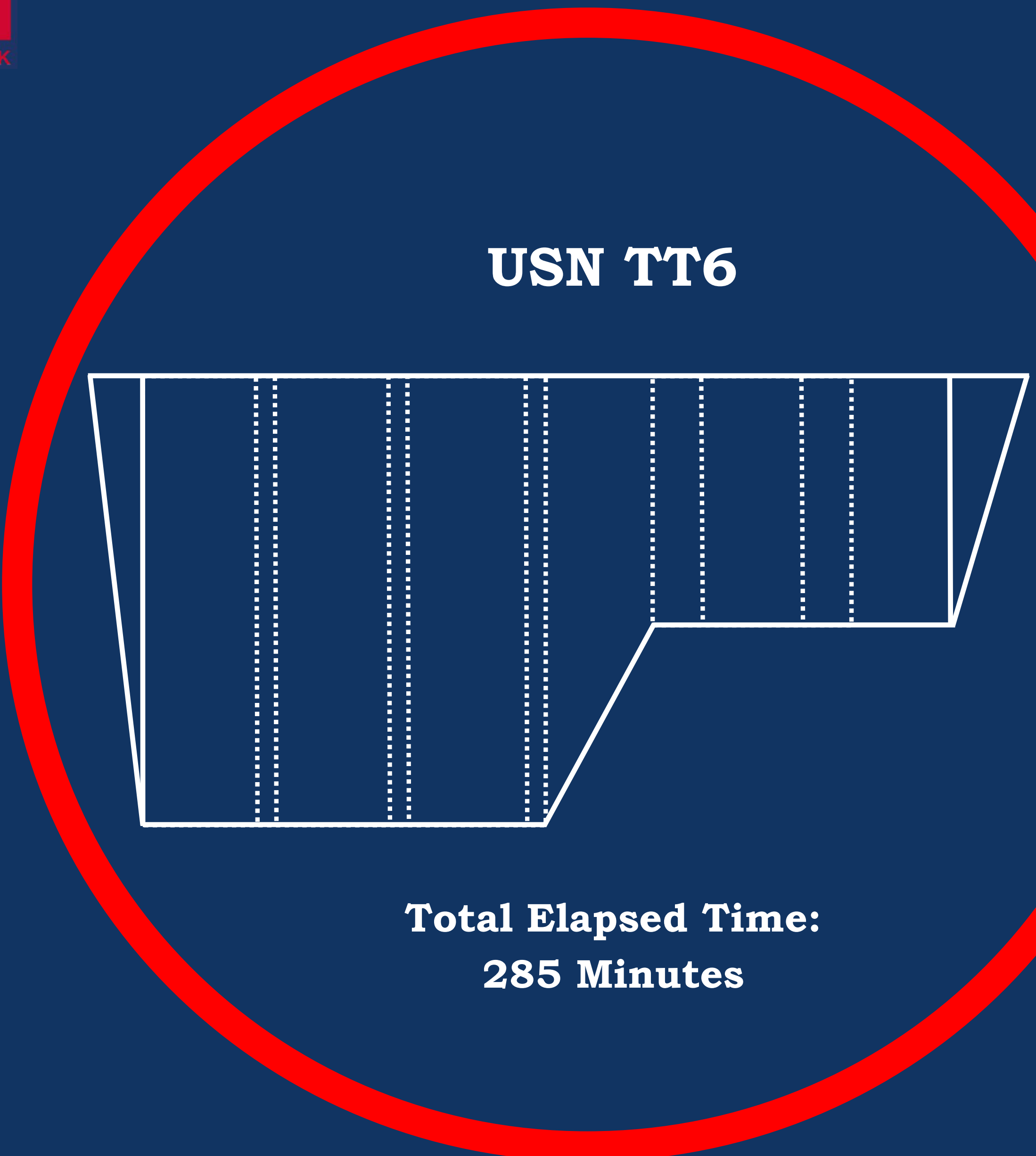


THE RCN BULLETIN

A Newsletter of the DAN Recompression Chamber Network

www.DAN.org

8th Edition—February 2023

RCN@DAN.org

WHAT'S INSIDE?

THE RCN WELCOME LETTER

2022 proved to be a busy year with the diving industry recovering rapidly. Here at DAN we dealt with a record number of medical calls, and with this, an increase in the number of recompression treatments provided. Islands that had been completely locked down starting welcoming divers back. From what we can see now, this trend will increase significantly in 2023.

Unfortunately, the pandemic did result in a number of recompression facilities losing staff, experiencing the degrading in staff skills, not being able to do proper maintenance, reducing their operating hours and availability, and some facilities have even closed down permanently.

However, from here we will look forward, and our team is pleased to share our first RCN Newsletter for 2023.

The focus on this edition is the question of different treatment tables, why and how they evolved, and once again emphasizing why the USN TT6 is the ***gold standard***.

In our RCN Newsletter #6 that was published in 2021, we provided an article on the USN treatment tables. In this newsletter, we will provide a history of the development of other tables that you may hear mentioned. Some of these are still provided in our industry, based on research, experience, specialized training, and improved outcomes. For most of you, however, you will learn that the USN oxygen tables remain the industry standard and other regions and countries are changing their practices to use these tables as well.

Simply put, you will not likely compromise a patient's recovery when using a USN TT6, especially for the first treatment. This remains DAN's recommended standard of care.

You will also learn about an essential aspect of ensuring safety in your facility: do what you have been taught and never allow yourselves to forget this. The one thing that we all learn from history is that we simply don't learn from history. You have a chance to stop this pattern by ruling out *complacency*.

As international hyperbaric standards

evolve, and hopefully provide more practical rules and guidance, we need to ensure that we take note of these and make changes where necessary. The DAN Risk Assessment Guide for Recompression Chambers is being updated once again to reflect all the significant changes over the past 2 years, ensuring that you have the latest guidance. A new revision should be available on our website before the end of March this year. Keep a look out for this: this publication is especially relevant to most of your facilities.

As we get back to the business of providing essential services to injured divers, please remember that we are always here to help, guide, and support you. You can email us directly at RCN@DAN.org.

- Francois Burman and the RCN Team

Complacency: The Universal Hazard

Robert Sheffield, BA, CHT-Admin
Director of Education, Int. ATMO, Inc.

A variety of hazards surround us in almost every endeavor. Whether crossing a street, driving a car, flying an airplane, SCUBA diving, or treating a hyperbaric patient, we must be mindful of the hazards to which we are exposed. The actual risk of a mishap from exposure to a particular hazard varies; but it can be quantified. It is a function of the frequency of exposure, the severity of consequences, and probability of the mishap occurring.

I just returned from a professional society meeting; and brought home COVID-19 – as did about 20% of those in attendance, including six of my personal friends. You might be thinking I was the culprit. However, I was fully vaccinated, had all the available boosters, and was asymptomatic before I went there. In fact, I flew in one afternoon and out early the next morning, only spending a few hours at the meeting.

After more than two years of the pandemic, most of us are frustrated by its impact on our lives and eager for things to be normal. As I write this, most places in the United States no longer have mask mandates or social distancing requirements. Most Americans are going to restaurants and other public places without masks. The actual risk for contracting COVID-19 varies by individual and by situation, but the hazard is still there. At my professional society meeting, there were more than 300 of us (mostly healthcare professionals), but only a few were wearing masks (I was not wearing a mask). We increased the probability of this risk by being complacent.

