psai.com

Professional Scuba Association International

The Professional Scuba Association - Since 1962

Safety Integrity

PSA International

Knowledge

Practical Trimix Diving

2005

Welcome to our program.

Please read this page very carefully and be sure to complete, prior to attending the course you have selected, the sections listed 1,2,3 and 4. **These must be done before the first class session.** When all candidates have this completed prior to the course, it saves valuable class time.

By following these instructions, your experience with our staff and diving programs should be free of any major misunderstandings.

1. Complete the following sheet labeled, 'student registration form'
2. Complete the 'Medical statement' form. If training deeper than 40m this form must be signed by a physician before the course.
3. Read, understand, sign and have witnessed the, 'Risk & Liability' form.
4. Read each section of the course manual and complete, before the course, any section reviews at the end of each chapter.
5. Contact PSA Regional Headquarters if you have any questions regarding the course that you have selected.
6. For the deep air diving levels you must take each level before the next, except for level 1 (30m) which will be at your instructors discretion.

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PSAI Tech Diver Registration

Divers

Print Name as it is to appear on C-Card	Complete Mailing Address (include City, State and Zip Code)	Phone Number E-mail Address
MANUAL SERIAL No:		
MANUAL SERIAL No:		
MANUAL SERIAL No:		
MANUAL SERIAL No:		
MANUAL SERIAL No:		

Course Rating

Check only ONE course per diver registration form.

- ☐ Sport Nitrox
- ☐ Advanced Principles of Nitrox
- ☐ Decompression Procedures
- ☐ Extended Range
- ☐ Advanced Wreck
- ☐ Trimix Level I ☐ Trimix Level II
- ☐ Trimix Level III
- ☐ Other (specify:______________)
- ☐ Rebreather (specify:__________________)
- ☐ Nitrox Blending
- ☐ Advanced Gas Blending
- ☐ Oxygen Servicing
- ☐ Cavern
- ☐ Intro Cave
- ☐ Full Cave
- ☐ Visual Inspection Procedures
- ☐ Solo/Self Sufficiency
- ☐ Full Face Mask
- ☐ Dry Suit
- ☐ Deep Air/Narcosis Mgt (specify level:________________)

onal

-7724

Instructor Name:

Instructor's PSA #:

Instructor Phone #:

Instructor Address:

Facility Name:

Facility Number:

I certify that the above named students have completed the PSA training course indicated and have reached the proficiency level required by PSA Standards before issuing these certifications. In addition, I agree to void all cards not issued within six months.

Instructor Signature (Required on each Form) Date Signed

Course Completion Date (mm/dd/yy):

2nd Inst./Asst. by: #:

☐ Freshwater Max training depth:
☐ Saltwater (Meters / feet):

Ship To Address: (*Add US$6 for international shipping)

☐ Instructor ☐ Facility
☐ Student (add US$3 per student address)
☐ Other (add US$3 for "other" address)

Name:
Street:
City/Post Code:
Country

Ltd

LH UK

371 19

Payment

CERTIFICATION FEE: ☐ C-Card Only ☐ C-Card & Certificate

Refer to your Country Pricelist for Certification Fees

Method of Payment

MasterCard ☐, Visa ☐, Direct Deposit ☐ (to: Local Bank near you - contact us for details)

Exp. Date:

Billing address for Credit Card: ____________________

Name: ______________ Signature: ______________

Notice

This manual is to be used in conjunction with an approved course of instruction. Diving is an inherently dangerous activity and must be approached with caution. Divers must be familiar with all aspects of their activities and use the appropriate equipment to ensure safety.

Name ______________________________

Instructor ______________________________

Course Date(s) ______________________________

Book Serial Number 1137

Professional Scuba Association International
Rev 0 (Released 15th May 2005)

Medical Statement

Participant Record------------Confidential Information

Please read carefully before signing.

This a statement in which you are informed of some potential risks involved in scuba diving and of the conduct required of you during the scuba training program offered by:

Instructor...

Facility...

In the town of..

County..

Read and discuss this statement before signing it. You must complete this medical statement, which includes the medical history section to enroll in the scuba training program. If you are a minor you must have a parent or guardian sign this statement. Diving is an exciting and demanding activity. When performed correctly, applying correct techniques, it is very safe. When established safety procedures are not followed, however, there are dangers. To scuba dive safely you must not be extremely overweight or out of condition. Diving can be strenuous under certain conditions. Your respiratory and circulatory systems must be in good health. All body air spaces must be normal and healthy. A person with heart trouble, a current cold or congestion, epilepsy, Asthma, a severe medical problem or who is under the influence of alcohol or drugs should not dive. If taking medication, consult your doctor and instructor before participation in this program. you will also need to learn from your instructor the important safety rules regarding breathing and equalization while scuba diving. Improper use of scuba equipment can result in serious injury, you must be thoroughly instructed in its use under direct supervision of a qualified instructor to use it safely. If you have ant additional Questions regarding this medical statement or the medical history section, review them with your instructor before signing.

Medical History

To the participant:

The purpose of this medical questionnaire is to find out if you should be examined by your doctor before participating in recreational diver training. A positive response to a question does not necessarily disqualify you from diving. A positive response means that there is a pre-existing condition that may effect your safety while diving and you must seek the advice your physician. Please answer the following questions on your past or present medical condition with a YES or NO. If you are not sure, answer YES. If any of these items apply to you we must request that you consult a physician prior to participating in scuba diving. Your instructor will supply you with a medical statement and guide lines for recreational scuba divers physical examination to take to your physician.

..... Are you pregnant or do you suspect you may be pregnant?

..... Do you regularly take prescription or non prescription medications (with the exception of birth control)

..... Are you over 45 years of age and have one or more of the following:

1. Currently smoke a pipe, cigars or cigarettes.
2. Have a high cholesterol level
3. Have a family history of heart attacks or strokes

HAVE YOU EVER HAD OR DO YOU CURRENTLY HAVE.......

..... Asthma or wheezing with breathing or wheezing with exercise?

..... Frequent or severe attacks of hayfever or allergy?

..... Frequent colds, sinusitis or bronchitis?

..... Any form of lung disease?

..... Pneumothorax (collapsed lung)

..... History of chest surgery?

..... Claustrophobia or agoraphobia (fear of closed or open spaces)

..... Behavioral health problems?

..... Epilepsy, seizures, convulsions or take medications to prevent them?

..... Recurring migraine headaches or Or take medications to prevent them?

..... History of blackouts or fainting?

..... Suffer from motion sickness?

..... History of diving accidents or Or decompression sickness?

..... History of recurrent back problems?

..... History of back surgery?

..... History of diabetes?

..... History of back, arm or leg problems following surgery, injury or fracture?

..... History of drug or alcohol abuse?

..... Inability to perform moderate exercise (walk 1 mile within 12 minutes)

..... History of high blood pressure or take medications to control it?

..... History of any heart disease?

..... History of heart attacks?

..... Angina or heart blood vessel surgery?

..... History of ear or sinus surgery?

..... History of ear disease, hearing Loss or problems with balance?

..... History of problems equalizing Ears with airplane or mountain Travel?

..... History of bleeding or other Blood disorders?

..... History of any hernias?

.....History of ulcers?

..... History of colostomy?

The information I have provided about my medical history is accurate to the best of my knowledge

Signature..Date...............................

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(back of Understanding & Risk form)

The Professional Scuba Association International

Course level (specify)_______________________________

(one course per form) under sanction through PSA International

Please read carefully before filling in this form as it reinforces the risks of scuba diving. It is also informing you of the circumstances in which you participate in the diving course at your own risk. Please read all of the information carefully. fill in all blanks and initial each paragraph before signing at the bottom. You should read the statement and understand the information provided. If you do not understand the information provided in this statement you **must** discuss with your instructor and seek further clarification. If you are a minor under the legal age of majority you **must** gain the initials and signature of your parent or guardian to participate.

WARNING

☐ Diving with compressed air, oxygen enriched air (nitrox), oxygen and trimix supplied by open, semi-closed or closed circuit scuba involves certain inherent risks. These include decompression sickness, embolism, oxygen toxicity, inert gas narcosis, marine life injuries, other barotrauma/hyperbaric injuries that can occur and that require treatment in a recompression chamber. The open water diving trips, which are necessary for training and certification, may be conducted at a site that is remote by either time distance or both from a recompression chamber. It is each individual participants choice as to whether or not they choose to proceed with such instructional dives in spite of the possible the absence of a recompression chamber in proximity to the dive site.

☐ Extended range diving activities are physically strenuous and that you will be exerting yourself during this diving course. Under these circumstancesit is possible that you may be injured by heart attack, panic, hyperventilation, oxygen toxicity, inert gas narcosis, drowning etc.

☐ You must truthfully and fully inform your instructor(s) and the facility through which this training is offered of your medical history. You must seek the signature of a medical professional for training beyond 40 metres.

☐ The diving activities in this course may place you deeper than you are safely able to perform a free ascent without breathing gas from.

☐ Where you may wish or be required to supply your own personal life support equipment as part of this course you are responsible for its operating condition and maintenance by following standard service intervals. all of the manufacturer instructions and subsequent manufacturer data sheets supplied with the equipment at time of purchase. You will be required to declare this use under the diving operations record required by the Health & Safety Diving at Work record sheet your Instructor or dive centre will provide for each dive. If an instructor or dive centre deems that your equipment is not suitable for the intended purpose they may offer a more robust and suitable alternative from their training stock.

EXCLUSION of LIABILITY

☐ Neither the instructor(s)_________________________________ the facility through which training is offered, _____________________ or PSA International & Asia/Pacific (PSAI), nor any of their respective employees, officers, agents or assigns, nor the authors of any materials. including text or tables used by the PSA for training and certification may be held liable or responsible in any way for any injury, death or other damages resulting from your own contributory actions which amounts to your own contributory negligence. In the absence of any negligence or other breach of duty on the part of the named Instructor(s), facility or PSA noted above , participation in this diving course is entirely at your own risk.

☐ In consideration of being allowed to enroll on this course, I hearby personally assume these risks in connection with the advanced training course.

ACKNOWLEDGEMENT OF PRIOR CERTIFICATION AND EXPERIENCE

☐ I state that I am already a qualified and certified scuba diver from the following training agency(s)__________________ and that I hold training to the level of_______________________ I am aware of the minimum certification level and experience required to enroll in the above diving course and stipulate that I meet the requirements. I have been a certified diver since_________ and have been diving for _________ years with a total of___________ dives to a maximum depth of __________ meters.

ACKNOWLEDGEMENT OF RECEIPT & UNDERSTANDING

In signing this document I agree to be bound by the terms and conditions for the course stated at the head of this form. I have had the opportunity to ask for clarification on points and if it was required, further information was made available.

Print Name______________________ Signature of participant_________________________ Date___________

Signature of Parent/Guardian (where applicable)_______________________________ Date____________

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Introduction

Your new adventure promises challenges and excitement, but it's time to grow up, do a reality check and be truthful with yourself. This course is a continuance of all the previous training you have received. If a diver doesn't know how to hover, fin turn, keep hands still, relax, then they are not ready for mixed gas diving! Decompression procedures, SMB deployment and stage bottles should all be second nature by now. The question would be if the student is not competent in these tasks - just how did they get this far anyway and manage the prerequisites?

Mixed gas diving offers a great many new opportunities, however, unlike the movies, it is not going to make diving easier!

The mixed gas diving course is not a culmination of education, it is another step. There are continuous advances in decompression understanding and modeling as well as the equipment that is available. The mix diver must keep up to date.

Your PSA International Instructor on the other hand, will acquaint you with the necessary procedures and techniques, as well as demonstrate the proper *attitude.* Your responsibility includes proper physical fitness, mental preparedness as well as financial awareness. Yes, this isn't going to be cheap! Mixed gas diving essentially forms a "virtual overhead" similar to that experienced by cave divers, thus requiring techniques and equipment for backup. Get the best you can, the life you save, will be your own!

Certainly by now the diver has been well indoctrinated in both the physics and physiology of diving. This course will review those subjects as well as introduce a third gas into the equation – helium.

Expect to take notes, solve fairly simple maths problems and learn techniques of gas use that will allow you to see things at depths well beyond what you have been used to before! Even better, since you will dramatically reduce the narcotic effects of nitrogen, you will remember dives clearly. Open water skills are extensions of equipment configuration, usage, dive planning and emergency skills. Practice them often, stay sharp and enjoy the realm of deeper diving!

This manual is intended to be used in a complete course with an authorized instructor sanctioned to teach mixed gas diving. No book or set of handouts takes the place of a proper course of instruction.

The complexion of Trimix diving has certainly changed since the beginning days when technical training agencies began offering the courses. In the "old days" it was one dive a day; some tattered tables passed around and fairly limited information on decompression and gases.

Today, there are quite a few easily accessible software programs, some on-line, others professionally developed for purchase from instructors and facilities, which allows the diver to select any conceivable gas combination and environmental situation. While some divers still do only one "mix dive" a day, it is more and more common to see two dives, including gas modifications and several different decompression gases. Recently, breathing gas analysis has had a big boost by the introduction of commonly available and reasonably priced systems that will selectively analyze oxygen as well as helium. No longer does the trimix diver have to guess about the real "mix" and training standards change to reflect this increased safety.

History of the Professional Scuba Association International

The Professional Scuba Association International is one of the oldest scuba instructional training agencies in the world. For many years it was a small, specialized organization that was predominantly involved with dive training associated with extended range, deep air diving. Virtually all of the early history centers on the founder, Hal Watts.

The Professional Scuba Association International (PSAI or simply PSA) was originally founded as the Florida Scuba Association in 1962 by Hal Watts in Orlando, Florida. Hal's experience with scuba had begun in 1955 while he was attending college earning a Masters Degree in Law.

During the 1960's Hal became devoted to extended range diving and developing proven, effective diving techniques for dives to depths greater than the normal recreational range of 40 meters (132 feet). In 1968, using methods he developed, Hal set the World's Record Depth by diving to 119 meters (390 feet) and was recognized in the Guinness Book of Records. It should be noted, that as time went on, it was accepted that extremely deep air dives were indeed hazardous and the current records represent remarkable achievements. Unfortunately the record is also at the very extreme edge of human physiological tolerance and so Guinness no longer publishes deep air records or attempts.

In 1970 Hal wrote and copyrighted the first manual for Extended Range Deep Diving for instructors and conducted specialty classes for those interested. One of the projects that Hal wanted was a film so he commissioned Ned Deloach of New World Productions to produce a 16 millimeter color film "Deep Diving" on location at Wakulla Springs, Florida.

Hal Watts formed a specialty diving club known as the "Forth Fathom Scubapros" that was very active diving all over Florida, especially at a sink hole that just happened to be 40 fathoms (72 meters) deep! Many of the other divers and organizations simply were not prepared to understand the desire of these early pioneers, so the Scubapros continued largely in the quiet. During the 1970's they continued refining techniques and skills to improve safety in deep diving activities.

PSA was in place as the mainstream technical agencies burst onto the market in the mid-1980s and continued their program of careful selection of instructors and adherence to safe diving techniques. Many of the agencies recognized PSA programs for the quality and afforded direct cross-over certification.

During the 1990s in particular, Hal had long discussions with Joe Odom, then the International Training Director for TDI, SDI and ERDI, a major training agency. Joe had also been the Chairman of the Board of Directors for the Cave Diving Section of the National Speleological Society (CDS-NSS) for two elected terms. Joe was a well known author of a wide variety of technical diving articles and training manuals that ranged the full spectrum from Nitrox to Advanced Trimix as well as Rebreathers. Joe had dove all over the world and was well known for his unique teaching style.

Many of Hal and Joe's idea of what should be included in courses and the importance of continuous in-water training clicked as they discussed their individual philosophies. It was only natural that when Joe resigned from TDI in 2004 that Hal wanted Joe as the ideal candidate to push PSA forward.

Joe Odom became the President of the Professional Scuba Association International in November 2004 as Hal Watts kept the mantle of Founder and CEO. Together, they are proud to bring the diving public many of the skills and techniques of safe extended range diving they have developed over their almost 90 years of combined diving experience.

PSA has its headquarters in Ocala, Florida and is expanding its offerings to a variety of international offices. Long established in places such as Italy in Europe, PSA continues to grow as both instructors and divers enjoy the quality of education afforded by the carefully reviewed standards and procedures. The plan is that PSA International headquarters will relocate to Orlando, Florida, approximately an hour and a half from Ocala to make travel convenient for international divers and instructors.

During organizational meetings in early 2005, the PSA course structure was reconfigured into course offerings. It was set up to include logical paths of their normal extended range programs, a traditional path of technical deep diving from nitrox to trimix and a rebreather path. This technique gives the prospective student the style and courses that fit their desired training objectives, without having to do unnecessary out of scope work. At the same time, every PSA diver will receive the highest quality training from the highest quality instructors.

International System of Units (SI)

The International System of Units, abbreviated SI (from the French *Le Système International d'Unités*), is commonly called the metric system. The decimal metric system began shortly after the French Revolution and in 1799 included the establishment of two units, the meter and the kilogram. These units were represented by a platinum bar of a precise length representing the meter and a platinum cube representing the kilogram. Obviously, this gives rise to the term "platinum standard".

All major countries in the world use the metric system for commerce and scientific writing. Unfortunately, even though a signatory to the Meter Convention (*Convention du Mètre*) in 1875 the United States still has not adopted metric terminology in common language. Weights and measures for food items in the U.S. are given in both SI and Imperial (English) units, but for some reason, people still resist making the full change.

For purposes of all PSA International manuals, we have chosen to write everything with the SI units as primary. Where applicable the corresponding imperial value will be shown. In many cases the values will not reflect exact mathematical correspondence for readability sake.

The following conventions will be used:

Depth will be shown in meters. Due to a huge confusion in the diving industry, it is important to note that even though the linear term meters is used, it represents pressure, not actual distance. This allows for differences in specific gravity, primarily due to salinity, to not influence practical decompression techniques. By definition 10 meters of sea water = 1 bar. Convention is to drop the "sea water" since the reference is for pressure. Hence, 24 meters will be shown as simply 24 m. Do not add "sw" or "fw" unless a specific scientific paper is being written where it makes a difference. Remember, depth gauges do not measure distance, they indicate pressure. For those depths shown in feet, it is assumed to be feet of sea water (fsw).

Pressure will be specified as bar. While this is not a strict interpretation of the metric value, it is the one commonly in use. Strict conformance with SI would require the use of the term pascal (Pa) for pressure. This is a derived unit, not a base unit, and represents force (newtons N) per area (meters squared m^2) as N/m^2. The common pressure used in most U.S. diving manuals is the atmosphere (atm). Often, to represent absolute pressure, it is abbreviated ata. The bar represents a pressure slightly less than an atmosphere, but for conventional use, they can be considered equivalent. 1 atmosphere = 1.01325 bar. Hence, when dealing with gas pressures, by simply replacing ata with bar will be result in an error to the safe side.

The official SI website in France refers back to the U.S. National Institute of Science and Technology (NIST) for specific writing guidelines. It is our attempt to blend legitimate SI usage with the common language of diving. The NIST makes available the essential documents for scientific writing on their website. The two documents of specific interest are NIST Special Publication 811 (SP 811) titled "*Guide for the Use of the International System of Units (SI)*" and SP 330 titled "*The International System of Units (SI)*". Both of these documents provide a complete (and laborious) explanation of the proper way to apply the metric guidelines to writing.

One additional convention that PSA International will adopt from the NIST publications is the spelling of meter. The NIST uses the spelling of meter instead of the French metre. This should not represent a huge confusion to the reading masses, so where you see meter, just pretend it is metre!

If there are any specific questions, feel free to contact PSA International's headquarters office about style and content.

The "technical attitude" has been debated many times. How can it be acquired? How can it be taught? CAN it be taught? As the diver moves into the realm of mixed gas diving basic skills are transformed into art.

Chapter 1 - The Diver and What Is Deep?

It's been said over and over again, that "deep" is relative. Numerous divers start their open water course saying "I'll never need to go deeper than 12 meters (40 feet)". However, they soon find that there really isn't much difference between 12 m and say, 18 m (40 feet to 60 feet). In fact, depending on the conditions where the dives are taking place they might find themselves at 30 m (100 feet) without any problems, other than their "air is going away faster".

