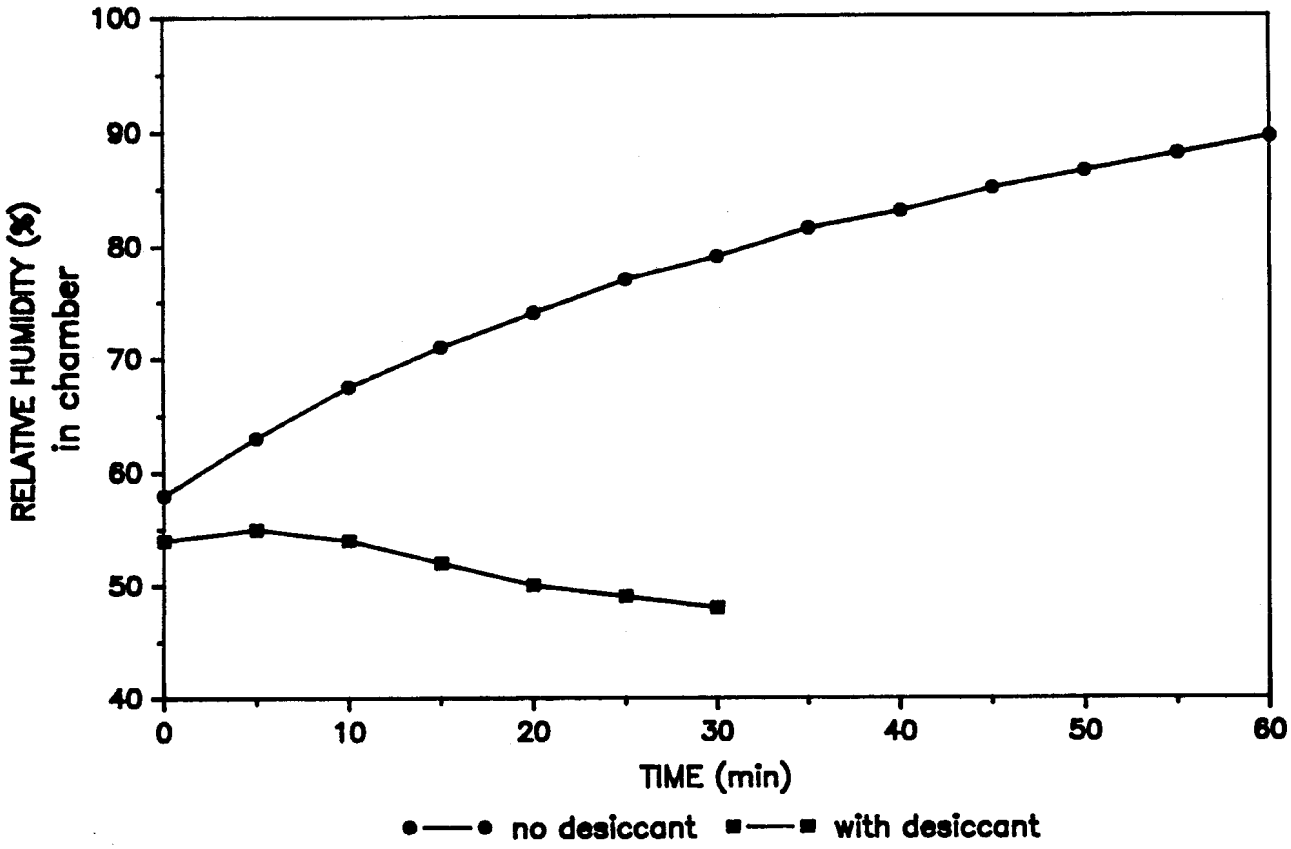
The PCO_2 data (corrected for the actual carbon dioxide addition rates) and relative humidity data for the main chamber trial are listed in Tables 2 and 3 and displayed in Figures 3 and 4. The data for the outer chamber trial are listed in Tables 4 and 5 and displayed in Figures 5 and 6.

