

THE RCN BULLETIN

A Newsletter of the DAN Recompression Chamber Network

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THE RCN WELCOME LETTER

Welcome to our 6th newsletter that we hope provides interesting and informative reading material for you all.

Please take a moment to navigate to our new website where we have a whole section on recompression chamber facilities, together with resources, FAQs and back-issues of our newsletters. Remember to send us your questions as we post those useful ones on the website. This is your section, so please feel free to use it.

The diving world is slowly opening in some places, but sadly others are still pretty much closed as these pandemic waves create their disturbances and setbacks. We've certainly learned lessons in infection control, which we should heed going forward; but our skills might also have become rusty so please remember to provide retraining to your staff so that you can conduct treatments safely and effectively.

In this edition, we're starting a series of articles on different types of treatment tables and hope to share those unique 'Catalina', 'Hawaii', Comex, DCIEM and other navy tables with you – together with the rationale for why they were developed and are being used. This edition starts with the familiar US Navy tables and we'll work our way through the others in subsequent editions.

Our regular discussions on chamber activities in worldwide regions continue, so stay posted for some exotic locations and experiences.

Since the last newsletter, we experienced a devastating, catastrophic failure of a monoplace chamber in a manner that was totally unexpected. However, from what we can piece together, it would appear that the fault did not lie with the facility staff but rather in the absence of manufacturing compliance with any recognized standard. It is so important to ensure that your chambers comply with these very well-developed design, fabrication, and certification requirements. During maintenance these requirements also need to be adhered to when it comes to repairs, modifications, and testing. We will try to provide more details in a future newsletter if we can gather accurate information. Monoplace chambers do not fail, but this one did and there will be a reason.

Some of you might be skeptical of the use of monoplace chambers in treating injured divers; we have included an article that assures you that they can be used. This has been shared with us by the author - a well-known and highly experienced expert in our industry, so be sure to follow the link to the article, which is provided in this edition.

We trust that you will find the articles that have all been written specifically for this newsletter of interest. We'd really like to publish your experiences too, so consider sharing your stories and expertise with us all.

We are here for you so remember to send your questions and comments to us at rcn@dan.org.

- Francois Burman and the DAN RCN Team

Challenges of Operating a Chamber on the Panama Canal During COVID-19

JAMES DENHAM

The first thing that may come to our mind when we hear the name “the Panama Canal” is about this narrow waterway across a very rainy, Central American country, which in a way is true. But what we don’t get to hear much is how intricate it can be to keep this important hundred-year-old linkage to international maritime trade running as well and safe as it was on day 1.

Work at the Panama Canal is done above, on, and under water. To keep up with the Panama Canal Authority (PCA)’s needs, preventive maintenance of the canal lock complex becomes as important as securing a sustained, fresh water supply to the canal.



The Panama Canal



Panama Canal Chamber

The Panama Canal has two main diving activities: canal lock maintenance and floating equipment maintenance, salvage, and repair. All maintenance units must be ready to respond to emergencies, 24-hours a day.

Maintenance required by lock divers include, among many other things, caisson installation and positioning for dry chamber overhauls, miter lock gates caulking, chamber wall fender recoveries, and culvert and rising stem valve maintenance, at depths between 60-80 fsw with almost zero visibility due to high water turbidity. Floating equipment maintenance includes rehabilitation and replacement of floating navigational aids, vessel maintenance, salvage, and recovery.

Upon entry into force of the Panama Canal Treaty of 1977 on October 1, 1979, the United States handed over what was then known as the Canal Zone to the government of Panama, which assumed plenary jurisdiction over the canal. In order for a smooth transition to occur, the new canal administration was required to maintain operations as flawlessly and safely as possible. Among other things, this included establishing safety and health norms and regulations such as the ones previously practiced under the US administration and as required by OSHA.

Since the 1910 CFR Subpart T (Commercial Diving Operations) could not be enforced after January 1st, 2000 in the Republic of Panama, the Panama Canal Dive Safety Board incorporated these standards and requirements as references into its diving operations manual. Having a hyperbaric chamber on site for all dives greater than 100-feet was an example of this.

The hyperbaric chambers that were transferred from the US Navy to the Panama Canal Commission in the 1980's happened to be the only two multiplace chambers available in the country, and possibly in the area, and aided in the treatment of cases referred by DAN as well as any local diving cases which needed recompression therapy.

Last year, the PCA replaced its 2 old chambers with 2 new double-lock, multiplace hyperbaric chambers built by Totalmat (Brazil) in compliance with ASME/PVHO-1 safety standards. One major upgrade was the ability of the new chambers to allow for patient transfer-under-pressure through a NATO flange for easy connection to portable recompression chambers.



Panama Canal Chamber

Hyperbaric oxygen therapy (HBOT) requires patients to be enclosed in a hyperbaric chamber for many hours while inhaling 100% oxygen at 2–3 times atmospheric pressure.

Oxygen is delivered by means of a mask. Patients need to take “airbreaks” by removing the mask from their faces. The use of masks led to many concerns about chamber personnel safety very early on at the start of the COVID-19 pandemic.

We were not only faced with substantial and entirely reasonable reluctance and apprehension by our patients when using shared masks, but also among our own in-chamber personnel with regards to the availability of personal protective equipment (PPE). This identified the need for infection control during inside patient tending and screening for COVID-19, at a time when rapid antigen tests were not readily available.

