

TREATMENT FOR AIR EMBOLISM AND  
DECOMPRESSION SICKNESS

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There are quite a variety of treatment procedures used around the world, however the most widely used are the US Navy oxygen treatment tables. There are saturation tables, there are French tables, there are British tables, the Russians have an air recompression table, I believe it goes to 380 feet and lasts 82 hours. Someone collected all the treatment tables from around the world and published them. Some of them are rather bizarre.

The US Navy Diving Manual several years ago had four minimal compression, 100% oxygen treatment procedures that were developed in 1965. Tables 5, 6, 5A and 6A have been the basis of most recompression therapy around the world. Table 5A is no longer in the manual, I do not know anyone who uses it anymore. 5A was a short table for air embolism and everybody agrees it is too short. So now we are down to three tables. We do not use Table 5 which was originally designed for mild decompression sickness (DCS), pain only cases, as initial treatment anymore. We are sick and tired of waking up at three in the morning the following night and doing retreatments when Table 5 has failed and it fails frequently. So rather than do a Table 5, which is only about 2 hours and 47 minutes, our initial treatment is a five hour table. I would rather do a Table 6 right away and not be awakened the following night to do a retreatment which you have to do with Table 6 anyway. If we believe an individual has decompression sickness our minimum initial treatment is a Table 6. So now we are down to Tables 6 and 6A. To them we add extensions.

Figure 1 shows Table 6A as used at Catalina. The only difference between Table 6 and Table 6A is the half hour excursion to 50 msw (165 feet). I have already mentioned why we use Table 6A - it works. There is a controversy at the moment about whether it is valid or not. The fact remains that clinically one sees incredible improvement. I feel we are bound to continue the practice until there is good evidence that it is unnecessary.

We do not use air at 50 msw (165 feet). We give them a mixture 53% nitrogen and 47% oxygen which is the equivalent of 100% oxygen at 18 msw (60 feet). It is a repetitive dive, but less nitrogen is taken up than when using air. When these tables were originally devised the extra nitrogen taken up on air was calculated into the whole scheme of decompression for the diver and the tenders. We have been giving nitrox for at least 10 years to all of our air embolism cases. Incidentally in Hallenbeck's articles on air embolism in dogs, it was air at 6 atmospheres that was used not nitrox.

Basically the treatment consists of repeated 20 minutes oxygen periods, with five minute air breaks. A straight Table 6 or 6A consists of three oxygen periods at 18 msw (60 feet) and 6 at 9 msw (30 feet). The ascent 18 msw (60 feet) to 9 msw (30 feet) and from 9 msw (30 feet) to the surface is 1 ft per minute. It is an extremely slow ascent and it is on 100% oxygen so these are 30 minute oxygen periods. One has options to extend, depending on the clinical condition of the patient.

We have made an additional change in that while the US Navy manual does not require the tenders to breathe oxygen at any time, we do. We have followed the US Air Force example which is that depending on

the length of the table we put our tenders on oxygen in the latter part of the treatment table. The reason is that there have been so many cases of DCS in the tenders in other chambers that I think it is warranted. In 554 treatments we have bent one tender. He was on an extended table and he did have a beard, I do not know whether he put his mask on correctly or not. Whatever the reason for his DCS we had to turn around and treat him. We have talked to the US Navy and other people who do not use oxygen for their tenders. They bend their tenders often. I find that objectionable, trading one patient for another does not add up in my simplistic mind. Also we use 20 minute oxygen periods and 5 minute air breaks throughout. The USN manual at 9 msw (30 feet) says 60 minutes on oxygen, 15 minutes on air. There have been several cases of oxygen toxicity in those 60 minutes. We give the same amount of oxygen with shorter air breaks. The purpose of the air breaks is to ward off oxygen toxicity. If one does not give air breaks the maximum treatment time available is 1.5 hours. That is insufficient for bubble resolution which is the objective of the treatment.

