WESTERN AUSTRALIAN PEARL DIVERS' MODE OF DIVING

Robert Wong

Years before Haldane was working on his decompression tables with goats, in Australia, pearl divers had been diving for pearl oysters, using hard hat helmets and hand pumps, since 1884. They did not have the benefit of decompression tables to guide them, they had to work by trial and error. The cost in terms of human lives was high.

Dr Graham Blick, the District Medical Officer in Broome (1900-1908) reported in an article entitled "Divers Paralysis" in the British Medical Journal on 25 December 1909 that there were in excess of 400 divers, and they dived to depths from 7 fathoms to 20 fathoms (13-36 m); sometimes even to 25 fathoms (46 m). Spinal cord decompression sickness (DCS) was so common that no diver would consider his outfit complete without a soft catheter.

In 1912, hand pumps were replaced by engine driven pumps and diving to greater depths was achieved resulting in more fatalities. In 1913, there were 29 deaths, and 1914, thirty three deaths from diving (Table 1). CE Heinke & Co, who supplied the diving equipment to the pearlers, donated a recompression chamber (RCC) to Broome for treatment of paralysed divers in 1913.

From those grim days, the pearl divers, out of necessity and self-preservation, evolved their own dive table; handed down over the years and refined in the process. The profiles used were not based on any scientific knowledge that they had, but the profiles worked for the pearl divers in that they contained the incidence of DCS to an acceptable level.

TABLE 1

FATALATIES IN WESTERN AUSTRALIAN PEARL DIVERS WORKING OUT OF BROOME 1910-1920

Year	Deaths
1910	11
1911	10
1912	9
1913	29
1914	33
1915	21
1916	19
1917	12
1918	1
1919	3
1920	4

For economic reasons, the aim was to maximise the bottom time in order to harvest as many oysters as possible. The old Japanese divers used to do 8 dives a day with 30 minutes on the bottom, not bottom time! They used to ascend slowly and do a decompression stop. On the last dive of the day, they would "hang off' for an hour or so before surfacing. Even then, they would sit very still for another hour before they would dare to move. The surface interval was about 10 minutes, this was the time taken for the pearling vessel to turn around for another drift. The current pearl divers' profiles are based on this well tried "recipe".

In 1971, hookah equipment was introduced into Broome after news of the successes of the abalone divers in NSW. The initial first 3 months was unsuccessful, the catch rate was only about 16% of the standard hard hat diving. Eventually a system of shot lines and drag ropes was devised, and by 1975, the last hard hat diver had retired.

In 1983, pure oxygen breathing was introduced for use in decompression by some of the pearl divers.

In late 1990, under the umbrella of the Pearl Producers Association Inc. (PPA), the 13 pearling companies agreed to dive to a set of profiles so these could be studied.

