RCN Bulletin:

A Newsletter of the DAN Recompression Chamber Network

THE DAN RCN BULLETIN

Firstly, thank you for the kind responses and endorsements to our first newsletter. Our intention is to share real issues and show that while destinations differ, so many recompression facilities that primarily treat injured scuba divers share the same concerns and challenges.

Secondly, you should have received the chamber information update form that we circulated. This information is entered into our database, and chambers that return the form are part of the DAN Recompression Chamber Network (RCN). This allows us to be able to find the nearest and most suitable treatment facility when we are dealing with injured divers requiring recompression treatment. Our medical hotline team of medical doctor and medical professionals who take these emergency calls are so reliant on this information to be up-to-date in terms of contact persons and availability. Thank you all for assisting us with this.

Many of you might wonder who the names are behind this program. Let me provide you with some of these – the DAN employees.

Drs. Matias Nochetto and Camilo Saraiva are our chamber operations and medicine support team. They are the ones who respond to the medical questions related to your facilities.

Sheryl Shea is a hyperbaric nurse. She responds to dive medicine questions and supports chamber operations. She assists with RCAP site visits, maintaining the chamber database, and Spanish support.

Chloe Strauss assists with our underwater and hyperbaric safety activities (like this newsletter), online education, safety programs, and updating the chamber database.

Guy Thomas is DAN Europe's safety workhorse. He assists with site visits, has provided us with all the updated RCN forms (yes, he is the one who keeps asking you for the forms to be filled in). He assists with creating public profiles of your facilities, and he makes sure that the DAN Europe chamber database is kept current with ours here.

Morne Christou, the new CEO of DAN Southern Africa, is Guy's counterpart. Morne has visited many of the chambers in the Southern African region too and is well known to some of you with the DAN chamber training programs we have provided.

Then lastly, me, who directs DAN's underwater and hyperbaric safety initiatives. I think that I have probably visited almost all of your chambers over the past 21 years; and I am sure that you have your chamber risk assessment report that we did together filed somewhere. My role here is to manage the RCN, to coordinate the RCAP activities, and to create programs that increase the level of safety in all the chambers in DAN's regions.

Since the last newsletter, we have visited two important contributors to the RCN, namely the chambers in Honolulu, Hawaii and San Juan, Puerto Rico. Divers being treated at these two centers are most definitely in good hands.

Indonesia and most of the other countries bordering the South China Sea and the Asia Pacific region are a current focus point for us. There are many recreational diver recompression facilities here that we rely on, and our information is somewhat lacking or outdated. With these chambers, our RCN count is now over 160 and growing.

DAN's ability to manage injured divers continues to improve thanks to the dedication and commitment of all of you.

Once again, we hope that you find this newsletter interesting, and we ask that you let us know what else you would like to read about.

-Francois Burman and the DAN RCN Team.

A welcome to the impressive hyperbaric facility in San Juan, Puerto Rico

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WELCOME TO THE DAN RCN BULLETIN

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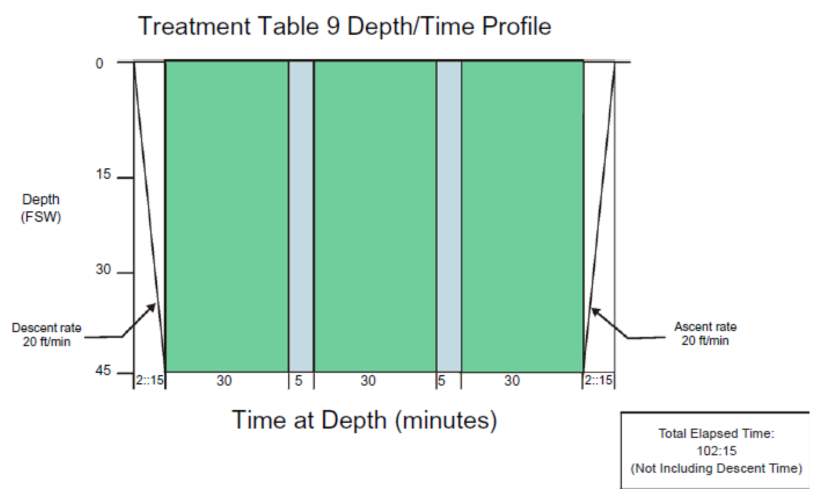
US Navy Treatment Table 9: Medical and Safety Benefits Frequently Overlooked

Dick Clarke

For more than a century, medical care for divers suffering decompression sickness (DCS) has been, and remains, recompression therapy using a hyperbaric chamber. The period spent in the chamber, choice of chamber pressure and type of breathing gas were continually fine-tuned until 1965. It was at this point that the US Navy Minimal Recompression Oxygen Breathing Treatment Tables (USN TT) were introduced. They were eventually adopted as standard care and on an international basis. Where the interval between onset of symptoms to presentation is brief, a careful pre-treatment medical assessment is undertaken, and correct table is selected, a single treatment is often sufficient.

It is not uncommon, however, for a well-managed treatment to not result in complete recovery. In these cases, and where the medical team is reasonably confident of the diagnosis, one or more additional treatments becomes necessary. Selection of the follow-up treatment table has likewise evolved over time. If the diver remains significantly impaired, it is common to repeat the initial table, usually a Table 6. Where improvement is noted but full recovery remains elusive, many providers will switch to Table 5 as the additional treatment. While never intended for follow-up therapy, Table 5 was introduced to treat Type 1 “minor” DCS[1] . It seemed reasonable to employ, rather than repeating Table 6, a longer and somewhat riskier option for minor residual complaints. Table 5 would likely continue until recovery had occurred or until no sustained improvement was evident over two consecutive treatments. It was this point that the US Navy would deem to be a therapeutic endpoint, as some cases never do fully recover. With the introduction of the 1999 edition of the US Navy Diving Manual, Table 9 made its appearance[2]. A key indication for a Table 9 is treatment of residual symptoms, and it offers two distinct advantages over a Table 5. Many hyperbaric teams are either unaware of Table 9 or do not recognize its value vs Table 5. Benefits extend to both the injured diver and the attendant accompanying the diver, and center around its treatment pressure of 45 feet of seawater[3](FSW), rather than 60 FSW dictated by Table 5. This lower pressure means that the diver breathing oxygen as their treatment gas is at a significantly reduced risk for a grand mal seizure, a well-recognized complication of hyperbaric oxygen therapy[4]. It also means that the air-breathing attendant is at reduced risk for DCS. It may surprise some to learn that the person supporting an injured diver while in the chamber is at risk for contracting that very same injury. Several attendants suffer DCS in this manner every year. In fact, two nurse attendants died of DCS after accompanying injured divers during exposure to US Navy treatment tables[5].