Deep diving requires accepting decompression as a fact of life. Acknowledging that in reality all dives are decompression dives, with "no decompression" being just a special case of time management, divers can get on with the act of planning a safe experience with full knowledge of the elements and risks involved.

If the diver is just looking for the thrill of going to a depth to say "been there, seen it, done it, got the T-shirt", then perhaps deep diving really is not going to be a good endeavor for them. This is probably not the guy you want as your dive buddy, since many times they have taken short cuts just for the thrill. What happens when this diver becomes entangled in a ball of monofilament fishing line at 70 m (230 feet)? Has he practiced emergency procedures from the beginning? Did he have the dedication to foresee these types of simple problems and appropriately rig for them? In short, he is his own worst enemy and may soon become yours as well.

Why would we want to even start this type of dive? Some people in the diving industry still believe that keeping depth limits at 30 m (100 feet) is just fine & dandy. Yet the special sense of accomplishment that is felt after safely traveling beyond those limits is reason enough and it is futile to engage in battle with the "nay sayers". Those are limits they have chosen, but if you are in this course, they are not yours!

The diver still has the responsibility to properly execute the dive, demonstrating professionalism and skill so that there is no doubt in the onlooker's mind that is a carefully planned endeavor. Proper equipment and procedures demonstrate that attitude. Don't show up on a dive boat and snicker at others just because they don't have all the toys you have packed aboard. If they show interest in your activity, be polite and answer their questions. Try not to embellish the activity so the "newbie" is psychologically challenged into pursuing technical diving because of an ego threat. Always end these conversations with the message that additional training and a significant investment in equipment is required to make these dives possible. Avoid making subtle threats to their ego; after all, everyone had to start somewhere.

Mixed gas diving should never be marketed as being suitable for everyone. This may make some instructors bristle but it is true. If someone is not ready and willing to accept the challenges and meet the requirements, then they are not ever going to be a mixed gas diver, regardless of what their "card" reads.

The Dive - A Quick Look

If you are taking this course, you have already had quite a few advanced diving courses, Nitrox in all of its forms, Decompression Procedures and Extended Range. When we first started diving we only considered one gas in air, nitrogen, as the element of major concern. All aspects of this gas were handled by simply using a single set of "tables" that outlined depth and time considerations. The diver was admonished not to dive deeper than 18, 27, 30, 40 m (60, 90, 100, 130 feet) (take your choice)!

Enriched Air Nitrox training emphasized the necessity of considering oxygen in the breathing mixture. Now the diver, through education, makes a more informed choice about the dive profile. This resulted in increased benefits, i.e. more bottom time, but also increased the responsibility that the diver assumed for each dive. Yes, there are computers out there that can do most, if not all, of the calculations, but ultimately the diver accepts the responsibility for the safe outcome of the dive. It should be noted that all gas mixtures have limits, flirt too close to the edge and the diver just might have an unpleasant experience.

The PSA International Advanced Nitrox Decompression Procedures and Extended Range courses taught the diver the importance of precision dive planning and how the effects of pressure seriously impacted gas consumption. These intermediate courses are designed to give the diver experience in deeper ranges and coping with the additional equipment loads.

Mixed Gas diving brings other gases into play, primarily helium. It is with helium (and other gases discussed later) that divers can venture deeper in a safer manner. In short, helium, with its lower narcotic properties, simply replaces a portion of the nitrogen. The helium also replaces some oxygen, lowering the PO_2 at depth to reduce the risk of oxygen toxicity. Since helium tends to be a bit on the pricey side, particularly in remote locations, the diver is faced with more decisions. In this course they are informed decisions. How much narcosis is tolerable? How much workload is expected on the dive? Don't forget the influence of diving conditions, current, temperature and visibility.

The Mixed Gas diver begins by selecting personal acceptable values. Where do these values come from? They are choices, which can only be based on education and experience. Only after these personal values are established, can the diver plan the dive. Some divers choose to simply follow standard tables that are designed to work at a range of depths. This approach can limit the flexibility of the diver to adapt to various sites and conditions. Today, it is normal for the mixed gas diver to utilize one of the many computer generated (semi-custom) software schedules.

Let's take a look at some of the initial thoughts that go into planning a mixed gas dive:

The very first thing we must know is the dive depth. Let's assume that we want to make a dive to 79 m (260 fsw). Before we can calculate any gas values, we must know the total pressure at the dive depth:

$$\mathbf{P\ (bar)} = (79 / 10) + 1 = 7.9 + 1 = 8.9\ \text{bar}$$

$$\mathbf{P\ (bar)} = (260 / 33) + 1 = 7.87 + 1 = 8.87\ \text{bar} \quad \text{(round to 8.9 bar)}$$

> **SI Note**: By definition, the pressure associated with 10 meters is 1 bar. As such, in the metric style of writing, there is no distinction between fresh and salt water. Depths are shown as "pressure depths" and may not be the actual linear distance. Therefore, you will see a SI depth written as *40 m* for example, while we will use feet (ft) in the Imperial system. There are minor differences in actual depth, but as long as you have properly programmed your software/computer there will be no problems. In any case, be sure to read and understand your equipment's manufacturers' manual before diving.

> **SI Note**: In the SI style guide, the unit "atmosphere" is considered an unacceptable unit and should be replaced by 101 325 Pa (Pascal). While we would like to keep as correct as possible, no one can argue the clearness of using the atmosphere. In the international diving world, the accepted unit of measurement is the "bar". In this manual, we will use bar as the standard pressure unit. For the purists, remember that there are slight differences between the bar and the atmosphere.

> ***The diver who is not completely comfortable with their understanding of depth and pressure will never properly understand mixed gas diving***

Start planning the dive by selecting a personal level of NARCOSIS tolerance, also known as the Equivalent Narcotic Depth (END). The Professional Scuba Association International firmly believes that all mixed gas divers need to understand the cause and effect of narcosis. The divers should have direct and practical experience, not just someone's guideline or long-past and dated experience. This is directly related to the pressure of nitrogen (PN_2). Later we will discuss some additional minor contributors, but the major effect is still nitrogen. The selected END ranges widely between both divers as well as dive conditions. Some divers choose relatively shallow narcotic depths such as 30 m (100 feet) but other divers choose much deeper values, such as 55 m (180 feet). Many times this is because the cost or the available amount of helium is the driving factor. In any case, regardless of the END chosen, the diver MUST have experience at that narcotic depth level before chosing it for mixed gas diving! The PSA Deep Air programme is designed to ensure any student has gained these skills and should always be encouraged to take this route as a pre-requisite to mixed gas diving

For our example, let's choose 40 m (132 feet) as the maximum narcotic depth. By now it should be intuitively obvious that 40 m (132 feet) is the home of 5 bar (atmospheres absolute) of pressure. If we were to examine just the nitrogen component, using Dalton's Law, we would find that breathing air at 40 m (132 feet) would result in:

(40 m / 10 m/bar) + 1	=	**5 bar**
(132 feet / 33 feet/bar) + 1	=	**5 bar**

Pg	=	**Pt / fg**
Pg	=	**5 bar / .79**
Pg	=	**3.95 bar**

> **SI Note:** Unless required for clarity, we will use bar as the standard of pressure and only show ata in those specific examples where the Imperial unit is needed. Incidentally, the "bar" is only temporarily accepted in professional SI writing! It is simply the "slang" accepted by the diving community.

So, while diving "air" at 40 m (132 feet) the diver is experiencing a narcotic dose of nitrogen equal to 3.95 bar. This is becomes your chosen narcosis limit – 3.95 bar. (In reality, wouldn't it make a lot more sense to round that off to 4 bar? But for the sake of "precision" we will leave it for now, some people just HAVE to have decimal points to play with.)

The next choice the diver must make is the oxygen exposure which should be very familiar by now. The industry standard is that we will not exceed an oxygen pressure of 1.6 bar as an absolute maximum and considering work load, dive conditions and personal differences, most choose to set 1.4 bar as their personal planning limit.

So now we have enough information to begin determining what gas would best suit the dive with the stated conditions. We know we do not want any more than 3.95 bar of nitrogen exposure nor do we want any more than 1.4 bar of oxygen exposure. If we add these:

Pressure of Nitrogen	=	**3.95 bar**
Pressure of Oxygen	=	**<u>1.4 bar</u>**
		5.35 bar

Since the total pressure at our chosen depth is 8.9 bar, subtract the known gas pressure from the total:

8.9 bar – 5.35 bar = 3.55 bar

What this means is that there is 3.55 bar left over that has to be made up of something other than nitrogen or oxygen. By now you know that helium is the most commonly used "diluent" gas. Adding 3.55 bar to the 5.35 bar of our nitrogen/oxygen values, completes our total diving pressure of 8.9 bar.

The only problem is, we need to know what to put into our cylinder(s). A gas blender wants to know the fraction of gas and so does your dive planning software. Let's now convert the pressures into fractions as follows:

fO_2 = 1.4 bar / 8.9 bar
= .157 (round to .16)

fHe = 3.55 bar / 8.9 bar
= .398 (round to .40)

fN_2 = 3.95 bar / 8.9 bar
= .443 (round to .44)

To check the math, add the values making sure they add up to 1.00:

Oxygen	**.16**
Helium	**.40**
Nitrogen	**.44**
Total	**1.00**

So our desired mix would be 16% oxygen, 40% helium and 44% nitrogen, commonly written as 16/40/44 or just 16/40. The standard is to show the oxygen value first, helium second and then nitrogen. Since they should always add up to 100%, the nitrogen value is sometimes left off. These are the values you would give to your friendly PSA International trimix gas blender as well as the desired fill pressure. After the cylinder is filled, the oxygen and helium are accurately analyzed to ensure correctness and logged out as required.

The next step would be to use the desired software program (or "hard tables" if the mix matches) to determine the dive time schedule. Here you will learn the decompression requirements of the dive.

Calculate the gas requirements (detailed later), factor in the desired safety factor and collect the necessary travel and decompression gas cylinders (and backup). All that is left is to load up the car, van, boat and get to the dive site!

Right away it should be obvious that Mixed Gas diving requires a whole lot more planning than diving air or nitrox. The good news is that the planning forces a mental rehearsal with leads to increased awareness and lower stress, if done properly. That is a big "IF", isn't it?

With the possible exception of the helium, everything in the preceding section should be familiar to the Mixed Gas student. We are simply using the tried and true formulas from all the previous courses! To make sure, let's have a brief review of gas physics and physiology.

Chapter 1 Review Questions

1. How many dives have you logged?

2. What is the deepest dive you have made?

3. How many dives below 40 m have you made?

4. How many decompression dives have you made?

5. What is your Surface Consumption Rate (SCR)?

6. What is the typical cylinder configuration you dive?

7. How much weight do you wear?

8. Do you have a Dive Insurance policy?

9. Are you a certified: Wreck diver?
   Cave diver?

And, most important of all:

Have you been honest with yourself and considered all the hazards of mixed gas deep diving?

If so, how about your family?

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The physical principles of diving are sometimes ignored by divers as being just too difficult and they really don't apply to their diving. Physics can be a scary word, but at the level we are diving now, it can be done with simple math and complete understanding.

Chapter 2 Physical Principles of Diving

By now you have seen this information over and over. There should be no surprises with things like Boyle's Law, Charles' Law, Dalton's Law and the usual gambit of unique diving calculations. Take a few minutes and make sure that all these items make sense to you.

A person going underwater is affected by one major physical property or factor above all others and that is pressure. **Pressure affects everything about the dive.** Pressure is the reason we have to take open water scuba courses in the first place! If you have taken previous PSA International courses, this should just be an echo, if this is your first PSA course, you might want to take some time to go back and read the progression of courses.

Boyle's Law is probably one of the most useful relationships in diving as it gives us information about how pressure affects volume. Since we need a "volume" of gas to fill our lungs, add to the buoyancy compensator and dry suit, we need to be able to relate our "cylinder pressure" to "usable volume". Boyle's Law is used in gas mixing and also determines such parameters as "time at depth"!

Boyle's Law simply states that the volume of a gas at a particular pressure is a constant. This is written mathematically as:

$$\mathbf{P \times V = k}$$

Now that doesn't look very familiar, does it? (All of you science majors are excluded here!) For most people, the formula can be re-written to a more useful form as:

$$\mathbf{P_1 \times V_1 = P_2 \times V_2}$$

This is read as:

Pressure one times volume one equals pressure two times volume two.

With this formula, the useful volume of a gas can be determined. This formula is useful at most pressures up to about 100 bar but tends to diverge at higher pressures. For our purposes, it is still handy for estimation purposes.

We can use Boyle's Law for many diving calculations, but perhaps one of the more common ways is to calculate gas supplies. Let's determine the amount of gas available in an 11 liter ("standard 80 cubic foot") cylinder at 73 m (240 feet). As always, the first step is to find the pressure at the dive depth:

Pt	=	**(73 m / 10 m) + 1**
	=	**7.3 + 1**
	=	**8.3 bar**

Pt	=	**(240 feet / 33 feet) + 1**
	=	**7.27 + 1**
	=	**8.27 bar (round to 8.3 bar)**

Let's assume that the cylinder is filled to 200 bar:

11 litres X 200 bar	=	**2200 free litres of gas**
2200 litres/8.3 ata	=	**265 available litres**

Additional step(s) for the Imperial system:

We know that the full cylinder has 80 cubic feet of available gas at the surface, home of 1 bar. Since we want to know how much gas is available at 73 m (240 feet), home of 8.3 bar, we can plug in the appropriate values into the Boyle's Law equation as follows:

$P_1 \times V_1$	=	$P_2 \times V_2$
1 bar X 80 ft³	=	**8.3 bar X V_2**
80 bar- ft³	=	**8.3 bar X V_2**
80 bar- ft³ / 8.3 bar	=	V_2
9.6 cubic feet	=	V_2

The implications are obvious! Assuming you breathe about 20 litres per minute (about ¾ ft^3/min) , don't factor in temperature, don't use any of the gas to fill your buoyancy compensator or dry suit, then this cylinder would last less than 13 minutes total! There is simply not enough time to descend, stabilize, turn around and surface, not to mention perform any deco or have a safety factor.

Each Mixed Gas diver must know their individual gas consumption rates for a variety of conditions. This should have been emphasized in previous courses. Some texts refer to Surface Air Consumption Rate (SAC or SACR), Surface Consumption Rate (SCR) or Respiratory Minute Volume (RMV). For purposes of this text, PSA will use RMV as the standard title. Divers should be able to estimate their gas consumption for three conditions, fairly low work level, i.e. at a decompression stop, a relaxed or medium swimming rate and then, of course, a high work load.

Surface consumption rates do not come from a book either. Each diver needs to make an effort to determine their rates based on actual diving conditions. Some divers like to check their RMV at a variety of depths. While it is fairly easy to do the data collection at, say 10 m (33 feet), if it is done at 30 m (100 feet) it might actually be more accurate and indicative of the consumption at deeper depths. Also when doing the check, the diver should be wearing all of the equipment that they intend to carry during a normal "mix dive". This includes all the drag inducing equipment such as lift bags, lights and travel/deco cylinders.

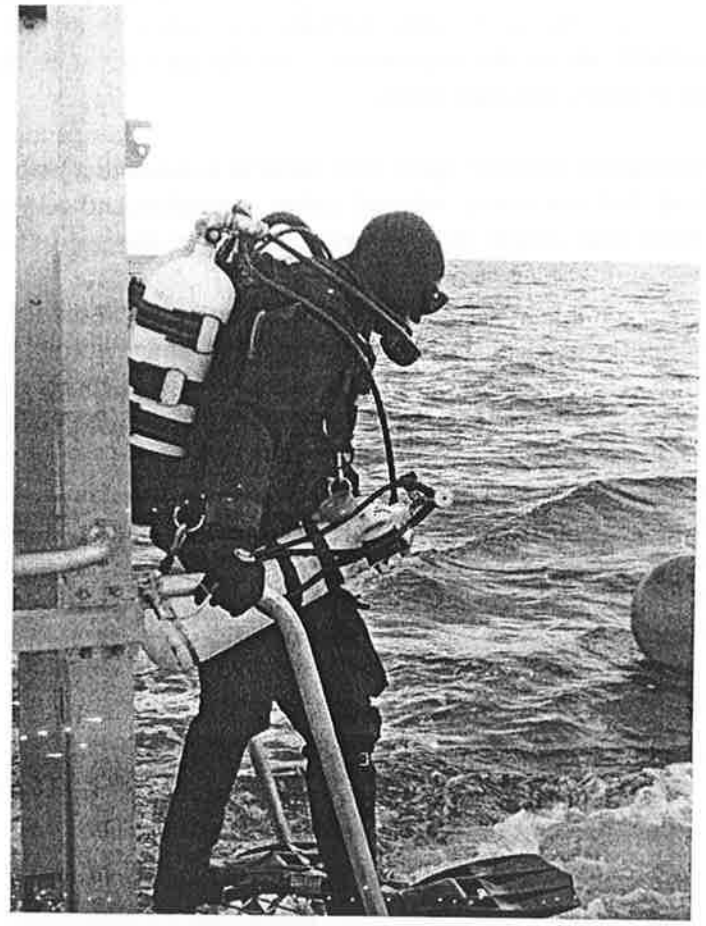

Fig. 1.
Mixed gas Diver carrying a minimum of the extra equipment available to him. All of it increases the drag effect in the water increasing RMV

To determine the Respiratory Minute Volume, look at the dive site available and try to find a depth that can be easily maintained, even while swimming. A quarry, lake with flat bottom or the outside of a wreck can all help hold a "constant depth". Let's assume that you were lucky and found a perfectly flat spot that was at 20 m (66 feet) while you were swimming comfortably above the bottom (to reduce silting, of course).

A digital pressure gauge is ideal, but many RMVs have been found using the traditional analog gauge. It may require a longer swim exposure with the analog gauge, but in any case, either can work. Checking the RMV for a 2 minute period is hardly accurate. Yes, long data collection dives can be boring, but, the goal is to have the most reliable information for your future dive planning, so you know what to actually expect.

In our example, let's descend and do some low exertion "station keeping". Just hover, do what you would normally do at decompression, but basically relax. After you have arrived at depth and given perhaps a few more minutes for the cylinders to cool to the water temperature (particularly if it was much warmer at the surface), log the beginning pressure. Relax, read your dive tables, perhaps easy swim around an object, again, what you would normally do at decompression. At the end of your chosen time, say, 10 minutes, log the cylinder pressure again.

Now, log the beginning pressure again and swim at a moderate pace, keeping your depth stable. Not hard, but not really relaxed either, something that approximates how you would like to have your deeper dive proceed. Again, at the end of a reasonable time, 10 minutes is excellent, log the ending pressure.

This is the hard part; you need to have a reasonable exertion. You do not need to swim to exhaustion, but you do need to get the breathing rate considerably higher than normal! Do not kick until you collapse, just until it feels like it! Find something to hold onto, log your beginning time and then start that exertion, keep it up for at least 3 to 5 minutes. Don't work so hard you can't go on; after all, what we are simulating is you getting caught in current and working back to a spot. It doesn't do any good to blow all your energy in 2 minutes. Log the time and pressure again. Relax, look around, and make sure your depth is still correct. When you are ready, go ahead and surface. You will probably have a slate that could look something like this:

SI (metric) Example:

Workload	Begin Pressure/Time	End Pressure/Time	Depth
Low	178.7 06	165.6 16	20 m
Med	164.2 18	140.8 28	20 m
Hi	138 31	106.9 35	20 m

Let's assume you were using twin 15 liter cylinders. Some minor calculation will be required, so first reduce the data to pressure used and time:

Low	178.7 – 165.6	=	13.1 bar in 10 minutes
Med	164.2 – 140.8	=	23.4 bar in 10 minutes
Hi	138 – 106.9	=	31.1 bar in 4 minutes

You can handle the data several ways now, such as change it to bar per minute or surface equivalent pressure. Let's first change the data to bar per minute at depth:

Low	13.1 bar/10 minutes	=	1.31 bar/minute
Med	23.4 bar/10 minutes	=	2.34 bar/minute
Hi	31.1 bar/4 minutes	=	7.8 bar/minute

Next, let's see what the volume used is at depth, again, using twin 15 liter cylinders as the example:

2 X 15 liter = 30 liter

Low	1.31 bar/min X 30 liters	=	39.3 bar-liters/min
Med	2.34 bar/min X 30 liters	=	70.2 bar-liters/min
Hi	7.8 bar/min X 30 liters	=	234 bar-liters/min

Finally, we must convert the 20 meter consumption, home of 3 bar, to the surface pressure:

Low	39.3 bar-liters/min / 3 bar	=	13.1 liters/minute
Med	70.2 bar-liters/min / 3 bar	=	23.4 liters/minute
Hi	234 bar-liters/min / 3 bar	=	78 liters/minute

There are a number of different formulas where a diver can "plug in" the values obtained, but again, the intention here is to show the steps and how the information can be derived, plus, most people can't remember the formula.