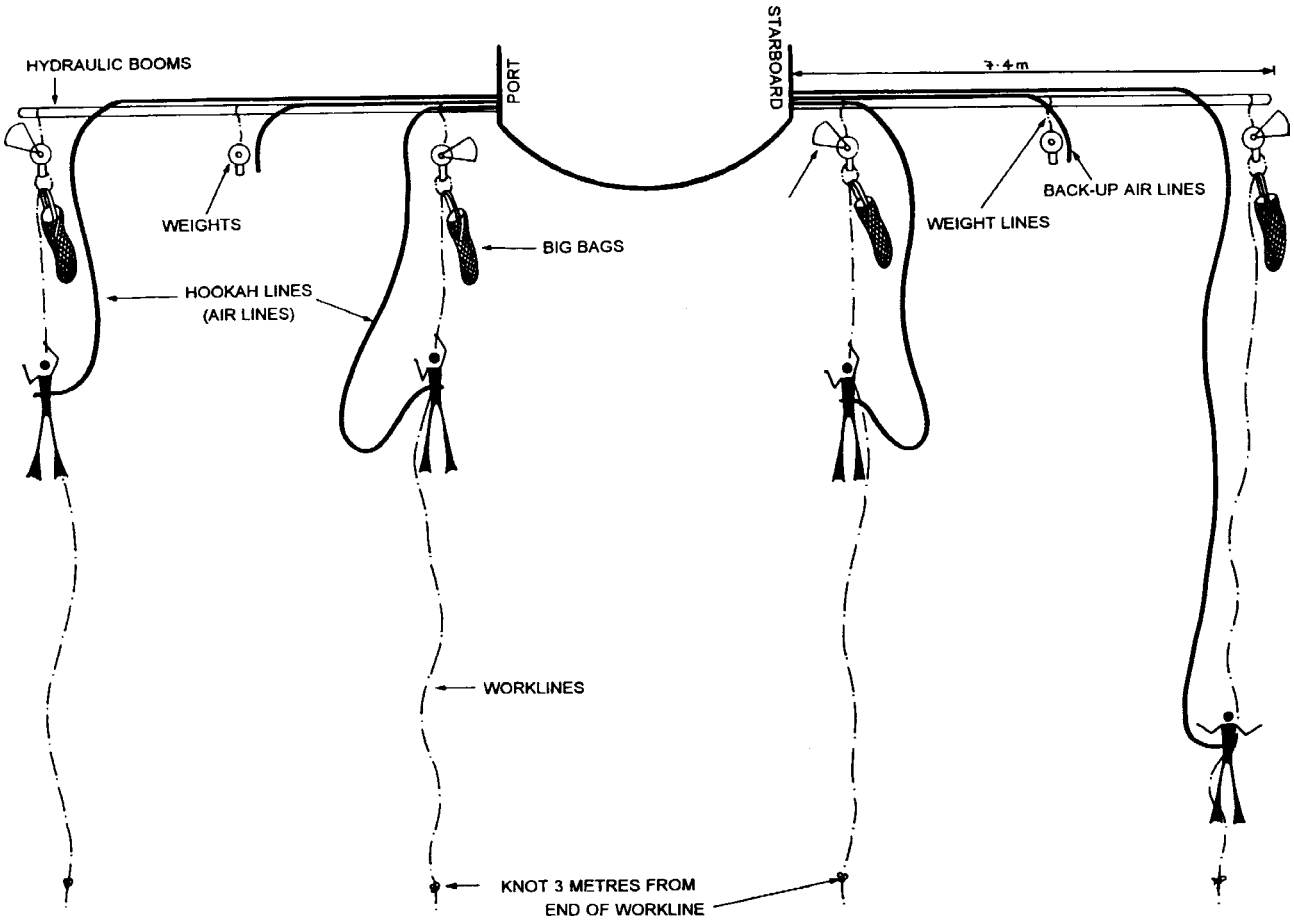
With the present method of working the boats have a hydraulic boom on either side near the stern. Two divers work each side of the boat. A shot line, weighted at the expected depth to be close to the bottom, goes down from the boom for each diver. This rope hangs almost vertically. A large catch bag is attached to the line near the weight with an inflatable bag to take it to the surface when full. The diver works from an extension of the weighted line (work line) which trails behind the weight. A knot is in the line approximately 3 m from the end to warn the diver that he is about to run out of line. The diver holds the line with one hand and picks up pearl oysters with the other putting it in a bag worn round his neck. When the bag is full he pulls himself up the line and empties it into the larger bag, then returns to shell gathering. When the large bag is full it is sent up to the surface using the inflatable bag. This set up is shown in Figs 1 (from above) and 2 (from the side).

Besides the hookah gear each diver wears a small cylinder of air with its own regulator (bail out or pony bottle) so that he has an air supply for decompression if the main hookah supply should fail for any reason.

In 1991, a RCC was purchased by the PPA and donated to the WA Department of Health and was installed

FIGURE 1

OVERHEAD VIEW OF PEARL DIVING OPERATION



in Broome District Hospital. Towards the end of 1991, Doppler ultrasound studies were begun at sea to record the bubble scores of the divers fishing for oysters.

In 1992, the profiles were studied in the RCC in strict accordance with the profiles printed in the Code of Practice of the PPA Inc. Any dive profile which scored higher than Grade II bubble scores were considered stressful and were modified by either decreasing the bottom time, increasing the decompression time, or decreasing the number of dives per day. The surface interval is not usually interfered with because it is the time that takes a fishing boat to turn around for another drift. After the RCC trials, most of the profiles have been modified.

Figure 3 and table 2 shows the number of dives performed at each depth (from <11 msw to 35 msw) from 1991-October 1994. In 1991 there were 30,095 dives resulting in 4 cases of musculo-skeletal DCS. The PPA Profiles start from 11 msw with 2 msw increments, up to a maximum of 35 msw.