USN TT9

The purpose of this brief summary, then, is to encourage chamber teams to favor Table 9 over Table 5 for follow-up treatments. Doing so represents a USN treatment standard; it is safer for the injured diver as it is safer for the attendant. In review of hundreds of cases of DCS annually, Table 9 features all too infrequently. The most common reason stated is that “We were taught to use Table 5”. That training may well have pre-dated the introduction of Table 9. Alternatively, the above noted advantages are unrecognized by those who teach diving medicine.

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[1] US Navy Diving Manual Revision 7 December 2016. Naval Sea systems Command. Washington DC. US Government Printing Office.

[2] US Navy Diving Manual Revision 4 January 1999. Naval Sea Systems Command. Washington DC. US Government Printing Office.

[3] The US Navy uses feet of seawater, or FSW, as a measure of depth. In countries or regions using the metric system, depth is measured in meters of seawater, or MSW. To convert from FSW to MSW, divide FSW by 3.3. 60 FSW depth is generally taken as 18 MW; 30 FSW as 9 MSW. 1 foot/minute is taken as 0.3 meters/minute

[4] Banham ND. Oxygen Toxicity Seizures: 20 years’ experience from a single hyperbaric unit. Diving Hyperbaric Medicine 2011;41:202-210

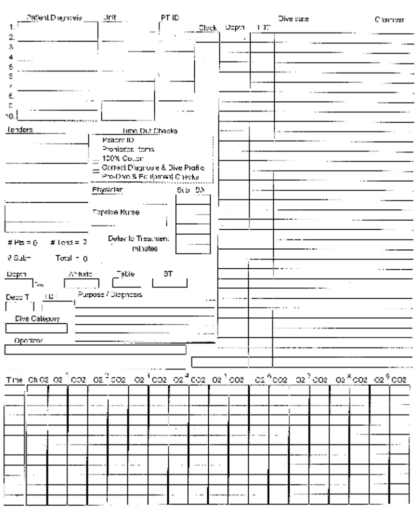
[5] Clarke RE. Health care worker decompression sickness: incidence, risk and mitigation. Undersea Hyperbaric Medicine 2017;44:(6):509-519

A Chamber Operator's Guide to Running a U.S. Navy Treatment Table 6

Eric Schinazi

The U.S. Navy Treatment Table 6 (TT6) is generally considered to be the standard of care for the first treatment in most cases of decompression sickness (DCS). There is an extensive amount of information regarding the medical and physiological aspects of treating divers, but little practical information about running a TT6. The objective of this article is to discuss the procedure of a TT6 from an operator's point of view.

Let's begin with the most important aspect of not only running a treatment table, but of becoming a competent chamber operator: practice, practice, practice. This means getting your hands on the chamber controls before you ever try to treat an injured diver. It also means maintaining these skills, especially where the chamber is not run often. By practicing on a regular basis, you will become familiar with how your chamber responds to the controls. Getting a feel for the control valves and their positioning when pressurizing and ventilating is vital for smooth operation. Most experienced operators say that you will get to know what the chamber sounds like when operating properly. Experienced operators will tell you that what the chamber sounds like tells them as much information as looking at the gauges. Having a properly prepared chamber system is vital to a safe and successful treatment. All equipment required for a safe and effective treatment, i.e. oxygen (0_2) masks, O_2 analyzers etc., should be in place. This is where startup and shutdown checklists are vital.



Sample Checklist

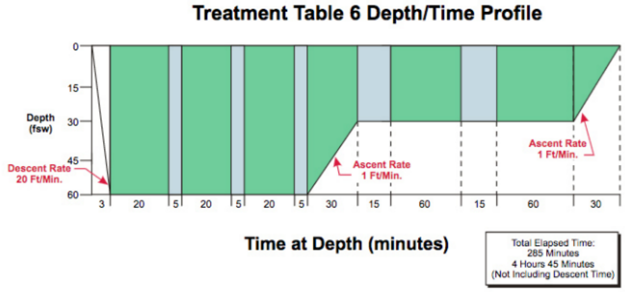
These checklists will be covered in a future article. For this article, we'll touch on some aspects that will help make the treatment run smoothly.

Before you begin any treatment, make sure you have the necessary equipment readily available. First, you need to have a dive log. You can refer to the U.S. Navy Diving Manual for an example, but we would recommend designing a dive log that you are comfortable with. Whichever form you choose, clear documentation is vital. This includes recording all times, events, O_2 readings, etc.

No treatment can be run without some sort of timing devices. It is highly recommended to use at least two reliable stop watches that are easy to read and operate. One is used for the total time of the dive from start of descent to the return to surface, and the other is used to time the O_2 periods and air breaks. Additionally, a clock or watch is needed to note start time and as a back up to your total dive time. Some facilities have a second operator acting as time keeper and event recorder. You should have a table or platform to write on. Trying to write on a piece of paper taped to the side of the chamber just doesn't work. Searching for a pencil or pen right before the start of the treatment adds unnecessary stress. Make sure you have the necessary supplies before you need them, as once the treatment has started, the operator must always remain at the console.

Let's examine a TT6 and break it down into its various stages. Take a look at the standard U.S. Navy Treatment Table 6 taken from Revision 7, the most current version of the U.S. Navy Diving Manual. The treatment lasts a total of 285 minutes (4 hours and 45 minutes), not including the initial compression. There are three 20-minute O_2, and three 5-minute air breathing periods at 60 FSW. There are two 60-minute O_2 and two 15-minute air breathing periods at 30 FSW. The ascent rate is 1 foot per minute from 60 to 30 FSW, and from 30 FSW to the surface. Extra O_2 breathing periods, called extensions, can be added to this table. These will be discussed later.

The TT6 specifies a 20 ft/min descent rate, but this can sometimes be a bit quick. Remember, your patients are sport divers, not navy divers. Most have never been in a chamber before and can be quite nervous. A slower descent, when allowed by the physician, gives them more time to equalize, and will also help keep the chamber temperature cooler. With regards to chamber temperature, adding some venting on descent can help reduce the heat buildup if your chamber does not have an environmental temperature control system. Giving the chamber a good vent for a few minutes once at 60 feet will also help cool it down.



Don't forget to start your timer when you start compression and note the time, as this timer will run for the duration of the treatment. It's been found over the years that the first thing the everyone wants to know is when will the treatment be over, so you may want to do a quick calculation based on a standard TT6 with no extensions (4 hours and 45 minutes plus descent time). This will change if extensions are added.