For decompression sickness there is Table 6 and Table 5. We do not use Table 5 as initial treatment anymore. Many years ago we took the tables from the manual and rearranged them into a frame that we found easier to use (Figure 2). At first glance it probably looks confusing but it is really quite simple. The thick black horizontal lines are the 20 minute O<sub>2</sub> periods, in between them are the 5 minute air breaks. In fact at our chamber we have stopped talking about Table 5, or Table 6. We talk about how many O<sub>2</sub> periods at what depth. It is more valuable to me to find out if that patient was treated on a four and nine, meaning that he had four O<sub>2</sub> periods at 18 msw (60 feet) and nine at 9 msw (30 feet). We found out early on that a number of our spinal cord patients who had been treated with a Table 6 still had symptoms so one added another oxygen period which is what we refer to as an extended Table 6. The symptoms still had not resolved. According to the manual one has to proceed on up at this point. If the patient is still paraplegic the manual allows one to repeat an extended Table 6. The next question was, why bother surfacing, why not hit them with the maximum immediately, and try to give it as soon as possible, rather than coming to the surface and then going back down and repeating. I am talking about patients who are paraplegic with very severe spinal cord decompression sickness. So we checked with the experts on oxygen toxicity whether we could do a double extended Table 6 continuously rather than surfacing and doing it again and the answer came back "Yes, you can". This was about 10 years ago. and we have been practising it ever since. We start at 18 msw (60 feet) on oxygen then we examine the patient every air break. Every air break they get a complete neurological examination. I should point out at this point that over 85 per cent of our patients are spinal cord decompression sickness.

Any person in our crew can do a neurological examination. Not to the extent that the physician or neurologist does, obviously, but in most cases to an adequate level. In our training course for chamber crew, the nurses and anyone else, we spend a great deal of time going over how to do a neurological examination for decompression sickness and air embolism. We get very specific and practice it a great deal. Most of the time there is either a paramedic or a nurse inside who does the actual examination. Most of the time you zero in on the particular area of the body that is afflicted and it does not take that much expertise to follow through on it. The initial examination is done by a physician in some cases, but in many



cases not, because the physician may not arrive for two hours. The first thing he does is walk in and does his own examination to verify what has already occurred and then he walks back out.

The physician is rarely in the chamber. The physician with many, many treatments never goes to the chamber, he is outside. We only have one physician at one time. One of our basic principles is if he is in the chamber his decisions are not valid because of narcosis. When he is in the chamber we pick up the phone and call his back-up in Los Angeles and verify all his decisions. We do not like having to do that so we keep the physician outside, except to do thorough neurological examinations and then we just simply walk them in and out and make repetitive dives.

We have very very few pain only bend cases, which is opposite to what the US Navy sees. The Miami Chamber has similar proportions to us. The main reason is assumed to be that sports divers if they have an elbow pain will not go to a chamber, whereas a Navy diver will. The other possibility and we have found this over and over again, is that if one does not do a very thorough neurological examination on a patient with a pain only bend one will miss neurological signs in that patient. The patients are not aware of some of the neurological losses they have. They may walk in with an elbow pain but on a thorough neurological examination one finds a slight weakness in one leg or sensory loss in one arm or what have you. It is no longer a simple case. We proceed at 60 feet until they have either totally resolved or resolved to a major extent, whatever that is. At some point one makes a judgement to come up to 9 msw (30 feet). We go period by period and we can go up to 8 periods at 18 msw (60 feet). The periods at 18 msw (60 feet) are followed by mandatory periods at 9 msw (30 feet). For example, with Table 6, there are three periods at 18 msw (60 feet) and six must be done at 9 msw (30 feet). Table 6 we refer to as a three and six. An extended 6 is four periods at 18 msw (60 feet) followed by a mandatory nine at 9 msw (30 feet), that is a four and nine. Five deep periods obligates 12 periods at 9 msw (30 feet) and so on. The maximum that was determined we could do was 8 periods at 18 msw (60 feet) and 18 at 9 msw (30 feet), that is an eight and eighteen. There is a big question mark oxygen toxicity beyond that. Actually oxygen toxicity starts occurring to significant degree towards the end of the table. Many of our patients develop pulmonary toxicity. That is nothing to get excited about. We continue. We may choose at some point to say "at the end of this period we will go ahead and terminate treatment", but it is nothing to get overly excited about. Oxygen toxicity is reversible. We are on a fine edge of trying to cure a severe illness, and we are trying to hit the bubbles as hard as possible and as early as possible. Philosophically we are willing to push pulmonary oxygen toxicity to the limit. There are other people who are not willing to do this. That is a matter of some discussion. We have done eight and eighteens probably 30 or 40 times. It is a 12 hour table and I am impressed with the results, I cannot give you the exact numbers because we have not worked them out statistically yet but I have to say I am impressed with the results.

