SAA/CMAS Decompression Tables with Micro-bubble control using DeeP-Stops

An Overview and Brief History

It's more than a hundred years since Haldane, Boycott and Damant produced their earth shattering paper on decompression, entitled "The Prevention of Compressed Air Illness". The information and advice contained within those pages changed the world of diving for ever. Almost at a stroke, Compressed Air Illness was looking to be a thing of the past. However, a century later Compressed Air Illness, or as it is now called Decompression Illness (DCI) is still around and researchers still seem confused.

Haldane and Co had worked out that during a dive; nitrogen is loaded into the tissues of the body and provided that the depth and duration of the dive was controlled correctly. He set the maximum tissue gas loadings as a ratio of not more than Two to One (ie the internal tissue pressure did not become more than twice the ambient pressure), everything would be alright. Since those early day researchers have tried to improve on this idea and give us safer diving.

Whilst diver safety was of great concern, extending bottom times for commercial reasons also became very important. Haldane's original five tissue compartment and his 2:1 ratio were fiddled with and adjusted in an attempt to obtain improved results. Furthermore, over the intervening years researchers have played with bottom times, ascent rates, tissue compartment half-times, and tissue compartment gas loadings called M-values (short for maximum values). Despite some modest improvements, all have failed to achieve the desired results: the elimination of DCI ie the "Bends". In short we are no closer to the root cause of the problem.

What we do know to be true is that Haldane told us DCI involved gas bubbles in the blood and/or tissues. However, we also now know that many dives produce micro-gas bubbles in the venous blood, despite the fact that most dives do not produce DCI.

What is also clear is that all divers with DCI have gas bubbles in their system. The type of illness produced seems to depend upon the size, number and location of these troublesome bubbles, the disturbance they cause to blood flow, the mechanical effects on tissues including nerves and changes in body chemistry.

The frustrating and annoying question that remains is: What turns a non-DCI bubble into a DCI. Is the problem the bubbles or is it the chemical changes that occur as a result of the bubbles?

Current thinking is that the bubbles are the culprit . . . but don't ask how or why, we just don't know! That being the case, what can do we do about it? Stop diving! . . . clearly that's a ridiculous solution. Let's take a closer look at some recent developments.

We know that most ordinary dives cause the production and growth of micro-bubbles. These micro-bubbles are washed by the venous blood circulation to the lungs where they become trapped in the very small blood vessels of the alveolus. The gases held within these micro-bubbles cannot directly exit the body: they have to diffuse back into the blood to enable them to be exhaled. During the time that these micro-bubbles remain in the lungs they, in effect, create a local traffic jam slowing the elimination of the excess nitrogen both in solution and the bubbles.

Traditional methods of decompression, such as the Royal Navy's decompression tables, were devised by testing decompression algorithms on animals and divers until a reasonably safe system was devised. At the time that these tables were designed and introduced, micro-bubbles had not been directly accounted for because there was no means of doing so. We now know that this means the bottom times and decompression stops set by this type of table include an unknown level of micro-bubble production and growth.

In subsequent years, researchers such as Walder, Spencer, Bühlmann and others recognised the importance and the effects of micro-bubbles on the elimination of nitrogen and reduced their bottom times with respect to those times allowed by the RN Navy Tables in an attempt to limit the production and growth of micro-bubbles. Furthermore, they reduced the rate of ascent to 10metres/minute and introduced the concept of safety-stops. This further reduces bubble production and growth. However, even these systems still allow micro-bubbles to develop.

The relatively recent development of "free-gas or bubble" algorithms is an attempt to reduce, still further, the production and growth of micro-bubbles. Some systems employ stops that are deeper than those required by the more traditional methods. The theory is that micro-bubbles, when very small, have a very high surface tension (or outer skin tension). At high surface tensions the gas within the bubble will tend to diffuse out through the permeable skin more quickly. To maintain the micro-bubble's relatively high surface tension the diver is required to make a short stop(s) {ie dwell} deeper than traditional systems require.

Deep stops act to maintain the MB surface tension and allow the contained gas to diffuse back into the blood, reducing bubble size and still further increasing MB out-gassing, which may cause them to collapse and even, if you're lucky, make them go away.

If this is successful, there will be less micro-bubbles arriving in the lungs during the shallower stops and thus dissolved gas will be eliminated quicker than with traditional decompression, and some say that this allows these stops to be shorter than would otherwise be possible, although don't try this at home.

Traditionally, however, divers are brought up to relatively shallow stops to create a pressure gradient that causes the nitrogen in solution to off-load quickly. Deeper stops are at odds with this idea. For this reason, there is a conflict between deep stops which control micro-bubbles but which may also allow some on-gassing, and the traditional stops which allow gas in solution to off-load quickly, but may cause micro-bubbles. The solution is a trade-off or compromise.

The Current Situation

Many thousands of Technical divers have been including deep-stops in their dive profiles to ward-off the effects of micro-bubbles. The divers on the British expedition to explore RMS Britannic also used the deep-stop concept to limit and control micro-bubbles. Subsequently, a number of major personal decompression computer (PDC) manufacturers have installed micro-bubble calculations into the algorithm of their PDCs. Only recently have the medical researchers of DAN Europe, under the guidance of Professor A Marroni, conducted experiments to determine the value, if any, of deploying deep-stops to limit micro-bubble production and growth. The results of this work point the way forward to include deep-stops as a method of micro-bubble control.