The only rapid screening tools available in our country were rapid lateral flow IgM/IgG antibody tests for SARS-CoV-2. However, this by no means ensured that our patients and our chamber tenders were not asymptomatic COVID-19 carriers. Sending patients to a laboratory for a PCR test during a diving emergency and before HBO treatment was impractical. The only logical option was to provide hoods with rubber neck seals for all patients; however, these could not be procured locally. Therefore, purchasing them from the US and temporarily restricting all non-emergency diving activities in canal waters seemed to be the only reasonable option, which carried the disadvantage of closing hyperbaric chamber activities until the issue was resolved.

Today we have a different picture than the one seen a year ago. COVID-19 safety and health protocols, rapid on-site antigen screening, hood protection, infection control and disinfection, and vaccinated personnel trained for handling patients during COVID-19 times certainly relieved some of the apprehension, although the risk and fear of a COVID-19 contagion is still the #1 challenge at our hyperbaric facilities.

Symptoms After Diving

GÖKHAN AKCALI

Symptoms after diving activities that suggest decompression illness need to be diagnosed and treated quickly. On the other hand, the fact that these symptoms are generally non-specific and taking place in a spectrum ranging from fatigue to loss of consciousness make a diagnosis difficult.

Time between symptom onset and treatment is the most important prognostic factor for an outcome and can limit the time allotted to detailed anamnesis and examination for differential diagnoses- especially in severe cases. Nevertheless, taking anamnesis and performing a thorough examination can rule out some differential diagnoses and provide information to physicians about the severity of the condition.

A 20 year old male diver presented to the emergency department of a hospital, which has a hyperbaric unit, with pain in the right shoulder. He was a 1-star CMAS diver with 7 lifetime SCUBA dives. On the first dive of the day, he submerged for 2 minutes at a depth of 16.7 meters, then ascended to 9 meters with his buddy who was a 3-star CMAS diver. In the 13th minute of the dive, he noticed a few drops of blood in his mask and started to feel anxious. He decided to abort the dive and ascend to the surface. Despite his buddy trying to hold him, he made an uncontrolled ascent.

His shoulder pain started immediately after he reached the surface. He presented to the hospital within 30 minutes of the end of his dive. There was no other significant history related to diving or his medical past. Asymmetry between shoulders was noted and his shoulder pain level was increased by active and passive movements.

Right shoulder subluxation was seen on X-Ray and his pain resolved after relocation of shoulder by an orthopedic surgeon. Pulmonary barotrauma was excluded by normal chest X-Ray. The dive profile was confirmed with the dive computer. The decompression table used by local SCUBA diving schools indicates that the no-decompression limit at 18 meters is 45 minutes. Although his dive profile was well within no-decompression limits with low risk for decompression sickness (DCS), DCS should always be taken into consideration in case of joint pain after diving.

Clinical experiences and some case reports show that divers can suffer from decompression sickness even after very conservative profiles. Also, history of uncontrolled ascent may suggest pulmonary barotrauma and arterial gas embolism. However, due to the nature of the underwater environment, accidents, traumas and other medical conditions unrelated to diving could also occur during diving activities. After the treatment of the subluxated shoulder, the diver and his buddy admitted that they had had a fight underwater. The buddy had pulled the diver's arm down in order to prevent an uncontrolled ascent but the diver escaped after punching him. It transpired that this underwater fight was concealed from healthcare providers in order to avoid legal proceedings.

Although an informative anamnesis could not be taken in this case at first, with a careful and calm examination the correct diagnosis was reached, and unnecessary hyperbaric treatment was avoided. As a note of self-criticism, healthcare providers should improve their communication skills to understand divers better. On the other hand, divers should not keep any information from the physicians, as it could mislead the diagnostic process and result in suboptimal care. Additionally, it is important that divers regularly practice emergency procedures, including behavior or aggressive instances, which would positively affect the decision making process should an emergency occur underwater.

Monoplace Chamber Treatment of Decompression Illness: Review and Commentary

RICHARD CLARKE

A detailed, well researched and very appropriate article written by Dick Clarke, one of our most experienced contributors to the treatment of injured recreational divers, was published in 2020 in the Diving and Hyperbaric Medicine journal. For those either interested, or perhaps skeptical about using such chambers, read his scientific article. He'll answer any of your concerns, which you can send to us to forward to him.

ABSTRACT

This paper summarises the history and capabilities of monoplace chambers in treatment of decompression illness (DCI); both in support of diving operations and in the hospital setting. In the field, monoplace hyperbaric chambers provide victims of DCI immediate access to recompression in settings where traditional multiplace chambers are not available. Alternatively, they may facilitate pressurised transport to a multiplace chamber for continued management. Recently, collapsible lightweight versions have improved suitability for field deployment aboard small vessels in remote settings, and for use by less technically capable military, occupational and civilian operators. The resulting elimination of treatment delays may prove lifesaving and central nervous system sparing, and avoid subsequent diving fitness disqualification. Monoplace chambers thus facilitate diving operations that would otherwise be difficult to condone on health and safety grounds. The 1960s saw the introduction of multiplace hyperbaric chambers into the hospital setting, as a number of non-diving conditions appeared to benefit from hyperbaric oxygen. This coincided with interest in hyperbaric oxygen as a solid tumour radiation sensitiser. Development of a novel acrylic-hulled single occupancy chamber enabled patients to undergo radiotherapy while pressurised within its oxygen atmosphere. Increasing numbers of health care facilities adopted this chamber type as a more economical, less complex alternative to the multiplace chamber. Incorporation of relevant biomedical technologies have allowed monoplace chambers to support increasingly complex patients in a safe, effective manner. Despite these advances, criticism of medical centre-based monoplace chamber treatment of DCI exists. This paper evaluates this controversy and presents relevant counter-arguments.