Imperial Example:

Workload	Begin Pressure/Time	End Pressure/Time	Depth
Low	2590 06	2400 16	66
Med	2380 18	2040 28	66
Hi	2000 31	1550 35	66

Now, it is time to get your calculator and a paper and pencil! What other information do you need to determine your RMV? You need to know what cylinders were used and some basic information about them. In this example, let's say that you used double low pressure steel "95s". You metric divers just relax and take a little break (and quit snickering).

In the Imperial system, it is not enough to know that the cylinders are "95 cubic foot"; you must also know the pressure at which the 95 cubic feet is obtained. Looking at the cylinder markings, you will see the fill pressure is 2400 psi, but upon closer examination, the hydro date shows something like: **11-99+**. This means the cylinders can be filled 10 percent over the stamped fill pressure:

2400 X .10 = 240 **2400 + 240 = 2640**

This is a clever bit of marketing by the cylinder people. The cylinders must be filled to the 10 percent extra in order to get the "full rated" volume. Unless a special request is made at the next hydro test, the cylinders would not be allowed (legally) to be filled above 2400 psi on the second and subsequent hydrostatic periods. In this case, the cylinders would only contain about 86 cubic feet instead of 95. Anyway, on with the example.

There are a number of quick formulas available, but our interest here is to show you how to get the information. Hopefully this will also lead to better understanding so that when you are away from that handy formula, you can "figure it out" anyway!

The next thing we do is determine the cylinder constant. We could do this as how many cubic feet per psi or how many psi per cubic foot. Each of them has their advantages, but we will use "how many cubic feet per psi" since that is the way we have taken our data.

Our cylinder is a 95 cubic foot cylinder when filled to 2640 psi, so we will divide in order to find out "cubic feet per psi":

95 cubic feet / 2640 psi = **.0359848 cubic foot / psi (round to .036)**

What this means is that for each "pound per square inch" of pressure there will be a corresponding .036 cubic foot of gas. Pretty small numbers, huh? (Later you will see how to use this number for dissimilar matching)

Don't forget though, you were diving "doubles", so that means you need to multiply the number by 2:

0.036 cubic foot / psi X 2 = 0.072 cubic foot / psi

The last little tidbit of information we need is the total pressure at the depth the data was taken, in this case, 66 feet (20 m). That is easy → 3 bar.

Let's take the first part, the relaxed data:

	2590/06	**2400/16**	
So you used:	**2590 psi – 2400 psi**	=	**190 psi**
In:	**0:16 min – 0:06 min**	=	**10 minutes**

Now, determine how many cubic feet total were used:

190 psi X 0.072 cubic foot / psi = 13.68 cubic feet
(round to 13.7)

Some divers would even round this UP to 14, to add a bit of safety factor.

So, at 66 fsw, home of 3 bar you used 13.7 cubic feet of gas in 10 minutes. We are getting close. Next determine the number of cubic feet of gas per minute:

13.7 cubic feet / 10 minutes = 1.37 ft^3/min

And finally, convert the volume at depth to the surface volume by dividing by the pressure at depth:

1.37 ft^3/m / 3 bar = 0.456666666 ft^3/min (Surface)

Ok, round that to 0.46 cubic foot per minute at the surface, a fairly reasonable breathing rate at rest! So, make a note in your log that your RMV at rest is 0.46 cubic feet per minute. Now, again, many divers would simply make that 0.5 cubic feet per minute, both for ease of number crunching as well as a bit of buffer.

The only thing left to do is calculate the other two values, for the medium and high workload:

Medium **2380/18** **2040/28**

2380 psi – 2040 psi	=	**340 psi**
0:28 min – 0:18 min	=	**10 min**

340 psi X .072 ft^3/psi	=	**24.48 ft^3**
24.48 cubic feet / 10 min	=	**2.448 ft^3/min**
2.448 ft^3/min / 3 ata	=	**0.816 ft^3/min (Surf)**

Round that to 0.82 cubic foot per minute or a bit higher.

High **2000/31** **1550/35**

2000 psi – 1550 psi	=	**450 psi**
0:35 min – 0:31 min	=	**0:04 min**

450 psi X 0.072 ft³/psi	=	**32.4 cubic feet**
32.4 cubic feet / 4 min	=	**8.1 ft³/min**
8.1 ft³/min / 3 ata	=	**2.7 ft³/min (Surf)**

Pretty neat, we have numbers for rest, normal work and high workload. A diver will occasionally verify these values and with more experience know how to adjust when possible.

A diver MUST know their surface consumption rates in order to accurately determine the amount of gas that is required for the bottom phase, the travel phase and the decompression phases. This is a practical example of using Boyle's Law in our everyday dive planning.

Dalton's Law is the familiar relationship of the total pressure of a gas mixture that is made up of a variety of different gasses. The law states that the "total pressure is the sum of all the constituent partial pressures". It can be written as:

$$P\ total = Pgas_1 + Pgas_2 + Pgas_3 + \ldots Pgas_{(n)}$$

Air is made up of a variety of gasses (see Table 1). As a generalization, mixed gas divers use the values of 79 percent for nitrogen and 21 percent for oxygen. Incidentally, be careful not to say "point seven nine percent", we commonly hear this in the field, even from instructors. The truth is .79% is a really small number!

Why not use the precise values shown in the table? With the field equipment we use, we simply cannot measure to any better precision than +/- 1 percent in oxygen anyway. To do math with a bunch of numbers following the decimal point has no real value. Keep it simple, either a whole percent or at the very most a tenth of a percent (only because some oxygen analyzers want you to think they are that accurate). Since there is a bit less than 1 percent of all the other gases and most of that is comprised of argon, it is common to add that one percent in with the 78 percent nitrogen and just consider the total diluent as 79 percent.

Some older diving texts used 14.7 psi for the surface ambient pressure and required lots of conversions. While a standard atmosphere could be 14.7 psi, 29.92 inches of mercury, 760 millimeters of mercury, 760 torr, 1.0132 bar, it can become rather confusing, so we simply use the bar.

Table 1 Composition of Air

Gas	Symbol	Units	% or ppm	
Nitrogen	N_2	78.084	%	
Oxygen	O_2	20.946	%	
Argon	Ar	0.934	%	
Carbon Dioxide	CO_2	0.033	%	
Neon	Ne	18.18	ppm	
Helium	He	5.24	ppm	
Krypton	Kr	1.14	ppm	
Xenon	Xe	0.09	ppm	

Using Dalton's Law, this would mean that at the surface, nitrogen and oxygen pressures would be:

N_2 79% X 1 bar = 0.79 bar

O_2 21% X 1 bar = 0.21 bar

We can rewrite Dalton's Law for this "single gas" consideration and end up with our standard "Nitrox 101" formula:

Pressure of the gas = Pressure Total X Fraction of the gas

Pg = Pt X fg

The basic formula shows the gas exposure for a given total pressure and gas fraction. It is the one we use to determine the narcosis level as well as the oxygen exposure.

The formula can be re-written to solve for each value as follows:

Pt = Pg / fg
(better known as the Maximum Operating Depth)

and

fg = Pg / Pt
(known as Best Mix)

These formulas can be easily remembered by some using the "circle T" format, or the "Dalton's Diamond".

Water is obviously heavier than air so it exerts a significantly higher pressure during descent. (Ok, we know that one pound of water "weighs" the same as one pound of air and that it is really "mass", but for those of you who were awake in science class, humor us with this departure from pure science.) If we were to be able to "measure" a one square inch column of air that extended up to space we would find that it weighed 14.696 pounds. A similar column of sea water would only have to be 33 feet high. This simply means that for each 33 feet we descend, there is an additional atmosphere (bar) of pressure. In the metric system, it is a bit simpler since by definition the pressure exerted by 10 meters of sea water (10 m) is 1 bar.

We can make a simple formula to convert depth to pressure as:

Pressure total (bar) = (Depth (meters)/ 10) + 1

Pressure total (bar) = (Depth (feet)/ 33) + 1

It can be re-written to convert a known pressure to depth as:

Depth (m) = (Pressure (bar) – 1) X 10

Depth (feet) = (Pressure (bar) – 1) X 33

The major difference in the Advanced Trimix course is that we can now see the effect of much greater depths than previous courses. While the Standards and Procedures for this PSAI course limit the training depth to 100 m (328 feet), it is not unusual for an Advanced Trimix diver to work up to depths routinely in the full 90 to 140 m (300 to 450 feet) range.

Let's assume we want to make a dive to 85 m (280 feet). An Advanced Trimix diver needs to always think in terms of pressure and not just depth. Remember that pressure is what determines virtually everything about the dive!

Pressure (bar)	=	**(85 m / 10 m) + 1**
	=	**8.5 + 1**
	=	**9.5 bar**
Pressure (bar)	=	**(280 feet / 33 feet) + 1**
	=	**8.48 + 1**
	=	**9.48 (round to 9.5 bar)**

Again, what this means is that whatever is happening on the dive is related to "9.5". Either something is 9.5 times less or 9.5 times more, in any case it is 9.5 times worse than you would want it to be!

Combining the pressure/depth relationship with Dalton's Law is how we determine the complete answer to "best mix", "gas exposure" and "maximum operating depth" questions.

With this example, as shown in the introductory chapter, we can determine our gas values. Assume that we do not want to exceed an oxygen exposure of 1.4 bar and a nitrogen exposure value of 3.2 bar (this is the approximate narcosis of 30 m (100 feet).

At 85 m (280 feet), home of 9.5 bar, this would give the following values:

fraction of oxygen	=	**Desired exposure / Pressure total**
fO_2	=	**1.4 bar / 9.5 bar**
fO_2	=	**0.14736 (round to 0.15)**

Some divers will round the value <u>down</u> to 0.14 in order to give a little extra margin on oxygen exposure, but considering the amount of time typically spent on Advanced Trimix dives, there is usually plenty of room with the 150 minute 1.4 bar PO_2 time limit. As you gain experience, you will be better able to judge this matter.

Once you know the mix, it can be used to calculate a buffer zone depth using the PO_2 of 1.6 bar.

Pressure total	=	**Desired exposure / fraction of oxygen**
Pt	=	**1.6 bar / 0.15**
Pt	=	**10.66666666 bar (round to 10.7 bar)**

Convert to depth:

Depth (m)	=	**(Pressure (bar) – 1) X 10 m**
	=	**10.7 bar X 10 m**
	=	**107 m**

Depth (feet)	=	**(Pressure (bar) – 1) X 33 fsw**
	=	**10.7 bar X 33 feet**
	=	**353.1 feet (round it to 350 feet)**

So, we can see that while the dive is planned to 85 m (280 feet), for oxygen purposes, the critical PO_2 of 1.6 bar would not be reached until much deeper – 107 m (350 feet). This should ease the mind of even the most paranoid diver.

Continue by calculating the fraction of nitrogen:

fN_2	=	**3.2 bar / 9.5 bar**
	=	**0.336842 (round to 0.34)**

Since we know that we have oxygen at 0.15 (15%) and nitrogen at 0.34 (34%) all we have to do is subtract them from 1.00 (100 percent) to get the fraction of helium that would be necessary to dilute the oxygen and nitrogen to the desired values:

1.0 – 0.15 – 0.34 = 0.51 (or 51% helium)

Unlike nitrox diving, rarely would a Trimix diver be handed a cylinder with a "pre-mixed" gas and be asked to determine the MOD. Virtually all dives are set up knowing the planned depth first followed by determining the "best mix". After mixing the appropriate trimix, then the diver will analyze and make any minor adjustments in the dive plan based on the actual gas values. Divers at this level should be able to easily determine any necessary correction values.

A significant part of Trimix diving requires using these pressure and volume formulas. They should be second nature, even if using computer software, the diver must be aware of the values and effects.

One additional law that is shown in diving texts is **Charles' Law**. While many times divers learn it, frequently they are not shown a practical application. Charles' Law relates to volume and temperature and can be written as:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

One of the tricky bits about the temperature is that it must be in "absolute temperature" values, either Kelvin for Celsius temperatures (SI or metric) or Rankine for Fahrenheit temperatures (Imperial). The conversion is simple:

Kelvin ° (degrees)	=	**Celsius ° + 273**
Rankine ° (degrees)	=	**Fahrenheit ° + 460**

Let's assume you are going to do a trimix dive where a definite thermocline exists and is quite cool on the bottom. Your boat arrives at the dive site and the outside air temperature is 36° C (97° F). This assumes that there is no additional heating from color absorption by the paint on the cylinders. If you are diving with double 16 liter cylinders ("steel 104s") filled to capacity, the total available gas would be about 5,890 liters (208 cubic feet). It is known that the bottom temperature is 5° C (42° F). What is the effect of temperature on the available gas supply?

Some conventions put Kelvin as K after the figure rather than °K. Use what you are used to but do not confuse yourself or others in the team.
Convert the temperatures to absolute temperatures, Kelvin or Rankine as desired:

Metric surface temp	=	**36° C + 273**
	=	**309° K**
Bottom temp	=	**5° C + 273**
	=	**278° K**
Imperial Surface temp	=	**97° F + 460**
	=	**557° R**
Bottom temp	=	**42° F + 460**
	=	**482° R**

Substitute the temperatures and the surface volume into the formula:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Metric Volume

$$\frac{5890 \text{ liters}}{309° \text{ K}} = \frac{V_2}{278° \text{ K}}$$

$$19.06 \text{ liters/°K} = \frac{V_2}{278° \text{ K}}$$

$$19.06 \text{ liters/°K} \times 278° \text{ K} = V_2$$

$$5298 \text{ liters} = V_2$$

Imperial Volume

$$\frac{208 \text{ ft}^3}{557° \text{ R}} = \frac{V_2}{482° \text{ R}}$$

$$0.3734 \text{ ft}^3\text{/ °R} = \frac{V_2}{482° \text{ R}}$$

$$0.3734 \text{ ft}^3\text{/°R} \times 482° \text{ R} = V_2$$

$$179.9 \text{ ft}^3 = V_2$$

So our SI Trimix diver will have lost some 592 liters of available gas and rounding to 180 cubic feet, the Imperial trimix diver has lost about 28 cubic feet! While this may not seem like a lot, look at it this way, you have just lost over 10 percent of your total gas.

Other useful applications of these formulas include such things as determining how large of a lift bag is necessary to raise an object that has a specific weight. This would involve several steps, including how much water was being displaced, the actual weight of the object and finally the volume of gas required to offset the weight. Get your instructor to show you how to calculate this for an interesting exercise. While it may look like a lot of steps, the solution is straight forward.

If you have any questions about these conversions and how to determine gas fractions and volumes, be sure to ask now before going further.

Chapter 2 Review Questions

1. Fill in the blanks:

bar	psi(a)	fsw	metres
1.0	14.7		
2			
			15
8.5			
		260	
		340	

2. What is the PO_2 of air at 64 m?

3. If a diver has a surface gas consumption of 17 litres/min, how many minutes would 68 bar provide from a single 10 litre cylinder at 67 m?

4. What is the PO_2 (ata) (bar) of a helium-oxygen mixture (heliox) that contains 5 percent oxygen at 122 m?

5. At what depth does trimix 10/45 (10% oxygen, 45% helium and 45% nitrogen) have a PO_2 of 0.20 bar?

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Experienced mixed gas and cave instructors have said many times over: "You can lie to us at the surface, but you can't lie to us underwater"

Chapter 3 Physiology for the Trimix Diver

Gases of Mixed Gas Diving and Their Effects

Oxygen is the gas that supports life in the human body, so it may seem strange that there are physiological limits, too much as well as too little can cause significant distress. The nitrox diver always considers the "too much" side of the equation, but the mixed gas diver needs to be acutely aware of the "too little" side.

Hypoxia is the term used to describe the lack of oxygen in the body. At oxygen partial pressures of 0.16 bar, the first signs of hypoxia may be noted. As the PO_2 declines to 0.12 bar many divers will become helpless if any exertion is required and below 0.10 bar unconsciousness or even death may result.

Why do mixed gas divers need to be aware of hypoxia? Quite simply, many of the mixtures used for depths below 60 m (200 feet) typically contain less than 10 to 15 percent oxygen!

Diving with gas mixes that only have 10 percent oxygen, it is possible to begin using them at depths as shallow as 6 m (20 fsw), but these gases would have a higher rate of diluent on-gassing. Some divers have said that all they have to do is "hurry down to 6 m (20 feet) and then they could use their "back gas". There are a multitude of problems with this thought process, not the least of which is some unforeseen delay at or near the surface where they are required to exert, such as swimming hard towards a descent line in heavy current? These are only a couple of the many reasons mixed gas divers use a "travel mix" whenever they are employing hypoxic bottom mixes.

Another more serious situation of hypoxia that has the potential of injury or death is the accidental use of argon. There is at least one case on file of a regulator being attached to an argon cylinder and breathed with near disastrous results. As such, every diver must insure against cross-filling or trans-filling errors and all gases must always be analyzed for proper oxygen content.

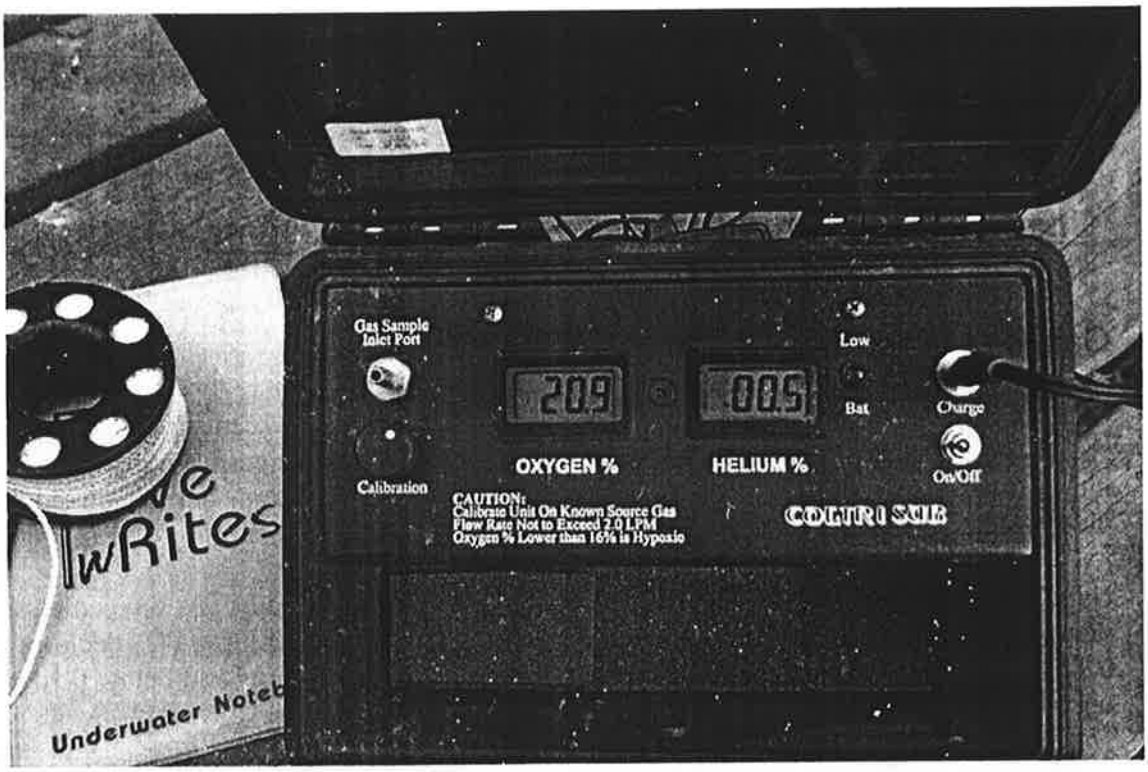

Fig. 2
A good Oxygen & Helium analyzer removes doubt and is a fundamental part of a dive team equipment requirement.