DISCUSSION

The PCO_2 data once again showed that the carbon dioxide scrubbing system operating in the main chamber was much less efficient than that in the outer chamber (Figures 3 and 5). In both chambers the PCO_2 was higher over the 60 minute period when desiccant granules were present. However, there was a much greater effect in the main chamber trial. After 20 minutes the PCO_2 had reached the 10 millibar exposure limit in the main chamber when desiccant granules were in the cannister compared to between 45 and 50 minutes when there was no silica gel present. In fact, the addition of carbon dioxide was halted after only 30 minutes when silica gel was present because at this time the PCO_2 measured 12.45 millibars which is well above the acceptable limit and hence made further carbon dioxide addition under those conditions unnecessary for the purposes of the trial. In contrast however the PCO_2 for both conditions in the outer chamber trial remained well below 10 millibars, reaching a maximum of 4.05 millibars when silica gel was present.

For both trials the relative humidity was much higher when there was no desiccant present to remove moisture from the chamber air (Figures 4 and 6). This was especially so for the outer chamber when the relative humidity reached 90% after only 20 minutes. These changes in relative humidity when no desiccant was present within the chamber can be compared with the changes in relative humidity

FIG.4
CARBON DIOXIDE—HUMIDITY TRIAL
MAIN CHAMBER



outside the chamber which were only of the order of 3% during the main chamber trial and 1% during the outer chamber trial.

The trial has shown that the cannister of silica gel attached to the carbon dioxide scrubber outlet will control the arbitrarily chosen high level of humidity generated by the carbon dioxide scrubber. This is true for both chambers of the RCC. It is important to note however that the duration of the trials was only sixty minutes and as therapeutic recompressions can take at least five hours to complete, it is possible that the moisture absorbing capacity of the 3 kilograms of silica gel used in each trial would have been exceeded within this time. This would require that fresh silica gel be placed in the cannister before the previous supply became saturated with water.

The major problem with this system for controlling humidity is that the silica gel was impairing the function of the carbon dioxide scrubber (Figures 3 and 5). This was probably because of the increased resistance to airflow produced by the desiccant granules as air passed from the carbon dioxide scrubber into the desiccant granule cannister and then out into the chamber. This increased airflow resistance severely compromised the function of the carbon dioxide scrubber in the main chamber. This was to be expected considering there was already a low flow rate through this carbon dioxide scrubber because of an electrical fault. However, only a small effect was noted in the outer chamber where carbon dioxide levels were raised by a maximum of 2.55 millibars but remained well below the MPC for carbon dioxide.

Oxygen make-up trial

The critical life-support variable in a RCC is oxygen. Control of oxygen involves both analysis and restoration of PO_2 to the required level (make-up). The proper level of oxygen to be maintained in the chamber is a function of the duration of the exposure, and it may range between a low of approximately 0.21 bars to as great as 1.6 bars[3]. It is important to remember that the significant factor with regard to toxicity is oxygen partial pressure and not concentration[4].

When conventional therapies do not resolve the symptoms and signs of either decompression sickness or cerebral arterial gas embolism, it may occasionally be necessary to use an air saturation therapy. Because such therapy involves exposures longer than 4 hours the PO_2 cannot exceed 0.6 bars (the pulmonary oxygen toxicity limit). Since there is metabolic consumption of oxygen by the RCC occupants the PO_2 will fall within the RCC. It follows that

TABLE 4

CARBON DIOXIDE HUMIDITY TRIAL

OUTER CHAMBER CARBON DIOXIDE LEVELS WITH AND WITHOUT DESICCANT

PCO2 in millibars

Time (minutes)	No Desiccant	With Desiccant
0	0	0
5	0.90	0.90
10	1.20	2.40
15	1.20	2.85
20	1.20	2.85
25	1.20	3.45
30	1.20	3.45
35	1.20	3.75
40	1.50	4.05
45	1.50	4.05
50	1.50	4.05
55	1.50	3.75
60	1.50	3.75

CO_2 addition rates

no desiccant 3/3.00 gC02/min
with desiccant 3/3.08 $gC0_2$/min

TABLE 5

CARBON DIOXIDE HUMIDITY TRIAL

OUTER CHAMBER HUMIDITY WITH AND WITHOUT DESICCANT

(Expressed as percent relative humidity)