TABLE 2

DEPTHS AND NUMBER OF DIVES
1991 TO OCTOBER 1994

Depth	**Number of dives**			
	1991	**1992**	**1993**	**1994**
<11	5,400	7,075	5,269	8,742
<13	5,189	6,821	4,429	5,226
<15	4,013	4,373	2,470	2,274
<17	3,898	3,168	1,738	1,080
<19	5,366	3,835	2,624	1,320
<21	3,682	2,856	2,189	1,212
<23	989	547	621	534
<25	38	35	12	48
<27	8	220	88	0
<29	101	269	316	0
<31	537	118	332	0
<33	861	455	764	0
<35	320	323	600	0
Totals	**30,402**	**30,095**	**21,452**	**20,436**

FIGURE 2

SIDE VIEW OF PEARL DIVING OPERATION.

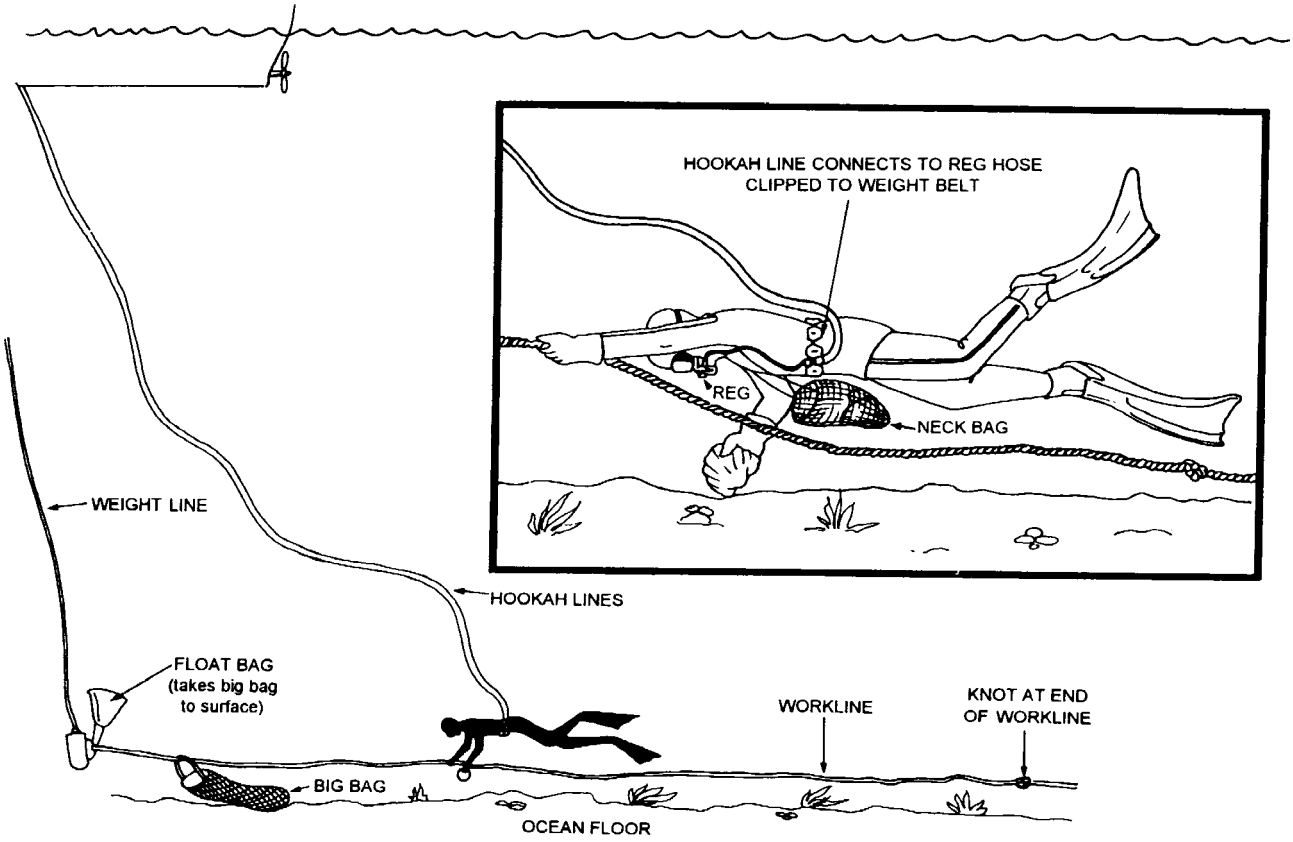
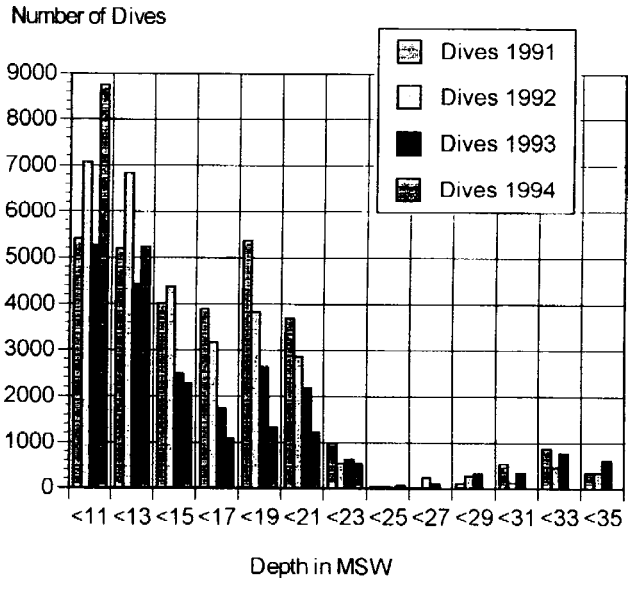