Hyperoxia is the condition where the oxygen pressure is too high. In mixed gas diving, the oxygen limit is 1.6 bar. By now you have been hammered with all the horrible stories of acute oxygen toxicity from your basic nitrox course through Extended Range. **The fact remains, oxygen toxicity is real.** This is not something that is made up to justify a diving procedure or a particular piece of equipment.

Plain truth: There have been fatalities directly associated with oxygen toxicity

More plain truth: Each of the cases involved someone who violated the rules or guidelines of oxygen exposure

So the human body only tolerates a fairly limited oxygen range of exposure, from about 0.16 bar to 1.6 bar. It is the mixed gas diver's responsibility to ensure all gases have been analyzed, properly marked and identified as well as the regulators that are associated with the cylinders.

Many researchers have investigated excessive oxygen exposures from as far back as Paul Bert in the 1800's. Excessive oxygen exposure can result in a number of problems, but the most serious effects are on the Central Nervous System. As you have learned in previous courses, the primary method of preventing acute oxygen toxicity (CNS oxygen toxicity) is by **prevention**.

Both the U.S. Navy and the National Oceanic and Atmospheric Administration (NOAA) have developed tables or charts for CNS oxygen toxicity, used universally, and these have formed the basis of your earlier nitrox courses. It is sufficient here to remind the diver of those limits (see Table 2). There are numerous waterproof and flexible tables that are commercially available to the diver to keep the limits readily available.

It cannot be overemphasized for the mixed gas diver, the importance of understanding CNS oxygen toxicity.

There have been cases where a diver only considered the bottom time exposure for oxygen and then during decompression violated the "oxygen clock" with resulting problems. There have been as many, if not more; incidents associated with improper gas use during decompression as there have been during the bottom phase of the dive. If a diver were to perform a dive at a PO_2 of 1.6 bar for 30 minutes, they would be well within the limits of the oxygen exposure table. Unfortunately, if that was just the bottom phase, then there is definitely going to be additional oxygen exposure, and for longer, at the decompression stop.

Oxygen clock: The time allowed for oxygen exposure adjusted for the oxygen pressure, usually expressed as a percentage of the total allowable time

Oxygen window: The difference in pressure of oxygen in the breathing mixture compared to the oxygen in the body's system, i.e. by using higher oxygen contents, you are "opening the window"

Divers that use oxygen for decompression at 6 m (20 fsw) have the oxygen clock running wide open and need to employ "air" breaks to reduce the oxygen tension, relaxing the "oxygen window". Another error that causes in increase in oxygen pressure is that most divers stay a "bit deeper" than the scheduled stop depth, "just in case". With consideration to oxygen exposure, it may be better to reduce the oxygen or employ it at a shallower depth to help alleviate any potential mistakes.

Divers who have taken or reviewed PSA International courses have already learned that the acronym ConVENTID is mostly for information, but promises no real prevention. ConVENTID describes some of the most common symptoms as well as the definite **sign**, Convulsion, of acute CNS oxygen toxicity. There have been a number of fatalities where there was no indication or sign given to a buddy to indicate there was a perceived problem. Besides the convulsions, vision problems, ear problems (ringing/tinnitus), nausea, twitching (facial/lips), irritability and dizziness are the most common symptoms, but by no means ALL of them. Since an oxygen convulsion may occur without warning, **prevention remains the diver's best defense.**

Some divers and researchers recommend limiting the oxygen exposure to 1.4 bar. Divers may consider using 1.4 bar PO_2 as their "normal operating depth" and 1.6 bar as the "maximum operating depth". This allows an excursion slightly deeper than originally planned for any number of reasons, i.e. contact a buddy, retrieve a dropped object, etc. While simply reducing the oxygen exposure pressure may have merit, there is an additional element that must also be considered - time. Just reducing the oxygen pressure to 1.4 bar by itself is not necessarily going to solve any problem if the oxygen exposure time limits are ignored.

Remember, there is no one magic number that is "safe". Each diver needs to weigh the risks and make an educated and informed choice. It might be prudent to note, that when faced with a critical problem or decision underwater, rarely does a diver have time to calculate a PO_2, so have pre-established depth limits and adhere to them.

The effect of exertion during periods of high oxygen concentration must not be minimized. Many experienced deep divers have recounted how a vision collapse happened shortly after a brief exertion. Unfortunately it is very difficult to convince new divers of the reality of this effect. They mistakenly believe that since they have not experienced any change in their perceptions or motor skills that they are immune. **WRONG!** And regardless of what you may have read, you cannot "tough out an oxygen convulsion".

"If anything seems wrong, it IS wrong! Ascend while you can."

Whole body oxygen toxicity, usually in the form of a pulmonary manifestation, is discussed at length in some dive courses, sometimes termed the "Lorraine Smith Effect". While this is a problem that has been identified in long term hospital environments as well as saturation diving exposures, there is little likelihood that it would be matter for the recreational technical diver.

Numerous articles, texts, software programs show how to track this exposure usually with the Oxygen Toxicity Unit (OTU) tracking method. Other techniques are the Unit Pulmonary Total Dose (UPTD), but in any case they both refer to the long term, lose dose oxygen exposure.

The formulas used to calculate pulmonary oxygen toxicity exposure are like many in diving; they are approximations and are not an exact monitor.

The fact is that even an aggressive diver would be hard pressed to reach OTU limits as long as the CNS exposure limits were adhered to – **and those MUST be rigorously monitored!** The Mixed Gas diver should be aware of the existence, but intensive tracking normally proves redundant.

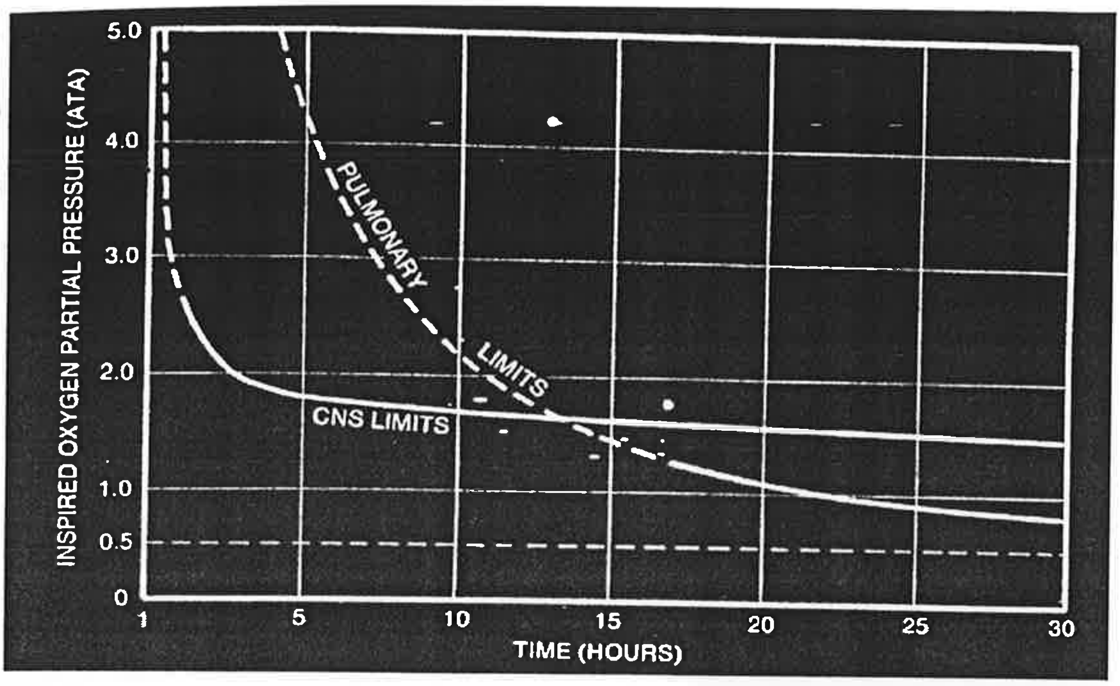

Fig. 3 Inspired oxygen showing CNS and Pulmonary curves. Pulmonary uptake should not affect us.

Track CNS times faithfully and the OTUs will take care of themselves.

Over the counter and prescription drugs may greatly influence the effects of high pressure oxygen. As a general rule, if you are ill to the point of requiring drug therapy, then you should not dive. Seek proper competent medical advice before diving with any drug. Instructors are well meaning, but unless they are a medical doctor, the limit of their advice should be "don't dive".

Nitrogen

Nitrogen is one of the reasons this course exists! If it weren't for the narcotic properties we wouldn't need to seek alternative breathing gasses such as trimix. In the quick look dive, the primary concern was for the narcotic property, as that would be what impairs the diver the most. The decompression obligation is secondary when considering depth limitations, i.e. it's a foregone conclusion that if you are making a trimix dive, decompression is going to take place. Even though many term nitrogen an "inert" gas, the effects of nitrogen are far from trivial in our physiology. With two direct actions, the narcotic effect and the dissolved gas effect, an understanding of the part nitrogen plays is particularly important to the diver.

The term "inert" is a carryover from early physiology texts. For a more accurate term, rebreather divers use "diluent" to describe any of the gases used to dilute oxygen or replace nitrogen. Some modern physiology writings use the term "non-metabolic" when talking about nitrogen in the gas form. Nitrogen is hardly "inert" when under pressure, as in diving. Interestingly enough, despite what many dive texts say, nitrogen is very important element to the human body, we just don't get it from breathing!

Fig. 4 Don't disregard the issue of nitrogen in decompression. Quick evacuation to a recompression chamber is the norm.

Nitrogen narcosis affects each diver in different ways and many times at different depths, even for the same diver. While some divers appear to be perfectly capable at depth in excess of 50 m (165 fsw), many times the degree of impairment isn't known until the diver is called upon to perform a task beyond the original scope of the dive plan. Some used to joke "Plan your dive, Dive your dive, Log your Plan!" probably because they didn't always remember the facts of the dive! Nitrogen narcosis can seriously distort or cloud the fine memory during and after a dive. Incidentally, narcosis does NOT go away by simply "ascending a meter or two" ("a few feet").

Nitrogen narcosis (or any other diluent gas narcosis) is generally thought to be caused by the movement of a soluble gas or fluid across the blood-brain barrier that causes an anesthetic affect to areas of the brain. Gas narcosis values have largely been based on their oil and water solubility's with "narcosis" factors being assigned based on this number. The table below shows some of these representative values. The term "Meyer-Overton effect" has been used to relate the narcotic effect based on lipid solubility, but this is not a perfectly consistent explanation. Incidentally, Meyer and Overton were independent researchers studying the various effects of drinking alcohol in the late 1800's, they were not examining the physiology of mixed gas diving!

The beauty of trimix diving is that we replace the nitrogen with the essentially non-narcotic helium. Even more so, we are able to "adjust" narcosis for any range of depths

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DCS. Unfortunately, the dose that is recommended exceeds even prescription levels and has the potential to cause serious liver damage. No dive is worth destroying your body's vital parts! Beware of the quacks.

Other sources of misguided information include lists of general drugs that have been taken out of context. For example, paraquat is listed as a drug that has oxygen toxicity concerns, however since it is a deadly herbicide, frequently fatal in even small doses, it is doubtful that anyone taking it would be diving! There are many medical articles that have been written but not all are applicable to diving. In this case, the association of paraquat and oxygen relates to accidental drug poisoning, not any possible diving situation.

Special considerations of the technical diver may include a visit to the dentist as well as the doctor. The extreme pressures of deep diving sometimes cause toothaches when the previous shallow diving didn't pose any problems to the diver. Often times however, the visit follows a deep dive after actually having a problem.

When "visiting" the dentist, it may save future problems if they understand that the diver is engaged in technical deep diving. When fillings or other dental work is performed, the inclusion of a small air pocket can cause significant pain upon descent. Dental professionals take great care even in normal circumstances to avoid any air inclusion, but it doesn't hurt to remind them. Aviators have routinely advised their attending dentists of their avocation due to the same effects.

Medications and Mixed Gas Diving

First and foremost, it is very important that the mixed gas diver understand that there is scant information about the biochemical effects of pharmaceuticals at high pressures. In the U.S. the various drugs are tested and monitored by the government, but only at normal sea level pressures (1 bar). Just as the gases we breathe alter certain physiological responses, drugs may also turn hazardous or even deadly when exposed to hyperbaric conditions. In general, a mixed gas diver should avoid diving while taking medications until the condition has cleared or unless competent hyperbaric medical authority has provided a written release.

One of the largest misused drug in diving is an antihistamine. Whether used for allergy or as a decongestant, the chemical action of an antihistamine can be such that a diver is completely impaired at depth. Drugs that we may not consider as being a problem with diving may have hidden interactions. Some antibiotics are known to have a CNS effect, which when combined with an increased oxygen pressure may result in unpredictable physiological reactions.

Pseudoephedrine, under a variety of trade names, although commonly available as an over-the-counter drug has been shown to increase or modify the diver's susceptibility to CNS oxygen toxicity. This is just one example of the many different drug interactions that must be considered by all divers, not just the mixed gas diver.

Drug interaction should be evaluated by a competent trained medical professional with an understanding and appropriate training in the hyperbaric realm of medicine. Many times they are well meaning, but unless a dive instructor is also an appropriately trained medical authority, it would be prudent to politely decline any medical advice other than not to dive!

Beware of unqualified or suspect information that floats around on the internet. Any drug, even if it is an "over-the-counter" (OTC) variety, must be cleared by a competent medical authority. One example of the "pseudo-medical experts" is an internet website that promotes taking large doses of a particular OTC pain medication as a way to prevent

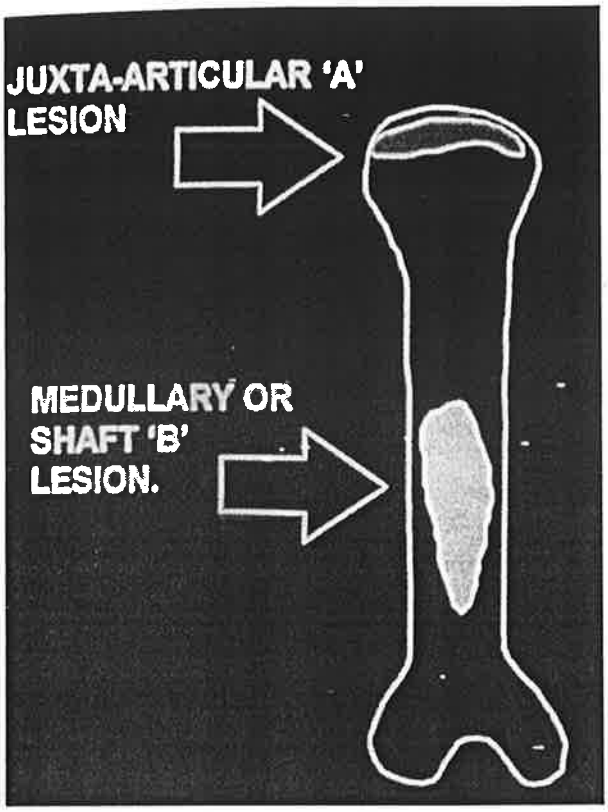

Fig. 6 Two areas necrosis of the bone often found. Reference to each particular type is by use of the term 'A' or 'B' lesions.

Diver Fitness

Without a doubt, mixed gas diving requires far more exertion and demands on the body than any other form of sport diving. The diver needs to be considerably at ease in the water in skills since extreme efforts are usually only met by the continuous water resistance or drag. The diver may be outfitted with several cylinders of various design and configuration, each adding to the task loading and resulting stress to the diver. The environment can conspire against the diver to require even more exertion at times when the diver needs to be at rest such as during decompression.

While the diver doesn't need to be able to leap tall buildings with a single bound, certainly a possibility of decompression illness lurks on each mixed gas dive. Excessive fat on the body is contraindicated for diving, as well as poor nourishment, poor hydration, alcohol or drug use/abuse, smoking and other medical conditions.

All divers should receive a thorough physical, and the attending doctor should be informed that it is a diving physical for the purpose of aggressive dive exposure beyond those recommended by the basic open water agencies. This bit of information to the doc may well turn up a potential problem that can be resolved before it becomes a risk to you and your dive partner. All of the standard physical items take on additional importance when considered in the light of hyperbaric exposures and it might well behoove the diver to find a doctor that is familiar with the extra investigation associated with diving physicals.

Unfortunately, this is a double problem, since the mixed gas diver can only carry so much gas and time is normally of the essence. Mixed gas divers contemplating dives beyond 120 m (400 fsw) should have many dives and experience prior to any deeper attempts. These dives require significant planning and support and are serious endeavors.

Compression Arthralgia

On dives as shallow as 30 m (100 fsw) but most often occurring on dives deeper than 90 m (300 fsw) some divers have noticed noise in their joints, such as the knees and elbows. This has been described as a scratchy, creaking noise which may or may not have any associated pain. While it is often seen in hyperbaric chambers, it also shows up with in-water activities. This noise may be due to the increased gas pressures which cause lubricating fluid to move away from the joint. The resulting "dry joint" makes the disturbing noises and, unlike DCS, appears upon arrival at the target depth rather than after surfacing. The good news is that it generally resolves rapidly at the surface and there is (currently) no evidence of long term physical harm.

Dysbaric Osteonecrosis

Also known as aseptic bone necrosis, some commercial divers have shown deterioration of bone mass, primarily in the long bones or rotator socket areas. This was previously thought to be related only to saturation diving, but studies have shown that it occurs in many forms of compressed gas breathing. While there are only a few cases reported for divers who dive to 30 m (100 fsw), the incidence increases in the 30 to 50 m (100 to 165 fsw) range.

Like most other hyperbaric problems, the cause of the deterioration of the bone structure is not fully known. Theories include gas bubbles blocking vital nutrients in blood vessels to the bone, fat embolisms and platelet thrombi.

Trimix diving is practiced by a relatively small population of the diving public and there are only a handful of trimix divers who have over 100 mixed gas dives. This means that there is very little information and virtually no study being done on this potential condition. Even less information is known about the long term effects, i.e. 20 or 30 years of activity. Trimix divers who perform large numbers of trimix dives or routinely push depths may want to consider a physical examination by a hyperbaric specialist and establish a set of reference x-ray films. These films are used by hyperbaric specialists to monitor changes in the long bones or bone joints and provide the definitive diagnosis.

symptoms of skin bends. Few cases of skin bends associated with counter diffusion have been reported. However, one of the most noticed effects has been inner-ear DCS (vestibular DCS) resulting in extreme vertigo and nausea which is not a pleasant experience! An explanation is that even though the pressure of helium in the blood falls rapidly, the middle ear still has high concentrations and it may continue to move through the oval and round window structures of the ear and the total pressure in the inner ear rises. In some rare cases, there has been severe reactions and swelling in the throat due to DCS.

In general, isobaric counter diffusion is prevented by planning gas mixes that do not cause large differences in gas tension. Many experienced heliox and trimix divers use heliox and trimix for decompression gases to keep these pressure differences from manifesting during the dive.

It is important to note that early trimix courses generally referred to counter diffusion only as it applied to skin bends or even "chokes" and as a result, many divers have disregarded it as a potential problem. There are divers and instructors that say "counter diffusion does not happen". The reality is, with the helium mixes in common use today, isobaric counter diffusion is happening more and more at gas switches. A trimix diver needs to be aware of this potential problem and prepared in the event they become disoriented or nauseated shortly after a gas switch.

There are a few reported cases of skin bends associated with counter diffusion and the medical literature still describes swelling of the throat tissues as a potential problem. Again, these are extreme cases and quite rare. Vestibular interference (vertigo) is the most common symptom and must be understood by the diver.

High Pressure Nervous Syndrome

Since helium allows a diver to descend to depths that may exceed 120 to 180 m (400 to 600 fsw), a central nervous system effect may be experienced, known as High Pressure Nervous Syndrome (HPNS). While it has sometimes been called "helium tremors", it is not directly related to a physiological effect of helium on the body. The effect is due to the rapid hydrostatic pressurization (descending too fast) of the body which results in central nervous system (nerve pathway) disruption or impairment. Typically the diver may experience shakes or tremors which, with continued descent, may become worse to the point of incapacitation. Normally this is well outside the range of normal recreational trimix diving exposure depths.