Complacency seems to be part of human nature. Repeated exposure to a hazard, without a mishap, builds confidence. It becomes easier to ignore a hazard because it hasn't bitten us yet. There is another problem with repetition. With routine tasks, at some point we go on autopilot and perform the task without thinking about it. This is a very common problem in utilization of checklists. Many people perform a checklist from memory without properly using the visual reminder. Others simply go through the motions of filling out the checklist (the documentation exercise) without paying attention to what they are doing. Maintaining diligence, especially with repetitive tasks, is a serious challenge. Becoming complacent increases the risk of any endeavor.

Knowledge is the key. With recommendations and requirements, there is a reason behind each recommendation in a guideline and each requirement in a safety code. Understanding why these specific recommendations / requirements exist is like a vaccination against complacency. It may not be 100% effective, but understanding should reduce the probability of the risk. And like some vaccinations, an occasional booster may be necessary. If we periodically remind ourselves why we take the safety measures we do, we are less likely to become complacent.

Click here to read an article about checklists.

Click here to read tips for changing complacent behavior.

Evolution and Performance of The Comex Tables

JP Imbert, M Eng (Biomedical)

Introduction

France has a long tradition in diving, and as a consequence, in treating bent divers.

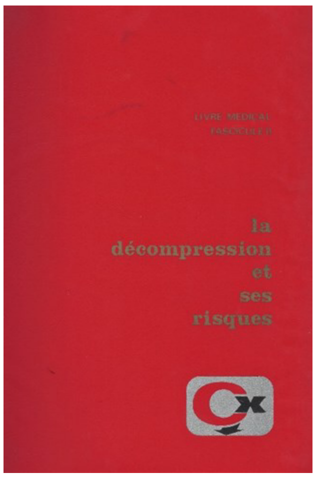
The first account of recompression treatments was published in 1854 by Pol and Wattelle who reported 16 cases of caisson workers experiencing DCS. Pol and Wattelle worked in coal mining in the north of France. Pol was the engineer and Wattelle, his friend, a medical doctor. Pol ran pressurized work to around 3 atm to prevent water ingress in the mine shafts and of course witnessed many cases of DCS. Dr. Wattelle described how he and Pol tried to understand the causes and attempted to cure the unfortunate workers. They finally used recompression to ease the symptoms. Pol was involved in the treatment of his workers and eventually died from consequences of severe decompression sickness after he had attended several recompressions with his workers. In the paper, written 10 years later, Dr. Wattelle recalled the dedication of Pol and concluded by the sentence: “you only pay when you leave”.

In 1878, Paul Bert published his famous book, “La Pression Barométrique”, where he demonstrated with dog experiments the benefit of oxygen in reducing bubbles produced by a decompression.

By the turn of last century, the development of caisson works permitted the edition of early treatment protocols. However, it was not until 1933 that Dr. Benkhe structured and edited the first US Navy treatment tables. In 1965, Dr. Workmann conducted the necessary revision work to give the treatment protocols their final form. Meanwhile, Dr. Val Hempleman designed the Royal Navy Treatment Procedures.

The US Navy treatment tables, and in particular the Table 6, have since remained the most used protocols, and the development of commercial diving has permitted the publication of alternative procedures.

At the time, Dr. Xavier Fructus was the medical advisor of Comex, a leading commercial diving company located in Marseille. He spent many nights on the phone, assisting work sites involved in divers’ treatment because at the time, the DCS incidence rate was around 10-15%. Based on his operational experience, Dr. Fructus developed in 1974 the first version of the Comex Medical book, which significantly differed from the Navy's practice. It was designed for a diving supervisor or a caisson master, lost on rig on the other side of the world with a small chamber, a few gas quads, and a fellow diver to treat, trying to establish a phone communication with Marseille.



The First Comex Medical Book, Edited in 1974

The 1974 Comex Medical Book

The early 70's offered the diving companies the North Sea market for which they were not really prepared. This was an exciting period for the development of diving procedures, but also a time where a lot of divers suffered decompression sickness.

Facing this situation, the medical doctors in charge started challenging the idea that prevailed at the time: first recompress the patient to the depth of relief. This concept was behind some deep British treatment tables and has remained underlying the US Navy table 6A, 1A, and 4 with their recompression on air to 50 msw (165 fsw.) However, it was known that in many cases, after the symptoms were relieved, the patient would be too deep, and his return to surface became a second problem.

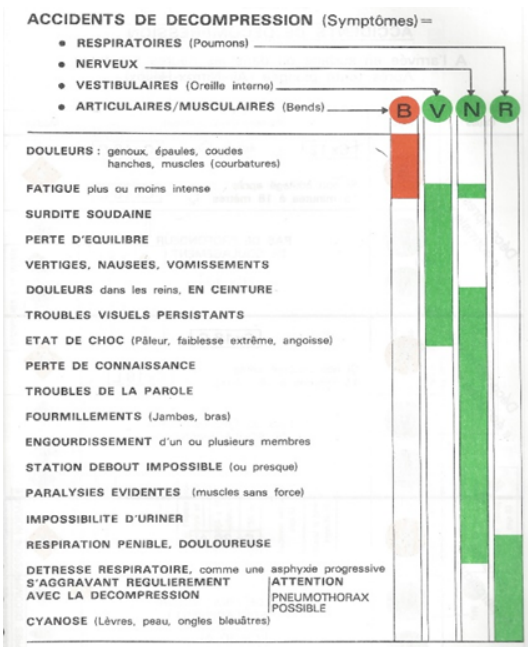
The alternative was to restrict the recompression depth and wait until the symptoms gradually resolved. In 1974, Dr. Fructus edited the Comex Medical Book as a blend of the US Navy and French Navy tables. He introduced the revolutionary Table Cx30 that included a 30 msw maximum recompression. His idea was to avoid deeper recompression, which he formulated as "give time to time".

Dr. Fructus also introduced an original list of DCS classifications based on four symptom types: B, V, N, R, standing for Bend (or articular pain), Vestibular, Neurological, or Respiratory (for chokes). This classification was used to enter the treatment flow charts similarly to the Type I/Type II classification in the US Navy manual.

For surface supplied operations, this first Comex medical book included a long series of treatment tables ranging from 12 msw to 30 msw:

- The Cx12 table, with two hours oxygen breathing at 12 msw, was the starting point of all the treatments for pain-only symptoms.

- The Cx18C, with 40 minutes oxygen breathing and the Cx18 L, with 60 minutes oxygen breathing at 18 msw (a short and standard version of the USN Table 6) was designed as a fallback for the Cx12.
- The Cx30 table, which included 40 minutes at 30 msw on 50/50 gas, was he ultimate table for the recompression of severe DCS cases.