[Article Linked Here](#)

Infection Control in Hyperbaric Chambers: Selecting Suitable Disinfectant Products

FRANCOIS BURMAN

The era of COVID-19 has introduced a new challenge to infection control in healthcare facilities. Disinfectants are selected based on the known or expected types of pathogens; however, the SARS-CoV-2 virus which causes COVID-19 does not appear as a microorganism in many of our products in use.

The US Environmental Protection Agency (EPA) has a well-developed process for the registration of what are referred to as 'pesticides'^[1]. While some of the registered products are only available in the US, the information contained in the submissions for registration often applies anywhere where the active ingredients are the same. This does not give a blanket approval for use, but it does provide answers to many of the questions we might ask thereby making it a valuable resource.

One of the key aspects to this includes the types of surfaces that can be disinfected – in the hyperbaric industry this includes non-porous chamber materials, acrylic windows, hard-to-access spaces, and other complex internal configurations.

A disinfectant product Safety Data Sheet (SDS), previously referred to as the Material SDS or MSDS, despite being somewhat difficult to interpret, should be used for hazard identification and how to mitigate the associated risks. A Technical Data Sheet (TDS) and the product application instructions may provide more useful information for our applications than the SDS.

Before we discuss how to select and decide on a suitable and effective product, we should first define the various terms we use with these products, and thereby ensure that we focus on the appropriate products.

1. Sterilization: this 'severe' process ensures that we kill or inactivate practically 100% of all microorganisms. The options here are steam or dry heat, chemical processes, gas, plasma, and radiation. Clearly this is not an option for our internal chamber environment.
2. Disinfection: this kills or inactivates at least 99% of all known pathogens but not all bacterial or fungal spores. Also, it rarely applies to porous surfaces – such as bedding, neoprene covers and mattress materials. This is typically achieved using chemicals (disinfectants), pasteurization (moderate heat and time), UV radiation and ozone.
3. Sanitization: this process significantly reduces the pathogen load but does not inactivate some viruses. However, it is effective on porous materials. Sanitizers are usually chemical products. One should take care to note whether the product is defined as a disinfectant or a sanitizer – this could make a difference where especially contagious pathogens could be transmitted.
4. Cleaning: the COVID-19 pandemic has taught us that well-developed cleaning techniques – using soap and water and agitating surfaces – are highly effective at removing and even inactivating vulnerable viruses such as SARS-CoV-2. This is an essential first step in any infection control process.
5. Sanitation: quite simply stated, this is the hygienic disposal of any waste materials.

[1] <https://www.epa.gov/safepestcontrol/search-registered-pesticide-products>

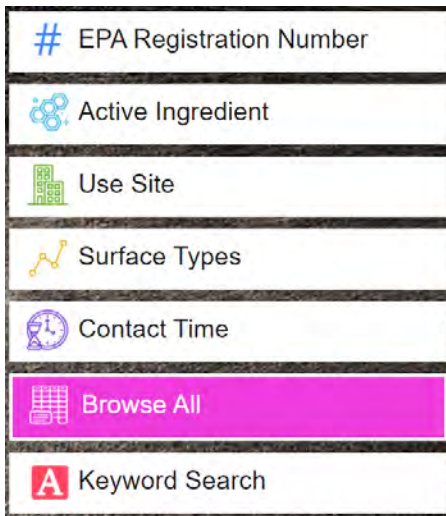
Selecting a suitable disinfectant for the inside of a hyperbaric chamber comes down to satisfying the following criteria; some easier to find answers for than others, but at least we will know what questions to ask the supplier.

1. Effectiveness against the known or expected pathogens, including bacteria, fungi, viruses, parasites, etc. The EPA submissions for products with specific active ingredients can assist here; most disinfectant manufacturers will identify the pathogens that they have tested for. For the SARS-CoV-2 virus in particular, the EPA maintains a List N^[2] for their registered products that will inactivate the virus. While the product registration may not specifically list the SARS-CoV-2 virus, List N will instruct the reader to disinfect according to a related virus.
2. Human compatibility. This requires checking whether the product could be harmful if ingested, inhaled or makes contact with the skin or mucosa. Much of this information should be in the product SDS. It does not mean that the product cannot be used, only that if you do decide to use it, you need to take the necessary precautions such as rinsing or wiping down afterwards.
3. Odor. Some products leave a lingering smell that may not be pleasant, such as bleach – a commonly used and highly effective disinfectant. There are steps that can be taken to reduce this, such as wiping down the surfaces with a damp cloth or rinsing in potable water after the required contact time, and then airing the chamber using a fan until dry.
4. Staff health and safety. During application of the product you need to identify any risks to your staff and provide the necessary personal protective equipment (PPE). This information should be contained in the SDS.

5. Residue. Once the chamber is ready for use, you should determine whether there would be any remaining residue that could be toxic. Use the SDS to check.
6. Fire safety. This is important both during application as well as when treatment commences. If flammable vapors are present, these need to be flushed out. Any oxygen-enriched environment (25% and more at typical hyperbaric pressures) may reduce ignition temperatures. Information on flammability should be contained in the SDS.
7. Chamber material compatibility. You need to ensure that the product is not corrosive and does not degrade materials such as plastics. Acrylic windows are especially of concern here. The SDS and the ASME PVHO-2 will have specific recommendations and cautions in this regard.
8. Application instructions, and soak and drying time. It is important that these can be complied with in order to disinfect appropriately. This information may be found in the EPA registration document, the TDS or the product application instructions.
9. Waste disposal or sanitation. Be aware of any restrictions in getting rid of any remaining disinfectant, including rinsing water. Many of these products are harmful to the environment and the SDS should indicate how to dispose of these materials safely and responsibly.
10. Availability and price. Some products are not allowed to be sold in certain regions, states or provinces; many products may simply not be available in your region; and affordability might be a restriction, especially where products are supplied ready to use. Concentrated form is cheaper to transport than an already made solution.

