SPUMS

STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 30th APRIL 1982

Opening Balance		
Investment Accounts - CBC Savings Bank Ltd	2234.36	
Investment Accounts - Mutual Acceptance Ltd (11.75%)	1000.00	
Cash at Bank - ANZ Banking Group Ltd	2856.43	
Cash on Hand	2.00	6092.79
Add Income		
Subscriptions	8311.79	
Interest Mutual Acceptance Ltd	126.72	
Interest CBC Savings Bank Ltd	248.84	
Refund - Balance of Conference Fees	1526.00	10213.35
		16306.14
Less Expenditure		
Secretarial Service	2586.50	
Post	1004.65	
Stationery	256.17	
Journal	3967.20	
Purchase of Filing Cabinet	112.50	
Bank Charges	83.36	
Design of Poster	200.00	8210.38
		8095.76
TOTAL FUNDS 30 April 1982		
Represented by:		
Investment Account CBC Savings Bank Ltd	2483.20	
Investment Account Mutual Acceptance Ltd (13.25%)	1000.00	
Cash at Bank ANZ Banking Group Ltd	4610.56	
Cash at Hand	2.00	$ 8095.76

AUDITOR'S REPORT

I have examined the above statement of receipts and payments for the South Pacific Underwater Medical Society and state that the statement gives a true and fair view of the financial transactions of the Society.

ROBERT G GODDARD
ARMIT (Com) FASA

SPUMS SCIENTIFIC MEETING 1982

DIVING AND ALTITUDE: RECOMMENDATIONS FOR DIVERS

Bruce E Bassett

There are many scenarios in which diving and altitude exposures are encountered either sequentially or simultaneously. Commercial divers on oil rigs may be flown by helicopter back to shore following air, mixed-gas or saturation diving. They may then proceed onward by commercial aircraft. Scientific divers may require air transportation following similar type diving throughout the world, as might military divers. In some military operations by such groups as the US Air Forces Rescue and Recovery Service or Forward Air Controllers, the US Army's Special Forces or the US Navy's Seal Teams, divers may need to be recovered by helicopter immediately upon surfacing from air or mixed-gas dives. The largest group of divers of all, the sport diver, may easily be lured into diving on the day of departure, by private or commercial aircraft, from vacations at dive resorts throughout the world. One such resort in the Bahamas even advertises, in the Skin Diver Magazine, "Two dives on day of departure".

Commercial divers may be called upon for construction jobs on dams located at high elevations. In some cases sport divers may reside at low elevations and drive to higher elevations to dive, or following dives in high altitude lakes may have to drive to even higher elevations in returning to their origin. This is common in Northern California divers who dive in Lake Tahoe. Likewise, military divers may dive in high altitude lakes located at or near some military operation, or may be transported to and from such locations by land or air.

The final scenario involves the transportation of diving casualties from remote locations by aircraft or over mountain passes by land transportation. Such casualties may include cases of decompression sickness or air embolism being transported to recompression facilities or travelling after recompression therapy. Injured or ill divers may also require transportation to definitive medical care facilities. The extreme within this category is the saturated commercial diver (or scientific diver) who becomes seriously ill or injured while saturated and requires transportation to appropriate medical facilities.

PREVIOUSLY EXISTING RULES

Procedures and Recommendations For Flying After Diving

One of the earliest recommendations regarding flying-after-diving that the author is acquainted with was a US Navy rule which specified that altitude exposures above 18,000 feet could not be made until 12 hours after any dive deeper than 30 feet. This rule, which was also used by the US Air Force, existed for military aircrew members up until the mid-1960's. In examining this rule it can be seen

that it allows very dangerous exposures, ie. deep dives followed by immediate ascent to any altitudes not exceeding 18,000 feet or long shallow dives (less than 30 feet) followed by immediate ascent to any altitude. This rule serves as an example of "experts" in aviation and aerospace medicine and physiology not being well enough versed in diving medicine and physiology to make sound judgements. It is noteworthy that at about this same period of time the diving medical experts at the experimental diving unit were using altitude exposures to 18,000 feet to test the "safety" of decompression schedules designed for "straight" sea level dives! The subjects were bending like pretzels and these tests were abandoned. The Naval Aviation rule was subsequently changed to specify no flying for 12 hours following any diving activity.