Time (minutes)	No Desiccant	With Desiccant
0	42.0	46.0
5	62.0	44.0
10	78.0	41.0
15	87.0	39.0
20	90.5	37.0
25	92.0	37.0
30	93.0	36.5
35	94.0	36.5
40	95.0	36.5
45	95.5	37.0
50	96.0	37.0
55	96.0	38.0
60	96.5	39.0

the oxygen levels must be carefully monitored and maintained. A commonly used technique to add oxygen to the RCC, in the absence of a dedicated oxygen make-up system, is to allow the built in breathing system (BIBS) for oxygen to free flow.

The consumption of oxygen is exercise dependent, varying from 250 ml oxygen STPD/min for an individual at rest to possibly 5,000 ml oxygen STPD/min during extreme work (depending on the size and physical fitness of the individual). A therapeutic RCC needs to be able to match the oxygen needs of 3 moderately exercising individuals (a patient convulsing and 2 attendants), which is an oxygen consumption rate of about 3,000 ml oxygen STPD/min. The main chamber volume of the RCC at AIMS is 7,600 dm^3, therefore an oxygen consumption of 180 dm^3/hour will decrease the oxygen concentration in the main chamber to approximately 18.5% after one hour. This represents a decrease in PO_2 from 585 millibars to 518 millibars when the chamber is pressurised on air to 2.8 bars. The RCC operator would therefore need to increase the PO_2 in the main chamber by an hourly increment of around 65 millibars to compensate for this level of oxygen consumption by the RCC occupants (an oxygen make-up). This will ensure that the PO_2 remains at the highest safe level possible in the RCC in order to minimise the amount of inert gas (nitrogen) present while the patient is breathing air.