[2] <https://cfpub.epa.gov/giwiz/disinfectants/index.cfm>

To assist you in your search, products containing hydrogen peroxide, thymol, sodium hypochlorite (the active ingredient in bleach) and quaternary ammonia compounds are usually very effective disinfectants, including inactivating the SARS-CoV-2 virus. While isopropyl alcohol, typically in 20% – 60% solutions, is an effective ingredient, there are several areas of concern, including damage to acrylic windows. Great care should be taken in using them.



Two additional processes are used or being considered for use^[3] in hyperbaric facilities, and these are UV light and ozone. Both of these are very effective at disinfecting for most pathogens, but there are several reasons to be concerned – especially regarding materials found inside the chamber and the acrylic window being only one of these. Both processes produce dangerous environments when in use.

The EPA does not review devices and List N only considers surface disinfectants. A recent study on UV light as a disinfectant in hyperbaric chambers has been published. The reality though is that UV is most effective on surfaces that have already been cleaned and requires direct access to be most effective.

[3] Efficacy of UV-C disinfection in hyperbaric chambers, Warren et al. Duke Center for Hyperbaric Medicine and Environmental Physiology, Durham NC USA. SHEA, 2020.

If the intention is to ensure thorough disinfection of frequent contact surfaces, it could be used in conjunction with existing disinfectants. Be especially careful to cover your acrylic windows with a non-permeable screen – this could be an additional acrylic cover, or a waterproof or resistant material.

As of February 2020, the FDA has not authorized the use of ozone as a disinfectant for patient breathing devices. While ozone is claimed as being effective as an air purifier, this is not the same as a surface disinfectant.

The EPA only permits soaking, spraying and wiping to disinfect. While the EPA clearly has no jurisdiction in many countries where chambers are located, this is good guidance to follow.

SAFETY DATA SHEET

Hydrogen Sulfide

Section 1. Identification	
GHS product identifier	: Hydrogen Sulfide
Chemical name	: hydrogen sulfide
Other means of identification	: Hydrogen sulfide; Hydrogen sulfide (H2S); Sulfuretted hydrogen; Sewer gas; Hydro-sulfuric acid; dihydrogen sulfide
Product use	: Synthetic/Analytical chemistry.
Synonym	: Hydrogen sulfide; Hydrogen sulfide (H2S); Sulfuretted hydrogen; Sewer gas; Hydro-sulfuric acid; dihydrogen sulfide
SDS #	: 001029
Supplier's details	:
Emergency telephone number (with hours of operation)	:
Section 2. Hazards Identification	
OSHA/HCS status	: This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).
Classification of the substance or mixture	: FLAMMABLE GASES - Category 1 GASES UNDER PRESSURE - Liquefied gas ACUTE TOXICITY (inhalation) - Category 2 SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE) (Respiratory tract irritation) - Category 3 AQUATIC HAZARD (ACUTE) - Category 1
GHS label elements	
Hazard pictograms	
Signal word	: Danger
Hazard statements	: Extremely flammable gas. May form explosive mixtures with air. Contains gas under pressure; may explode if heated. May cause frostbite. Fatal if inhaled. Extended exposure to gas reduces the ability to smell sulfides. May cause respiratory irritation. Very toxic to aquatic life.
Precautionary statements	

A final note: Based on research, experience, current practices, EPA registrations & CDC advice, existing disinfection products & methods for other known pathogens appear to be effective in inactivating the SARS-CoV-2 virus strains. The important point is to continue to practice infection control, regardless of when the COVID-19 pandemic is finally brought under control, or any time after this.

Remote HBOT Safety and Operational Issues: The Need for Experience and Intervention

ROLY GOUGH ALLEN

I came into UK HBOT in 1984 after working as a commercial diving instructor at Europe's largest commercial diving school near Plymouth, South West England. Since July 2008 I have been working predominantly in Asia and Oceania. Some of the chambers I have been responsible for are fairly remote and time consuming to travel to. Micronesia, for example, includes a string of islands between Asia and Hawaii. To get there from Australia you first travel to Cairns, Queensland, then to Guam, and then east on flights which are more like taking a bus ride with regular short stops.

Indonesia & the Philippines are made up of many small islands, and travel there can be slow and awkward. Keeping remote chambers serviced and ready to accept diving accidents is a big challenge.

In the western world we accept many things we see every day as normal. The terms: clean, safe, fit for purpose, serviced, inspected etc. are understood to mean much the same to all of us.

However, the value we place on life, health and what is safe in one community may be drastically different to another.

Hyperbaric chambers (just like vehicles) are becoming more and more sophisticated with many more features and controls which makes them easier to operate (but more difficult to repair) and consumers seem to want more and more of these features.

Hyperbaric Oxygen treatment just needs a safe, uncomplicated chamber system, with oxygen, and appropriately trained and experienced staff.

I also work for a company in Australia that sells, hires, leases, services, & installs chambers for hospitals, military, dive & tunnel sites. We train teams at our own facilities and at facilities belonging to others.

Experience is needed and skills can be difficult to maintain if your chamber only treats an occasional case of DCI and is located away from a hospital. Teams ideally would include dive instructors, technicians, nurses and especially doctors. Any interest in diving is a great advantage. Moving a treatment chamber (although not always easy) to a local hospital has many benefits, which should normally outweigh the disadvantages (bureaucracy & internal political maneuvering).

My personal experience has shown me that the following eleven issues are the most frequent problems in remote diver treatment chambers and require positive intervention.