Start your second timer when the patient goes on O_2 upon reaching 60 FSW. Some physicians like to do a quick assessment when the chamber reaches treatment depth, so you may have to allow time for that. After 20 minutes, the patient takes a 5-minute air break. Don't forget to reset your second timer. Typically, this is when the evaluation is done. Try not to do any heavy venting during air breaks so as not to make too much noise. Remember to record all O_2 and air periods in the dive log. If the patient is using an oxygen mask, whether to strap the mask on the patient is a decision for the physician in charge.
Follow the treatment table for O_2 and air periods at 60 FSW. Let the physician know when the patient is approaching the last air breathing period at 60 FSW, so they can be ready to re-evaluate the patient and decide whether any extensions are needed.

Extra O_2 periods at 60 FSW, called extensions, can be added at the physician's discretion. Note # 5 of the USN Diving Manual TT6 states that up to two extensions can be added at 60 FSW, and two at 30 FSW. Any time an extension is added it must include an air break. Extensions are 25 minutes each (20 minutes of O_2 and 5 minutes of air) at 60 FSW, and 75 minutes (60 minutes of O_2 and 15 minutes of air) at 30 FSW. Remember to log all extensions.

Let's assume that no extensions were required, and you are ready to begin the ascent to 30 FSW. The patient always ascends on O_2. The table specifies a 1 foot/minute ascent rate. This is SLOW. This is where all the practice comes into play. Reset your second timer and use it to monitor your ascent rate. It's been found that most new chamber operators almost always ascend too quickly. With experienced operators, when the ascent rate is either too fast or too slow, it is usually because the operator is not paying attention. Short of a mechanical or medical issue, there is no excuse for not maintaining the proper ascent rate. PUT YOUR CELL PHONES DOWN AND PAY ATTENTION. The standard procedure if the ascent rate is off is to <u>not increase</u> the rate for going to slow, and to halt the ascent if too fast and let the clock catch up. Either way, if you're way off on your travel time, you haven't been paying attention.

So now you've reached 30 FSW and, according to the table, it's time for a 15-minute air break. The first task is to re-evaluate the patient to make sure no symptoms have recurred with ascent. This is a good time to have the patient eat and drink. Some facilities prefer to break up the longer 60-minute O_2 periods and 15-minute air periods into three 20- and 5-minute periods. This must first be approved by the attending physician. Some prefer to do the longer period for the first one, as this allows more time for evaluation and eating. Then, at the discretion of the physician, you could break up the second O_2 and air breathing period into shorter ones. Some patients tolerate the shorter periods better.

Now let's look at the O_2 breathing requirements for the tender. The USN Diving Manual TT6 Note 6 states that the tender shall breathe O_2 for 30 minutes *prior* to leaving 30 FSW and on ascent to the surface for a standard TT6 or a TT6 with *only one single* extension at either 60 or 30 FSW. If there has been more than one extension at any time, the tender goes on O_2 for 60 minutes at 30 FSW and stays on during the ascent. If the tender has had a hyperbaric exposure within the past 18 hours, they get an additional 60 minutes of O_2 added on to the previous requirements. This "hyperbaric exposure" doesn't mean just in a chamber. Many remote facilities have Dive Masters and Instructors act as inside tenders. So, if they have been diving in the past 18 hours, give them the extra O_2.

Begin your ascent from 30 FSW to the surface at the designated time. Just as with the ascent from 60 to 30, PAY ATTENTION. Both the patient and tender remain on O_2 all the way to the surface. If they are using masks, tell the patient it will get harder to exhale through the mask as they get closer to the surface. Upon reaching the surface, assist the patient and tender out of the chamber. The physician will do an evaluation of the patient upon exit. Inquire about the condition of the tender.

Once the treatment is over, follow your shutdown procedures checklist. Secure all gases, compressors, etc. It is often the middle of the night when the treatment ends, and everyone wants to go home, but the chamber must be disinfected, re-stocked and left prepared for the next patient.

Hopefully this article touched on a few things that will make your treatment go smoothly. Becoming a competent chamber operator takes time and practice. The more you practice, the more confident you will become, and the more confident chamber staff and patients will be in you!

High-Pressure Gas Storage Cylinders

Mark Gresham

Gas storage cylinders used in the diving and related industries today are often misunderstood. We hear the slang terminology “cascade”, “bank gas”, “K-bottles” or the specific name of a gas being stored. Let’s examine the types used in gas storage today.

Cylinders most commonly used for gas storage are primarily made of two types of steel. Carbon Steel (US DOT specification 3A) was traditionally used and we see this in some of the oldest cylinders in service, with some as old as the early 1920’s. Chrome molybdenum (Cr-Mo) steel (US DOT specification 3AA) is most often used in the general gas service in almost every country in the world. The specifications mentioned here simply refer to the type of steel used to construct the cylinder defined by the US DOT in Title 49 of the Code of Federal Regulations (49 CFR). In recent years the US DOT has included International Standards Organization (UN/ISO) cylinders in 49 CFR for use in the US and its territories. This type of steel cylinder (also a Cr-Mo steel) is manufactured under ISO Standards 9809-1,2,3, with differences in the three types being tensile strength ratings. The primary advantages of ISO solid wall cylinders are the higher service pressures, and a requalification interval of 10 years versus 5 in most US DOT cylinders.

Since 1972, aluminum cylinders have been used in the beverage industry, sport diving, general gas transportation and storage, and other industrial settings. They are not commonly used as gas storage cylinders in hyperbaric facilities largely due to the lack of understanding of their use in this manner.

Furthermore, since the beginning of the 20th century, steel cylinders have been produced in such large numbers that aluminum cylinders are simply overlooked. In medical facilities where magnetic imaging is used you will only see aluminum cylinders used because of their non-magnetic properties.

There are additional types of storage cylinders used today that are Carbon Fiber Full Composite (CFFC). All of these are constructed to approved governmental standards (US DOT or UN/ISO). US DOT composite cylinders are manufactured with approval of the Special Permits Office and issued a cylinder specific Special Permit. The primary reason that this type of cylinder is not often seen in use is their high cost and limited lifespan, with some only authorized for use for 15 years. Recently there have been newer types of CFFC cylinders being produced specifically for gas storage with longer lifespans of up to 40 years. Requalification is a requirement for all high-pressure vessels used today and there are several methodologies. The most common method of requalification is hydrostatic test, with ultrasonic testing being a more technologically advanced method that may be used for all types of cylinders. Only composite cylinders may be tested using the Modal Acoustic Emission Test. Several Special Permit CFFC cylinders allow for proof pressure testing. Intervals and types of testing are based on the type of cylinder, not its use or geographic location. There is a pervasive, yet erroneous belief, that if the cylinder is not used for commerce or transported on the highway then no requalification is required. Although rare, there are some instances where geography and distance economically prohibit requalification of cylinders, so in lieu of requalification a visual inspection to applicable standards is performed.