Early trimix was actually an attempt to moderate these tremors by the incorporation of small amounts of nitrogen to buffer the HPNS, by adding a controlled level of narcosis.

These nervous tremors are typical in extreme pressure exposures and the only real prevention is to slow the descent speed. Research has shown that descent rates of 1.5 to 2 meters per hour (5 to 8 feet per hour) help alleviate HPNS effects in susceptible persons.

"cherry red lips and nail beds" may only occur in 16-20% of CO poisoning cases – virtually all fatal.

Instead, divers need to be keenly aware of any taste or odor in the gas. While CO is colorless and odorless, it is formed by other actions which have taste and odor associated, i.e. oil flashing in a compressor, contaminated air intake to the compressor, etc.

An insidious method of carbon monoxide production may occur by improper gas blending techniques. This involves cylinders and/or filling stations that have contaminated interiors that then react with high concentrations of oxygen during partial pressure fills. While some may argue that regulators do not need to be oxygen cleaned as long as the oxygen concentration is less than 40%, it should be recognized that cylinders really are exposed to much higher oxygen concentrations, approaching 100% during this type of blending. Obviously, purchasing gas from reputable facilities with trained gas blenders is the safest method of guarding against this possibility. Occasionally a diver may purchase a gas that has an odor, as a general rule if the gas smells (tastes bad) it could be contaminated and the diver should always err to the side of caution!

Other Physiological Effects Associated with Mixed Gas Diving

As mixed gas divers have gained more experience with a wide range of gases at depths increasingly deeper than 100 m (328 fsw), some of the lesser known effects have begun to manifest. As time goes on and more trimix dives performed, new information may result about the maladies associated with deep mixed gas diving in the recreational segment.

Isobaric Diluent Gas Counter Diffusion

Isobaric counter diffusion is normally rare in mixed gas diving, but has increased in its frequency of occurrence as divers have pushed to higher helium concentrations or when using heliox, both in closed circuit rebreathers and open circuit systems. Isobaric means "at the same pressure", so this is a condition that relates to the effects of changing gases while at a uniform pressure.

The most common situation of counter diffusion occurs when a diver switches from one gas to another where there are large concentration differences, i.e. a diver using a trimix with 50 percent helium or more, switches to a nitrox mix for decompression. Suddenly there is a huge difference between the helium in the tissues compared to the breathing mixture. What is happening is that the breathed gas is diffusing into the tissues slower than the dissolved gas is being removed. The diver is being "bent" even though they are still at depth!

In early courses divers commonly thought about isobaric counter diffusion in relation to the difference in gas breathed and gas in the dry suit which results in classical "itching"

Since helium is a significantly lighter gas than nitrogen it behaves quite differently and this results in special tables or computer models being required for helium decompression use. Helium is an effective gas in many depth ranges and the Mixed Gas diver can explore a wide variety of applications where it proves to be the superior diving diluent gas.

A word of caution for those who have discovered the Heliox tables in the U.S. Navy Diving Manual Volume 2 (Mixed-Gas Diving). Careful examination reveals that these tables start 100% oxygen decompression at depths of up to 15 m (50 fsw). These tables assume a "hard hat" or full helmet so that in the event of an oxygen convulsion the diver will not drown. They are not appropriate for technical open circuit use!

Helium used for diving should conform to standard breathing specifications and can be found in a variety of sources. The U.S. Navy Diving Manual lists the specifications for respirable (breathing) helium and the gas can be purchased by its military specification, MIL-P-27407, Type One, Grade B. Its purity is specified as 99.997 percent pure with a dew point of -61° C (-78° F). Different gas suppliers have their own technical specification, such as "ultrapure". It is the diver's responsibility to ensure that the purity requirement as well as any carbohydron contamination is within human physiological limits.

Carbon Dioxide

As previously described, carbon dioxide (CO_2) is a significant catalyst in the onset of oxygen convulsions as well as increasing the effects of nitrogen narcosis. Where does it come from? The cylinder? As is well known, the body produces the CO_2 as a byproduct or waste gas from respiration.

Several factors do contribute to CO_2 build-up as mentioned. Poor equipment maintenance is quite common in cases of CO_2 problems. Excessive breathing resistance may cause a build-up of carbon dioxide. Poor breathing techniques, such as skip breathing, need to be avoided as well as excessive exertion, tight fitting constrictive clothing that reduces the ease of breathing. The goal is for long, slow and deep inhalations that allow complete ventilation in the breathing process. If unsure how to breathe completely, a serious diver might consult an appropriate text or even a respiratory coach for diaphragm breathing exercises.

Carbon Monoxide

No discussion of diving gas would be complete without mentioning carbon monoxide (CO). Carbon monoxide is well known for its property of tenaciously attaching to hemoglobin, the oxygen transport mechanism. In diving there is a commonly discussed symptom, "cherry red lips and nail-beds" which unfortunately has a significant defect. At an Emergency Room Physician seminar, it was noted that the oft quoted and famous

Fig. 5 Preparation for a deep dive should be relaxed and thorough. Comfort on the dive will be increased with good thermal protection.

First is helium's insulating ability. It doesn't have any. It is important for the diver to consider this to make sure proper exposure protection is taken. Helium mixtures should never be used for dry suit inflation - it's just too chilly. Helium does not absorb heat from the body during breathing any faster than normal air, but it may still seem like it is colder to some divers. Nitrox or argon is commonly used for drysuit inflation gases during trimix dives to provide extra insulation and warmth to the diver.

Heliair

Helium is the least narcotic of the diluent gases and continues to be the gas of choice, whether incorporated in a tri-mix or alone with oxygen termed "heliox". Popular with expeditions is a helium and air mixture so that oxygen errors don't occur during mixing and less oxygen has to be transported to remote dive sites. The term "heliair" is used to describe this gas, whose major defect is the high level of nitrogen narcosis required when approaching a limiting partial pressure of oxygen. It's not prohibitive, just not optimum.

The depth at which the oxygen in air reaches a PO_2 of 1.6 bar is 66 m (218 fsw), home of 7.6 bar. If the total pressure is 7.6 bar and the PO_2 is 1.6 bar, then that means the PN_2 (nitrogen component) would be 6 bar. Thus, any time heliair is used to a depth where the PO_2 would be 1.6 bar, that would mean the narcosis depth would be equivalent to 66 m (218 fsw), which is deeper than desirable for many trimix divers.

"What works... is what works."

It is impossible to totally eliminate the possibility of bends in divers, but a few positive actions by the diver can lessen the risk. These include:

Physical fitness	Proper rest
Proper fluid balance	No Drugs and alcohol
Reduced Caffeine	No smoking
and the list goes on.	

Probably the most important factor of DCS prevention is proper fluid balance. Drinking lots of water will greatly reduce the diver's risk. Avoid excessive electrolyte replacement drinks; while the ads sound great and you can put a lot of "fluid" in the body, unfortunately it is also possible that the cells of the body actually become dehydrated! The typical diet contains far more soluble electrolytes than needed so a good rule of thumb is to dilute any electrolyte drink with an equal amount of water. Other preventative techniques consist of not becoming overheated prior to the dive, not exerting with too much unnecessary equipment prior to the dive and of course - No Smoking.

Helium

Helium is a gas that allows the diver to reduce the partial pressure of oxygen in order to reduce CNS toxicity effects and also reduce the partial pressure of nitrogen to eliminate the narcotic effect. Helium is known as a "noble gas", meaning that it has all of the outer shell valence electrons, so that it should not combine with other elements. Early chemistry texts called the noble gases "inert". It was then determined that under some circumstances they would and in the 1960's the term inert was replaced by noble.

Helium is a very lightweight gas probably best known for its ability to let balloons and zeppelins float in the air. The U.S. has the largest supply of helium in the world after it was found to be present in natural gas wells in the Central U.S. For many years it was considered a strategic commodity due to the threat of enemy airships. Helium also allows sound to travel faster than in air, explaining the "Donald Duck" speech characteristics after sucking it in from a toy balloon. (How many people have nearly passed out after inhaling the contents of a child's helium balloon? Helium by itself is an asphyxiant. In the US, some commercial balloon helium has oxygen added to reduce possibility that an ill-informed consumer doesn't pass out, fall and hit their head.)

Helium tends to be expensive, but in the U.S. it is much less than other countries. While cost is one problem, there are a few physiological considerations.

$$= \frac{153}{293} \times .79$$

$$= .52 \times .79$$

$$= .41 \text{ or } 41\%$$

There are other diluent gases and each behaves in its own characteristic way. The gases and their relative narcotic value are shown in the following chart:

Narcotic Value Referenced to Nitrogen

Helium (He)	4.26	Least Narcotic
Neon (Ne)	3.80	
Hydrogen (H_2)	1.83	
Nitrogen (N_2)	1.00	Standard
Argon (Ar)	0.43	
Krypton (Kr)	0.14	
Xenon (Xe)	0.039	Most Narcotic

Do not assume that just because a gas is listed above that it is prudent or safe to use in diving or even 1 bar applications! Hydrogen is obviously extremely hazardous!

This chart is based solely on "solubility" factors and while useful, does not really provide practical alternatives other than to show that the gas of choice for trimix diving is helium. There are many other factors to consider before jumping on the "designer gas" of the year, physical breathing properties have to be considered and do not forget cost! If you think helium is expensive, run down to your local gas supplier and try to buy a cylinder of breathable grade neon!

Nitrogen Saturation, which could lead to decompression sickness, has been the original diving malady as well as the scourge of caisson workers world-wide. It would seem that with the vast experience with this gas, everything would be well defined and understood. Tables should be fool proof, schedules clearly understood and never a case of DCS. Oh well... such is not the case.

As nitrogen dissolves into the divers tissues and fluids, this gas tension must be reduced gradually during ascent otherwise the diver risks the "bends". In mixed gas diving, a variety of tables and techniques are used to prevent DCS, but nothing is totally sure and each diver accepts a modicum of risk. While a lively discussion of Buhlmann vs. Haldane vs. DCIEM vs. et cetera could be stimulating, remember at all times the sage advice:

that we would like to explore. Diving to 90 m (300 feet) using air is out of the question as the narcotic effects would render most divers helpless, or at the very least a babbling, incoherent hazard to himself.

Each diver should pick a narcosis level that is within their known comfort zone. As previously noted, some divers may pick 30 m (100 feet) while others may pick 50 m (165 feet). There is no one positively right answer. The narcosis level picked does however result in the determination of the amount of helium required for the dive. Since helium is more expensive than nitrogen or more difficult to obtain in remote locations, divers may try to keep the narcosis depth (END) as deep as tolerable. Quite possibly these divers should relax the grip on their wallet and recognize the problems associated with nitrogen narcosis.

If a diver chooses a personal value for the Equivalent Narcosis Depth (END), then to determine the fraction of nitrogen the following formula may be used:

Metric
$$fN_2 = \frac{(END + 10)}{(Depth + 10)} \times .79$$

Imperial
$$fN_2 = \frac{(END + 33)}{(Depth + 33)} \times .79$$

Metric Example: A diver desires an END of 30 m. The planned dive maximum depth is 80 m:

$$fN_2 = \frac{(30 + 10)}{(80 + 10)} \times .79$$

$$= \frac{40}{90} \times .79$$

$$= .444 \times .79$$

$$= .35 \text{ or } 35\%$$

Imperial Example: A diver desires an END of 120 fsw. The planned dive maximum depth is 260 fsw.

$$fN_2 = \frac{(120 + 33)}{(260 + 33)} \times .79$$

Chapter 3 Review Questions

1. If a diver chooses an Equivalent Narcotic Depth (END) of 40 m, what is the maximum fN_2 for a dive to 85 m?

2. Which is more narcotic, nitrogen or helium?

3. At what depth range does helium begin to cause physiological problems in the human body?

4. What is the major difficulty with using US Navy Heliox tables?

5. Why should cylinders be thoroughly cleaned for partial pressure blending?

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We can talk all day long about decompression, but if the diver cannot actually "dive the dive" according to the plan, then it is essentially a waste of time!!

Chapter 4. Decompression

Ever since decompression sickness was noted in man in the mid-1800's, the quest for a perfect model has been pursued. As a mixed gas diver, decompression becomes a fact of life. The air at the surface is not a friend, at least not until the diver takes steps to "off-gas" to acceptable levels.

A trimix diver not only has to consider nitrogen but helium out-gassing as well. Custom tables and software programs exist to compute the ascent profile much the same way standard dive tables handle air diving. There is much work taking place in software, and no doubt will be popular for cost reasons. A truly custom set of tables can be bought from one of several sources specializing in this type offering.

When planning the dive, an important consideration is the various gases to be used. For example, the descent gas may be EAN36 from the surface to 30 m (100 fsw), switch to bottom mix, and then on the ascent go back to EAN36 until about 6 m (20 fsw) where the switch to very high oxygen mixtures takes place. What is the effect of these other gases on decompression? Let's look at a fairly simple dive: descend to 30 m (100 fsw) on air and stay 30 minutes. Utilizing a popular computer generated table software the following decompression schedules were given:

Gas at 6 m (20 fsw)	6m (20')Stop	3m (10')Stop	Total Time
Air	5 min	12 min	17 min
EAN36	4	10	14
EAN50	3	9	12
EAN80	3	6	9
100% O_2	2	6	8

Gas	Minutes Saved Compared to Air	
EAN36	3	(21% Advantage)
EAN50	5	(42%)
EAN80	8	(89%)
100% O_2	9	(113%)

The tables chosen will describe the gases required, note however that even though utilizing 100% oxygen at 6 m (20 fsw) saves time, don't forget the oxygen CNS clock. It is running wide open at 1.6 bar at 6 m (20 fsw). The usage of EAN80 has been mocked by some factional groups of divers, but the original intent of diluting the 100 percent oxygen was to provide a higher pressure in the cylinder, hence a longer duration of higher level oxygen supplies. The EAN80 number was not picked for its special curative properties, but rather because if you took a standard cylinder and transfilled oxygen from a bottle supply (without a booster) then topped with air to the rated fill pressure, the oxygen content was approximately 80 percent. Since the available time increased with only a slight decrease in efficiency between the 80 percent and 100 percent, it was felt to be a worthwhile tradeoff. Some divers plan their decompression around EAN80 with transition to EAN80 taking place at 6 m (20 fsw) but will use "anything that is EAN80 or higher". This allows them to use either high volume EAN80 cylinders or switch to a staged oxygen cylinder without having to worry about changing decompression times or obligations. There have been some anecdotal writings showing that adding back a little nitrogen reduces the swelling in the lung tissues associated with pure oxygen breathing. In any case, the important thing to remember is that whatever gas you use, make sure it is properly analyzed and that the decompression schedule is developed with the gas being used.

For those accustomed to decompression on air dives or even EAN dives, the first thing that will be noticed when diving helium mixtures is the first stop depth is significantly deeper than usual. In some cases, stops may start at 27 to 30 m (90-100 fsw) for so called "normal trimix" dives. Don't fret, the times tend to be shorter so it may not be as bad as it initially looks.

In all cases of mandatory decompression, the diver needs to be acutely aware of the responsibility that needs to be exercised towards the prevention of decompression problems. Only with proper training and proper execution of the plan can the tables or computer model selected be reasonably expected to perform as desired.

Fig. 7 Decompression on Nitrox whilst hanging on a surface marker buoy

DCS denial is evident in many divers. In today's world, there are a variety of insurances available that will provide for proper treatment of diving related maladies. It's a small price for such peace of mind. If the diver suspects DCS, the quicker an evaluation takes place the more likely a fully resolved treatment can be effected. On the other hand, denial followed by extremely tardy treatment may not result in complete healing or at least require multiple treatments.

What about remote locations? Does anyone sanction in-water recompression? The diver, the pre-dive plan, the local authorities all play a part in the answer. Many expedition divers have a contingency plan for in-water deco. Since this usually requires higher inspired PO_2s, a full face mask becomes mandatory. Consult the specialist of your choice if a possibility of in-water treatment is contemplated, but always remember, it is going to take a LOT of oxygen and you gotta come up sometime! Care must be taken to ensure that any in-water treatment does not result in even more problems. It is difficult to anticipate the emergence of further symptoms since a patient may transition from a Type I condition to a Type II condition. In-water treatment of neurological DCS can result in more unanticipated problems and is avoided since it may result in serious injury or death.

Decompression Sickness

In diving literature there are a number of confusing terms and definitions. In general, we have tried to use the terminology that is found in the US Navy Diving Manual. The whole realm of decompression and pressure related maladies has been termed Decompression Illness (DCI) and this includes the standard "bends" as well as Arterial Gas Embolism (AGE) and other barotrauma (overexpansion) injuries.

Decompression Sickness (DCS) is caused by the inadequate elimination of dissolved non-metabolic gas(es) (in our case, principally nitrogen and helium) which results in the formation of bubbles, no matter how small, in the blood and tissues of the body. There are a variety of conditions that may either cause absorption of an excessive amount of non-metabolic gas(es) or else may slow the elimination of the gas(es) during decompression. Any form of decompression sickness must be treated by a competent medical facility equipped with a recompression chamber.

The US Navy divides decompression sickness symptoms into two categories based on the symptoms displayed by the diver. Type I DCS is typically termed "pain only bends" and is associated with skin, joint or muscle pain. While mostly uncomfortable it is not fatal. Type II DCS can become life threatening and unfortunately sometimes both types may exist simultaneously.

While some texts have moved away from classifying various DCS categories, the US Navy continues with the nomenclature, so we will follow suit. There is wise advise that if you have any "type" of DCS, the other types may be on the way. Or, put another way, Type I DCS is simply the precursor to Type II!

Experience in the field indicates that once again, as with the normal recreational depths, many times a diver will have a DCS hit even though all the dive parameters were correct. With mixed gas diving, the dive team should have a good understanding of DCS symptoms as well as appropriate first aid available at the scene.

Type I DCS

Type I DCS includes symptoms of skin itches or rash, joint pain or pain in the lymph nodes. The pain usually begins slowly and may be difficult to pin-point as to the exact location. Pre-existing pain such as bruises or pulled muscles may also interfere with determining the existence of this type of DCS. As most divers know, the usual location of pain is in the joints of the extremities, i.e. shoulder, elbow, wrist, hip, knee, etc. Typical of Type I DCS is the dull, aching pain usually confined to one region.

Since it is difficult to differentiate between a pulled muscle, sprain or a bruise or impact injury, the usual course of action is to treat for DCS unless the diver can adequately substantiate the actual injury. Now for the bad news, the normal action is to not provide drug therapy for the pain as it may hide or mask the site or other more significant symptoms. An important aspect of Type I DCS is that the pain is localized without radiating into other areas of the body.

Another manifestation of Type I DCS is the skin symptoms. This shows as an itching or rash and should not be confused with "bugs" that may inhabit the diver's exposure suit. Normally the itching does not require recompression, however if the event continues so that the skin becomes patchy or mottled, this condition will require recompression. Be careful of any changes in the coloration of the skin or changes in the "feel", i.e. thickened or swollen.

Fig. 8

Divers manning a chamber at Lake Zimbabwe

Swelling of the lymph nodes and surrounding tissues can be quickly be resolved by recompression therapy and provide relief from the pain. Many times even after recompression therapy, the lymphatic system still may exhibit swelling and take considerable time to relax after the treatment is finished.

Fatigue is frequent after a dive, but if it is severe or other conditions cause concern, a consultation is absolutely necessary to ensure that the symptoms don't continue to progress.

Field administration of oxygen is indicated for any of these symptoms and may actually result in some relief. Even if all symptoms go away with oxygen breathing, the diver must still seek proper medical attention.

Type II DCS

Type II DCS symptoms are serious and broadly grouped into two categories, respiratory and neurological. A significant problem with Type II DCS is that the condition may not be immediately evident, with the diver being weak and assuming that it is due to over work or exertion. Type II DCS may also have similar symptoms to Arterial Gas Embolism (AGE) but the initial course of treatment is identical for both maladies.

Respiratory Symptoms

Sometimes described as the "chokes", the respiratory involvement of Type II DCS is caused by the congestion of bubbles in lung circulation. It may be noted as chest pain that gets worse when breathing deep. Also noted is an increased breathing rate. If this condition continues it may ultimately result in loss of consciousness and death.