The single best piece of advice I was given when taking on this job in 2008 was: After a service or training visit, leave a system & team in a state that you would be happy to refer your child to if suffering from DCI.

I could expand more on any of these eleven items, but let's first see what reaction I get from you the readers.

Please feel free to send your comments to: roly.gough.allen@gmail.com

No.	The Problem	The Fix
1	Lack of team skills & size	All treatment facilities need at least one dedicated manager who can communicate well (may need two languages) with their own team and with regular outside support / assistance providers. Regular monthly training meetings should be arranged and promoted to all.
2	Lack of experience & therefore loss of interest by team members	A simple, consistent and timely reimbursement system for all team members. Managers need to keep the team motivated, interested and involved with regular monthly updates.
3	Turnover of staff & therefore the need for constant team retraining.	The ability to treat (& be reimbursed for) local non-diving patients (for example non-healing diabetic wounds). This maintains the use of the system and team experience and is a huge benefit to the local population and the chamber team.
4	Oxygen analyzer failure	A means of obtaining replacement parts. For example, sending a small parcel from Australia to Indonesia will, in most cases, never arrive. But if sent to Singapore, it could be hand carried by anyone who regularly travels there (if this is an option). A spare O2 cell should be obtained every 12-18 months and not before (they can decay as soon as they are manufactured if not packaged correctly). Chambers should not be without at least one working O2 analyser.
5	Compressed air system failure & contamination.	Systems need an annual service visit, parts delivery, and additional team training. Service tools alone may weigh 15 kgs (more than ½ your checked in luggage allowance). New filter elements may be needed every 12 to 18 months (another 5 kgs). Teams need to be able to analyse their compressed air supplies.
6	Erratic or unreliable oxygen supply	Being hospital-based should ensure better access to high pressure cylinder supplies or liquid oxygen, but a backup, secure supply that other departments cannot see, access, or borrow provides an added level of redundancy.
7	Ability to receive goods via normal shipping methods.	Develop a courier system with visiting divers via local dive resorts. O2 cells, compressor parts, etc., can all be transported by supportive or safety-aware divers in their luggage when visiting on holiday. This may not be a reliable solution nor customs compliant, but then regular shipping channels may be equally unreliable.
8	Keeping the facility maintained, clean & secure.	The manager or their deputy may need to hold the keys to the facility. Keys should not be given to others regardless of however much they insist that they need them. Install & maintain a system that adheres to the KISS (keep it simple, stupid) principle. Fit interlocks where really necessary to maintain safety. Remove / relocate sources of contamination including decaying vegetation near compressor intakes.
9	Dishonesty, bribery, laziness, delays & alternative agendas.	Document everything and don't pay for anything improper/illegal or of unknown origin. All payments need signed receipts and hard records should be kept. Communicate all important facts to the whole team. Don't accept irregular or alternative agendas - expose them! Only do a job once and do it to your best ability. Do not accept short inappropriate treatment protocols or improper medical / neurological examinations for DCI cases just because it's late in the day and some team members want to go home 2½ hours early. A USNTT6 will be the best treatment option for 99% of your patients.
10	Time for training & practical skills	Develop robust team communication systems (WhatsApp, etc.). Have a regular team meeting at the chamber - once a month, record who attends, practice an emergency action plan at least once a month. Report all faults to outside service providers as soon as possible, preferably on a simple template to ensure effective communication. Maintain a simple but accurate and up-to-date maintenance logbook.
11	Poor printing ability	Get a reliable printer for use within the chamber facility that can be maintained locally and keep it stocked with consumables.

Recompression Chambers for Treatment of Decompression Illness

SHERYL SHEA

The use of oxygen recompression tables in a hyperbaric chamber is the definitive choice for the treatment of DCI. The correct choice of treatment tables is very important to the successful resolution of each case. Under-treatment can result in an unsatisfactory treatment outcome and the need for further recompression or result in permanent injury. Over-treatment can result in physical adverse effects such as oxygen toxicity, and added stress due to additional cost, lost time from work, and travel logistics if away from home.

Once the cause of DCI in caisson workers was discovered by Paul Bert, a French physiologist in 1878, he found that gradually returning the workers to the surface relieved or prevented symptoms of what was then known as Caisson disease. In the early 1900's, J.S. Haldane, an English physiologist, developed a system of staged decompression that evolved over the years to become today's oxygen recompression tables. There are versions by various institutions – for example the British Royal Navy tables, the French Navy tables and the Comex tables. The most well-known and widely used in the treatment of DCI are the US Navy treatment tables, mainly USN Treatment Tables 5 & 6, which allow breathing oxygen at 2.8 ATA with a low probability of oxygen toxicity when administered correctly. They have been found to be effective for symptoms of DCI in 90% of cases.

The USN treatment tables are applicable to surface-supplied and open and closed-circuit SCUBA diving, whether breathing air, nitrox, helium-oxygen, or 100 percent oxygen.

There are treatment tables available that involve deeper and longer treatment periods such as the USN treatment table 6A, Comex, and Catalina tables, but most practitioners rely on the US Navy treatment table 6 for all initial DCI treatments, utilizing allowed extensions of time if the patient does not have adequate resolution of symptoms, rather than deeper depths. It can be used for Arterial gas embolism, Type I & II DCS symptoms, Cutis marmorata, asymptomatic omitted decompression, symptomatic uncontrolled ascent, and recurrence of symptoms shallower than 60 fsw.

Many chambers have depth or operational limitations and are either unable or unwilling to pressurize their chamber to the depths required for deeper treatment tables. For example, the chamber may only be rated for a depth of 3 atmospheres, or the facility medical director decides that treatment tables deeper than 3.0 ATA are unnecessary.