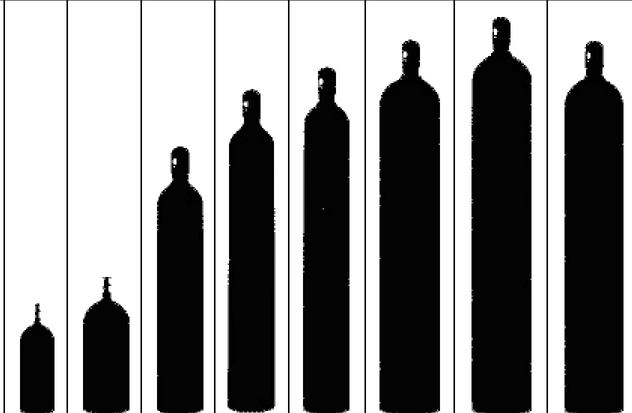
Hydrostatic testing

Slang terminology commonly applied to cylinders today can cause confusion. For example, a “K-bottle” is most often assumed to be any large storage cylinder; when it is only one size of several used. K is a storage cylinder ~9 inches in diameter and ~50 inches tall holding ~250 cubic feet of gas.[6]

[6] Units used in computing cylinder sizes and volumes vary. The European and metric systems provide the diameter and overall length in cm, and the internal volume, as actual computed space or water capacity, in liters. In the US, diameter and length are expressed in inches and volume in the total capacity of the cylinder when filled to maximum working pressure. Without consistent fill pressure values, it is difficult to compare capacities. In the case of the DOT T-cylinder, the US capacity is around 335 ft^3. The metric version, a 50-liter water capacity cylinder filled to the standard storage pressure of 200 bar (2900 psi,) holds 10,000 liters of air (353 ft^3).

Most gas storage cylinders purchased and used today are T cylinders which are ~9 inches in diameter and ~55 inches tall, holding ~335 cubic feet of gas. There are additional sizes available, such as an S cylinder, but they are not as commonly used. Sizes of cylinder may be referenced by liter capacity which is always the case when discussing sizes of ISO cylinders. As an example, an ISO cylinder equivalent to a US DOT T cylinder is 50 liters capacity with the same dimensions as the T cylinder but calculated using water capacity versus gas capacity.

High Pressure Cylinders



Size	R	RR	Q	LD	S	K	T	KHP
Height (In)	14	17	32	43	47	51	55	51
Weight (Lbs)	11	24	46	58	61	113	139	188
Nominal Volume (CU FT)	20	40	80	122	150	244	330	N/A

Types of high-pressure storage cylinders

Another common misunderstanding is the connections specifically required for the type of gas used. Most assume a valve may be used for any gas but that is simply incorrect. When unsure of type of valve required, assume nothing and verify everything. Following the guidelines established by the Compressed Gas Association (CGA) air service cylinders should use CGA 346/347 valves. For any gas with a percentage of oxygen 23.5% or greater, a CGA 540 valve must be used. Valve types in US DOT or ISO cylinders have the same type of valve outlet but are different in the valve to cylinder connection; which is metric on ISO cylinders.

A few guidelines for the handling and storage of cylinders:

Cylinder Handling:

- Handle cylinders with care and avoid dropping or striking them against anything.
- Follow proper procedures and use the right equipment including safety glasses, heavy-duty gloves, and protective footwear.
- Ensure safety measures, such as caps or guards, are securely installed when not in use and when transporting.
- Use a cart or hand truck instead of dragging or rolling cylinders.
- Use proper cradles, nets or platforms if using a lifting device.
- Avoid lifting cylinders by their caps or guards or with magnets or slings, which can damage the valves.

Cylinder Storage:

- Secure cylinders upright with a chain or strap in a proper cylinder cart.
- Store cylinders at least 20 feet from combustible materials in a dry, ventilated place.
- Keep oxygen cylinders at least 20 feet from fuel gas cylinders.
- Ensure valves are completely closed and any protection devices are secured.
- Avoid storing cylinders in lockers or storage rooms without proper ventilation – a leak could result in a dangerous gas buildup.
- Post proper warning signs at the entrance of areas where cylinders are stored.
- Keep cylinders in a location free from vehicle traffic, excessive heat and electrical circuits.
- Keep empty cylinders away from full cylinders.

There is a tremendous amount of information regarding storage cylinders used today and we have only scratched the surface in this article. I would urge any operator or owner of any facility that uses storage cylinders become more familiar with their cylinders and requirements for safe handling and use, valve requirements, gas types and requalification schedules.

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Chamber Maintenance Needs

Sheryl Shea

Determining what needs maintenance on a hyperbaric chamber and when can be a challenge.

There are a myriad of standards found in scattered locations, such as the NFPA, CGA, PVHO, and recommendations by manufacturers, just to name a few. Add to that local regulations, if they exist at all, and it can be difficult to figure out what really needs to be done and how often.

In a remote location where parts and specialized supplies can take a long time to arrive, routine maintenance must be planned well in advance to ensure the items will be on hand when needed. So determining which supplies will be needed, and when, is crucial to maintaining a functional, safe and clean chamber that is always at the ready to receive divers.

At a minimum, a comprehensive preventative maintenance plan should include:

- periodic testing of all safety related equipment - gauges, valves, meters, deluge and warning systems, etc.;
- checking of oxygen piping systems for leaks;
- checking that gas flows remain unobstructed;
- ensuring continued operation of all automatic drains (where no condensate is discharged then the drain valves should be checked for blockages and the filter elements checked to ensure that these are not saturated);
- replacement of filters, lubricants and coolants;
- checking of fluid levels (lubricants, coolants, etc.);
- adjustment of regulators, sensors, safety valves and switches;
- correct and effective activation of safety systems (i.e. deluge system, electrical alarms, emergency power, back-up gas supplies);
- analysis of gases;
- monitoring of viewports, pressure boundaries, calibration and statutory testing status;
- updating logs of all periodic tests; and
- compressor maintenance

Fortunately, DAN has a tool which can help with this planning. The following table lists maintenance actions and suggested intervals for carrying out these actions, taking into account well accepted standards such as NFPA, CGA, and PVHO.