If we do an eight and eighteen or an eight and twelve or something in between we can say that patient has had a sufficient dose of oxygen toxicity. We will not retreat them for at least 24 hours to give their lungs a rest. On the table we have instructions about the tenders going on oxygen. Up to a three and six (Table 5) they go on oxygen for the ascent to the surface of 30 minutes. Between a three and six and a four and nine they go on oxygen for 30 minutes prior to the

ascent plus the ascent to the surface, which is a total of minutes. Beyond a four and nine they have 90 minutes of continuous oxygen, 60 minutes at 9 msw (30 feet) plus the 30 minutes ascent to the surface. Sometimes it is difficult to decide whether there has been an adequate response, or whether one needs to continue treatment.

Let us take for example, someone who comes in with an objective weakness on one leg, some muscle groups, and perhaps some abnormal reflexes and pain elsewhere and perhaps a minimal sensory loss of some sort. The typical situation is you go down to 18 msw (60 feet) and within the first oxygen period the pain has gone. He may have lost his sensory deficit very quickly, but the weakness in his right leg is still somewhat there. We go out to three periods and at the end of that time he is re-examined. He still has some abnormal reflexes, he still has some weakness in the leg. So we choose to go another 0<sub>2</sub> period, we go four periods because we consider his DCS is serious. As the signs are still present we add a fifth period. At the end of the fifth period perhaps it has all improved slightly but it is still there. We go onto a sixth period, after which it is better but not completely gone. We may go a seventh period, after which it has diminished to the point where it is hard to tell whether there is anything there. We may choose at that point to come up to 30 feet because we know we have a long time to 30 feet yet to go. We do not arbitrarily stay down because we know that we are going to push this patient's lungs into oxygen toxicity. We do not want to overdo that if we can avoid it. So for so many periods we go up to 9 msw (30 feet) and we now are locked in to 12 periods at 9 msw (30 feet). At the end of the 12 we do a very thorough neurological examination again. We have done neurological examinations all along but at that point we do a very thorough one. However at that point suddenly we find the weakness is back. We have the choice of continuing at 9 msw (30 feet) or going back down to 18 msw (60 feet). For one more period to 60 I do not think we would choose to do that. We would simply extend to 9 msw (30 feet). But if we had only done three at 18 msw (60 feet) and there is a recurrence of some sort we would go back to 18 msw (60 feet) and do as many extra periods, up to 8 in all, as we feel are necessary. Our treatment is a decision process based on neurological examination and assessment of progress. One of the reasons why I object to monoplace chambers and most two-man chambers, is that one cannot do an adequate neurological examination in those chambers. Our whole treatment is based on neurological examination otherwise how do you know where you are. That is a point that is often missed by those that have never treated a patient in a chamber.

Now if at the end of an eight and eighteen or some long table, the patient is still paralysed or has severe symptomology we will wait 24 hours before retreating him. Usually we fly him back to the hospital, have a neurologist look at him and do a complete work up and then he goes back to the chamber. Our approach is to give Table 5s. We call them retreatments. Follow up treatments perhaps is a better term. We give Table 5s every 12 hours. Table 5 is two 0<sub>2</sub> periods at 18 msw (60 feet) and one at 9 msw (30 feet), a short table. The idea at this point is that the bubbles are gone and that we are dealing with oedema and hypoxia. In the spinal cord cases we assume we are dealing with spinal cord oedema and hyperbaric oxygen presumably is of value in that situation. So we do follow up treatments. We stop follow up treatments where the patient stops improving, or when the patient's lungs reach a point of oxygen toxicity where they really have a difficult time continuing. The most we have done was 15 treatments in 8 days after the