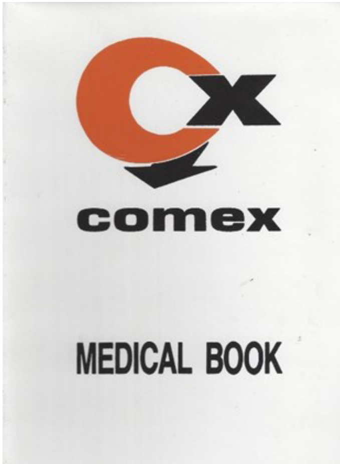
The Comex 1974 Medical Book and its Table for Identification of DCS

The Cx30 was derived from a 30 msw recompression table initially designed by Prof. Bathélémy at the French Navy Diving Department. In the 1974 edition of the Comex medical book, the Cx30 existed in several versions, Cx30, Cx30 A, and Cx30 AL (60 minutes on mix, or 90 minutes on air after an oxygen convulsion). The instructions associated with the Cx30 tables only specified the oxygen percentage without indicating the nature of the treatment mix. Dr. Fructus kept the option for operational flexibility so that people on board could use whatever 50/50 nitrox or heliox they had available. However, he admitted that he already suspected that heliox was particularly efficient in the treatment of air DCS.

The 1986 Comex Medical Book

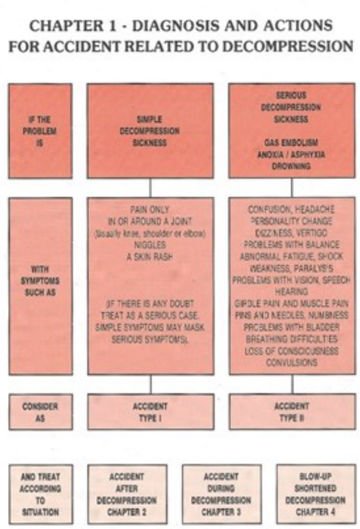
In the 80's, operations changed in the North Sea from platform installation, which requires bottom work performed in saturation, to inspection and maintenance jobs, which mostly concern shallow structures and air diving. Dr. Philip James joined the Comex company when air diving suddenly increased and recruited many severe neurological DCS cases. Dr. James was on the front line and directed a lot of Cx30 tables, which he systematically performed using 50/50 heliox.

In 1986, there was a drastic revision of all the Comex diving manuals, associated to the introduction of new air tables, new saturation procedures, and of course, a revised set of treatment tables.



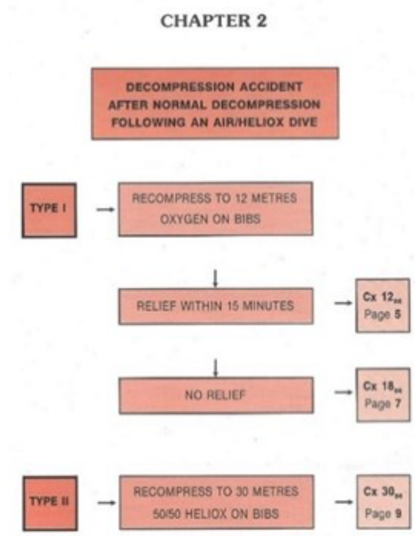
The Second Comex Medical Book, Edited in 1986

Dr. Philip James was instrumental in this revision and wanted to simplify the Comex treatment procedures. He first reduced the DCS type identification table to only two options, simple and serious, as for Type I/Type II in the US Navy manual.



Comex 1986 Medical Book: Table for DCS Type

Then, Dr. James reduced the number of treatment tables by combining the Cx18C and Cx18L tables into a new Cx1886 table similar to an extended USN Table 6 with 90 minutes oxygen breathing at 18 msw. This way, three tables only could cover DCS occurrence after surface-supplied diving.



Comex 1986 Medical Book: Treatment Chart for Symptoms after Surface-Supplied Diving

Finally, Dr. James relooked the Cx30 table and gave it the format that it has kept since. 50/50 heliox was specified, regardless of the diving mix.

The problem with heliox was associated to isobaric counter diffusion. The effects are sometimes beneficial, sometimes detrimental, and they depend on:

- The counter diffusing gases, in this case nitrogen and helium.
- The direction of the exchanges. If the two gases changed sides, the end result may change from super-

saturation to under-saturation.

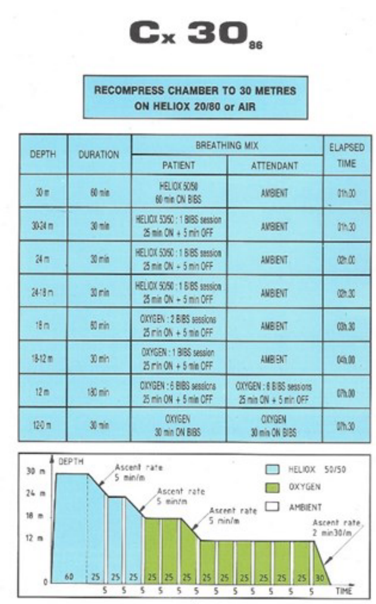
- The ambient pressure and thus the depth.

In Russia, at the time, Dr. Sokolov had developed a systematic approach for the treatment of severe cases of DCS using heliox saturation.

In Denmark, Dr. Hyldegaard conducted a series of animal experiments and demonstrated the capacity of helium breathing to reduce the size of nitrogen bubbles. He explained that the diffusion of helium into the bubble combined with the diffusion of nitrogen out of the bubble creates a situation of counter diffusion. The result is the shrinking of the bubble when the tissue is fatty, as can be assumed for a neurological tissue (Hyldegaard O, Madsen J. Influence of heliox, oxygen and N2O-O2 breathing on N2 bubbles in adipose tissue. Undersea Biomed. Research (1989) 16: 185-193.). He concluded the higher efficiency of 50/50 heliox breathing in the treatment of severe DCS after an air dive. The principle was later endorsed by DMAC (DMAC. Note 23. The Use of Heliox in Treating Decompression Illness. 1993 – now replaced by DMAC C 23 Rev.1 – 2014).

Secondly, Dr. James modified the breathing protocol of the attendant after one case of DCS had been recorded. In the new 1986 version, the attendant started taking oxygen at the 12 msw stop and kept it during the ascent to surface.

This version of the Cx30 table later became a standard in the offshore industry through Comex and its further avatars (Stolt, Nilson, Acergy, Subsea 7, etc.). The Cx30 was also adopted by Dr. Yehuda Melamed for the Israeli Navy and soon appeared in many other navy manuals (for instance the Norwegian Navy). It finally reached recreational diving, and DAN centers refer to the Cx30 in several places around the world (for instance Malta Mater Dei hospital on Malta). The Cx30 became a classic.


Cx 30 86

RECOMPRESS CHAMBER TO 30 METRES ON HELIOX 20/80 or AIR

DEPTH	DURATION	BREATHING MIX		ELAPSED TIME
		PATIENT	ATTENDANT	
30 m	60 min	HELIOX 50/50 60 min ON BIBS	AMBIENT	01h.30
30-24 m	30 min	HELIOX 50/50 : 1 BIBS session 25 min ON + 5 min OFF	AMBIENT	01h.30
24 m	30 min	HELIOX 50/50 : 1 BIBS session 25 min ON + 5 min OFF	AMBIENT	02h.00
24-18 m	30 min	HELIOX 50/50 : 1 BIBS session 25 min ON + 5 min OFF	AMBIENT	02h.30
18 m	60 min	OXYGEN : 2 BIBS sessions 25 min ON + 5 min OFF	AMBIENT	03h.30
18-12 m	30 min	OXYGEN : 1 BIBS session 25 min ON + 5 min OFF	AMBIENT	04h.00
12 m	180 min	OXYGEN : 6 BIBS sessions 25 min ON + 5 min OFF	OXYGEN : 6 BIBS sessions 25 min ON + 5 min OFF	07h.00
12-0 m	30 min	OXYGEN 30 min ON BIBS	OXYGEN 30 min ON BIBS	07h.30

The 1986 "Classic" Comex Cx30 Table

Offshore performances of the Comex

1986 treatment tables were published using the Comex database containing at the time around 500 treatments of DCS (Imbert, JP. Evolution and offshore performances of the Comex Treatment Tables. Workshop on Decompression Illness Treatment; 18-19 June 1995; Palm Beach, Florida: Undersea Biomedical Hyperbaric Society; 1995).