SAA DeeP-Stop Programme

As the SAA Decompression Officer, the SAA's representative on the CMAS Technical Commission and Technical Director of that Commission I have a duty to keep abreast of decompression developments and to evaluate them with a view to improving the safety of our training and diving within the SAA. This also involves keeping an eye on accident statistics both at home and abroad.

In the UK the number of treated DCI case reported in the National Annual Incident Report has been steady at less the 200 per annum. In general the number of cases reported rise only in response to weather condition: the better the weather the more people go diving therefore there are more cases of DCI requiring treatment. In recent years the reports have highlighted a trend in diver error. They show that between 36 and 43% of all DCI cases involve fast ascents of one kind or another. And within this number there are between 14 and 18% that involve faulty BCD/Dry suit inlet and/or outlet valves. Furthermore, around 10% of divers presenting for DCI treatment have a shunt of one kind or another {Patent Foremen Ovale (PFO) or Pulmonary Arteriovenous Malformations (PAVMs) ie a lung shunt or a by-pass in the lungs}. This is becoming increasing important because divers and others will be unaware that they have such a condition. Unfortunately, there is no non-invasive PFO/PAVM testing method, and doctors won't routinely test for them during normal diver medicals, because of the risks and cost involved. So, in general, most people with a PFO/PAVM find out only after suffering an unearned DCI.

With this relatively new information in mind I felt that we should try to do something to reduce the risk to our recreational divers. The genie is out of the bottle and can't be ignored. What to do? Well that's a good question. There are diver behaviour factors that can be introduced that may reduce the risk of micro-bubble production and growth one of which is, you've guessed it, DeeP-Stops. There are other factors and I've included them in Chapter 4 of the SAA Bühlmann DeeP-Stop System.

The deep-stop table programme was produced in conjunction the CMAS who stumped up the money for the development. This programme cost the SAA nothing!

We used Albert Bühlmann's ZHL16B Table algorithm as the primary system, because it has proven to work so well in the real world of diving. I was insistent that we should not exceed any of the safety parameters set by Bühlmann, so the critical tolerance (some might call them M-values) remain the same as does the 10 metre/minute maximum rate of ascent.

We trailed a number of deep-stop times including half a minute, one minute and two minutes. The half minute stop made little impression and the two minute stop impinged too much on subsequent dive whereas the one minute deep-stop gave a good compromise.

This approach has reduced the average ascent rate without slowing the exit ascent rate at the end of the bottom time eg For a 30 metre safety-stop dive using the SAA Bühlmann System the average ascent rate would be (30/three minutes for the ascent + one minute for the safety -stop = Average Ascent Rate 7.5 metres/minute. For the same dive but using the new Deep-Stop System (30/ 15/1 + 9/1 + 6/2 + 3 = Average Ascent Rate 4.28 metres/minute).

In fact, in general, this caused the leading tissues (ie those tissues that determine the surfacing time) to move one or two compartments to the right thus lowering the tension in the faster compartments. This is a good thing and it also lengthens the surface interval (SI) required between dives. Keep in mind that a SI is a zero metre decompression stop during which you not only off-gas dissolved nitrogen but you dissipate the free-gas (micro-bubbles). In general the longer the SI the safer the next dive will be. It takes around three hours to eliminate most micro-bubbles. As a trained diver, it is your job to use the advantages gained by this system to better protect yourself from DCI.

Furthermore, this all works to the advantage of all divers, including those with a PFO/PAVM. Potentially, dives that produce fewer micro-bubbles are safer for everyone; see my article on PFOs and the Diver on this web-page for more information.

If you now add the diver behaviour factors outlined in Chapter 4 of the SAA Bühlmann DeeP-Stop System you can see the potential for a safer outcome to your diving.

The Need for Better Buoyancy and Ascent Skills

There is more to the SAA Bühlmann DeeP-Stop System than changes in the tables. You now know that up to 43% of all reported cases of treated DCI involve poor diving skills - primarily buoyancy and ascent skills. Before the SAA Bühlmann DeeP-Stop System, divers seemed to consider buoyancy only at depth and at the traditional stops. The new system now makes essential that you must have full control throughout your dive including the Deep-Stops. This means that Instructors will have to re-think their Skills training methods. They have received a new lecture programme and a Skills Review Programme. All of which when added to the practise expected of trainees, will improve our divers overall diving knowledge and skills.

Routine BCD/Dry suit Maintenance

The story is not finished yet! I said that within that 43% of divers making a fast ascent to the surface were about 18% with faulty valves in their BCDs and or dry suits. These valves either stick open and gas continues to flow into the suit/BCD and or the dump valve fails to work properly and maybe not at all!

For this reason I've increased the training/information on the Users Routine Maintenance of BCD & Dry suit inflation and dump valves. You will be shown how this should be done and you will have to demonstrate that you can apply what you have been shown.

Conclusion

Used correctly the new SAA Bühlmann DeeP-Stop System will better protect you from DCI. Keep in mind that the system is more than just operating the Tables. Take the time to really listen at the lectures and then read the System's book. Practise your skills and get your buoyancy correct for every point of the dive. Ensure your equipment is fully functional prior to leaving home for the dive.

Kind regards and Safe Diving

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