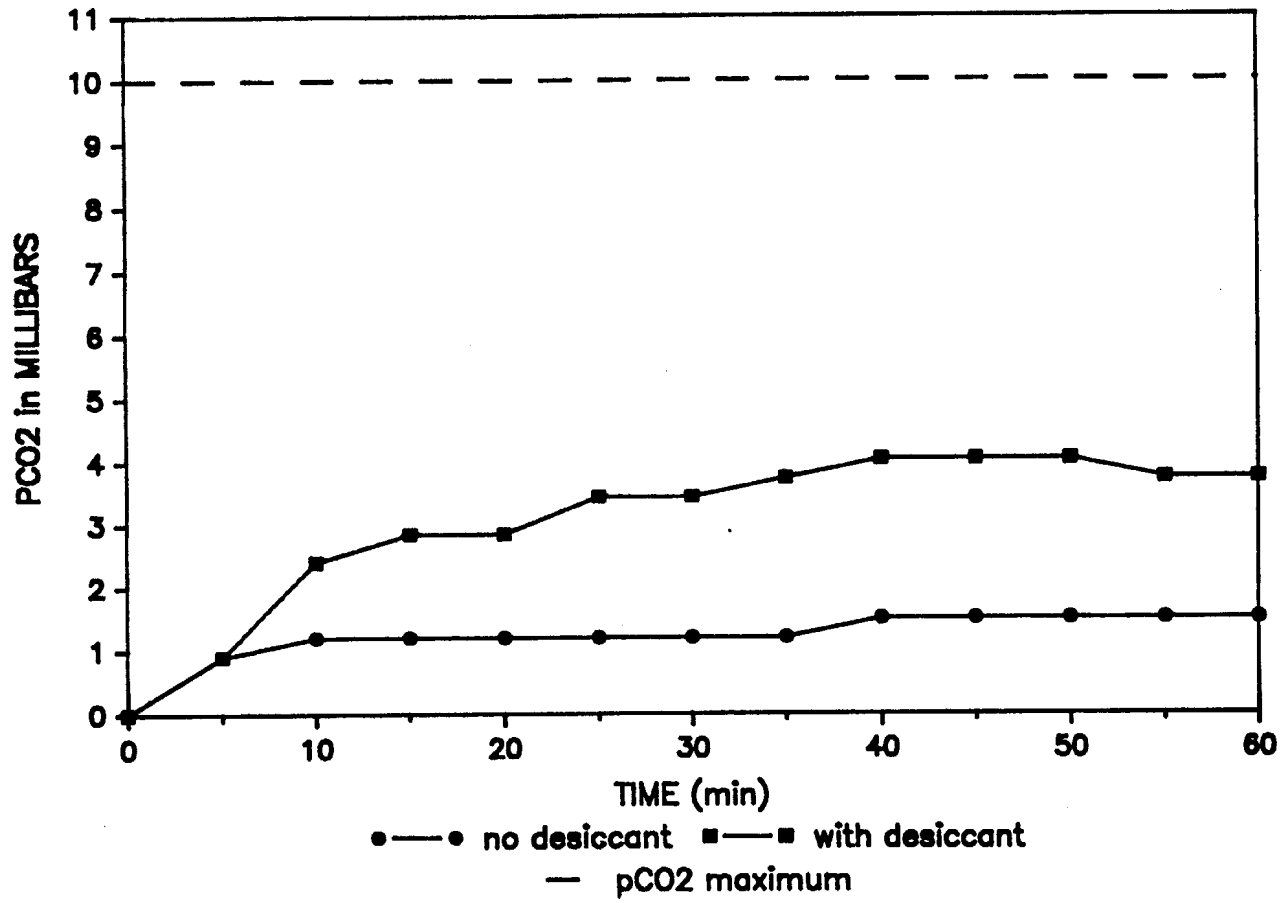
AIM OF STUDY

To develop a standard technique for oxygen make-up of 50 to 60 millibars in the main chamber of the RCC.

METHODS

An oxygen make-up trial was conducted in the main chamber of the RCC at a pressure within the chamber of 2.8

FIG.5
CARBON DIOXIDE–HUMIDITY TRIAL
OUTER CHAMBER



bars absolute (the pressure chosen for an air-saturation therapy). The main chamber was flushed with nitrogen to reduce the PO_2 (to around 500 millibars). A needle valve outside the chamber was turned on to allow the BIBS input line to free flow for a variable amount of time. The oxygen level within the main chamber was monitored continuously by drawing air from the chamber and passing the stream through a galvanic cell sensor (placed in a T-piece adaptor) of a precalibrated oxygen monitor (Hudson Model 5550).

This monitor has an analog galvanometer needle which shows oxygen concentration in 1% graduations: a small portable voltmeter (Fluke Model 8022A Multimeter) was connected to the monitor which enabled its output to be recorded in 0.1% graduations.

Atmospheric air and gases of known concentration as determined from Lloyd-Haldane analysis were used to assess the accuracy of this oxygen analysis system throughout the expected range of measurement. It was found that the voltmeter reading provided an accurate means by which the oxygen concentration in the RCC could be determined. The percent reading of the oxygen analysis system was converted to PO_2 in millibars (% oxygen x Pamb x 10).

At the beginning of each oxygen make-up a starting PO_2 reading was taken before the valve was opened. A second PO_2 reading was then taken two minutes after the valve was shut off. Following this the chamber was again flushed with nitrogen to return the PO_2 to approximately 500 millibars. This procedure was performed 7 times.