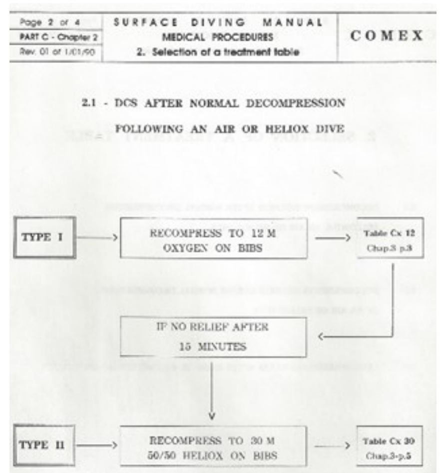
The 1990 Comex Medical Book

In the 90's, the offshore diving industry became a mature industry and better controlled its operating procedures. DCS became limited to predictable cases: articular pain in the last 10 msw of saturation decompression or neurological symptoms after a surface decompression.

In 1990, there was a new revision of the Comex diving manual and its medical procedures.

Dr. Philip James, still in charge of the North Sea, but also Dr. JY Massimelli in Marseille, further reduced the number of treatment tables by eliminating the Cx18 (tables Cx12 and Cx30 were kept unchanged).

The rationale was that if the symptoms were pain only, a Cx12 would do the job. If the symptoms were serious, compressing to 18 msw would be a waste of time since a Cx30 would be much more efficient. It was also explained that a compression at 18 msw provides too high a PO2 that should be optimized to around 2 bar, which is the case in the tables Cx12 and Cx30. The decision flow chart after a surface-supplied dive only considered two treatment tables.

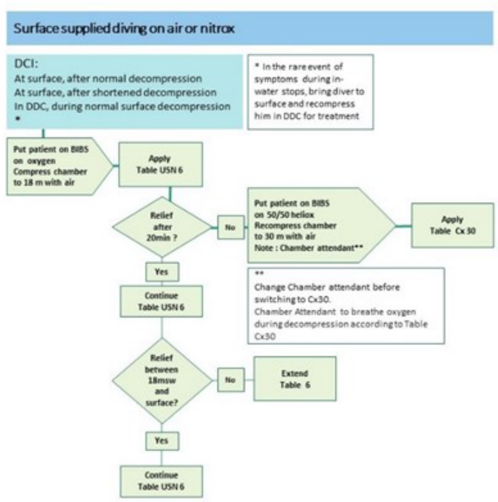


Comex 1994 Medical Treatment Chart for Symptoms after Surface-Supplied Diving

Current Commercial Diving Practice

Today, Comex has disappeared into the history files, but its contributions still remain. The industry has further improved and DCS has become a rare event. Companies operating in the North Sea report around one case of DCS every 10 years. The culture has changed too, and the emergency medical coverage is subcontracted to external companies. Therefore, the trend is towards standardization and simplification because the hyperbaric doctor in charge will have to deal with many clients and varied treatment procedures.

A typical decision flow chart is presented below. There is no need anymore to make a diagnostic. The recompression starts with a systematic Table 6 and is oriented for the rest of the treatment depending on the response of the patient at 18 msw. The Cx30 is only there for the serious cases, but most of the time, the patient benefits from successive extensions to the Table 6.



A typical offshore commercial diving medical book in 2022

Conclusion

The Comex medical book was typical of a commercial diving company. It came after the Navies had published their treatment procedures and used a different experience. The treatments and the tables were not the same.

They were also unique in a sense that Comex was very involved in hyperbaric research. In particular, the table Cx30 has been very successful and deep recompression treatment tables have progressively disappeared from the diving manuals.

These original procedures also evolved with time and adapted to the concerns raised by specific worksites. If initially the treatment procedures were a matter of company culture, the international dimension of the offshore industry now requires standardization, and as a consequence, simplification.

The Comex Cx30 tables have survived this evolution and have become an international standard, mainly prescribed as a fallback to the Table 6 for severe cases. It still appears in many large commercial diving manuals.

The Catalina Tables for Scuba Divers

Karl Huggins, MS Bioengineering
Twin Harbors, Catalina Island, CA

Summary

Initially, the University of Southern California (USC) utilized the US Air Force (USAF) Treatment Table 8, designed for altitude decompression sickness. This is based on the US Navy (USN) Treatment Table 6 during the 30 fsw (1.9 ATA or 9 msw) stage, but instead of 60-minute sessions with 15-minute air-breaks, it used 20-minute treatment sessions with 5-minute air-breaks for the same overall duration.

Catalina Hyperbaric Chamber

Why were they developed?

In response to a review by T.E. Berghage in about 1980 stating, “The current recompression treatment procedures [US Navy Oxygen Treatment Tables] appear to provide adequate therapy for mild to moderately severe cases of illness due to pressure reduction. For severe cases, those that make up a large portion of the civilian cases treated by the Navy, it appears that existing recompression procedures are only marginally effective.”

What indications are they used for?

Decompression Sickness and Air Embolism

What are the advantages and disadvantages of the Catalina treatment tables?

Advantages:

- Strives to get the most resolution out of the initial treatment.
- Allows the resolution of symptoms to determine the length of the treatment protocol.
- Provides the ability to extend beyond 5 oxygen periods at 60 fsw (1.9 ATA or 18 msw), without going into a saturation table (USN TT7).
- Is a single table for all treatment combinations and tender oxygen decompression requirements.
- Allows a return to 60 fsw (1.9 ATA or 18 msw) if symptoms reoccur during treatment as long as there is not exposure beyond the maximum

of 8 periods at 60 fsw.

- If 8 treatments have been done at 60 fsw (1.9 ATA or 18 msw), then a return to 30 fsw is allowed and additional treatments can be given until symptom resolution or pulmonary oxygen toxicity limits prevent further treatment.

Disadvantages:

- Can result in treatments of up to 12 hours in duration.
- The potential exists of pulmonary oxygen toxicity in the tailing end of long treatments.

Suitability for the Recompression of Scuba Divers vs. Military / Commercial Divers:

This table is primarily used for the recompression of recreational divers, although it has been used on some deep trimix and commercial divers.

When would one of these be used instead of a USN TT6?

When symptoms are still not resolving during the 5th (extended) oxygen period at 60 fsw (1.9 ATA or 18 msw).

Are they still in use?

Yes

Are there any special considerations – like chamber set-up and tender training?

The tender needs to be aware that they could be in the chamber for up to 12 hours.

Tenders can be swapped out if needs be, but the preference is to “burn” only one tender at a time.

Are they suitable for treatments in remote areas?

Yes, but it will depend upon how much oxygen is available and if a comfortable temperature can be maintained in the chamber.