Of course, if there are facility policies, local regulations or manufacturer required intervals, these would take precedence.

Daily or after last use		Weekly		Monthly		6 monthly		Yearly	
Oxygen delivery equipment	Cln	Lighting	Insp	Lubricate seals	Serv	Air quality: oil, CO, H_2O, CO_2	Test	Safety valves - override	Test
Disinfect & clean chamber	Cln	Emergency lighting	Insp	Leak test seals	Test	Replace dryer chemicals	Serv	Leak test piping & hoses	Test
Medical equipment, if used	Cln	Communications	Insp	Oxygen delivery equipment	Insp	Fire protection systems	Test	Leak test manifolds	Test
Drain bilge, clean if needed	Cln	Emergency communications	Insp	Gauge function	Insp	Deluge, handlines, portable		Leak test valve ctls	Test
Check air & gas supplies	Rec	Electrical grounding	Test	Unused systems function	Test	Oxygen delivery equipment	Cln	Leak test viewports	Test
Fire deluge water/pressure	Rec	Analysers - cell integrity	Insp	Security of HP cylinders	Insp	Medical lock interlock	Test	Emergency breathing	Test
Systems function properly	Insp	ECS	Insp	Silencers & mufflers	Insp	Med lock doors alignment	Insp	In-line filters	Cln
Isolate appl. supplies	Serv	Housekeeping	Insp	Timing devices	Test	Chamber door alignment	Insp	Gauge calibration	Test
Door seals	Insp			HP outlet filter cartridges	Insp	LP outlet filter cartridges	Insp	*HP outlet filters*	*Repl*
Vent applicable lines	Serv			Compressor drains	Insp	Compressor intake filters	Cln	Electrical joints & wiring	Serv
Windows - operational insp	Insp			Compressor oil	Insp	Mechanical separators	Cln	Deluge water	Repl
Analysers - span	Serv			Compressor belts	Insp	Alarm systems	Test	Fire extinguishers	Serv
				Conditioning fluids	Insp	Batteries	Insp	Door hinges	Lube
				Labels	Insp	Expiry of HP cylinders	Insp	O_2 sensor	Repl
				Valve sealing wire	Insp	ECS	Insp	Set regulators	Test
				Valves (all) - damage	Insp	Safety valves	Insp	Fasteners & seals	Insp
				Valves: unused - activate	Insp			*Compressor oil*	*Repl*
				Windows - visual	Insp			Compressor maintenance	Insp
				Analyser dryers	Insp			Medical equipment	Serv
				Bilges - remove deck plates	Cln			Replace dispos.batteries	Serv
				GFI & LIM test functions	Test			Fire alarms	Test

2 Yearly		3/4 Yearly		5 Yearly		10 Yearly	
HP Cylinders visual	Insp	Change all HP gases	Repl	Regulators, soft goods	Serv	Windows service life expiry	Insp
Windows: seat & seal	Insp	Oxygen delivery equipment	Serv	Valve: seals & seats	Serv	Replace w/ seals, if required	
Windows: acrylics‡	Insp	Chamber shell: visual, NDT,	Insp	Door seals	Repl	Or recertify if appropriate	Rec
Conditioning fluids	*Repl*	pneumo or hydro, certify†	Test	Medical lock seals	Serv	HP cylinders: visual, NDT,	Insp
Compressor inlet filters	*Repl*	Vessels: visual, NDT,	Insp	Medical lock interlock	Serv	hydro & certify	Test
LP outlet filters	*Repl*	pneumo or hydro, certify†	Test	Penetrator seals	Serv	Oxygen clean piping	Cln
Refrigerant dryer	Serv	Fire exting. hydro & certify†	Test	Safety valves, seals/springs	Serv	Oxygen clean controls	Cln
Compressor maintenance	Serv	ECS: service & fluid change	Serv				
Pressure test hoses	Test						
Batteries - recharge. repl.	Serv						
Safety valves - set pressure	Test						

† Country specific requirements apply

‡ 36 months - initial service life

Action	
Cln	Clean
Insp	Inspect
Lube	Lubricate
Rec	Record
Repl	Replace
Serv	Service
Test	Test & record

*Manufacturer specified intervals**		
Compressor oil	Repl	Typically every 1000 hrs
LP air filters	Repl	Typically 12 months/6000hrs‡
HP air filters	Repl	Typically 50 hours†
Compressor intake filters	Repl	Typically every 500 hours
Conditioning fluids	Repl	Typically every 2 years
Compressor service	Insp	Typically every year/2000 hrs
Compressor maintenance	Serv	Typically every 4000-6000 hrs

* If not specified, then latest dates shown

‡ 12 months for coalescers, 6000 hrs for activated carbon

† HP filters replaced at 50 hrs (chemical) or air volume based.

In the “action’ table above, the abbreviations are explained. This table should serve as guideline only, each hyperbaric center will need to individualize their plan. For example, if you do not have a medical lock, you wouldn’t need to test it.

It is imperative to keep a maintenance log to document what has been done, when and by whom. The log should be kept near the chamber, so that it does not become misplaced, and be considered a permanent legal record which does not disappear with changes in staff. The log will help with planning and serve as proof that the maintenance has been carried out if inspection authorities request it.

For actions which are carried out frequently, checklists should be created, such as pre- and post-treatment checklists, and these should also be maintained as permanent chamber records.

We hope you find this information helpful in creating or improving the routine maintenance program at your hyperbaric facility and ensuring a safe operation for both chamber staff and patients.

If you have any questions, please do not hesitate to contact DAN at rcn@dan.org

How Often Do We Need to Change Our Chamber Windows?

Guy Thomas

In the past, acrylic windows had a design and service life of 10 years. This meant that they had to be replaced every 10 years regardless of how often they were used. However, with the publication of the (ASME) PVHO-2 standard, for a window that was initially manufactured and certified to (ASME) PVHO-1, the service life can be extended by an additional 10 years, or 5,000 operating cycles (for a typical twin lock, multiplace chamber), based on visual inspection alone.