One treatment is often enough, but the USN TT6 can be repeated if the patient is still symptomatic, or follow-up treatments can consist of a USN TT5 or an additional US Navy treatment table, the TT9 at 1.9 ATA, which is sometimes used for treatment of residual symptoms. The patient is usually re-evaluated after each treatment, including a neurological assessment. Further treatment, if needed, is prescribed by the treating physician until the patient either recovers completely, or reaches a “plateau”, meaning that they are no longer improving.

Use of the USN TT5 as an initial treatment is allowed in rare instances. The TT5 should never be used as an initial treatment due to time or cost considerations. The treatment protocols give very specific instructions for when the USN TT5 is allowed as an initial treatment for type I DCS

symptoms (excluding cutis marmorata) when a complete neurological examination has revealed no other abnormality. In pain-only DCS, the TT5 should be converted to a TT6 if relief is not complete within 10 minutes at 60 feet or where pain is severe and immediate recompression must be instituted before a neurological examination can be performed. After arrival at 60 fsw, a neurological exam shall be performed to ensure that no neurological symptoms are present. If any are found, the diver should be treated using Treatment Table 6.

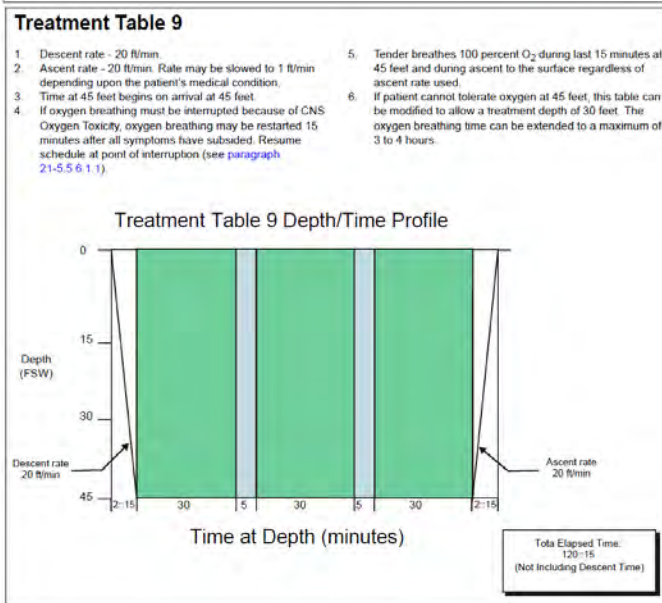
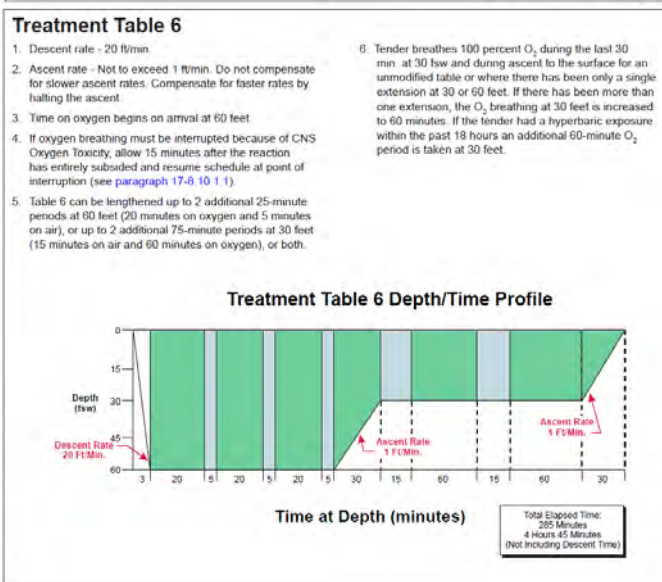
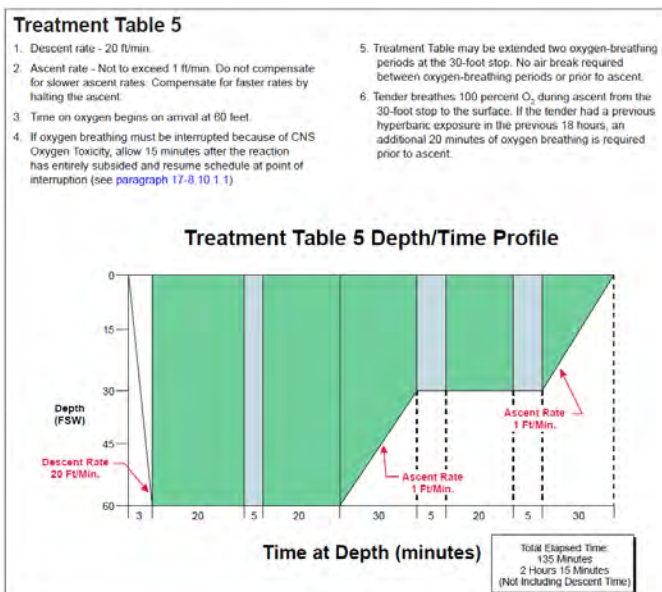
USN TT5 can also be indicated for asymptomatic omitted decompression and for follow-up treatments for residual symptoms. Time extensions are also allowed on a USN TT5. The USN TT9 in diving cases is only used for residual symptoms remaining after initial treatment of AGE/DCS.

Listed on this page are the treatment regimens and rules for USN TT6, USN TT5 and USN TT9.