Hawaiian Deep Tables

Bob Sanders, DMT, MD, FACEP, FUHM

With a recognition to Dr. Richard Smerz, DO, who has documented the history of the Hawaiian Tables and whose work formed the foundation for much of this summary.

Summary

In the Late 70's and early 80's, recreational diving was exploding! The SPG became the "standard", the octopus (safe second, etc.) was a new item, and the horse collar was switching over to the vest-style BC, allowing the experienced divers to venture further and further. In addition, folks who thought diving was only for the explorer started to try the sport. Of course, with this explosion came a significant increase in recreational dive accidents.

Rich in its own history, Hawaii offers exquisite warm tropical waters, amazing views, and varied recreation, all with the luxury of United States safety, familiarity, and resources. As such it has been for many years, an ideal travel destination for people around the word, especially for divers. With the military presence in Hawaii and the need to support the pacific fleet, a hyperbaric chamber was established at Pearl Harbor and the Navy took on the role of treating civilian diving accidents.

Researchers like Yount, Kunkle, and Beckman at the University of Hawaii were trying to "crack the DCS code" by developing their variable permeability model to gain a better understanding of the whys and wherefores of decompression stress and bubble formation/ dissolution. Spencer was doing his work with doppler to understand bubble dynamics. Gernhardt, as an undergraduate, and later working with Dr. Lambertsen, was developing his Tissue Bubble Dynamics Model. Bennett was setting a world depth record in a hyperbaric chamber of 2250'. It was a great time for diving research, and while it was clear that Haldane's work was too simplistic, the solution to the "DCS code" was still not known.

What was demonstrated by Beckman and Kunkle was that rapid dissolution of bubbles required immediate rapid recompression, and that the length of time required to dissolve bubbles was directly proportional to the size of the bubble. They found that bubbles grew to a size of 1mm in diameter in about 5 hours, and that after a 60 fsw exposure, it would require about 80 minutes to dissolve, whereas at 220 fsw it would require only about 17 minutes. Given the fragility of nerve tissue (brain and spinal cord) to compromised blood flow and hypoxia (brain cell death occurs in 4 minutes; spinal cord cell death in 30 minutes), a combination of maximal recompression (bubble shrinkage) and oxygenation (optimal ppO_2) appeared to be the best solution (Presented at 2nd Japan Working Divers Symposium, 1980).

Why were the Hawaiian Tables developed?

As early as 1975, Erde and Edmonds (and supported by Davis in 1979 and then locally by Kizer in 1980), found that the US Navy Dive tables were not sufficient for the recreational accidents that were occurring. In 1980, T.E. Berghage stated, "The current recompression treatment procedures [US Navy Oxygen Treatment Tables] appear to provide adequate therapy for mild to moderately severe cases of illness due to pressure reduction. For severe cases, those that make up a large portion of the civilian cases treated by the Navy, it appears that existing recompression procedures are only marginally effective".

From Kizer's work in the Hawaiian diving population (n = 255 cases) prior to the development of the Hawaiian Treatment tables, the following figures were produced:

- Type I Cases = 41%
- Type II Cases = 59%
- Serious Cases = 49%
- 59% of all cases achieved complete recovery; 7% had no improvement
- 48% of serious cases had complete recovery
- 60% of Type I cases had complete recovery
- Average Time Delay to Treatment = 6.6 Hours

Hawaii (at least from 1988 - 2007) was seeing approximately 10% of the US recreational cases and as much as 5% of the reported worldwide recreational dive accidents (Sanders, unpublished research). Such a number was significantly impacting the Navy's operations in Pearl Harbor and there was great pressure on the state to take over the treatment of recreational cases. With the work of Frank Farm and the Hawaii Legislature, in 1983 the University of Hawaii at Manoa, John A. Burns School of Medicine Hyperbaric Treatment Center (HTC), was opened to address both the issue of numbers of cases and poor outcomes with the Navy Tables. The goal: Improve Outcomes.

To do this, Beckman and Kunkle, using

the work of this Hawaiian "tiny bubbles" group, began by looking at the Royal Navy Physiologic Labs tables, and then modifying the US Navy Tables 6 and 6A to the HTC TT60 and TT160. Deep tables were added, specifically to treat the resistant "Neurologic DCS Cases" (brain and spinal cord injury). Interestingly enough, all the Hawaii tables use a staged (slowed) ascent from depth to 60 fsw, an addition that the US Navy would adopt some 20 years later.

What indications are they used for?

The Hawaiian "deep tables" (TT160, TT220, TT280), the truly unique tables, are used primarily for Neurologic Decompression Sickness and Air Embolism, but the entire library of Hawaiian Tables (TT45 [was 47], TTCO, TT60, TT160, TT220, TT280) are used to treat all 16 approved indications for HBO.

What are the advantages and disadvantages of the Hawaiian treatment tables?

Advantages:

- Uses pressure (depth) to destabilize the bubble ("crush it") to favor reabsorption and improve outcomes.
- Strives to get the best resolution out of the initial treatment.
- Allows the resolution of symptoms to determine the length of the treatment protocol.
- Provides the ability to extend multiple periods at any given depth without going into a saturation table (such as the USN TT7).
- Maximizes pressure and thereby destabilizes bubbles, to minimize the time a bubble is in contact with the tissues and causing injury.
- Possible improved outcomes (Smerz et al, 2005 retrospective):
    - All symptomatic cases treated (n = 889):
        - 92.9% of all cases achieved complete functional recovery; 3.5% had no improvement
        - 76.4% of severe cases achieved complete functional recovery
    - Review: USN Stats
        - 59% of all cases achieved complete recovery; 7% had no improvement
        - 48% of serious cases had complete recovery
    - Divers Alert Network (DAN), in their annual review and analysis of US diving accidents and fatalities reports:
        - 70% - 75% of cases achieved

- complete recovery at discharge
- 48% of cases required only 1 treatment; (HTC = 59.2%)
- Average number of treatments was 3.3 per case; (HTC = 2.1)
- 82.5% of DAN-reported cases were treated using USN tables

Disadvantages:

- Requires a "non-standard" facility and 3 inside tenders with unique training.
- Can result in treatments of up to 12 hours or more in duration.
- The potential exists of pulmonary oxygen toxicity after long treatments or with tailing treatments.

Suitability for the Recompression of Scuba Divers vs Military / Commercial Diving

While these tables were developed primarily for the treatment of recreational divers, they been used very effectively on military, deep, trimix, and commercial divers.

When would one of these be used instead of a USN TT6?

- Neurologic Decompression Sickness
- Arterial Gas Embolism

Are they still in use?

Unfortunately, these tables are not in use currently, but there are efforts to bring them back online.

Are there any special considerations – like chamber set-up and tender training?

- The chamber system needs to be capable of depths of 230 feet or more.
- There needs to be multiple locks to allow the ingress of tenders (and physicians) while supporting the decompression of others.
- These tables require training and experience.

Are they suitable for treatments in remote areas?