PVHO-2 states that, for the first 10 years, no mandatory visual inspections are needed. At reaching an operation age of 10 years, the multiplace chamber windows need to be removed, visually inspected according to certain criteria contained in PVHO-2, the seals and the seat need to be inspected, and at this stage, the service life of the windows can be extended. However, voluntary inspections every 36 months (or 18 months for severe service conditions) are still recommended.
Once the service life has been extended, mandatory periodic inspections are required as follows:

- For chambers in a protected environment (meaning inside an environmentally controlled building), a visual inspection must be performed every 24 months after re-certifying the window until the service life reaches 20 years. These inspections can be done with the window in place.
- For chambers outside of such a protected environment (deck or containerized systems that are exposed to temperatures above 82°F [7]or the weather), at 10 years one of the windows must be removed, from the same batch, and destructive testing performed to determine whether there has been any weakening as a result of exposure to the elements. Based on acceptable results, the service life of the remaining windows can be extended by an additional 10 years/5,000 cycles. Thereafter, visual inspections must be performed every 12 months.

Acrylic and heat don't mix. Be careful of the lamp you use!

At 20 years, no matter whether a chamber is in a protected or an exposed environment, additional service life extensions can only be approved where one window from the batch is mechanically tested. The mandatory inspection intervals would remain the same.

While destructive testing must be done by specialized companies, visual inspection can be done by staff members who are specifically trained for this. DAN has organized acrylic windows inspection and maintenance courses since 2007 and has invited technicians from within the Recompression Chamber Network to participate in such courses at a minimal cost. This has made it possible for chamber personnel to do in-house inspection and maintenance of viewports, avoiding expensive outsourced maintenance and inspection services, and normally doubling the life of their windows.

Removing chamber windows for inspection

[7] 28°C

Chamber Profile:

Madagascar Nosy Be

Morne Christou

Madagascar is a mystical place where time always seems to stand still, and thanks to its particular geologic past, is a place where flora and fauna prosper almost completely endemically, both above and below the sea's surface, so much so as to be defined by scholars as a kind of "natural laboratory."

Nosy Be is a small tropical island situated Northwest of Madagascar, at the mouth of the Mozambique Canal, where both untouched nature and all the comforts of civilized man meet. Despite the extreme poverty of the country, high quality facilities and services are perfectly integrated with a "magic" atmosphere that becomes apparent the minute you step off the plane.

The climate is tropical and consists of three main seasons: the dry season from April to September, with better visibility underwater and lower temperatures (between 77 and 81 degrees Fahrenheit[8]); the humid season, from October to January, with warm waters (between 82 and 86 degrees F[9]) and many fish; and the rainy season from February to March, during which diving is not recommended due to scarce visibility and unfavorable sea conditions.

The diving points are dispersed over 62 miles[10]: from the Mitsio Archipelago in the North to Nosy Iranja in the South. They can be reached by boat in 10 to 70 minutes (depending on the destination). Colorful, active reefs emerge from the deep blue, shipwrecks surrounded by schools of fish, sandy sea floors where you can lose yourself searching for the smallest and strangest creatures, gardens of giant Gorgonians or large banks of coral frequented by small sharks, Carangidae, and tuna… From the smallest sea slug to the grandest whale, variety is guaranteed.

What happens if you have a diving emergency in a place like Nosy Be? It a diving paradise but extremely remote. The first question divers always ask… is there a chamber? This is a good question but not the only important question to ask. It's no good having a chamber available if it is not operational or operated by qualified people. It's also advisable to have a medical facility nearby or attached to the chamber facility. To help answer these questions DAN developed programs to assist divers and remote dive destinations like Nosy Be.

DAN has been working hard over the past 25 years to assist remote chamber facilities through the Recompression Chamber Assistance Program (RCAP). Chambers that are associated with DAN through RCAP take advantage of the technical assistance and training that DAN provides which generally means that they are fit for the intended purpose and have been visited and inspected by DAN. These chamber facilities and dive destinations often heavily promote this (it's in their interest to be seen as safe).

What is RCAP?

RCAP focuses on recompression chambers that primarily treat injured recreational divers, usually in more remote locations, and throughout the different DAN regions. A review begins with a safety and risk assessment of the facility. After the assessment has been completed, DAN works hand-in-hand with the chamber staff to create the best possible facility, in terms of safety, training and operation.

Nosy Be Chamber

[8] 25-27°C
[9] 28-30°C
[10] 100 km

How Does it Work?

When a chamber is assisted by RCAP, the staff and management are all involved in the process so that each person can be confident in the safety practices and training provided by DAN. The assessment begins when DAN staff head out to visit a chamber. During their visit, the team will examine every aspect of the facility, beginning with the chamber itself and ending with the staff appointed to operate it. Following this assessment, a detailed report is compiled with recommendations, where indicated, to increase safety standards.

RCAP Certification

After a facility has satisfactorily complied with the recommendations suggested by DAN in the assessment report, it is issued with a Certificate of Compliance that acts as their commitment to safety and their recognition by DAN as a partner in dive safety.

The Nosy Be Project

In 2014, the DAN team visited the Nosy Be chamber facility to assist the "Life for Madagascar" association with their chamber facility.
Life for Madagascar is a non-profit association founded in Milan in 2011 by a group of professionals operating in the medical area. It aims to support Madagascar's disadvantaged and needy populations using health and social interventions in strict harmony and cooperation with local health authorities and international organizations engaged in the same field.

Life for Madagascar has created the Ambatoloka multi-purpose health center on the island of Nosy Be. The health facility is equipped with clinics for specialist medical examinations (dentistry, ophthalmology, gynecology and orthopedics), rooms and equipment for radiological and ultrasound examinations and, finally, a laboratory for medical analyses. The Centre is also equipped with a hyperbaric chamber with the dual purpose of treating some serious infections that affect the local population and to provide first aid to divers affected by gas embolism. The hyperbaric chamber was donated to the Association by the ATiP of Padua and was finally tested on location in February 2013. In the building there are also rooms for the stay of volunteer doctors who are part of the periodic missions. Francois Burman and Morne Christou met with Carlo Lanza, an Italian hyperbaric technician, at the facility in May 2014. The aim was to introduce RCAP and provide any advice needed to ensure the chamber was safe to assist DAN members and fellow divers.

In July 2014 Morne Christou, Dr Cecilia Roberts and Marco Ditommaso headed back to Nosy Be to train the dive professionals in assisting injured divers using a recompression chamber, as well as how to operate the chamber. The chamber course was broken into two parts. The chamber attendant's module focused on the inside of the chamber and how to deal with emergencies. This is especially necessary where an emergency treatment is necessary. The chamber operator's module focusses on the competency of the chamber operators, managing the chamber hardware when a treatment is being given.
The local dive professionals thoroughly enjoyed the course. Jose Vieira from Sakatia Lodge took on the overall maintenance responsibilities of the chamber facility and continues to do so today.

Currently, the chamber facility is fully operational and available to divers that visit Nosy Be. Once again, this proves that DAN likes to go the extra mile to ensure the safety of divers. Without a doubt DAN remains a vital part of the diving industry!