In the mid-1960's the US Air Force, which was then becoming involved in recompression chamber operations established an interval rule of 24 hours between any dive and any altitude exposure. This was not based on any evidence that 12 hours was insufficient other than the fact that the onset of delayed decompression sickness from altitude exposure had, in a few rare cases, exceeded 12 hours. To be safely conservative, the doubling of the Navy's recommended interval of 12 hours was arbitrarily chosen to protect the personnel working in the Air Force's hyperbaric chambers. This was also felt to be an adequate rule for aircrew members who might be sport divers. However, no thought was given to divers in the Air Force's Rescue and Recovery Service and this oversight created a major problem for that group for many years.

These military divers had two situations where this rule created real hardship. First were operations which called for direct helicopter recovery following dives made at sea level. These were generally special and limited operations for which revised no decompression limits were calculated to allow for direct ascent to 10,000 feet for a duration of four hours. The limits calculated and provided (by myself) always contained the notation that these limits had not been validated by manned testing. There were no reported problems with the use of these limits, but how often they were used and the details of their use were never reported.

The second problem area created was of a greater order of magnitude. Proficiency SCUBA dives are required for these divers, yet whenever they performed such dives they were grounded for 24 hours and could therefore not be scheduled to be on mission alert. In times of minimal manpower allocations this created much hairpulling by those tasked with training and scheduling of the pararescue personnel.

In 1969 Edel et al. reported their recommendations regarding flying-after-diving based on calculations and manned testing performed under contract to NASA. NASA's requirement existed because of water-immersion weightlessness simulation exercises conducted in conjunction with the Apollo programme. Astronauts were exposed on compressed air to depths to 50 fsw for rather lengthy periods, sometimes repetitively. NASA needed to know how soon after such exposures these busy astronauts could safely fly or be flown back to Houston or some other location. While the report to NASA contained such options as reducing the surface interval by breathing 100% oxygen, the recommendations that were picked up and promoted by various groups for various divers were that dives made exclusively within the no decompression limits of the USN tables during the preceding 12 hours could be followed by flight in commercial aircraft (cabin altitude not above 8,000) after a surface interval of two hours. If decompression dives were made, the surface interval requirement was increased to 24 hours. I have passed these recommendations along to thousands of sport divers. It became the rule adopted by, among others, the British Sub-Aqua Club.

The 1973 edition of the US Navy Diving manual states that divers must definitely not fly for at least 12 hours after diving with surface supplied air. No mention is made of restrictions regarding flying after SCUBA diving on air. No restrictions for any other diving in this edition of the manual may be found. In a later amendment the time restrictions were changed to two hours after No Stop air dives and 12 hours after air dives involving decompression. For saturation dives on mixed gas, 24 to 36 hours was the rule at the USN Experimental Diving Unit.

The Royal Navy Diving Manual takes a different approach and specifies surface intervals according to the altitude involved. For No Decompression dives the surface interval is under one hour before ascent to 1,000 feet one to two hours for 5,000 feet and over two hours for "unlimited" exposure altitude. For decompression dives the intervals are under four hours for 1,000 feet, 4-8 hours for 5,000 feet and over 8 hours for "unlimited". For saturation dives the interval is 48 hours.

The Canadian Defense and Civil Institute of Environmental Medicine rules are 12 hours for No Decompression dives, 24 hours for decompression dives and 72 hours to one week for saturation dives! Duke University, like the USAF, specifies 24 hours for any dive and 72 hours to one week after saturation.

Now we come to the rule most widely promoted in the Sport Diving community and also in the second edition of the NOAA Manual. This rule specifies that flights can be made in commercial aircraft as long as the USN Repetitive Group is no higher than D. This has two interpretations. If one surfaces from a dive with a D group then immediate ascent to altitude can occur. If a higher Repetitive Group is incurred, a surface interval which allows decay to a D group is specified. NOAA, also being concerned with saturation diving, specifies 36 hours before flight following such exposures.