FIGURE 3

NUMBER OF DIVES AND DEPTHS 191 TO OCTOBER 1994



The main aim of the PPA profiles is to achieve the maximum time in a 12 hour day-light working day, from about 0600 to 1800.

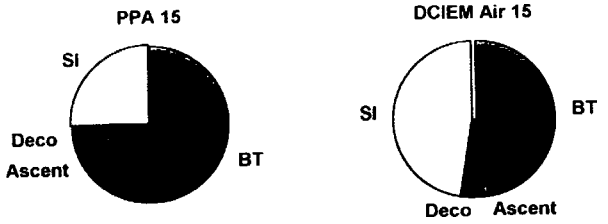
In the shallow depths, they try to achieve 500 minutes of bottom time (BT) for the day e.g. for 11 msw, they use a BT of 90 minutes per dive; for 13 msw, they use a BT of 60 minutes per dive. With deeper depths, they reduce the bottom time of each dive as well as the number of dives for the day, such that at 35 msw, they dive for a bottom time of 25 minutes and perform only 4 dives for the day. As for surface intervals, for dives up to 23 msw depth, the surface interval is fixed at 20 minutes. For deeper depths, the surface interval is increased by extra 10 minutes after each dive e.g. for 35 msw dive, the surface intervals are 80, 90 and 100 minutes. The ascent rate is fixed at 3 msw/minute this is achieved by ascending slowly hand over hand on the shot rope. At the end of the day, regardless of depths of the dive, all divers do a compulsory decompression stop.

Figure 4 compares the PPA profiles with the DCIEM tables (15 msw air; 21 msw oxygen and 33 msw oxygen decompression tables). It can be seen that the PPA profiles have longer bottom times; the combined ascent time and

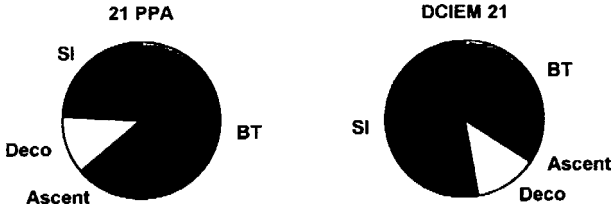
FIGURE 4

COMPARISON OF PPA AND DCIEM PROFILES

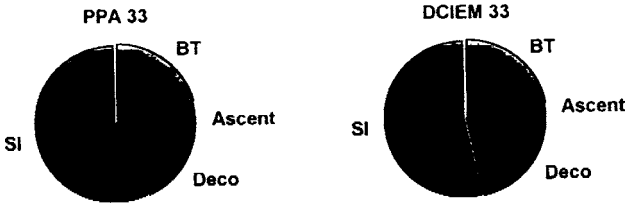
The areas in each pie graph represent the percentage of the total working time



15 msw profiles
PPA compared with DCIEM Standard Air
Bottom Time PPA 450 minutes, DCIEM 315 minutes
Total Time PPA 710 minutes, DCIEM 672 minutes