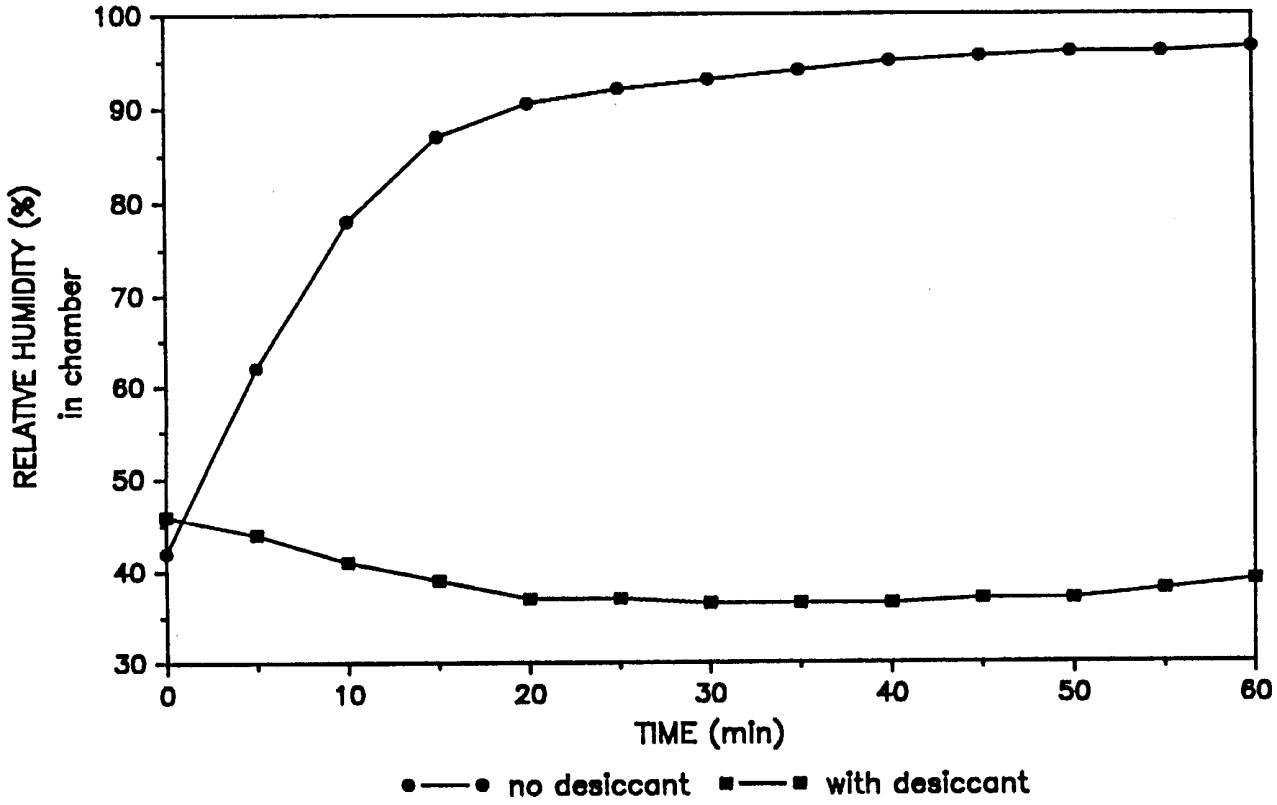
RESULTS

The first oxygen make-up increased the PO_2 by 30 millibars. On the second oxygen make-up it was found that turning the valve one full turn and leaving it open for 40 seconds raised the PO_2 by 56 millibars. This exact regimen was repeated another five times, the PO_2 on each occasion rising by either 56 or 59 millibars i.e. a change in oxygen concentration of 2.0 or 2.1%.

DISCUSSION

It was discovered that a 40 second period of opening the oxygen make-up valve one full turn reliably and predictably raised the PO_2 by 56 to 59 millibars. This technique is recommended as a simple and reliable method of raising the PO_2 in the chamber...

FIG.6
CARBON DIOXIDE–HUMIDITY TRIAL
OUTER CHAMBER



During each oxygen make-up when oxygen was added to the RCC environment, the percentage oxygen reading of the analyser increased by 8 to 10% initially. The reading then decreased over 1 to 1 1/2 minutes before stabilising. This artefact was caused by the proximity within the chamber of the oxygen make-up input and the oxygen analyser pick-up valve; an arrangement which needs to be changed.

Summary

The trials carried out on the RCC at AIMS discovered inadequacies associated with the control of carbon dioxide and humidity levels within the main chamber of the RCC.

The carbon dioxide absorbent system in the main chamber was not functioning properly. It could not maintain a PCO_2 level of less than 10 millibars when subjected to extreme conditions of carbon dioxide production. This unsatisfactory situation in the main chamber was due to an inadequate air flow through its carbon dioxide scrubber. This was due to a faulty electrical terminal connected to the carbon dioxide scrubber.