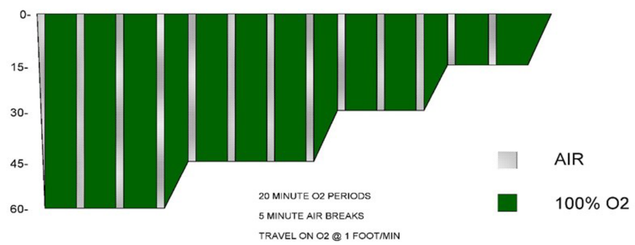
The tender safety and single-treatment patient success rate make them ideal for remote areas, but the equipment requirements and staffing requirements make them less practical than some other treatment tables that can be run easily in a smaller chamber (Deck Decompression Chamber [DDC]) with minimal staff (Consolidated Catalina Treatment Table [CCTT], Cx30, etc.)

Bottom line: Myself and the other physicians who have used the tables routinely continue to have confidence in the efficacy and efficiency of the Hawaiian Deep Tables.

HTC TT60

Total Time (Without Extensions): 5 Hours 20 Minutes

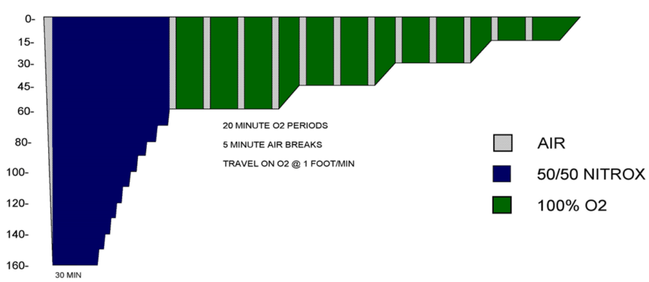
UPTD = 791



This table was based on the USN Table 6 (USAF modifications) and Royal Navy Physiological Laboratory (RNPL) tables with decompression stops at 45 fsw and 15 fsw.

HTC TT160

Total Time (Without Extensions): 6 Hours 18 Minutes

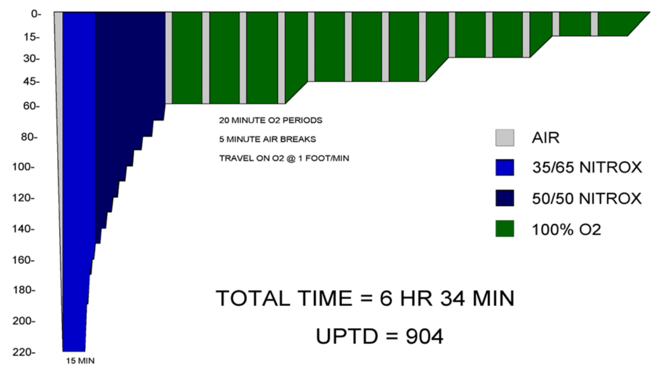


Starting with the USN 6A, the depth was reduced to 160 fsw to allow for the use of 50/50 heliox (changed to nitrox for cost reasons), and a more gradual staged ascent from 160 fsw to 60 fsw was added (the US Navy followed suit some 20 years later). The TT60 changes were also included.

15 fsw - 4.7 msw
45 fsw - 14 msw
150 fsw - 46 msw
160 fsw - 49 msw
220 fsw - 67 msw

HTC Dual Nitrox TT220

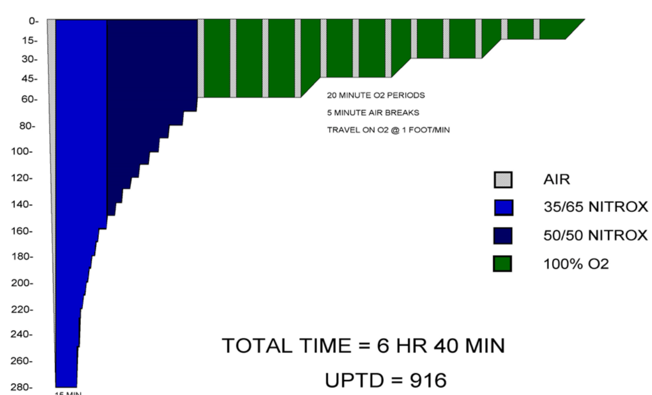
Total Time (Without Extensions): 6 Hours 34 Minutes



Based on the multitude of severe cases which failed to completely recover using the USN protocols, the TT220 was conceived which uses 65/35 Heliox/Nitrox at 220 fsw, switching to 50/50 Heliox/Nitrox at 150 fsw while ascending at a staged manner, then moving to the TT60.

HTC Dual Nitrox TT280

Total Time (Without Extensions): 6 Hours 40 Minutes



Later, the dual nitrox/heliox TT280 was devised for more resistant cases, although it was only used 29 times (Smerz, 2005).

Editor's Note

Due to the extensive experience and facilities required for the safe implementation of these tables, one must caution against their use in remote locations.

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DAN Recompression Chamber Network Referral Database

Sheryl Shea, RN, CHT

DAN maintains a worldwide database of recompression chambers that treat divers. It is most often used to refer divers with symptoms of decompression illness. These are mainly recreational or technical divers, but we also receive calls about pilots, military, commercial, public safety, scientific, and aquarium divers. We also regularly get inquiries from emergency rooms with carbon monoxide toxicity patients looking for the nearest chamber.

We receive frequent calls and emails from divers and dive leaders who are in the process of creating an Emergency Action Plan for an upcoming dive trip, or commercial or military operation, and need to know chamber locations for their destination.

Information on recompression chambers is available to anyone who requests it, at no cost, and they do not have to be a DAN member, although DAN membership helps support this important service. They can call any of the DANs on their information line, or send an inquiry to Ask-a-Medic on DAN.org/Ask-a-Medic. In case of emergencies, the DAN Hotline can be used for this purpose.

The chamber database is not publicly accessible. That is because of the changing nature of the operational status of recompression chambers. Chambers often go off and online due to maintenance, breakdowns, staffing limitations, and funding issues, among other reasons. By giving each chamber information request individual attention, we can give more accurate, up-to-date information.

There are currently 390 chambers in the DAN RCN database that treat divers and are available 24/7. They tend to be in areas where a lot of recreational diving takes place, like Mexico, the Caribbean, USA, Philippines, Maldives, Thailand, and Egypt.

DAN Hyperbaric Chamber Map

But there are also chambers in unexpected places where scientific, commercial, and / or military diving takes place, like Antarctica.

Unfortunately, in the USA, the number of chambers available to treat emergencies is declining. The cost for maintenance and training, and staff time commitments are major factors in this decline. Chambers that treat non-diving patients, such as wound care, but rarely receive an after-hours emergency may decide it is not worth the expense and commitment. So, they may still treat divers, but only during regular business hours. Unfortunately, most dive-related accidents don't occur during business hours. Chambers that exist mainly for treating emergencies, but rarely receive one, may close permanently. This can result in extended evacuation times over long distances, and extreme treatment delays.

This is where the DAN Recompression Chamber Network and chambers that treat divers can help each other. The RCN Network needs more chambers, and once a chamber is listed, there is the possibility of the chamber receiving more patients. If you are affiliated with a chamber that treats divers or are aware of one, please contact us! If you are not sure if a chamber is already listed, let us know and we will check.

We need some important information to get started with adding a chamber to the RCN, and by filing in this form, we can be sure that details are accurate, complete, and accessible to us. This will assist in making a rapid referral where there is an injured diver.

Once we receive this form, we will communicate with the chamber to verify contact details and let them know that they are in the RCN database.

Please note that the form cannot be filled in using a web-browser. It needs to be downloaded to a computer that has Acrobat installed.