Neurological Symptoms

Decompression sickness events that are neurological often involve the peripheral nervous system instead of the central nervous system. The central nervous system consists of the brain, the spinal cord and the optic nerve and eye. The peripheral nervous system is all of the other nerve tissues throughout the body including the cranial nerves.

Numbness and tingling, muscle weakness and reduction in motor skills are all signs of the nervous system being involved in DCS. Vertigo or ear ringing indicates involvement as well as amnesia and personality changes. Bubble insult to the spinal cord may result in a wide variety of problems such as urinary incontinence. Since some of these signs start out subtle and gradually progress the diver needs to be especially alert when performing decompression dives to the post-dive time periods.

The appendix includes a sample field neurological test procedure. Mixed gas divers should be familiar with this form. Keep a copy and be aware of any developing problems. Denial of neurological symptoms may lead to serious health problems or even death. Once again, no matter how big and tough, a diver cannot "shrug off" a neurological hit.

As with Type I DCS, if any symptoms are noted, field oxygen should be administered. With Type II choke, for example, the patient may not have enough pulmonary effort to effectively use a demand valve regulator, so the mixed gas diver's first air supplies must also include a mask with reservoir and liter-flow regulator. There have been cases of sudden onset of breathing problems following a mixed gas dive and quick recognition and prompt oxygen administration may mean the difference between life or death.

Type III DCS

While not clearly identified by the US Navy as Type III, some authors have used it to define "vestibular DCS" or "ear bends". Vestibular DCS can be extremely debilitating and to make matters worse, rarely responds to recompression therapy. Whenever the middle and inner ear are involved in decompression sickness, the diver almost always experiences serious vertigo. Several who have experienced this malady have described the vertigo as "rotational" rather than spinning around. This means that as you look forward, items in view turn upside down and rotate, which is extremely nauseating and forces the diver to keep their eyes closed. A diver that is experiencing vertigo induced nausea (also known as "puking your guts up") needs proper medical treatment and appropriate drug therapy to be as comfortable as possible. Field oxygen should be administered when it can be tolerated by the nauseated diver. In any event, it may take 24 to 72 hours to completely resolve.

Type IV DCS

Again, while not an official US Navy term, Type IV has been used to describe dysbaric osteonecrosis, a disease that results in bone mass loss as well as deterioration of the structure. This affects the long bones such as the leg and arm, but also shows up in joints. While the incidence is not clear with the exposures normally associated with recreational trimix diving, some divers are accumulating significant exposures and perhaps should consider some of the monitoring techniques that are associated with deep commercial diving. These include routine medical examinations as well as base line radiographs (x-rays) to detect early formation of any areas of bone necrotic involvement. This is not an acute problem and would not be detectable in the field.

Chapter 4 Review Questions

1. What is the primary advantage of 80% O_2 decompression gas over the use of 100% O_2?

2. What is the difference between Type I and Type II DCS?

3. What are some advantages of a full face mask during deco?

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Buying all the "right" equipment is not the only step to being a safe and competent mixed gas diver, it is just the start. Without diving skills being mastered, even the best equipment cannot save an incompetent diver.

Chapter 5. Equipment Requirements

Mixed gas divers should recognize that the diving equipment requirements are far more complex than the normal open water diver. While the PSA Technical Diver has been introduced to additional equipment requirements through the various development courses up to Extended Range, there are still more when switching to advanced mixed gas diving.

Fig. 9 Hanging off the bow at 60 metres! Good kit placement is a significant issue.

CYLINDERS

Cylinders chosen for dives should contain sufficient gas for the chosen dive. This may require the use of "doubles" or in some cases a high capacity single cylinder may be more appropriate. In either case, the system must include a dual valve outlet allowing for redundant first stages. If doubles are selected, the cylinders may be connected via a manifold. The manifold should incorporate an isolation valve in order to eliminate the possibility of total gas loss due to a first stage failure, blown O-ring or even a ruptured burst disc. The down side of using a single cylinder is that if the burst disc were to fail, a total gas loss would result. Reserve rules need to be reviewed and contingency plans set out. The primary bottom mix cylinders are typically back mounted, usually with some form of "technical" buoyancy compensator, commonly known as "wings". The bottom mix cylinders are frequently connected together with a manifold preferably equipped with an isolation valve or shutoff. This way if there is a failure of a regulator the diver reaches back and turns off the offending post, however with an o-ring failure or manifold dent/rupture the isolation valve serves to prevent total loss of gas. Cylinders need to be properly marked and regulators properly identified to prevent any mix-up. Remember, the bottom mix may in fact be hypoxic at deco depths and shallower, while travel mixes and deco gas can produce rapid oxygen toxicity if used at depth. Gas MODs need to be clearly visible to the diver at the neck of the cylinder so they may verify the mix easily. It is also common for the MOD to be in large numerals on the side of the cylinder so that there is no confusion of the contents. While it may be admirable to think that the buddy would actually assist in identifying gases, the reality is that they rarely do, nor should any competent mixed gas diver expect them to!

By far the most common cylinders for mixed gas diving are those made of steel. These cylinders cut down on the necessity of wearing a weight belt, may have huge volume capacities (depending on your weight lifting capabilities!) and the low pressure versions are able to have their full capacity with most fill station operations. Aluminum cylinders, particularly when used in a doubles configuration, may become excessively buoyant causing difficulties at decompression. Using a "V-weight" adds the necessary extra ballast while keeping the system streamlined.

One item of consideration is the mix of primary cylinders and decompression cylinders, using aluminum deco cylinders when using steel primary cylinders. If a diver uses steel primary cylinders and steel decompression cylinders, they need to know exactly the weight load and insure they have adequate lift capacity to surface! It is embarrassingly dangerous to have to pull out a lift bag or SMB to raise the weight of your dive system to the surface! Even more critical, is that there have been fatalities associated with mixed gas diving and inadequate lift capacity.

VALVES

D.I.N. valves for technical diving are the norm since the O-ring is captured and the system tends to be more rugged. This additional ruggedness should not exempt the diver from the care required in an overhead environment or when using a diver propulsion vehicle (DPV or scooter). No valve is designed to withstand sudden impact. The standard American A-yoke, also known as a CGA 850 valve, simply does not provide the degree of safety required by the technical diver. Think of the times an O-ring has suddenly started leaking, a few seconds to many minutes after attaching the regulator to the cylinder. While the DIN valve is not necessarily the "magic genie" to fix all possibilities, it is more robust and affords a greater degree of reliability in the system.

CYLINDER MOUNTING

Travel cylinders and decompression cylinders represent unique challenges to mounting and carrying during the dive. Many technical divers place a pair of snap-links on the cylinder, one at the top and one at the bottom. The bottom snap is then attached to a D-ring on the back mounted cylinder(s). The top is either used with a neck harness, chest D-ring or D-ring mounted on a shoulder strap. The snap-links are attached to the travel/deco cylinder(s) with a long screw clamp, with the clamp sometimes being covered with a nylon sleeve to protect the diver from sharp edges and to prevent entanglement. The travel/deco cylinder's regulator and pressure gauge are typically held close by either a bungee or wide rubber band that may be cut from a large inner tube. Some manufacturers provide an optional short high pressure hose to make it easier to manage. Long hoses tend to be troublesome and the added stress isn't worth the bother.

BUOYANCY COMPENSATORS

Fortunately the technical diver now has a much wider selection of Buoyancy Compensator and harness options than ever before. Ranging from modern versions of the backplate and wings combination to specially integrated softpack style systems, the diver can select the one that fits the best and satisfies all the needs of accessory attachment to compact packing for traveling. A major item of consideration is the lift capacity required for the cylinder configuration of the dive. Redundancy in buoyancy compensators is accomplished either by dual sets of wings or even dual bladder systems now commercially available. Some technical divers using dry suits consider the dry suit to be the back-up in the event of a failure of the BC bladder. The back mounted "wings" seem to be the favored style, but again the type of diving and amount of equipment carried will greatly influence the B.C. selection. In any case the copious inclusion of D-rings gives the system much more utility. Be sure any D-ring used for the harness has adequate strength as the technical systems may frequently exceed 50 to 70 kg (100 to 150 pounds) out of the water.

DRY SUIT INFLATION

A dry suit should not be inflated with helium mixtures due to the poor insulating properties. For the Tri-mix diver this means that a cylinder must be made available for suit inflation. While this may be one of the travel mix or deco cylinders, many divers opt for a separate suit inflation system. This frequently includes the use of a gas such as argon as it exhibits superior insulating properties. Also if using a dry suit, practice prior to any deep dive with all equipment to become aware of the unique buoyancy characteristics.

Under no circumstances should a regulator with a breathing mouthpiece be attached to an argon cylinder. There have been situations where a diver had a problem with the regulator on the argon system and at the last moment pulled out on of their backup regulators. Remember that the second stage must be removed, not just clipped off in order to prevent a potentially fatal problem.

Any regulator used with argon or a separate inflation gas should have an over-pressure valve installed on the first stage. This valve will release any excess intermediate pressure in the event of a first stage failure or "creep". The over pressure valve prevents the possibility of a hose rupture at the most inopportune moment.

REGULATORS

In your PSA Extended Range course, the importance of high quality regulators was emphasized. Regulators are even more important now that the gas diver has entered the world of the virtual overhead. This compounded with the increased depth, demands a high performance regulator capable of being reliable as well as delivering the desired gas with the ease of breathing that prevents CO_2 loading. Many divers have their favorite manufacturer of equipment, but at the same time, what works well at sport diving depths may not always work well at technical depths. Seek out qualified advice if there are any doubts as to the suitability of a particular regulator for technical diving.

Every cylinder needs a pressure gauge (contents gauge). With doubles, one gauge is sufficient as shown in the earlier courses. A diver needs to be aware of the gauge indications that may show an isolator turned off, etc. By now this should be second nature. Back-up regulators and safe second stages need to be as reliable and easy to breathe as the primary regulator.

DEPTH AND TIME MONITORING

The technical diver needs to have a minimum of two independent depth gauge monitors as well as two independent time monitors. This may take the form of two computers or one computer and a watch plus a depth gauge. In any event, a careful study of the computer's capability is necessary. Does it accurately measure depth for the full range of the dive plan? How does it enter "gauge mode"? Can you manually switch the dive computer into "gauge mode" so that it does not "lock out" or violate? Does it simply shut down or does it continue to operate as a depth gauge and bottom timer? There are a wide range of answers to these questions, each especially important to the technical diver. Some noted deep divers have found that the most faithful timers used were the cheap "$29.95" variety sports watch which continued to perform even when more expensive units had failed.

Depending on the manufacturer, computers may be calibrated in meters/feet of fresh water (m/f fw) or in meters/feet of sea water (m/f sw); some even automatically sense the conductivity of the water and determine if it is fresh or "salty". Depth gauges need to be calibrated and checked against known good units frequently during the dive season. Many analog depth gauges are not able to be used at technical depths and should not be relied on unless they have adequate resolution, have been calibrated and shown to be accurate and reliable at the range of expected depths.

As mixed gas diving has developed, several dive computers designed to accommodate the various trimix, heliox and nitrox mixes that may be used during the entire profile. These computers allow pre-programming of the mixes that are to be used for the dive, some allowing in excess of 10 different mixes. A few have the capability of changing the values of the mix "on the fly" (during the dive) in the event additional gases are needed or used during decompression for example.

Even though the manufacturers strive to make these mixed gas computers as simple to use as possible, they are indeed complex. They also require a high degree of interaction from the diver during the dive, i.e. notifying the computer that a gas has been changed at the time it actually was changed, not several minutes later!

The earlier comment about actually adhering to a schedule may become very obvious while using a mixed gas dive computer. Some divers have complained that the "computer is more restrictive", forcing more decompression than the software schedule they had printed out, allegedly from the same algorithm! In virtually all cases there was a simple explanation... the diver did NOT follow the dive plan! Descent rates, depth control and ascent rates are all part of the profile and many divers are careless about adhering to these parameters. It is not the computer's fault if a diver ascends more rapidly than the allowed value in the program.

In any case, if you have a new super duper mixed gas computer, driving to the dive site or sitting on the boat at the dive site is NOT the time to begin reading the owners manual for a dive computer or timing system!

REELS AND LIFT BAGS

Other dive equipment will include line reels and surface marker buoys (SMB) or lift bags. While cave divers will probably scream bloody murder over this, the fact remains that there are some salt-water blue holes with cave systems attached. Cave divers have been making everyone else duplicate their systems, it's only fitting that the Cave Diver get a new toy. The purpose of the lift bag is to make in water decompression practicable when an up line is not available. Sufficient line must be on the reel to reach from the depth of at least the first deco stop. Wreck divers typically consider the minimum to be from the wreck itself. Since many times this is a regional issue, consult with your PSA instructor to verify the requirements. The lift bag should be of a 20 to 25 kg (44 to 55 pound) minimum lift capacity and can be neatly stored under a bungee on a primary cylinder.

The line reel should be operable with a single hand and include a locking mechanism. There are several fine reels on the commercial market now that are entirely suitable for in-water decompression. Avoid placing too much line on the reel as it tends to swell and may jam the reel. Practice with the reel and lift bag prior to a deep water deployment so you don't get tangled in your own line. Another note, when you have a mandatory deco obligation, then attempt to deploy the reel, if it jams and starts to drag you up - LET GO! Simply continue your deco open-water style paying careful attention to depth control. If the diver is planning to enter the overhead environment, i.e. a cave or wreck, then an additional reel should be planned for as a navigation aid in accordance with the standards of each type of diving. This reel should not be counted on for the deco reel, as it may be necessary to leave the reel in an emergency or an entanglement may reduce the line capacity.

Reels are frequently attached with snap-links to D-rings on the harness. A simple technique to avoid fumbling for them would be to place the reels on the right hand side of the diver.

OTHER EQUIPMENT

Another aid is some form of a decompression line, such as a Jon-line. This 2 to 3 meter (6 to 10 foot) line is attached to an up line or anchor line and the diver holds on making deco easier. If the seas are rough, the line allows the diver to "ride the rollers" in more comfort than holding onto an anchor line. It is possible for a diver holding onto an anchor line to experience large and rapid changes in depth which may be dangerous as well as uncomfortable. There are a number of clips that can be used to attach a line or even a simple prusik knot serves the same purpose.

Submersible tables are a must as well as contingency tables in the event the dive does not go as planned. A dive slate and pencil (with backup) is necessary to monitor actual times and keep a history of the dive including surface information or even having to communicate with the surface. The slate should be small and easily stowed in the BC pocket or pouch. Some divers mount their compass on the slate, particularly those using air integrated computers which don't provide a "console" for mounting purposes. Other compass mounting techniques are on the inflator hose, etc. Be especially aware of the position of the compass in use when using certain steel cylinders. Some have noted significant aberrations in heading information with the use of steel cylinders and close proximity compasses.

Adequate thermal protection for decompression is necessary, but in warm waters caution is advised against overheating as well as getting too chilled. Don't forget a hood even in cool water, as the head is a significant source of heat loss and above all be aware of core heat loss if the water is very cold. Consider argon for an inflation system if diving in cold waters for the added insulation.

Even though the technical diver is not trying to overload with extras, another item that is frequently carried is a spare mask. Cave divers may incorporate a spare mask in their kit due to the critical aspect of that style of diving. There are even manufacturers that make "mask pouches" to attach to the BC system or are incorporated in various dry/wet suit pockets. These back up masks need to be checked frequently, since storing in a pocket or pouch may effectively ruin their ability to seal.

Two line cutting devices are required. At least one should be a very small, exceptionally sharp device, like the Z-knife, that can do quick work on monofilament fishing line and the like, particularly on wrecks that are popular with fishermen. Avoid the Samurai Sword type dive knife, attached to your leg like a splint. .

If lights are required for the dive, again some form of redundancy is required. Note that technical depths sometimes impose limits on these lights not previously noted in shallower applications. More and more mixed gas divers are adopting many of the rigging styles more common with cave divers. Mounting equipment on D-rings attached to cylinders has become less in favor to the attachment points on the harness. Mounting backup lights on the "left" side continues an order so that the diver doesn't have to try to remember which side they are on when in colder waters where the diver may have to wear heavier gloves. Light - Left - get it? Primary lights have undergone a tremendous evolution from the early unreliable lights to well developed HID systems that work well at any depth the mixed gas diver may encounter.

Thought might also be given to some form of gaining the surface crew's attention. Open water decompression may require the use of a surface marker buoy (SMB). Most divers have gotten away from open bottom lift bags as the manufacturers have expanded their line of offering specific to technical divers. In addition to a SMB for decompression, a backup, normally of a different color is also carried. Some divers use the SMB bouncing while others use a "signal sausage". In any case the incorporation of a safety diver in the plan is a very important part in decompression diving. If you are at the surface and drifting, the signal sausage combined with an audible alert device will go a long way towards helping the boat crew find you in choppy waters. Off-shore mixed gas divers are now carrying portable global positioning systems (GPS) that are integrated into an emergency positioning beacon (EPIRB) that would allow emergency rescue services to locate them even in the worst seas or fog.

Still other techniques of local diving include hot (warm) water suit flooding for those that use a wetsuit. This can greatly aid in comfort during the decompression stop.

Again, equipment and configuration tends to be somewhat regional. Your PSA instructor will have some very good ideas and suggestions about how to best setup and assist you with your equipment.

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Chapter 5 Review Questions

1. What is the difference between **hypoxic** and **hyperoxic**?
2. What is an advantage of a DIN valve?
3. Should a manifold have an isolator valve?
4. Should all members of a dive team each have a SMB? Why?
5. Can the bottom mix be used for dry suit inflation?

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Chapter 6. Dive Planning and Execution

Team Selection is one of the first steps in dive planning. Here again, a level of maturity is required. If you have a dive buddy that concerns you with his haphazard techniques then this is not the buddy for deep diving! Be very careful. For years cave divers have been very particular about who they dive with, for good reason too. Technical divers need to be honest about their abilities, comfort zone and buddy choice.

Now is the time to consider an aspect of emergency planning, **what are you going to do if your buddy runs out of air/gas?** You may plan on diving solo or that it's every diver for himself. The seriousness of this question is something every technical diver **must** answer. If the answer is to assist the out of air partner, then a change in the amount of gas carried immediately becomes apparent. In any case - we must plan our dive accurately, to include the contingencies that we are able to forecast or predict.

Another thing to consider is do you want to dive with someone you suspect might run out of air/gas???? Did you see them pick up an old o-ring from the deck and put it on their valve? Did you see them "playing with" a second stage to get it to stop leaking? Did you see them verify valves open? Did you see them plan their gas consumption?

Support operations include the boat (if used), surface crew, gas handlers, etc. It's simply not fair to show up on the local dive boat with your assortment of dive equipment and then proceed to a dive that requires an hour deco while all the open water divers have been admonished to be back in 35 minutes. The Captain of the vessel is one of the most important members of the dive team, treat him/her accordingly. The support operation may also include a surface gas supply with drop regulators. Your instructor will explain the local procedures and before diving in a new location, acquaint yourself with the local practices.

Gas selection and quantity requirements can turn out to be significant! By now the diver should know the surface consumption rate at rest and at work.

The first consideration is the bottom mix. What PO_2 will be used? What PN_2 (equivalent narcotic depth, END)? What is the depth? How long is the bottom time expected? A gas planning worksheet can be useful, but only if it is used. The fact remains, virtually all divers today use some form of computer planning software.

Software planners should be used as aids and not take the place of common sense. A diver should know what bottom mix should be used simply based on the planned depth. The software may compute a more precise value, but the diver should know that if they are planning a 90 m (295 fsw) excursion, home of 10 bar, then absolutely no more than 16 percent oxygen (preferably 14 percent) can be in the mix! If you are a little slow as to the reason, go back and review the physics and physiology sections again and again, until it is crystal clear.

It is the diver that is responsible for determining the conditions of the dive. The software is a tool to help. On the plus side, software can frequently prevent "calculator errors" and math mistakes.