# CATALINA MARINE SCIENCE CENTER

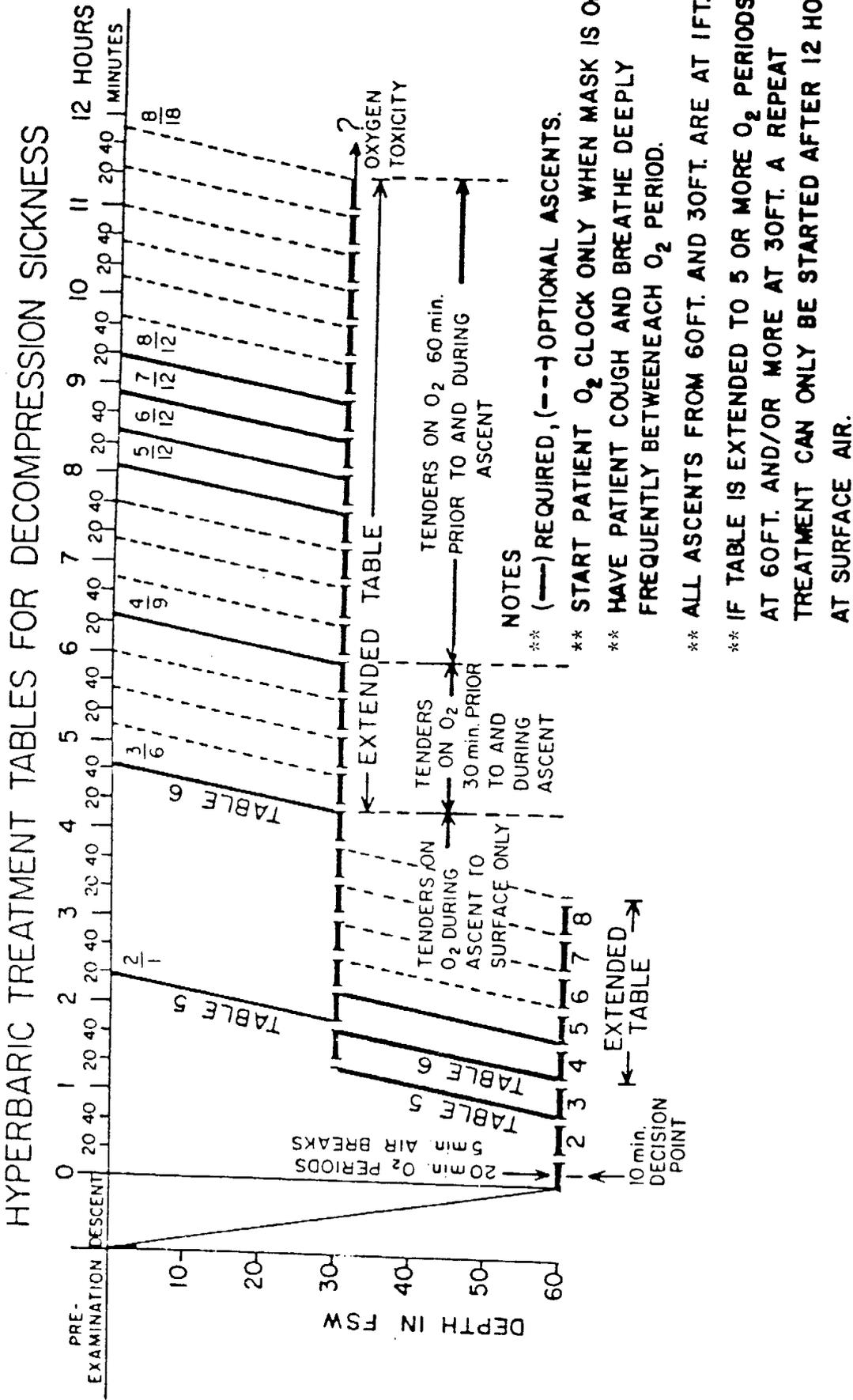


Figure 2. Hyperbaric tables used for treating decompression sickness at the Catalina Marine Science Center.