Procedures and Recommendation for Diving at High Altitudes

Most professional/military organizations have ignored this problem. Thus there have been no USAF, USN, Canadian or University rules for this specific decompression

problem. Sport divers seem to have come to grips with this problem due to diving in such locations as Lake Tahoe. One Sport diving publication, *Skin Diver Magazine*, reported on a procedure for diving at high altitudes in the late 1960's and again in the early 1970's. This procedure, which was apparently first promulgated by a Frenchman, came to be called the "Cross correction" after ER Cross who published the procedure in the Technifacts column in *Skin Diver*. This procedure attempts to compensate for surfacing from a dive at a pressure less than one atmosphere by reducing exposure limits for depths. It does so by assuming the dives at altitude are performed at greater depth than sea level. A factor is calculated from the barometric pressure at sea level divided by the barometric pressure at altitude, which always gives a value greater than 1.0. This value is then multiplied by the actual depth to give a "High Altitude Compensated Depth", which is greater than actual. This procedure, while never validated by manned testing, has apparently been used by many sport divers. It has also been recommended as a procedure for flying immediately after diving. In this application you dive at sea level as though you were at altitude thus reducing your limits or increasing your decompression obligation.

In 1976 the Swiss reported on man-validated Air Decompression Tables for different altitudes. As an example of their tables, a dive to 60 feet at an elevation of 8,100 to 10,500 feet would have a no-decompression limit of 5 minutes, but in fact all their "no-decompression" limits involve a three minute stop. In this altitude range the stop is at 7 feet.

RESULTS OF RECENT STUDIES

Altitude Diving

In 1979 Bell reported on dives tested at Lake Tahoe, both in chambers and in open water. His derived limits at 6,000 feet were 40/148, 50/84, 80/30, 100/19 and 160/5. In 168 exposures in 15 subjects no bends were encountered, nor were circulating bubbles detected. The results of these tests are very surprising when his limits are so drastically less conservative than others. This is the only recent work done or reported on diving at altitude. The Swiss tables continue to be used by the Swiss and they report no problems.

Flying After Diving with a Surface Interval

In 1979 Balladin reported on manned tests involving no-decompression dives (50/100 or 130/10), a surface interval of three hours, followed by exposure to 10,000, 6,000 or 3,000 feet for two hours. While no cases or bends occurred, 60% had venous bubbles at 10,000 feet, 30% at 6,000 feet and 10% at 3,000 feet.

Flying After Diving Without a Surface Interval

My experience is in the situation of flying immediately after diving. A validation test programme was conducted during 1979-1981 which exposed a total of 59 subjects to 110 tests of six dive schedules followed by immediate ascent to 10,000 feet for four hours. The dive schedules were 130/7, 100/10, 80/14, 60/20, 40/34 and 10.75/1440. These exposures resulted in 6.4% early termination for bends or serious intravascular bubbling. Of the remaining subjects who were then taken to 16,000 feet for one hour, an additional 4.8% experienced bends or serious bubbling. When the altitudes were lowered to 8,500 feet and 14,250 respectively, the termination rates in 28 subjects on 57 tests of three dive schedules, were 0% at 8,500 feet and 5.2% at 14,250 feet. In the 10,000/16,000 feet tests the overall bends incidence was 4.6% and serious bubbling was 6.4%. In the lower altitude tests they were 1.8% and 3.5%.

Flying after Saturation Diving

No manned testing has ever been performed in this area aside from my 10.75/1440 flying after diving exposures. In the areas of deep oxy-helium or shallower nitrox saturation dives no tests have been conducted. The rules previously described have been based on gut feelings or occasional case histories of "hits" during flight in previously saturated divers.

Edel has recently provided guidelines for either the use of surface oxygen breathing to reduce the surface interval before flight following Nitrox and Heliox saturation, or modification of the final stages of saturation decompression for the same purpose. As an example, six to 12 hours after a nitrox saturation dive, oxygen would be breathed for four hours (on a 60/15 intermittent schedule) and flight could follow five hours later. Thus the surface interval would be from 15 hours 45 minutes to 21 hours 45 minutes. These procedures, generated by Edel's AUTODEC program and supplied to the Association of Diving Contractors have not been validated by manned testing.