Assume that a dive will be to 76 m (250 fsw) for 20 minute time on bottom. Trimix 16/40/44 is the chosen gas and software tables constructed. Even though the tables are now available to the diver, a quick check of the narcotic penalty and O_2 exposure is required as follows:

$$\textbf{Pt (bar)} = \frac{76}{10} + 1 = 8.6$$

END = **approximately 41 m (135 fsw)**
PO_2 = **1.38 bar**

Both within accepted limits

Standard practices for gas at depth include a variety of rules, depending on the mission. Open water diving, without overhead environments involved, should as a minimum use the 1/2 plus 10 bar (200 psi) rule. Round down the actual cylinder pressures to the nearest value easily divisible by 2, and subtract an additional 10 bar (200 psi). In the overhead environment areas, the 1/3 rule is required, again rounding down to the nearest number easily divisible by 3. This 1/3 is then subtracted from the beginning cylinder pressure which may give a few hundred psi extra margin. Cave divers know that this rule is the absolute minimum, and probably not adequate for an exit if the air failure occurs at maximum penetration. At that point there is not enough gas for two divers to get out if there is an elevated breathing rate. Gas requirements need to include:

Travel mix and travel mix switch depth. Some divers prefer EAN36 to 30 meters (100 fsw) and then a switch to bottom mix. Still others will use air to depths of up to 60+ meters (200+ fsw) before making the switch.

Bottom mix needs to include the above contingency plans as well as equipment configuration. If separate cylinders are used the gas remaining in each one needs to be adequate to ascend to the first stop.

Decompression gases may include air, EAN or 100% O_2 and combinations of all. Deco gas requirements may exceed the bottom mix requirements by a large amount.

Assume that the diver has a surface air consumption rate of 18 liters per minute. If the dive is to be conducted at a depth of 76 meters (250 fsw), then the total pressure will be about 8.6 bar. For a 20 minute dive, with 6 minutes of descent and ascent time on trimix, the surface gas requirement would be:

$$18 l/min \times 8.6 bar = 154.8 l/min$$

Therefore, the gas requirement at 76 meters (250 fsw) would be:

$$154.8 l/min \times (20 + 6) min = 4024.8 liters$$

For reserve purposes consider that 4025 liters represents 2/3 of the gas, so the total bottom mix would be:

$$\frac{4025}{2} = 2012.5 \text{ (represents 1/3 of bottom mix)}$$

$$2012.5 \times 3 = 6037.5 \text{ liters (total bottom mix)}$$

Two gases are used, one for travel and initial decompression, the second for final decompression. The travel mix is EAN36 with the final deco gas being EAN80. Using the program, the decompression obligation requires approximately 2200 liters of EAN36 and 2500 liters of EAN80.

The EAN36 can be handled with a single 10 liter and the EAN80 with a 11.5 or 12 liter. cylinder. Since the deco gases are computed at the deepest depth, there is a built in safety factor. How much is required depends on each individual diver, who should evaluate the conditions of the dive, probability of difficulty, etc. to arrive at the number that eases the stress of the diver.

Divers should realize that in the event they are unable to locate or return to the anchor/upline that the decompression obligation will have to be effected by the lift bag technique. This requires each diver to carry the required deco gases during the entire dive, something not to be taken lightly. In this example, a minimum of two cylinders in addition to the bottom mix are required. By utilizing the two cylinders, the diver is only capable of supporting one decompression. In the event a buddy experiences a failure of a deco bottle, additional emergency procedures will have to be taken.

As a point of reference, before the British or U.S. Navy engages in decompression diving, normally a Diving Medical Officer, a recompression chamber as well as significant reserves of other gas are available. The Diving Supervisor, Diving Officer and the DMO all are there to support the diver in the event of a problem. It's not likely that the average technical diver will have these resources readily at hand, so realistic dive planning is necessary to prevent possible problems.

Short of major problems on the bottom, which can only be handled by a calm mind, everything must be handled without panic. Easier said than done at times, but always remember Stop, Breathe, Relax, Breathe, Solve, Breathe (some say to Stop, Breathe, Think, Act - someone will probably think that these orders are sacred - just remember, being in control and acting responsibly will help ensure a satisfactory outcome!).

Omitted decompression may happen due to a shortage of gas or equipment failure. In the event it is due to inclement weather, then the following may not be practical. For years, the published omitted deco procedure is as follows:

Return and complete all stops greater than 12 m (40 fsw), then ascend to:

12 m (40 fsw) for	¼ the 3 m (10 fsw) stop time
9 m (30 fsw)	1/3 the 3 m (10 fsw) time
6 m (20 fsw)	½ the 3 m (10 fsw) time
3 m (10 fsw)	1 ½ times the 3 m (10 fsw) time

Unfortunately there is only one problem with this technique - it was only designed for AIR! The trimix diver may or may not be safe in using this method. The latest versions of the USN Diving Manual have modified the procedure also, essentially multiplying all stop depths by 1.5X, but there are additional considerations. Make sure to consult the latest reference before actually using this technique and remember, it is far better to "Plan the Dive and Dive the Plan" than it is to have to make a mad dash to a recompression chamber!

This technique can be enhanced by using EAN mixtures which do not exceed PO_2s of 1.6 bar at the stops. In any case a safety diver needs to monitor the condition of a diver that misses a stop. Unusual occurrences can best be handled by a clear mind and cool head. Plan for the best and expect something to jump out and mess it up. Don't carry too much equipment, but be sure to have enough.

As previously discussed, the incorporation of a safety or support diver in the dive team greatly enhances the uneventful outcome of the dive. If someone needs additional cylinders for decompression, is experiencing weighting problems at deco or just to off-load some of the bottom equipment, the support diver is a welcome sight.

Oxygen toxicity is a problem that can only be resolved by reducing the PO_2. Immediately get off the oxygen rich mixture. Be sure breathing is normal, no skip breathing, etc. If a full face mask is available, use it. Watch the stricken diver very carefully. A support diver is invaluable in these situations.

Decompression sickness as previously discussed may result due to improper application of the dive profile, loss of gas resulting in having to surface for more or even the weather may deteriorate to the point of forcing the diver up before completing the schedule. A prior plan, that includes knowing the location of the nearest recompression facility and how to call for assistance, will first of all emphasize the seriousness of the nature of technical diving and also ensure that if a problem does occur that it will go as smooth as possible. Review those procedures with the boat Captain and crew beforehand so that there are no misunderstandings and that each person clearly understands what is expected.

The U.S. Navy analyzed several thousand air dives, although not as large a database as some others that have been accomplished, finding that DCS symptom onset occurred as follows:

42% occurred within one hour
60% occurred within three hours
83% occurred within eight hours
98% occurred within 24 hours

Other problems that need to be considered by the diver are the same as may occur at the normal sport diving depths, however take on new dimension at technical depths. These include but are not limited to lost (disoriented) diver, lost buddy, seasickness at depth, entanglement and physical injury.

Planned Dive Comparison

A dive is to be conducted to 79 meters (260 fsw) for a bottom time of 15 minutes. Assume the diver's gas consumption rate is 17 liters (.6 ft^3) /minute. An available 16/45/39 table will be used for planning.

The tables are designed for a 20 meters (66 fsw)/minute descent rate and an ascent rate of the same to the first deco stop. Between stops the ascent rate changes to 10 meters (33 fsw)/minute. Final ascent should take at least 2 minutes.

Descent may be on bottom mix or with EAN36 to 30 meters (100 fsw).

STEPS in metric

Total Pressure at Depth $= \frac{79\text{ m}}{10} + 1$
$= 8.9$ bar

Max Bottom $PO_2 = .16\ fO_2 \times 8.9$ bar
$= 1.42$ bar

Max Bottom $PN_2 = .39\ fN_2 \times 8.9$ bar
$= 3.47$ bar

END $= \frac{.39}{.79} \times (79 + 10) - 10$
$= 32$ meters

Descent Gas	=	EAN36
Bottom Mix	=	Trimix 16/45/39
First Deco Gas	=	EAN36
Second Deco Gas	=	EAN60
liters required	=	time x bar x 17 l/min

liters required is computed at the maximum depth for the time period. Wasted gas is assumed for set-up, entering water, a little initial free flow, etc.

Event	Depth	Time/ Deco Rqd	bar	liters Required	Gas
Wasted Gas	Surface		1	140	EAN36
Start	Surface	5:00	1	85	EAN36
Descent	33m	2:00	4.3	146.2	EAN36
Gas Switch Trimix	33 m				
Descent	79 m	2:30	8.9	378.25	Trimix
Time on Bottom	79 m	15:00	8.9	2269.5	Trimix
Ascent to 110 FSW	79 m	2:30	8.9	378.25	Trimix
Gas Switch EAN36	33 m				
Ascent to 30 m	33 m	1:00	4.3	73.1	EAN36
Deco Stop	30 m	1:00	4.0	68	EAN36
Deco Stop	27 m	1:00	3.7	62.9	EAN36
Deco Stop	24 m	2:00	3.4	115.6	EAN36
Deco Stop	21 m	2:00	3.1	105.4	EAN36
Deco Stop	18 m	2:00	2.8	95.2	EAN36
Deco Stop	15 m	2:00	2.5	85	EAN36
Gas Switch/Deco	12 m	5:00	2.2	187	EAN60
Deco Stop	9 m	5:00	1.9	161.5	EAN60

Deco Stop	6 m	41:00	1.6	1115.2	EAN60
Ascent	Surface	2:00	1.6	54.4	EAN60

EAN36 GAS REQUIRED	=	976.4 liters
EAN60 GAS REQUIRED	=	1518.1 liters
TRIMIX REQUIRED	=	3026 liters

NO RESERVES ARE CONSIDERED IN THE ABOVE FIGURES

Reserves can be figured at approximately 50% for the descent, ascent and decompression gases as follows:

Volume (to be) Used x 1.5

EAN36 = 976.4 x 1.5
= 1464.6 liters

A 6.5 liter cylinder would be adequate

EAN60 = 1518.1 x 1.5
= 2277.15 liters

A 10 liter cylinder would be adequate

Reserves for bottom mix in this example will be figured on the "thirds rule" where 2/3 of the gas will be consumed upon reaching the gas switch depth of 33 m.

Trimix Required on Bottom	=	3026 liters
Trimix Required with Reserves	=	Bottom Gas/.66
	=	3026/.66
	=	4584.85 liters

Twin 10 liters would be adequate

Total EAN36 Required	=	**1464.6 liters**
Total EAN60 Required	=	**2275.15 liters**
Total Trimix Required	=	**4584.85 liters**

Diver configuration will be 4 total cylinders:

A single 7 for the EAN36
A single 10 for the EAN60
Double 10's for the Trimix

The last item of gas planning and management is the CNS toxicity determination. OTUs will also be calculated to demonstrate that CNS tracking is the primary determining factor. The %CNS and the OTU values are from the chart in the Appendix and based on the partial pressure of oxygen, PO_2, at each depth along with the time. Again, the maximum PO_2 and total time will be used for periods of descent and ascent.

%CNS = Chart PO_2 Value x time (minutes)
OTU = Chart PO_2 Value x time (minutes)
PO_2 = BAR x fO_2, rounded up to the nearest chart value

Both the CNS% and the OTU are rounded up to the next decimal, even though the actual validity of the decimal is lost during the dive!

Event	Depth	BAR	PO_2	Time	CNS%	OTUs
Start Gas = EAN36						
Start	Surface	1	.36	5:00	n/a	n/a
(Since the PO_2 is less than .5, the value is not tracked)						
Descent	33 m	4.3	1.55	2:00	2 x 1.12 2.3 %	2 x 1.85 3.7 OTU
Gas Switch = Trimix 16/45/39						
Descent	79 m	8.9	1.45	2:30	2.5 x 0.73 1.9 %	2.5 x 1.7 4.3 OTU
(time converted to decimal units)						
Bottom	79 m	8.9	1.45	15:00	15 x 0.73 11 %	15 x 1.7 25.5 OTU
Ascent	79 m	8.9	1.45	2:30	Same as above Descent 1.9 %	4.3 OTU

Gas Switch = EAN36

Ascent	33 m	4.3	1.55	1:00	1 x 1.12 1.2 %	1 x 1.85 1.9 OTU
Deco	30 m	4.0	1.45	1:00	1 x 0.73 0.8 %	1 x 1.7 1.7 OTU
Deco	27 m	3.7	1.35	1:00	1 x 0.61 0.7 %	1 x 1.55 1.6 OTU
Deco	24 m	3.4	1.25	2:00	2 x 0.51 1.1 %	2 x 1.4 2.8 OTU
Deco	21 m	3.1	1.15	2:00	2 x 0.44 0.9 %	2 x 1.24 2.5 OTU
Deco	18 m	2.8	1.00	2:00	2 x 0.33 0.7 %	2 x 1.00 2 OTU
Deco	15 m	2.5	0.9	2:00	2 x 0.28 0.6 %	2 x 0.83 1.7 OTU

Gas Switch = EAN60

Deco	12 m	2.2	1.35	5:00	5 x 0.61 3.1 %	5 x 1.55 7.8 OTU
Deco	9 m	1.9	1.15	5:00	5 x 0.44 2.2 %	5 x 1.24 6.2 OTU
Deco	6 m	1.6	1.00	41:00	41 x 0.33 13.6 % 41 OTU	41 x 1.00
Ascent	Surface	1.6	1.00 0.7 %	2:00	2 x 0.33 2 OTU	2 x 1.00

Totaling all the CNS% values and the OTUs gives a dive total of:

CNS%	=	**42.7% (round to 43%)**
OTUs	=	**109**

This shows that even with a relatively deep dive with a fairly long decompression results in only 109 OTUs, a third of the allowable amount, while the CNS% is over 40%. In practice, a diver should probably calculate a few dives with the OTU tracking to verify (convince themselves) that the CNS% is really the driving quantity to verify.

STEPS (in imperial)

Total Pressure at Depth $= \frac{260 \text{ fsw}}{33} + 1$

$= 8.9$ ata

Max Bottom PO_2 = .16 fO_2 x 8.9 ata

$=$ 1.42 ata

Max Bottom PN_2 = .39 fN_2 x 8.9 ata

$=$ 3.47 ata

END $= \frac{.39}{.79} \times (260 + 33) - 33$

$=$ 112 fsw

Descent Gas = EAN36

Bottom Mix = Trimix 16/45/39

First Deco Gas = EAN36

Second Deco Gas = EAN60

ft^3 required = time x ata x .6 ft^3

- ft^3 required is computed at the maximum depth for the time period. Wasted gas is assumed for set-up, entering water, a little initial free flow, etc.

Event	Depth	Time/ Deco Rqd	ata	ft^3 Required	Gas
Wasted Gas	Surface		1	5.0	EAN36
Start	Surface	5:00	1	3.0	EAN36
Descent	110 fsw	2:00	4.3	5.2	EAN36
Gas Switch Trimix	110 fsw				
Descent	260 fsw	2:30	8.9	13.4	Trimix
Time on Bottom	260 fsw	15:00	8.9	80.1	Trimix
Ascent to 110 FSW	260 fsw	2:30	8.9	13.4	Trimix
Gas Switch EAN36	110 fsw				
Ascent to 100 fsw	110 fsw	1:00	4.3	2.6	EAN36
Deco Stop	100 fsw	1:00	4.0	2.4	EAN36
Deco Stop	90 fsw	1:00	3.7	2.2	EAN36
Deco Stop	80 fsw	2:00	3.4	4.1	EAN36
Deco Stop	70 fsw	2:00	3.1	3.7	EAN36
Deco Stop	60 fsw	2:00	2.8	3.4	EAN36
Deco Stop	50 fsw	2:00	2.5	3.0	EAN36
Gas Switch/Deco	40 fsw	5:00	2.2	6.6	EAN60
Deco Stop	30 fsw	5:00	1.9	5.7	EAN60
Deco Stop	20 fsw	41:00	1.6	39.4	EAN60
Ascent	Surface	2:00	1.6	1.9	EAN60

EAN36 GAS REQUIRED = 34.6 ft^3

EAN60 GAS REQUIRED = 53.6 ft^3

TRIMIX REQUIRED = 107 ft^3

NO RESERVES ARE CONSIDERED IN THE ABOVE FIGURES

Reserves can be figured at approximately 50% for the descent, ascent and decompression gases as follows:

Volume (to be) Used x 1.5

EAN36	=	$34.6\ ft^3 \times 1.5$
	=	$51.9\ ft^3$

A 50 ft^3 cylinder would be adequate

EAN60	=	$53.6\ ft^3 \times 1.5$
	=	$80.4\ ft^3$

A 80 ft^3 cylinder would be adequate

Reserves for bottom mix in this example will be figured on the "thirds rule" where 2/3 of the gas will be consumed upon reaching the gas switch depth of 110 fsw.

Trimix Required on Bottom	=	107 ft^3
Trimix Required with Reserves	=	Bottom Gas/.66
	=	107 ft^3/.66
	=	160.5 ft^3

Total EAN36 Required	**=**	**52 ft^3**
Total EAN60 Required	**=**	**81 ft^3**
Total Trimix Required	**=**	**161 ft^3**

Diver configuration will be 4 total cylinders:

A single 50 ft^3 for the EAN36
A single 80 ft^3 for the EAN60
Double 80's for the Trimix

The last item of gas planning and management is the CNS toxicity determination. OTUs will also be calculated to demonstrate that CNS tracking is the primary determining factor. The %CNS and the OTU values are from the chart in the Appendix and based on the partial pressure of oxygen, PO_2, at each depth along with the time. Again, the maximum PO_2 and total time will be used for periods of descent and ascent.

%CNS	=	Chart PO_2 Value x time (minutes)
OTU	=	Chart PO_2 Value x time (minutes)
PO_2	=	ATA x fO_2, rounded up to the nearest chart value

Both the CNS% and the OTU are rounded up to the next decimal, even though the actual validity of the decimal is lost during the dive!

Event	Depth	ATA	PO_2	Time	CNS%	OTUs
Start	Gas = EAN36					
Start	Surface	1	.36	5:00	n/a	n/a
	(Since the PO_2 is less than .5, the value is not tracked)					
Descent	110 fsw	4.3	1.55	2:00	2 x 1.12 2.3 %	2 x 1.85 3.7 OTU
Gas Switch	= Trimix 16/45/39					
Descent	260 fsw	8.9	1.45	2:30	2.5 x 0.73 1.9 %	2.5 x 1.7 4.3 OTU
	(time converted to decimal units).					
Bottom	260 fsw	8.9	1.45	15:00	15 x 0.73 11 %	15 x 1.7 25.5 OTU
Ascent	260 fsw	8.9	1.45	2:30	Same as above Descent 1.9 %	4.3 OTU
Gas Switch	= EAN36					
Ascent	110 fsw	4.3	1.55	1:00	1 x 1.12 1.2 %	1 x 1.85 1.9 OTU
Deco	100 fsw	4.0	1.45	1:00	1 x 0.73 0.8 %	1 x 1.7 1.7 OTU
Deco	90 fsw	3.7	1.35	1:00	1 x 0.61 0.7 %	1 x 1.55 1.6 OTU
Deco	80 fsw	3.4	1.25	2:00	2 x 0.51 1.1 %	2 x 1.4 2.8 OTU
Deco	70 fsw	3.1	1.15	2:00	2 x 0.44 0.9 %	2 x 1.24 2.5 OTU
Deco	60 fsw	2.8	1.00	2:00	2 x 0.33 0.7 %	2 x 1.00 2 OTU
Deco	50 fsw	2.5	0.9	2:00	2 x 0.28 0.6 %	2 x 0.83 1.7 OTU

Gas Switch = EAN60

Deco 40 fsw 2.2 1.35 5:00 5 x 0.61 5 x 1.55
3.1 % 7.8 OTU

Deco 30 fsw 1.9 1.15 5:00 5 x 0.44 5 x 1.24
2.2 % 6.2 OTU

Deco 20 fsw 1.6 1.00 41:00 41 x 0.33 41 x 1.00
13.6 % 41 OTU

Ascent Surface 1.6 1.00 2:00 2 x 0.33 2 x 1.00
0.7 % 2 OTU

Totaling all the CNS% values and the OTUs gives a dive total of:

CNS%	=	**42.7% (round to 43%)**
OTUs	=	**109**

This shows that even with a relatively deep dive with a fairly long decompression results in only 109 OTUs, a third of the allowable amount, while the CNS% is over 40%. In practice, a diver should probably calculate a few dives with the OTU tracking to verify (convince themselves) that the CNS% is really the driving quantity to verify.

The following page has a similar worksheet for the same dive that was produced by a commercially available software program, Abyss. There are quite a few of these including Decomp, Decap, Dr.X as well as others. Some of the software programs are not updated or have short lives. While many consider copying software to be a great American pastime, the importance of keeping the most current data and research available should be obvious. If a diver decides on software for planning purposes, it should be registered with the developer. Believe it or not there are sometimes “bugs” that need to be corrected and only registered software provides the diver with the best insurance policy of getting these important updates.