You will notice that all three tables have some rules in common – descent rate not to exceed 20 feet/minute, time on oxygen begins on arrival at treatment depth, and the allowance of a 15-minute air break for symptoms of oxygen toxicity. Descent time is not included in the total treatment time, which will vary according to patient's ability to equalize. Ascent rates are maximum 1 ft./minute except for the USN TT9 which allows for a faster ascent, 20 ft./minute.

Allowed modifications to each table and inside tender oxygen breathing obligations are listed within each table. Oxygen breathing periods are highlighted green, and air-breaks are gray.

Please feel free to send any related medical or technical questions to RCN@dan.org.



1. Guiding Principles in choosing a therapeutic table for DCI hyperbaric therapy, C. Antonelli Minerva Anesthesiology 2009;75:151-61
 2. https://www.uhms.org/images/DCS-and-AGE-Journal-Watch/antonelli_guiding_principle.pdf
 3. U.S. Navy Diving Manual, Revision 7, Naval Sea Systems Command, April 1 2017
 4. https://www.navsea.navy.mil/Portals/103/Documents/SUPSALV/Diving/US%20DIVING%20MANUAL_REV7.pdf?ver=2017-01-11-102354-393

UHMS Guidelines for Hyperbaric Facility Operations (3rd edition)

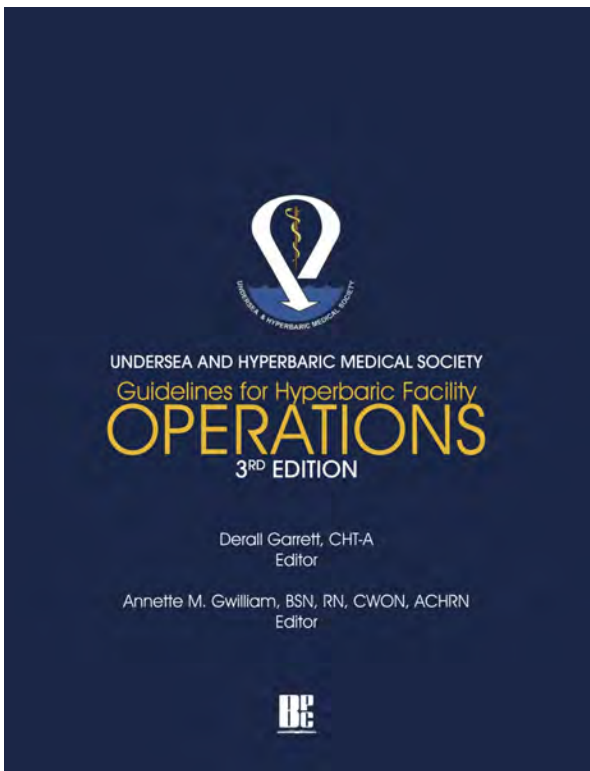
While UHMS facility accreditation is not often considered for facilities established primarily to treat injured divers, this publication does contain excellent guidance in training, staffing, safety and quality assurance. These are all attributes that apply to all facilities in some form or other.

You can order this very modestly priced but extremely useful publication from [Best Publishing](#).

The UHMS Guidelines for Hyperbaric Facility Operations provides UHMS guidance related to training, responsibility, staffing, safety, and quality assurance for hyperbaric medicine facilities. This 3rd Edition includes the following updates:

- New section on research, teaching, and publication
- Physician/NPP proctorship and credentials
- RN guidelines and responsibilities
- Enhanced section on LPN/LVN job description
- Addition of the CHS /CHWS certifications
- Safety changes and updates
- Nonclinical manager changes to job description and recommended training

These guidelines are essential for facilities that are new to hyperbaric medicine in establishing best practices. Existing facilities will find this reference indispensable in understanding the current standards and recommendations in maintaining an exceptional hyperbaric program. These guidelines are referenced by the UHMS Hyperbaric Facility Accreditation Manual and therefore are vital in planning and preparing for the hyperbaric survey to receive accreditation status.



FREQUENTLY ASKED QUESTIONS

Q: We have some rust in our bilge area. Can we fix this ourselves and what should we be concerned about?

A: A chamber would need to have suffered significant neglect before corrosion becomes a major concern; small on-site repairs should be safe and easy to do yourselves.

A decision to perform local paint repairs has two aspects to it: when corrosion damage is too extensive for a local repair by anyone other than a pressure vessel fabricator or repair service, and what should you do when you discover rust.

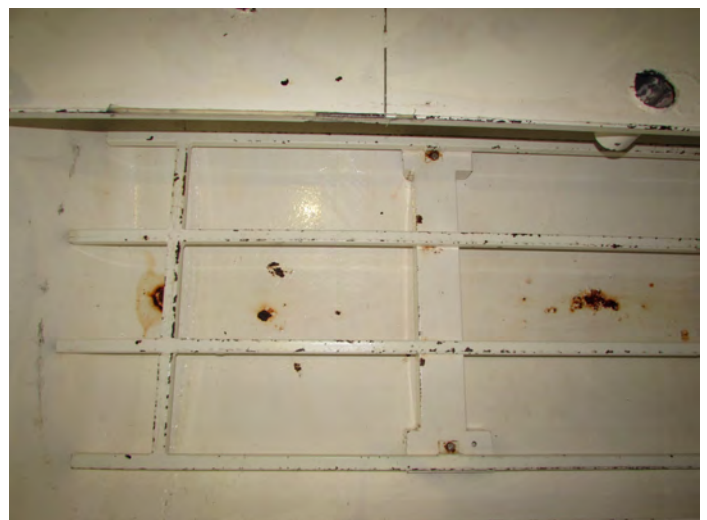
Steel pressure vessels are usually designed with at least some degree of corrosion allowance, and this is almost always the case where the designer understands the likelihood that moisture can accumulate in hidden places – such as in a bilge. A corrosion allowance is often noted on the nameplate.