RECOMMENDATIONS RESULTING FROM A RECENT WORKSHOP

In January 1982 a workshop was sponsored by the UK association of Offshore Diving Contractors and the Diving Medical Advisory Committee in response to questions posed by air carriers transporting commercial divers from operations in the North Sea. This two day affair consisted of a review of the data and of the rules, recommendations and procedures discussed above, followed by operational inputs from diving contractors, vigorous discussion and finally a set of recommended guidelines. The proposed guidelines are detailed in Table One.

COMMENTS ON THESE RECOMMENDATIONS

Air Diving

All in all I feel the recommendations proposed by the workshop are adequately conservative. The few areas of concern involve the question of just how long bubbles,

once formed, persist and/or how long do they continue to form once initiated. There is anecdotal evidence from case histories that this may involve exceptionally long periods, in excess of 48 hours, in at least some cases. In two studies cited, those of Balladin and myself, there is evidence that asymptomatic and/or undetectable bubbles persist for at least three to four hours after dives made to the no-decompression limits which then become detectable and may produce symptoms with an ascent to only 3,000 to 4,000 feet altitudes or elevations. In the case of my findings and those in other laboratories as well, the change that may be necessary is a revision of the dive limits with or without the addition of "safety stops" for no-decompression dives.

TABLE ONE

SURFACE INTERVAL ON AIR BEFORE FLIGHT TO A MAXIMUM CABIN ALTITUDE OF:

		2,000 ft	8,000 ft
AIR DIVING			
a.	No Stop Dives Total time under pressure less than 60 minutes within the previous 12 hours	2 hrs	4 hrs
b.	All other Air Diving (less than 4 hours under pressure)	12 hrs	12 hrs
c.	Air or Nitrox ** Saturation More than 4 hours under pressure	24 hrs	48 hrs
	** Caution		
MIXED GAS		12 hrs	12 hrs

DYSBARIC ILLNESS

Time from Completion of Therapy

		2,000 ft	4,000 ft
a.	Successfully Treated	24 hours	48 hours

b. Residual symptoms after treatment or flying restrictions to be decided on an individual basis by a diving medical consultant.

Regarding decompression dives on air, there is no published evidence that these are more likely to produce problems, and yet the restriction for exposure to altitude is greater by a factor of three to six fold. The twelve hours restriction here however, as with mixed-gas diving, was based on operational considerations more than scientific evidence. That is, most commercial offshore operations require a twelve hour observation period at the site of the chamber following such dives. So why reduce it, especially since no laboratory evidence can be offered to justify a change?

The restrictions on altitude exposure following Air or Nitrox saturations were almost totally pulled out of thin air. No laboratory data and little operational experience exists to back up or refute the recommendations. This was an acknowledged deficiency recognized at the workshop, and resulted in a "caution" note being added to the 48 hour restriction for such dives.

Mixed Gas Diving

Since no human laboratory evidence is available, the restriction here was based 100% on the operational input. That is, there have been no problems reported following operational dives, be they surface supplied, bell operations or saturation exposures, with the 12 hour "bends watch" being the standard. The anecdotal evidence of problems arising during flights after saturation, with much longer surface intervals than 12 hours, were discounted because they occurred following "experimental dives" as opposed to "operational dives". The bottom line was basically "who can argue with success?" In view of the lack of hard evidence to the contrary, the answer is obviously, "no-one!"

Dysbaric Illness

Since provisions do exist in the North Sea for the evacuation of injured or seriously ill divers under saturation (at least to about 750 fsw), this problem area was not considered at the workshop. Variations on this problem are thus left to those individuals charged with the medical responsibility for such operations, be they scientific, experimental or operational (ie. in areas other than the North Sea). Rigid physical screening of divers, safety engineering considerations, safety review board considerations of procedural aspects, and luck are on the side of those responsible as well as the diver's side. Murphy's Law is on the other side along with the postulate which states that Murphy was an optimist! Donald Boon of Taylor Diving and Barry Cannon of the US Navy are evidence of the latter.

Regarding successfully treated cases of dysbaric illness, the restrictions are again based on little more than an educated guess. And for the untreated case or those with residuals, it is back in the laps of those charged with such decision making responsibilities. That is the price paid for being a member of a small, elite and unrecognised group of medical specialists.