21 msw profiles
PPA compared with DCIEM oxygen decompression
Bottom Time PPA 360 minutes, DCIEM 240 minutes
Total Time PPA 663 minutes, DCIEM 738 minutes



33 msw profiles
PPA compared with DCIEM oxygen decompression
Bottom Time PPA 125 minutes, DCIEM 125 minutes
Total Time PPA 700 minutes, DClEM 562 minutes

the decompression time of the PPA profiles are similar to those of the DCIEM. The major deviation is the much shorter surface interval of the PPA profiles. It is also of note that the PPA and the DCIEM profiles tend to converge at the 33 msw depth, where the 2 profiles are very similar.

It is superfluous to state that the safety of a set of decompression tables depends not only on the incidence of decompression illness (DCI), but also on the manifestations of DCI. Since the modifications of the PPA Profiles at the end of 1991, the incidence of DCI had been low:

1992	- 4 cases, all musculo-skeletal DCI
1993	- 3 cases, all musculo-skeletal DCI
1994 (to October)	- 0 cases.

Discussion

As is common in the Northern parts of Australia, tidal variation is large, hence the divers only dive during the neap tides.

Despite the multi-day diving of up to 7 to 8 consecutive days during the neap tides, repetitive dives of up to 10 dives a day (in shallow waters and reducing to 4 dives a day at 35 msw) and they frequently dive from shallow to deep waters in contravention to conventional wisdom, because of the tidal variations. The incidence of DCI in the pearl divers since 1992 has been less than 0.01%.

Since the introduction of oxygen in decompression, the pearl divers have not recorded a single case of oxygen toxicity.

One must emphasise that the PPA profiles are all “dived profiles” and not mathematical calculations and extrapolations.

The reasons for their relative safety despite their differences from the conventional profiles might be due to the following four factors:

Slow rate of ascent

The pearl divers ascend at 3 msw/minute as opposed to 18 msw/minute in the standard decompression tables.

Zannini reported that the Italian commercial divers now routinely use a 10 m/minute rate of ascent and recorded no incidence of DCS over 24 ,000 dives at depths ranging from 10-50 msw.

Mano demonstrated with his agar gel experiments that as ascent rate decreases, the number of bubbles also decreases. Mano indicated that the optimum rate of ascent was 9 m/minute.

Daniels has calculated that if the rate of ascent was to decrease to some 25 times in a saturation dive, then bubble formation could be avoided.

In accordance with the DCIEM Decompression Manual, if an ascent rate is too slow, then a penalty is added to the dive as extra bottom time. This is not done in the PPA profiles.

It appears that this slow rate of ascent has not been adequately studied, and the pearl divers, by trial and error, having attempted various rates of ascent, from fast to very slow, managed to "discover" a safe, workable ascent rate for themselves.

The current available data on ascent rates indicated that the slower ascent rates decrease the likelihood of bubble formation and that a shallow stop for a short period significantly decreases the risk of pressure related injury.

In-water oxygen decompression

There are well known decompression tables which employ oxygen in decompression.

Oxygen decompression decreases decompression time by 50% for 15 msw dives and 30% for 60 msw dives (Comex tables); and it has been reported that the incidence of DCS with 0_2 decompression was 2-3 times lower than with air decompression for dives of the same depth and bottom time.

Oxygen decompression was used in the excavation of a stone age shipwreck with dives to depths between 50-60 msw. Of the 7,500 air dives, there were 3 cases of DCS and no incidence of oxygen toxicity was encountered.

Suitable inter-dive surface interval

The actual surface interval for complete nitrogen clearance is unknown. The theoretical intervals from various decompression tables vary from 6 hours (Rogers), 12 hours (USN) to 18 hours (DCIEM). As the calculation of repetitive dives is dependent on the residual nitrogen load, one could hypothesise that with the appropriate rate of ascent and suitable decompression stops, the elimination of inert gas could be maximised and bubble formation minimised.

It is known that dissolved and free gases do not behave in the same manner and bubble formation is initiated by micronuclei. It was noted that bubbles were more numerous during the first ascent than the second during saturation dives, it has been postulated that this might be due to nuclei being used up and insufficient time for them to regenerate. Therefore, a suitable interdive interval may bestow some benefit to repetitive dives by a reduction in the number of bubbles. Repetitive dives might consume such micronuclei such that subsequent dives are made more safe by having less number of micronuclei to form bubbles.