USE WHEN 165' EXPOSURE IS BETWEEN 30 - 120 MINUTES

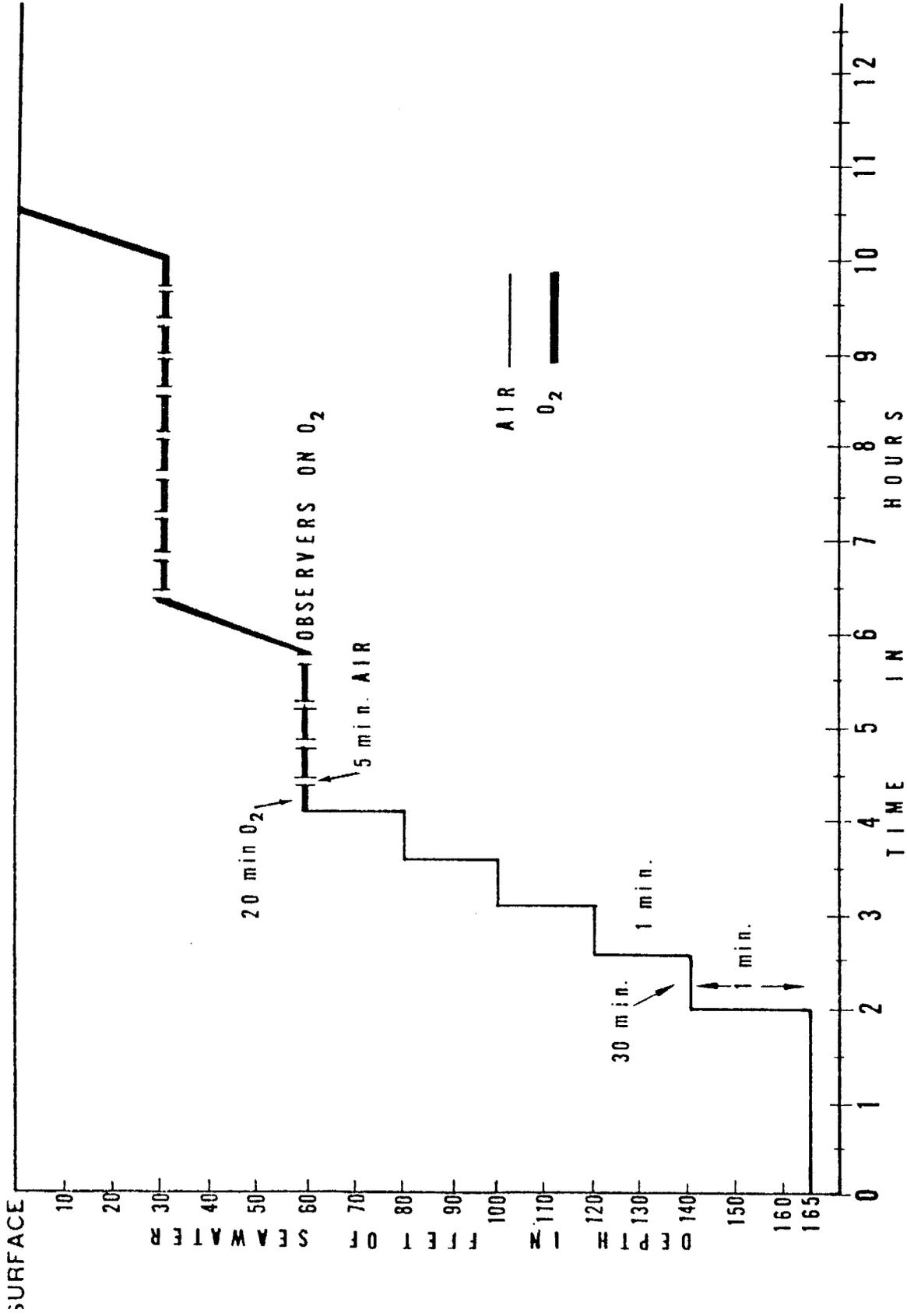


Figure 3. Modified USN Table 6A prepared at the Catalina Marine Science Center for use when the period at 165 fsw exceeds 30 minutes. This table has never been used.

initial extended treatment. We got substantial improvement. He came in with nothing below the nipple line. He had some good improvement in initial treatment. Then very, very slowly with each retreatment the neurological deficit moved down. At the end of 15 treatments he had gained bowel and bladder control. At that point there were other factors that entered the picture. He was suicidal, he needed physiotherapy, the improvement that we were seeing had diminished. He needed other treatment more and at that point we stopped.

The question is often asked, "do you go beyond 30 minutes on the air embolism 6A table at 50 msw (165 feet)?" In our 12 years of experience we have never kept an air embolism patient longer than the half hour at 50 msw (165 feet). I hope we never will. The only way we would is if on ascent from 50 msw (165 feet) to 18 msw (60 feet) he became critical, he was literally dying. It would take that extreme situation for us with our philosophy to keep him at 50 msw (165 feet). We have brought all our patients from 50 msw (165 feet) to 18 msw (60 feet). We have never had a problem with that.