Why Support DAN?

If you dive for long enough you will ultimately hear of divers becoming "bent", and often what you hear will not necessarily be the full story. It may be exaggerated, or it may exclude key facts. This is especially true with stories of divers treated in foreign countries or remote locations. These regions seem to do things differently from how we may expect things to be done at home. The question is: Is this the way things should be done?
Okay, so we can say that health systems vary greatly from one country to another, and unless a person has adequate insurance, they may not have access to these facilities at all. Look at it this way: If a person travels to a foreign country, what makes them entitled to free health care? The answer is nothing. Even if countries have a complete social health care system, it will not be free to tourists and visitors. So, the first thing we need to ensure is that we have proper insurance that covers us for the type of diving we expect to do.

What to Expect from Remote Chambers?

Well, that's the lecture about insurance over with. Now let's look at what we can expect from a hyperbaric chamber in a remote area. The first thing to note is that not all chambers are the same. What we mean by this is that not only do they differ in what they look like or how many people they can accommodate, but also what they specialize in. You will find that if you are diving near a big city, that chamber may specialize in hyperbaric oxygen and therefore may run daily hyperbaric treatments for conditions unrelated to diving. You may find that these chambers are quite large, based in a hospital and that they do not treat many divers, so may seek advice before treating you. But don't worry, this is usually nothing more than a phone call.

When we look at remote resort chambers, most are based in a simple clinic (not in a hospital). These chambers often only treat divers and can have a wealth of experience in treating DCI. They are often small chambers designed for two or three people at most (often known as deck chambers as they can be former commercial diving chambers which are used on the decks of diving barges). They should all be staffed by competent, trained attendants and operators. Most of the staff members that work at these chambers are from the local diving community and are trained as attendant operators. These chambers are still under the control and guidance of a qualified and licensed doctor. If they are not, it may be worth going elsewhere if possible.

If you need to stay in a hospital after your treatment, and many chambers will arrange this as a precaution, it is often arranged with a local hospital affiliated with the chamber. It may mean that the hospital will bill your insurance separately from the chamber, which may cause a few minor complications with communication if the insurance company is not made aware that the hospital is a different company.

Summary

Although a remote chamber may seem small or in a bit of a rundown part of town, these chambers can have a lot of experience and support which will ensure that you receive the best treatment available. Chambers affiliated with the DAN RCAP are considered safe and are staffed by persons who have received appropriate training. Even so, we hope you don't need to use them on your next trip!

Chamber Profile:

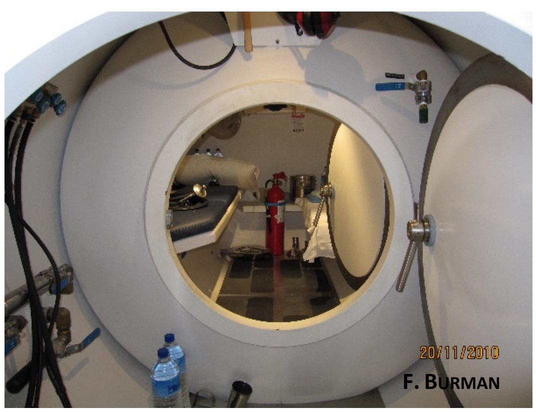
Prodivers, Kuredu, Maldives

Guy Thomas

With its 1192 islands and around 2500 reefs spread across 26 atolls, covering an area of over 500 nautical miles, the Maldives remains a popular dive destination in the Indian Ocean. Kuredu is located in the Lhaviyani Atoll, 90 miles[11] north of the capital city of Male and its international airport. The island stretches 1.1 miles[12] long by 0.2 miles[13] wide, about 141 acres[14].

This island is home to a small clinic, housing one of 3 currently operational hyperbaric chambers in the Maldives. It is the farthest north in the archipelago and available to divers from other islands as well. The recompression chamber is run by Prodivers, a PADI 5 Star Instructor Development Centre located on the island.

The 231 cubic foot[15] twin-lock cylindrical "Hytech" chamber is comfortably rated for 1 patient and 1 attendant. The dedicated chamber building is fitted with air conditioning and the facility lay out is compliant with industry practices. The chamber can provide a US Navy treatment Table 6 and is pressurized using a high-pressure air supply system.



Kuredu Chamber

High pressure oxygen is provided for treatments. The facility has 2 DMOs, Drs Kocabas and Ceken, who are permanently on site to make sure the chamber is available 24/7.

The facility has a website that provides additional information about the chamber and DCS: www.kureduclinic.com.

No capabilities for critical patient care or advanced life-support are currently installed inside the chamber, so in case of a seriously ill diver, a 40-minute, low-level flight can transport them to Male where full hospital, but non-hyperbaric facilities are available. Transfer by boat is possible during daytime only and takes significantly longer.

Since the first Recompression Chamber Assistance Program (RCAP) visit to this island back in 2005, an excellent collaboration has been established between DAN and the facility. A series of Chamber Attendant and Chamber Operator training courses and a more recent Nuts and Bolts maintenance course has been provided by DAN to the local staff members.

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[11] 145 km
[12] 1800 m
[13] 325 m
[14] 57 ha
[15] 6.54 m^3

Case Study:

Urinary Retention and Ataxia

Sheryl Shea

A diver in his mid-60's was doing a series of 3 days of recreational ocean dives in warm water, on an island. His breathing gas was air, and he wore a wetsuit. The deepest dive was to 100 FSW (30 MSW). The last dive prior to the onset of his symptoms was to 50 FSW (15 MSW) for 45 minutes. He did a 5-minute safety stop. The dives went well, there were no missed deco stops or rapid ascents. He had one remaining dive to complete before returning home.

Upon re-boarding the boat for the surface interval, he stated that he had a sudden urge to lie down. He felt exhausted, weak and off-balance. The boat crew provided 100% oxygen via NRB mask and left him lying in the boat cabin while they completed the last dive. He breathed the oxygen for an hour and stated that he then felt great. He was able to climb up the stair to the dive deck, and went to the dive platform to urinate, but was unable. Two hours later, he reports he "couldn't walk right" and was still unable to urinate.

After 2 more hours, now 5 hours post-dive, he developed abdominal discomfort and went to the local island clinic, where he was catheterized for urinary retention, with a return of 800cc. The doctor assumed that it was related to his history of mild benign prostatic hyperplasia (BPH), which has been well-controlled on Tamsulosin and Finasteride. He had no previous history of urinary retention, or of any condition that would explain his current gait and balance disturbance. He denied taking any medications that could cause urinary retention, such as decongestants or anticholinergic drugs. He was discharged to his hotel.