If you know of a chamber that treats divers and is perhaps not in the DAN database, please feel free to email us at RCN@DAN.org, or have them email us. We will reach out to them.

Compiling a Hyperbaric Facility Safety Manual

Francois Burman, PE

Confidence in the operational safety of a hyperbaric treatment facility begins with documentation. Management, whether the unit's medical director or the healthcare facility management team, and certainly any external audit team, will all want to see how the safety system has been documented.

In the unfortunate case of an accident, investigators always start with a review of the documentation.

Even where staff do a great job in taking care of their own team, patients, and the public, the old saying "if it does not exist in writing, it does not exist" always applies.

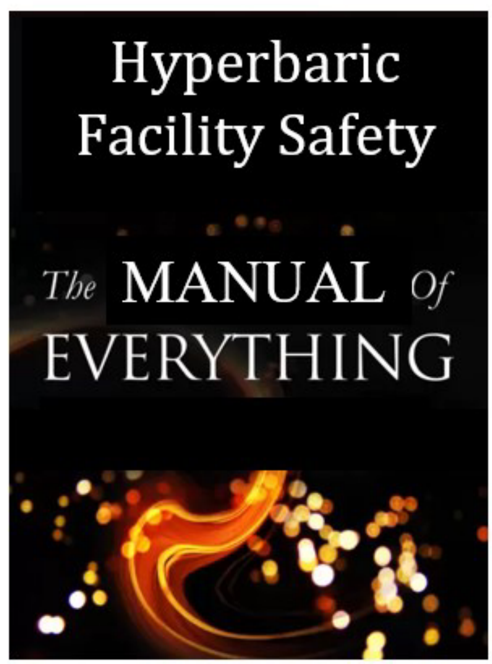
Conversely, a well-documented system gives everyone a greater sense of confidence, and in the event of any investigation, will provide management and staff with a far greater chance of effectively defending their actions.

Even when a system is well-documented, if these documents cannot be easily accessed and presented on enquiry, once again confidence breaks down.

All of this requires the safety officer to carefully collect all documentation, make sure that the relevant documents are kept up to date, make sure that the filing system works, and be ready to produce any required document or record when asked.

A hyperbaric facility safety system comprises many elements, most of which come down to policies and procedures, staff records, equipment, and maintenance records.

With the modern information technology and online storage facilities, this can be done using a secure electronic, paperless system.



Guidelines for Compiling a Safety Manual

Compiling a safety manual is not simply a tedious task for the safety officer; instead, the whole idea is to produce a highly relevant, practical reference guide to:

- enable effective management
- ensure consistency in practices
- enable all new appointees to understand the full scope of their activities and responsibilities
- provide specific job responsibilities
- ensure system readiness and preparedness
- provide for safety in all operations
- provide a curriculum for specific system training
- provide a single place of storage for all required documentation
- provide instruction on use, maintenance and care of the facility and equipment; and
- assure a safe, effective, and available treatment facility.

The safety manual should include all policies and procedures, operating instructions, essential reporting forms, assessment and monitoring instructions, maintenance schedules, liability-reducing registration documents, and client and staff instructions and records.

It should also provide a system for the maintenance of records, to assure proof of a robust safety system.

To achieve all of these objectives, a safety manual incorporates various elements. The following list provides typical headings rather than the details, and it should be individualized based on the actual facility operation. The focus should be more on including essential information and documents rather than lengthy descriptions and repetition: short but inclusive of the details.

Safety Policy and Scope of Services

A safety policy portrays a facility's commitment to ensuring safety and compliance with relevant legal requirements and industry standards.

The scope of services (medical and technical) should be clearly defined to ensure proper transfer and referral of patients.

The facility should be organized, integrated, staffed, and directed commensurately with the scope of services offered.

Operating Procedures & Instructions

All standard operating procedures and work instructions should be documented and importantly, regularly reviewed and updated as the facility's functions and operations evolve.

Patient registration procedures, including signed waivers, indemnifications, and release from obligations must be consistently applied and carefully retained.

Personnel

Letters of appointment, clear job descriptions and expectations, and any disciplinary actions must be recorded.

Careful attention needs to be paid to qualifications and competences.

Safety in the Workplace: A Legal Requirement

Occupational health and safety in the workplace applies to all owners of facilities where workers are exposed to risks associated with injuries, illness, or any other form of harm.

This specialized area of safety requires more in-depth knowledge of workplace risks, requirements to ensure safety, and the obligations of business owners.

Many facilities will be required to have a separate Health and Safety Manual explaining workplace risks and how these are mitigated.

Emergency Action Plans (EAPs)

In the event of an accident potentially endangering the lives of people, equipment and facilities, the environment, or even the business itself, a rapid, predetermined course of action is required.

A realistic assessment of emergencies is required, as well as emergency plans developed to ensure rapid and effective responses.

Records of EAPs, the implementation thereof, and drills and practices should be retained in the manual.

Safety Evaluation and Monitoring

All facilities should perform documented risk assessments on all existing and new equipment and procedures. This improves confidence through knowing that risks are being continuously mitigated.

All events such as incidents, accidents, near misses, non-compliances with procedures, system failures, or other undesirable situations should be recorded to demonstrate the commitment to a safe operation.

These will help in determining the effectiveness of risk mitigation actions.

Maintenance of Equipment & Facilities

Regularly planned maintenance is an essential part of ensuring function, reliability and availability of critical equipment. Inspections and service reports, calibration and testing certificates, repairs undertaken, and failure investigations should be recorded and retained.

A policy on authorization to work, and the quality of replacement parts and materials, should be established and documented.

Skills Assessments

All required duties and actions, including performing standard and emergency operations, operating equipment, and even managing patients, require regular refreshing of skills and competencies.

This is especially important where treatments and associated activities are infrequently performed – as is often the case in remote diver treatment facilities.

Assessments should be recorded and filed in either personnel files or operating records as applicable.

Closing Notes

Each safety manual will be unique to the facility's actual operations, staffing, location, utilization, and scope of services being offered.

The 8 elements above are suggestions to aid in providing structure to the system. Each element might be filed in a different place, and in this case, a single document listing where each element is retained would be very useful for management, new employees, auditors and assessors, and especially investigators.

A safety manual is a live document recording real-time processes. Do not let it be forgotten about and just regarded as something that needs to be done. It is your assurance of safety to everyone who enters your facility.

Please contact us at RCN@DAN.org if you need assistance in compiling your own manual.

FREQUENTLY ASKED QUESTIONS

Q: What gas quality standard applies to hyperbaric chambers compressed using air?

A: There are several international standards that apply to breathing air quality and the first step is to determine which of these may apply to your facility. There is no single universal standard for hyperbaric chambers, but a few countries do provide acceptable quality levels for use under their national compliance system.

Assuming that your region does not have a hyperbaric air quality standard, your best approach is to see if there is anything governing surface breathing air (e.g., for breathing in spray paint booths or gas tanks), underwater breathing air (typically for commercial diving), low pressure air, high pressure air (e.g., for firefighters), and oxygen compatible air.

Most standards focus on elements such as carbon dioxide (CO_2), carbon monoxide (CO), oil (mist or vapor), volatile hydrocarbons (e.g., methane), moisture (water), particulates, and odor. There is no one standard that addresses all of these, and yet most of these may have a detrimental effect on your chamber occupants.