The humidity control system tested in the RCC prevented the rise in humidity that took place when no such system was fitted to the RCC. However, it decreased the ability of the carbon dioxide scrubber units to remove carbon dioxide from the chamber atmosphere. This was especially evident in the main chamber where function of the carbon dioxide scrubber was already inadequate.

The oxygen make-up trial found a reliable technique by which the PO_2 in the main chamber could be predictably increased by the required 56 to 59 millibars.

Conclusions and recommendations

The faulty electrical terminal causing the poor function of the carbon dioxide scrubber in the main chamber needs to be repaired. Once this has been done the carbon dioxide absorption trial should be repeated in the main chamber over a period of 5 hours to determine if the PCO_2 in the chamber can be kept below 10 millibars for this duration of carbon dioxide production.

A further trial should be conducted on the main chamber with a view to developing an effective humidity control system. It should be conducted in the same manner as the carbon dioxide humidity trial previously outlined but with three important differences. The carbon dioxide scrubber needs to be fully operational. A larger desiccant granule

cannister (4 or 5 litres) should be used. The trial should last for a period of 5 hours (based on RN Table 62). It would only remain then to test the desiccant granule cannister system while a therapeutic recompression is taking place. The aim should be to develop a system that keeps the relative humidity in the main chamber at less than 75% and does not allow the PCO_2 to reach 10 millibars.

The outer chamber carbon dioxide and humidity control systems are functioning adequately and need no further testing.

The need for air saturation therapy of DCS and/or CAGE is rare. However, the oxygen make-up trial has provided information that will prove useful to the operators of the RCC at AIMS in the event that they need to make-up oxygen in the main chamber. It is important that the oxygen sampler valve be relocated to avoid the problem of a spuriously high oxygen analyser reading when adding oxygen to the main chamber. It could be relocated to an area close to the carbon dioxide scrubber outlet. This would enable the added oxygen to be distributed around the chamber more efficiently and allow a more accurate analysis of the actual chamber PO_2.

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Andrew Peacock is a medical student at Flinders University of South Australia and Ray Palmer was the Hyperbaric Chamber Supervisor for the National Safety Council of Australia (Victorian Division), Townsville.

Since this paper was submitted the National Safety Council of Australia (Victorian Division) has gone into liquidation.

WOMEN AND DIVING

Margie Cole

Introduction

Scuba diving today is a rapidly growing sport. The increase in leisure time and leisure money has seen many people take up diving as an addition to their other sporting activities. The growth in the industry in general has created a large financial interest in developing ever newer and more attractive (and more expensive) and safer diving gear. The emphasis in diving has similarly changed from spearing fish and spearfishing competitions to photography, travel and marine biology. Because of these changes women have been more inclined to join their men friends, and venture into the deep.

Although these days women like to consider themselves men's equals, there are some important differences to take into consideration when it comes to safety in diving. These medical aspects have only recently been addressed and as yet there are many unanswered questions.

Historically women have been diving for centuries. The Ama divers of Japan and Korea have been commercially involved in diving for some 2,000 years. They free dive all year round to depths of 10 to 70 feet They are mainly involved in collecting shellfish and seaweed for food and medicinal purposes. Traditionally they have been women although there have been some male divers. The reasons for the female predominance are unclear but one theory is that it was because there was a belief that diving reduced male fertility and hence the women were given the job by default1. These women are fewer in number nowadays and their profession not as highly esteemed as previously. They are obviously extremely proficient divers diving all year round in waters often as cold as 10 degrees. They free dive from small boats, often with an attendant on the surface to help pull up the diver and the catch. Traditionally they wore only cotton cloths wrapped around them or even dived naked. These days many wear wet suits. They make an interesting study when considering the effects of temperature acclimatisation and cold adaptation, as well as the long term effects of repetitive diving in these conditions.

Our society seems to have taken slightly longer to accept females in a divers' role. It only takes a quick look through old diving magazines to realise the changes that have taken place. Luckily times have changed.

With all this put in perspective I would now like to briefly discuss some of the more relevant medical aspects of women in diving.

Menstruation

The effects of menstruation on different women can vary greatly. Symptoms of menstruation can include ab-