At 3am, 15 hours post-dive, he woke up with abdominal discomfort again and was still unable to urinate, but the clinic was closed. At 7am, he went back to the clinic, and woke up the doctor, who placed an indwelling urinary catheter.

He boarded a private vessel at 8:30 am for the 2 ½ hour trip home. Onboard the boat, he attempted to assist his dive buddies with loading the tanks and gear, but he was unable to because of the gait and balance abnormality and had to lie down for the remainder of the trip.

Upon arrival to the mainland, he was taken directly to an ER, where the doctor became suspicious of decompression sickness (DCS) and contacted DAN. The medical staff at DAN concurred with his suspicion and referred the patient to the nearest facility with a hyperbaric chamber, and a physician with extensive knowledge of dive medicine.
He was subsequently diagnosed with DCS and treated with a USN TT6. His gait and balance began to improve, but he remained catheterized. After 3 additional HBO treatments, his gait and balance returned to normal, and the urinary catheter was removed. He was able to urinate on his own, but with some hesitancy (difficulty starting the urine stream). He was seen by a urologist, who said that his prostate was slightly enlarged. A spinal MRI was done, which did not show anything significant.

He was discharged to home with normal gait and balance, but the urinary hesitancy remained. He came back the next day for one final HBO treatment, referred to the urologist for future follow-up, and advised not to dive again for at least 90 days.

Luckily, the emergency physician recognized the possibility of spinal DCS, and called DAN. His HBO treatment was commenced about 30 hours after the accident. In this case, the need for HBO treatment was clear to the physician because of the sudden onset of ataxia. The cause of the urinary retention was not 100% clear due to the history of BPH, however the treating physician stated that he would likely have treated him even if urinary retention had been the only issue as long as HBO treatment carried no contraindication for the patient. He felt that the urinary retention alone was highly suspicious for DCS, even with his history of BPH, due to the sudden onset, the lack of history of urinary retention, and the fact that his urology consult showed only mild BPH.

DAN's Take:

This case is a good example of frequent treatment dilemmas faced by dive physicians. To treat or not? Looking at the evolving picture from when he first becomes symptomatic is key to successful disposition. Complicating medical conditions should be considered but should not be allowed to obscure the events. People with medical conditions that may mimic decompression accidents can still suffer DCI. Often, the answer is not always clear, and becomes even more difficult in more remote locations where diagnostic testing equipment may be limited and specialists who can help with diagnosis may be far away. However, DAN physicians are always just a phone call away, and always available, as in this case, to help decide whether DCI should be suspected.

FAQ Frequently Asked Questions

The following are some frequently asked questions that DAN receives.

Does our chamber need both internal and external hull isolation valves?

Piping which passes through the chamber hull must have isolation (shutoff) valves to prevent uncontrolled pressurization or depressurization of the chamber, or leaks in any of the other gas lines that might affect control of the chamber environment should a malfunction occur. It is preferable to have isolation valves both on the exterior and interior sides of the hull.

This requirement is typically set for commercial and military diving systems. However, many clinical chambers are not fitted with this capability – this is especially true for monoplace chambers.

Recompression chambers used for treating injured scuba divers fall into a unique category – they treat neither fit and healthy commercial or military divers, nor sick patients who may be infirm and difficult to manage.

The key to meeting this requirement is thus the assessment of real risk.

The primary concern is loss of control if a system fails – say rapid, run-away pressurization or depressurization, a safety valve opening well below set-pressure, a bilge valve leaking, or a leak in a pressure gauge line. Without being able to isolate the line, control of the chamber and thus the safety of the occupants would be severely compromised.

Secondarily, there is the concern of an inattentive or even an absent operator on the outside. How would the inside attendant deal with such loss of control?

This means that a lack of control on the outside or the inability to control on the inside, without dual shell valves, would be very difficult to achieve.

ASME PVHO-1, the design code that most chambers are designed to, requires a minimum of an external shell valve on all gas lines into or out of the chamber. A recompression chamber must at least meet this requirement. The unlikely event of an absent, disabled or inattentive operator should be evaluated on a case by case basis, and either a policy put in place for minimum of two people to attend the outside of the chamber, or a fail-safe or dead-man's switch should be installed that will bring the chamber to the surface safely and shut off all pressurization lines.

Dual shell valves would, however, be good practice for all remote chambers with limited staffing.

[Link to a real-life example of where an internal isolation valve would have mitigated a potential accident].

F. Burman

Dual safety valve

What is the correct pressure for our chamber safety valve to be set at?

There are a few things to consider here.

- Some hyperbaric chambers are designed for depths allowing some degree of commercial diving to be done – say up to 225 psi (± 16 ATA), and many are produced to provide up to a 165 FSW (50 MSW) for a US Navy treatment table 6A.
- The most common treatment table for a scuba diver suffering from DCS is the US Navy TT6, requiring only 29 psi (2.8 ATA). Remember also that oxygen as a therapeutic gas becomes increasingly toxic when one exceeds this pressure.
- Occasionally a facility might also use a mixed-gas treatment table, using heliox or nitrox at 100 FSW (30 MSW).
- The safety of the chamber as a pressure vessel is affected by the maximum air supply pressure that could potentially take the chamber pressure to a level above the design pressure.
- The codes require the safety valve to be set to be fully open at no greater than design pressure.
- Finally, one needs to be able to test the safety valve; preferably while still fitted to the chamber.

Based on the typical requirements for an injured diver recompression chamber, safe practice would thus be a combination of the following:

- Install a safety valve that would be fully open at no more than 10% above the maximum, actual treatment pressure. This would prevent taking the patient to below the deepest, safe pressure, or to exceed the safe level for oxygen toxicity.
- Consider an additional safety valve, fitted with an external isolating valve, set to protect against depths exceeding oxygen toxicity levels – typically for the US Navy TT6 table. The isolating valve will allow for deeper treatments to be performed. This is easy to install using a T-piece before the existing safety valve.
- If the compressed air system can exceed the chamber design pressure if either of the two above safety valves have been isolated, then fit an additional safety valve to prevent exceeding the chamber design pressure.

Typical safety valves settings might be:

- US Navy TT6 or equivalent oxygen table, set to 72 FSW (22 MSW or 32 psi)
- Comex 30 or equivalent heliox/nitrox table, set to 108 FSW (33 MSW or 48 psi)
- US Navy TT6A or equivalent deep air table, set to 180 FSW (55 MSW or 80 psi)