Many standards are based on high pressure air where elements such as moisture are relatively easy to remove, and one concern is freezing up of regulators. This is not the same for low pressure air (gas supply pressures for recompression chambers are typically less than 220 psi or 15 bar).

The sensible approach is to determine what is safe for recompression chamber treatments, considering fire, equipment, and physiological hazards. Also remember to perform a detailed assessment of where your compressor intakes are located to determine whether there are any potential contaminants that don't appear on any national breathing air standard.

DAN has researched this topic extensively, analyzed the effects of contaminants on the hyperbaric environment, and determined what is safe for all concerned with the facility.

The recommendations below are entirely achievable where compressors and filters are properly maintained, and where air intakes are secured against ingress of any other hazardous compounds.

	HP Air	LP Air	OCA
CO_2	500 ppm_v	500 ppm_v	500 ppm_v
CO	5 ppm_v	5 ppm_v	5 ppm_v
Moisture	50 mg/m^3	160 mg/m^3	50 mg/m^3
Oil (VOC)	0.5 mg/m^3	0.5 mg/m^3	0.1 mg/m^3
Odor	Slight	Slight	None
Other THC	25 ppm_v	25 ppm_v	25 ppm_v

Determining odor is subjective, however, any indication of an irritant, harsh, or otherwise unpleasant smell is not acceptable. There should in fact be no smell in the compressed air.

The limits shown above would meet all international specifications and are certainly as safe as breathing air can be.

If you use your regular compressed air system to provide air-breaks, or to provide air to the BIBS in an emergency, the air needs to be free of any oil – this is what we refer to as Oxygen Compatible Air (OCA). The concern is that oil or other volatile products are a potential source of fuel, and mixing this with pure oxygen increases the chance of a fire in the system

If your only option is the regular air you use to pressurize your chamber, it is important to pay attention to the compressor servicing and filter change-out requirements, together with regular air analysis. Oil is usually undetectable in a well-maintained compressed air system.

When receiving air quality test results, do not only look for the pass or fail outcome; observe the trends where one element is increasing over time. This is an early warning sign that something is not right.

We are also often asked how often air quality tests need to be performed. Many regions will provide minimum requirements such as 3-, 6-, or 12-month air testing.

What is more important is to consider your risks and the likelihood of contamination when making this decision. In the event of any suspected contamination, changes in the environment, strange odors, or where the air quality levels fail during subsequent tests, action should be taken to ensure that the situation is back under control.

So, unless you have an online, real-time analyzer, remember that your spot checks only tell you want was in the air at the moment you took the sample. It does not provide any assurance that the situation will be the same immediately after a sample is drawn.

ABOUT THE AUTHORS

Rob Sheffield, BA, CHT-Admin (USA)

Rob is currently the Director of Education for International ATMO, Inc. He is a Certified Hyperbaric Technologist with over 35 years of experience in hyperbaric medicine. He is the former Chair of both the Undersea & Hyperbaric Medical Society Safety Committee and the National Fire Protection Association Technical Committee on Hyperbaric and Hypobaric Facilities. He is author of several publications, including three textbook chapters. He is a frequent lecturer on various hyperbaric medicine and hyperbaric safety topics.

JP Imbert, M Eng (Biomedical) (France)

JP Imbert spent 19 years at Comex, a leading historical diving company, first as a research engineer, then as Diving and Safety Manager. He was involved in the Comex deep research programs and edited decompression tables. He participated in the Norwegian deep projects of the 80's and developed the Comex deep diving procedures used in Brazil.

He then became involved with technical diving. He became the IANTD Licensee in France and trained trimix and rebreather divers during 10 years.

In 2004, JP Imbert was back to the offshore industry as a diving consultant. He has since worked in the North Sea for the main diving contractors editing diving manuals and decompression procedures. He is currently leading research projects on divers' monitoring and decompression modeling.

ABOUT THE AUTHORS

Karl Huggins, MS Bioengineering (USA)

Karl Huggins has been the Director of the Catalina Hyperbaric Chamber Facility at the USC Wrigley Marine Science Center since 1992 and has been involved with the treatment of hundreds of divers during that time. He is noted for his work in decompression theory and models, which resulted in the Michigan Sea Grant (HUGI) tables and his participation in the development of the EDGE dive computer.

Karl enjoys educating divers in the area of decompression (making divers more aware of the limitations of dive tables and computers) and diving safety. To that end he has given hundreds of lectures, seminars, and workshops as a featured speaker at conferences around the world. Karl is the 1990 recipient of the Leonard Greenstone Diving Safety Award, the DAN/Rolex Diver of the Year for 1993, the 2004 Conrad Limbaugh Memorial Award for Scientific Diving Leadership, and the 2008 California Scuba Service Award.

ABOUT THE AUTHORS

Bob Sanders, DMT, MD, FACEP, FUHM (USA)

Dr. Sanders' "medical" career began in 1989 as an EMT and Ski Patrol member, and in 1993 he ventured into hyperbarics as a technician and supervisor at the USC/Catalina Hyperbaric Chamber. He also served as a Dive Medic in Antarctica for 4 seasons collecting single-celled organisms in 28° water 100' below 12' of ice.

Needing to learn more, Sanders received an MD from Chicago Medical School. After residency in Emergency Medicine at the University of Pittsburgh, he became boarded in Emergency Medicine, and Undersea & Hyperbaric Medicine.

Currently, Sanders is a Flight Surgeon for NASA serving as the Program Medical Officer for the EVA (spacewalking) and Human Surface Mobility (Lunar Rovers) Program. Previously, he spent 8 years on contract to NASA's Neutral Buoyancy Laboratory from UTMB as the Medical Director. He has also been the Medical Director for American Hyperbaric Centers in Anchorage AK (overseeing clinical hyperbarics; commercial dive operations), and an Attending Emergency Department Physician. Prior, he was at the University of Hawaii's Hyperbaric Treatment Center, and served as Medical Advisor for Pittsburgh River Rescue, and as a Flight Physician for Stat MedEvac.

Dr. Sanders serves as the tactical medicine physician for the Harris County Sheriff's Office Dive Team, after spending 8 years diving with the LA County Sheriff conducting search and recovery of bodies and evidence. He is an avid technical (Cave, Wreck, Ice) and scientific diver. He has conducted shark diving and tagging operations, and worked as a set medic and water safety coordinator in Hollywood. He is a recognized author and educator in emergency medicine, hyperbaric medicine, and diving medicine.

ABOUT THE AUTHORS

Sheryl Shea, RN, CHT (Mexico)

Sheryl is a registered nurse, a certified Clinical Hyperbaric Technologist, and works with 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, works as an agent on the DAN Emergency Hotline, and assists in the coordination of the DAN Recompression Chamber Network.

Francois Burman, PE (South Africa)

Francois is a registered professional engineer and Vice President of Safety Services 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 of 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

CONTACT INFORMATION

- Divers Alert Network . . . . +1 919-684-2948
- Recompression Chamber Network . . . . RCN@DAN.org
- DAN Recompression Chamber Assistance Program . . . . RCAP@DAN.org
- Recompression Chamber and Medicine Inquiries . . . . Medic@DAN.org
- General Diving Safety Inquires . . . . RiskMitigation@DAN.org
- Chamber Operation Safety Website . . . . Chamber-Operational-Safety