In addition to this, the depth of any corrosion is actually less significant than the extent – a small area can withstand a few millimeters of local pitting; an extensive area could well mean that local repair is not possible.

As a guideline, small areas (say less than 12 mm or ½ inch in diameter or length) could allow for material thinning of up to ¼ of the plate thickness or say 1 – 2 mm.

However, several of such pits in a concentrated area (typically 150 mm or 6 inches in diameter or length) where the corrosion exceeds 1 mm could be of concern. In this case, one would need to approach a professional shop or design engineer to evaluate whether local repair would be possible. A door or viewport flange can sustain more significant damage as long as this is not on the sealing surface.

So, the important thing is to inspect your vulnerable areas regularly and when you notice either ‘crusty’ bubbles, red oxide weeping from a bubble, or simply clear rusting, you should take action as soon as possible. Rust is generally a slow process, but one would want to conduct inspections at least monthly.



Reparable rust spots in the chamber bilge

Where you notice or suspect corrosion, use a scraper or some other hand instrument to probe the area. Do not use force and certainly do not grind out or use other machine tools to remove corrosion. Once you are able to determine the extent and it appears to be light (less than say 1 mm), use sanding paper or a sanding machine to clean up any rust and the adjacent area at least 25 mm (1") from any corrosion. Make sure to go down to bare metal. 'Feather' the paint where it borders on the bare metal – meaning, lightly sand so that there is no clear ridge between remaining paint and the bare metal.

Clean the area thoroughly, preferably with a solvent or some form of rust converter, and please be very careful when using any flammable liquids in confined spaces – only take a wetted rag into the chamber and not any of the liquid. It is important to remove all forms of oil, dust, debris or fingerprints.



Reparable rust spots in the chamber bilge

As soon as the area is dry, apply a suitable paint or etch primer. Then allow this to dry and if at all possible, use a fan to circulate the area. Follow the primer instructions as to when it should be suitably dry.

To improve the appearance, you can lightly sand the primed paint to remove any brush marks or raised areas. Be sure to then clean this area as before.

Finally, you can apply the topcoat in one or more layers. Once again, lightly sand the area after each coat has been applied if you wish to make the paint look as pleasing as possible.

Allow to dry thoroughly (usually 72 hours or until 'dry-to-service') and be sure that there is no strong or unpleasant odor remaining.

Finally, observe the freshly painted areas after the first few treatments to ensure that there are no bubbles being formed due to any form of oil, dirt or fingerprints that will prevent a firm bonding of the paint to the underlying surfaces.

These minor repairs will be as good as the paint on a new chamber as long as you are sure to remove all the previous corrosion, clean thoroughly between coats, and allow to dry properly between each coat.

The next question will likely be what paint that can be used for these repairs?

You can enquire from a reputable chamber manufacturer or check with the paint supplier, or failing this, any marine application two-part epoxy or two-part polyurethane paint, with a low VOC (volatile organic compound) content and that does not ignite, burn, support combustion or release flammable vapors when subject to fire or heat once applied should be good. You can contact us at RCN@dan.org if you have any paint-related questions.

About The Authors

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Gökhan is a hyperbaric and underwater medicine specialist. After he finished his 3 years residency in 2016 in Turkey, he gained experience in recreational, commercial and military diving on different projects. He currently works at the Gozo General Hospital (Malta), which provides a high quality hyperbaric service for the entire Gozo, utilizing a multiplace chamber. When he is not on-call, he enjoys diving as a CMAS certified diver."

Roly Gough Allen

Roly worked at a UK commercial diving school until 1984 as a diving instructor. Then moved into clinical Hyperbaric Medicine. Roly is a CHT, European Certified Hyperbaric chamber operator and Safety Manager (ECHCO & ECHSM) and has experience installing, servicing and operating facilities for diving, hospitals, military and tunnel sites. Roly has contributed to a number of British & European hyperbaric guidelines & recommendations. He moved to Australia in 2008 where he is Operations, Training, Safety and Quality Manger for Hyperbaric Health (HH). HH has offices in Malaysia and Australia and services and installs chambers all over Asia & Oceania and in some fairly remote (not necessary exotic) locations. At present there are about 40 systems in 10 countries under HH's care.

Francois Burman

Francois is a registered professional engineer and Director of Underwater and Hyperbaric Safety at Divers Alert Network, based in Durham, NC (USA). He is the author of the Risk Assessment Guide for Recompression Facilities, first published in 2001, and has performed over 150 on-site recompression chamber safety assessments around the world. He has over 35 years' experience in designing, manufacturing, installing, supporting and providing training in recompression chambers, has been with DAN since 1996 and is very active in supporting recompression chambers, especially through education and training.

James Denham

James Denham is a licensed physician with recognized experience in occupational and maritime medicine. He has served as the Occupational Medical Physician in charge of the Diving Medical Program at the Panama Canal Authority for 16 years and as the Hyperbaric and Subaquatic Medicine Program Coordinator at the Panama Canal since 1995. He also holds an MBA, a Master's degree in Maritime Health, is an approved UHMS diving qualified physician (since 2003) and is a graduate of the NOAA/UHMS Physicians Training in Diving Medicine Course in Seattle, USA.

Sheryl Shea

Sheryl is a registered nurse, a certified Clinical Hyperbaric Technologist and works in the Medicine Department at Divers Alert Network. She has worked as a chamber operator and attendant, trained chamber personnel, worked for many years at a dive shop, has received extensive training in hyperbaric facility safety and technology, performed chamber safety assessments, and serves as both the chamber medical resource and diving medicine information specialist.

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