I do know other chambers that do have a problem and have been forced to go back down to 50 msw (165 feet), so we asked ourselves the question, "What are we going to do". If you look in the book it says use a Table 4. I never want to use a Table 4, I do not want to subject my tenders to a Table 4 and I do not want to subject that patient to a Table 4. It is a 38 hour table that has about a 50 per cent incidence of bending the tenders. We looked around for another answer and what we came up with was that for anything from a half hour to two hours of bottom time at 50 msw (165 feet), we would use what is in Table 4 up to 60 feet (Figure 3). That is you go up in increments of 6 msw (20 feet), spend 30 minutes at each of those depths until you reach 18 msw (60 feet). At that point we would enter the equivalent of an extended Table 6, that is 4 periods at 18 msw (60 feet) and 9 at 9 msw (30 feet). We have never used this table. It is a contingency table that we keep around. I hope we are not forced into it but this is the route we would take rather than use a Table 4. One thing that worries me tremendously, is the observers (tenders) must start 100% O<sub>2</sub> at the start of the ascent from 60 to 30 and stay on it for the rest of the time. That is a lot of oxygen. If I ever use this table I would probably give some air breaks. In any event we have not used this table but it is available in the back of the book.

A Test of Pressure is very handy with patients who are borderline. Do they have DCS or not? One goes through all their history and examinations. They had or have some subjective sensations that come and go. Their dive profile is marginal and hard to define. One cannot identify any other reason why they are having this pain. One does not know whether to go ahead and treat them with a Table 6 which will take four hours and 40 minutes. In those cases we sometimes chose to do a test of pressure. We will compress them to 18 msw (60 feet), do one 20 minute period of O<sub>2</sub> and then ask the question, "Has anything changed?". If anything has changed, even in the slightest, we assume it is a bend and continue with Table 6. With one O<sub>2</sub> period at 18 msw (60 feet) one may not eliminate the pain totally if it is a bend, but there should be some change, either in location, or in intensity or some subjective manner. So, if something changes for the better we assume that it is decompression sickness and treat it. If absolutely nothing changes and it is a real borderline situation, we simply bring them to the surface and send them home. In many cases this procedure is useful also in convincing sports divers to come to the

chamber, otherwise they simply will not show

Our chamber has very small pipes for its volume size, the result is we come up slowly whether we like it or not.

## SUMMARY

We do not use 5A, and Table 5 is used for retreatments only. We push the patients to the threshold of oxygen toxicity in serious cases. We re-treat with a Table 5. Tenders are decompressed on oxygen. We only use 20 minute O<sub>2</sub> periods and 5 minute air breaks. We never use air treatment tables nor saturation treatment. There has been a lot of discussion and some practice saturating patients with severe air embolism and decompression sickness in the chamber at different depths. The depth depends on which facility you talk to. There is a recent paper that went through 20 years of experience of saturation treatments that have been done. Basically that survey showed that they did nothing better than what one would do with a straight Table 6 approach. I do not believe in going deep. There are certain individuals in the field who like to go to 57 msw (190 feet), or 63 msw (210 feet). The Hawaii group, in severe cases, will saturate at 18 msw (60 feet) and once a day or twice a day bounce that patient a very short run to 63 msw (210 feet) and back up to 18 msw (60 feet) continuing that procedure for about 3 to 7 days. I think it is beyond the scope of this meeting to go into the reasons why they do it and what the arguments for and against are. But I would just point out that there are certain groups that do practice both saturation treatment and deep excursions. We are one of the groups that does not. Our deepest is 50 msw (165 feet) for half an hour for air embolism. We are believers in oxygen rather than depth.

## REFERENCES

Hattori T. Scuba accidents on the Monterey Peninsula and experience with a single lock chamber. 1971-1981. SPUMS J 1983; 13 (3): 10-15.

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## DIVING SAFETY MEMORANDA

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### DIVING SAFETY MEMORANDUM NO. 4/1986 McKISSICK SNATCH BLOCKS (418 AND 419 SERIES)

The following Safety Alert was issued on 25 June 1986 by the Operations and Safety Branch of the Department of Energy. As the Diving Industry does not normally receive these Safety Alerts the text is being copied in this memorandum.

1. An incident occurred recently on an Offshore Installation when a 419 series snatch block failed during a load test.

2. The Department of Energy is currently investigating the incident in detail but in the meantime the following recommendations are made:-