In the Doppler studies, bubble grades tend to peak at or around 2 hours after surfacing. If, however, the surface interval was to decrease, the bubbles which were formed might be forced back into solution.

It has also long been assumed that "yo-yo" diving predisposes to DCI. However, a recent study refuted this. Although, Parker et al. using the USN 1993 model suggest that DCI risk of yo-yo diving might be higher if a large number of ascents (>10) were made. Perhaps the rate of ascent might play a major part, which has not yet been studied.

In the past the assumption has been made that when the surface interval is too short the bubbles which were formed on decompression could cross the pulmonary circulation, on recompression, and lead to serious forms of DCI. This has not been observed in the pearl divers.

Adaptation to decompression.

Adaptation is unlikely, as the pearl divers dive from 4 to 8 consecutive days, then have a break of 7 to 8 days. Also adaptation, in tunnel workers, was specific for each pressure, whereas, the pearl divers diving depths vary according to where the pearls are found, irrespective of depths.

In the analysis of the DCI cases, they seemed to occur at a random basis. It has to be said that at the beginning of the diving season, all the divers take particular care in avoiding DCI, as they seem to be aware that they are more prone to DCI after a lay off period.

The long term health effects of this mode of diving are not known. However, all the divers are obliged to have annual diving medical examination in accordance with the AS2299, including skeletal surveys. No abnormalities have been detected at this stage ()ctober 1994).

Conclusion

Compared to conventional decompression tables, at first glance, the PPA profiles appear to be grossly inadequate in their decompression stops (including oxygen

decompression), and surface intervals for their repetitive and multi-day diving.

However, this study has shown the profiles to be safe. The incidence of DCI has been less than 0.01%.

It appears that the most important contribution to the success of the PPA profiles is the slow ascent rate at 3 msw/minute. The pearl divers mode of diving would not suit other divers, but the profiles have made great contribution towards diving safety in repetitive and multi-day diving.

The profiles are being continuously assessed and evaluated.

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AN EXCELLENT SAFETY RECORD DESPITE THE RISKS

Rod Punshon

Introduction

PRO DIVE Cairns is one of the largest diver training centres in the world. We currently train, under the PADI system, approximately 4,000 divers each year. This number is made up of predominantly open water certifications (80%) with the balance being advanced or higher level training.

PRO DIVE Cairns has been in operation since September 1983 and has trained 35,000 (thirty-five thousand) divers to date. In addition to diver training, PRO DIVE also carry certified divers on their three day/two night live-aboard trips, approximately 1,000 per annum.

In conducting these activities, we can accurately calculate the number of dives carried out each year from our vessels as follows:

1 Divers under training, 12,800 per annum
2 Dives conducted by newly certified divers whilst on their certification trip, 16,000 per annum
3 Divers engaged in higher level training, 7,200 dives per annum
4 Certified dives (non-training), 10,000 dives per annum
5. Staff dives (Instructors), 5,000 dives per annum

Therefore, the total non-staff dives equal 46,000 and total staff dives equal 5,000, totalling 51,000 dives conducted annually, as multiple dives in multiple days, from our two vessels.

Dive location

Since our inception, all of our diving has been conducted at the same three reef locations on the Cairns outer reef. Common influencing factors at these three sites are as follows:

a Open water training dives are conducted in a maximum depth of 18 m, but all skills training is conducted between 8 and 12 m. Non-training and higher level certification dives are to maximum depth of 30 m (excluding deep dive training).
b Visibility is normally 10 - 30 m.
c All dives are conducted where current is less than half a knot.
d Temperature variates between 22 and 29°C in Cairns.
e All dives are conducted on the protected side of the reef where surface conditions are negligible even in reasonably adverse weather.
f All moorings have been strategically located to minimise the need for prolonged swims to the dive site.
g All equipment supplied is current model and undergoes a quarterly preventative maintenance program. 5 mm wetsuits are provided to all divers as part of their equipment.

Decompression illness

We have broken down our reporting of incidents into a six and a five year period, 1983 to 1989 and 1990 onward. Our reason for this was that in 1990, our Company Code of Practice and operational procedures was revised in light of current industry knowledge and practice.

In the period 1983 to 1989, we recorded 21 incidents of decompression illness (DCI) requiring treatment at the chamber in Townsville, which in those