The appendix has a sample worksheet for keeping track of various depth, gas requirements and times. Many divers formulate their own type of sheet after gaining experience in planning dives. Some of the software programs also provide planning sections with the ability to input gas requirements and personal data to include environmental factors.

CHAPTER 6 ~ FINAL REVIEW

Using the tables provided in the appendix, completely plan a dive with the following conditions:

Depth	=	75 msw
Time	=	20 minutes
SAC	=	15 litres/min.

INCLUDE ALL GAS MIXES AND QUANTITIES REQUIRED FOR BOTTOM, DECO AND TRAVEL GAS.

Extended Range Recreational Dive Planning Slate

DATA

Depth	4-minute (time & depth)	Direction/compass	Up Signal
Bottom time	6-minute (time & Bar)	Turn-around gas	Decompression
Level-off (1 & 2)	Object ID	1-minute BT left	Depth & Times

(depth/time/contingency)

- *Check pressure every two minutes after four minutes and until the "UP" is given
- Anyone may abort at anytime
- *Three "C's" (communicate-confess-conform)
- *Review estimated gas consumption of each diver (see back of slate):
- 1. Descent phase; 2. Bottom phase; 3. TTFS phase; 4. Deco phase
- *Gas supply and volume of each diver's cylinder(s)
- *Review turn-around gas remaining (will very with cylinder volumes)
- On the first dive, during or after deco stop, do an SCR swim at five metres for X minutes
- *Review lost buddy procedure (ascend above highest object, look 360°. If no sighting, surface and look for them
- *Review emergency use of compass from area of dive, in case of getting lost (write this on back of the PSA slate)
- Omitted or interrupted decompression procedure (1/4, 1/3, ½, 1 ½)
- Review ascent procedures (entire team maintaining eye contact)
- Review exit method (explain safest and easiest method for dive site)
- Diving accident local emergency phone number
- Directions and protocol for use of nearest hospital or recompression chamber.

*These items must be discussed before each training dive.

PSA Gas Management Worksheet

Maximum Depth ____________ Rated Cylinder Capacity ____________

Bottom Time ____________

SCR in Litres / Min ____________ Starting Cylinder Pressure ____________

Formulae

Rated Cylinder Capacity ÷ Rated Cylinder Pressure = Litres / Bar Value ____________

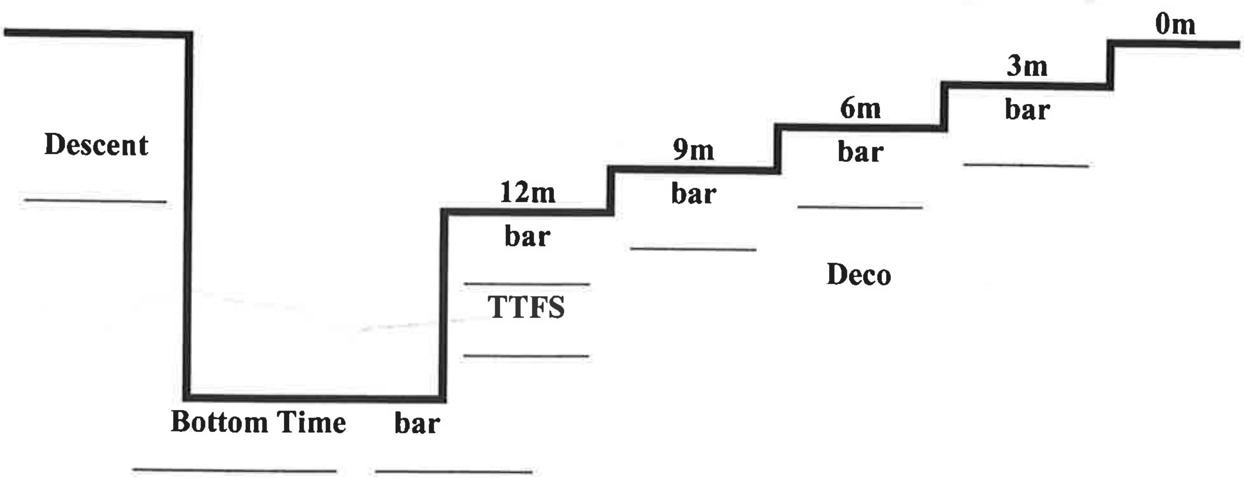
Starting Cylinder Pressure x Rated Cylinder Capacity = Starting Cylinder Volume ____________

1. (Depth + 10) ÷ 10 = bar

2. Starting Cylinder Volume (or previous Litres remaining) - Litres Used = Litres Remaining

3. Litres Used ÷ Rated Cylinder Capacity = Bar Used

1. Litres Remaining ÷ Rated Cylinder Capacity = Bar Remaining



Formula No			1		2	3	4
PHASE	**Time X**	**SCR (Litres/Min)**	**X bar =**	**Litres Used**	**Litres Remaining**	**Bar Used**	**Bar Remaining**
Descent							
Bottom							
TTFS							
Deco 1							
Deco 2							
Deco 3							
Deco 4							
Deco 5							
Deco 6							

PSA CNS Tracking Sheet

Dive Parameters

Rates

Descent		SCR	
Ascent			

Mix FO_2

Descent 1	
Descent 2	
Bottom	
Ascent 1	
Ascent 2	
Deco 1	
Deco 2	

Depth

	Metres	BAR
Max		
Switch 1		
Switch 2		
Switch 3		
Deco 1		
Deco 2		
Deco 3		
Deco 4		
Deco 5		
Deco 6		
Deco 7		

Times

Descent 1		Deco 1	
Descent 2		Deco 2	
Bottom		Deco 3	
Ascent 1		Deco 4	
Ascent 2		Deco 5	
		Deco 6	
		Deco 7	

BAR	X	FO_2	=	PPO_2	Time @	/Allowed	=	CNS%
	Descent 1							
	Descent 2							
	Bottom							
	Ascent 1							
	Ascent 2							
	Deco 1							
	Deco 2							
	Deco 3							
	Deco 4							
	Deco 5							
	Deco 6							
	Deco 7							
							This Dive	

	Pg	
	Fg	P

Residual ________

Total ________

CNS ________

Pg = Partial Pressure of a gas in a mix (exposure)
Fg = Fraction of a gas in a mix (best mix)
P = Pressure (depth) expressed in bar

To find the CNS% divide the time of exposure by the exposure time allowed
If the CNS exceeds 50%, a minimum SIT time of 45 minutes is required
If the CNS exceeds 90%, a minimum SIT time of 2 hours is required

~ Plan Your Dive & Dive Your Plan ~

Helium Fill Pressures for HeliAir

Fill (Bar) (O_2/He/N_2)	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
18/14/68	21	22.4	23.8	25.2	26.6	28	29.4	30.8	32.2	33.6	35	36.4	37.8	39.2	40.6	42
17/19/64	28.5	30.4	32.3	34.2	36.1	38	39.9	41.8	43.7	45.6	47.5	49.4	51.3	53.2	55.1	57
16/24/60	36	38.4	40.8	43.2	45.6	48	50.4	52.8	55.2	57.6	60	62.4	64.8	67.2	69.6	72
15/28/57	42	44.8	47.6	50.4	53.2	56	58.8	61.6	64.4	67.2	70	72.8	75.6	78.4	81.2	84
14/33/53	49.5	52.8	56.1	59.4	62.7	66	69.3	72.6	75.9	79.2	82.5	85.8	89.1	92.4	95.7	99
13/38/49	57	60.8	64.6	68.4	72.2	76	79.8	83.6	87.4	91.2	95	98.8	102.6	106.4	110.2	114
12/43/45	64.5	68.8	73.1	77.4	81.7	86	90.3	94.6	98.9	103.2	107.5	111.8	116.1	120.4	124.7	129
11/49/40	73.5	78.4	83.3	88.2	93.1	98	102.9	107.8	112.7	117.6	122.5	127.4	132.3	137.2	142.1	147
10/52/38	78	83.2	88.4	93.6	98.8	104	109.2	114.4	119.6	124.8	130	135.2	140.4	145.6	150.8	156
9/57/34	85.5	91.2	96.9	102.6	108.3	114	119.7	125.4	131.1	136.8	142.5	148.2	153.9	159.6	165.3	171
8/62/30	93	99.2	105.4	111.6	117.8	124	130.2	136.4	142.6	148.8	155	161.2	167.4	173.6	179.8	186
7/67/26	100.5	107.2	113.9	120.6	127.3	134	140.7	147.4	154.1	160.8	167.5	174.2	180.9	187.6	194.3	201
6/72/22	108	115.2	122.4	129.6	136.8	144	151.2	158.4	165.6	172.8	180	187.2	194.4	201.6	208.8	216

The above chart provides the amount of helium to add (in Bar) to an empty cylinder to create the various HeliAir mixtures. To use the chart find the intersection of the row containing the desired ending cylinder pressure (at top) and the column containing the desired HeliAir mixture (at left). After adding the required amount of helium, top off the cylinder to the desired pressure with air.

Trimix Best-Mix Fill Pressures Best Mix Defined as PPO2 = 1.4 bar, END = 40 metres

Depth (metres)	O2/He/ N2 %	Fill (Bar)	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
51m	23%	Bar O2	8.6	9.2	9.8	10.3	10.9	11.5	12.0	12.6	13.2	13.8	14.3	14.9	15.5	16.1	16.6	17.2
	12%	Bar He	18.4	19.7	20.9	22.1	23.4	24.6	25.8	27.0	28.3	29.5	30.7	32.0	33.2	34.4	35.7	36.9
	65%	Bar Air	123.0	131.1	139.3	147.5	155.7	163.9	172.1	180.3	188.5	196.7	204.9	213.1	221.3	229.5	237.7	[illegible]
57m	21%	Bar O2	7.8	8.4	8.9	9.4	9.9	10.4	11.0	11.5	12.0	12.5	13.1	13.6	14.1	14.6	15.1	[illegible]
	20%	Bar He	30.2	32.2	34.3	36.3	38.3	40.3	42.3	44.3	46.3	48.4	50.4	52.4	54.4	56.4	58.4	[illegible]
	59%	Bar Air	111.9	119.4	126.9	134.3	141.8	149.3	156.7	164.2	171.6	179.1	186.6	194.0	201.5	209.0	216.4	[illegible]
63m	19%	Bar O2	7.2	7.7	8.2	8.6	9.1	9.6	10.1	10.5	11.0	11.5	12.0	12.5	12.9	13.4	13.9	14.4
	27%	Bar He	40.1	42.7	45.4	48.1	50.8	53.4	56.1	58.8	61.4	64.1	66.8	69.5	72.1	74.8	77.5	[illegible]
	54%	Bar Air	102.7	109.6	116.4	123.3	130.1	137.0	143.8	150.7	157.5	164.4	171.2	178.1	184.9	191.8	198.6	205.5
69m	18%	Bar O2	6.6	7.1	7.5	8.0	8.4	8.9	9.3	9.7	10.2	10.6	11.1	11.5	12.0	12.4	12.8	[illegible]
	32%	Bar He	48.4	51.6	54.9	58.1	61.3	64.6	67.8	71.0	74.2	77.5	80.7	83.9	87.2	90.4	93.6	[illegible]
	50%	Bar Air	94.9	101.3	107.6	113.9	120.3	126.6	132.9	139.2	145.6	151.9	158.2	164.6	170.9	177.2	183.5	[illegible]
75m	16%	Bar O2	6.2	6.6	7.0	7.4	7.8	8.2	8.6	9.1	9.5	9.9	10.3	10.7	11.1	11.5	11.9	12.4
	37%	Bar He	55.6	59.3	63.0	66.7	70.4	74.1	77.8	81.5	85.2	88.9	92.6	96.4	100.1	103.8	107.5	111.2
	46%	Bar Air	88.2	94.1	100.0	105.9	111.8	117.6	123.5	129.4	135.3	141.2	147.1	152.9	158.8	164.7	170.6	176.5
81m	15%	Bar O2	5.8	6.2	6.5	6.9	7.3	7.7	8.1	8.5	8.8	9.2	9.6	10.0	10.4	10.8	11.2	11.5
	41%	Bar He	61.8	65.9	70.1	74.2	78.3	82.4	86.5	90.7	94.8	98.9	103.0	107.1	111.3	115.4	119.5	123.6
	43%	Bar Air	82.4	87.9	93.4	98.9	104.4	109.9	115.4	120.9	126.4	131.9	137.4	142.9	148.4	153.8	159.3	[illegible]
87m	14%	Bar O2	5.4	5.8	6.1	6.5	6.9	7.2	7.6	7.9	8.3	8.7	9.0	9.4	9.7	10.1	10.5	10.8
	45%	Bar He	67.3	71.8	76.2	80.7	85.2	89.7	94.2	98.7	103.1	107.6	112.1	116.6	121.1	125.6	130.1	134.5
	41%	Bar Air	77.3	82.5	87.6	92.8	97.9	103.1	108.2	113.4	118.6	123.7	128.9	134.0	139.2	144.3	149.5	154.6
93m	14%	Bar O2	5.1	5.4	5.8	6.1	6.5	6.8	7.1	7.5	7.8	8.2	8.5	8.8	9.2	9.5	9.9	10.2
	48%	Bar He	72.1	76.9	81.7	86.5	91.3	96.1	100.9	105.7	110.5	115.3	120.1	125.0	129.8	134.6	139.4	144.2
	38%	Bar Air	72.8	77.7	82.5	87.4	92.2	97.1	101.9	106.8	111.7	116.5	121.4	126.2	131.1	135.9	140.8	145.6
99m	13%	Bar O2	4.8	5.1	5.5	5.8	6.1	6.4	6.7	7.1	7.4	7.7	8.0	8.3	8.7	9.0	9.3	9.6
	51%	Bar He	76.4	81.5	86.6	91.7	96.7	101.8	106.9	112.0	117.1	122.2	127.3	132.4	137.5	142.6	147.7	152.8
	36%	Bar Air	68.8	73.4	78.0	82.6	87.2	91.7	96.3	100.9	105.5	110.1	114.7	119.3	123.9	128.4	133.0	137.6
105m	12%	Bar O2	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3	7.6	7.9	8.2	8.5	8.8	9.1
	53%	Bar He	80.2	85.6	90.9	96.3	101.6	107.0	112.3	117.7	123.0	128.3	133.7	139.0	144.4	149.7	155.1	[illegible]
	34%	Bar Air	65.2	69.6	73.9	78.3	82.6	87.0	91.3	95.7	100.0	104.3	108.7	113.0	117.4	121.7	126.1	[illegible]
111m	12%	Bar O2	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	6.9	7.2	7.5	7.8	8.1	8.4	8.7
	56%	Bar He	83.7	89.3	94.8	100.4	106.0	111.6	117.1	122.7	128.3	133.9	139.5	145.0	150.6	156.2	161.8	167.4
	33%	Bar Air	62.0	66.1	70.2	74.4	78.5	82.6	86.8	90.9	95.0	99.2	103.3	107.4	111.6	115.7	119.8	124.0
117m	11%	Bar O2	4.1	4.4	4.7	5.0	5.2	5.5	5.8	6.1	6.3	6.6	6.9	7.2	7.4	7.7	8.0	8.3
	58%	Bar He	86.8	92.6	98.4	104.2	110.0	115.7	121.5	127.3	133.1	138.9	144.7	150.5	156.3	162.0	167.8	173.6
	31%	Bar Air	59.1	63.0	66.9	70.9	74.8	78.7	82.7	86.6	90.6	94.5	98.4	102.4	106.3	110.2	114.2	[illegible]
123m	11%	Bar O2	3.9	4.2	4.5	4.7	5.0	5.3	5.5	5.8	6.1	6.3	6.6	6.8	7.1	7.4	7.6	7.9
	60%	Bar He	89.7	95.6	101.6	107.6	113.6	119.5	125.5	131.5	137.5	143.5	149.4	155.4	161.4	167.4	173.3	179.3
	30%	Bar Air	56.4	60.2	63.9	67.7	71.4	75.2	78.9	82.7	86.5	90.2	94.0	97.7	101.5	105.3	109.0	112.8
129m	10%	Bar O2	3.8	4.0	4.3	4.5	4.8	5.0	5.3	5.5	5.8	6.0	6.3	6.5	6.8	7.1	7.3	7.6
	62%	Bar He	92.3	98.4	104.6	110.7	116.9	123.0	129.2	135.3	141.5	147.6	153.8	159.9	166.1	172.2	178.4	184.5
	28%	Bar Air	54.0	57.6	61.2	64.7	68.3	71.9	75.5	79.1	82.7	86.3	89.9	93.5	97.1	100.7	104.3	107.9
135m	10%	Bar O2	3.6	3.9	4.1	4.3	4.6	4.8	5.1	5.3	5.6	5.8	6.0	6.3	6.5	6.8	7.0	7.2
	63%	Bar He	94.7	101.0	107.3	113.6	119.9	126.2	132.5	138.8	145.1	151.4	157.8	164.1	170.4	176.7	183.0	189.3
	27%	Bar Air	51.7	55.2	58.6	62.1	65.5	69.0	72.4	75.9	79.3	82.8	86.2	89.7	93.1	96.6	100.0	103.4

Accident Analysis

The following information deals with results of some research done in Australia.

According to an article written by Dr. Peter Bennett, who is chief executive director of Divers Alert Network (DAN), dealing with 100 Australian scuba diving deaths.

- 38% indicated no training certification
- 33% to 50% of the victims appeared to show signs of panic
- 50%+ occurred in calm water, only 9% were due to strong currents
- 8% had failed to turn on their air before entering the water
- 52% failed to inflate their buoyancy control devices
- 86% failed to get rid of their weight systems
- 3% tried to ditch their weights, but the weights became entangled and remained attached
- 21% were diving alone
- 32% were diving with a less experienced buddy
- 41% had an experienced buddy
- 92% had become separated from their buddy

Please, learn how to **'PLAN YOUR DIVE** and **DIVE YOUR PLAN'**

Field Neuro Exam

Perform the following steps and place a check mark next to any item that has abnormal or questionable results.

1. ORIENTATION – Ask the divers name, current date, and details about the dive. Although the diver may appear alert, asking these questions may reveal confusion.

2. EYES – Have the diver hold their head still. Ask the diver to follow your hand (45cm from the divers face) while you move it up and down and side to side. Their eyes should track smoothly in all directions and should not jerk from side to side. Check peripheral vision. See if pupils are equal in size and respond to light.

3. FOREHEAD – Have diver close his/her eyes while you lightly touch the divers forehead and face. Check that feeling is present and note if there is a difference. With eyes shut tight, check for muscle strength by trying to open eyes above the brow. Have the diver furrow their brows and note if there is a difference. Check for skin sensation.

4. FACE – tell the diver to whistle. Check to see if the diver can pucker their lips. Have the diver smile. Note if there is a difference in facial muscles. Ask the diver to clench their teeth. Feel their jaw. Muscles should be of equal strength. Note if there is a difference. Check for skin sensation.

5. EARS – Have the diver close their eyes. Ask if their hearing is abnormal. Check hearing by holding your hand approximately 50cm from the divers ears and rubbing thumb and finger together. Move your hands closer until the diver hears the sound.

6. GAG REFLEX – Instruct the diver to swallow while watching 'Adams apple' move up and down (if female) look for swallow action.

7. TONGUE – Instruct the diver to stick out their tongue. It should come out straight, in the middle of their mouth, without deviating to either side.

8. SHOULDERS – place your hands firmly on the divers shoulders. Tell the diver to shrug their shoulders. Note if there is a difference in strength. Check for skin sensation.

9. ARMS – Have the diver squeeze your fingers. Note if there a difference in strength. Have the diver grasp your hands at chest level, elbows high. Gently push then pull elbows while the diver resists the motion. Note if there is a difference in strength. Check for skin sensation.

10. CHEST – have the diver close their eyes. Check for skin sensation.

11. LEGS – Have the diver lay flat. Raise and lower the divers legs while they resist the motion. Note if there is a difference in strength. Have the diver stand. Check balance and co-ordination by having the diver walk heel-toe. Ensure the diver does not fall. Check for skin sensation.

The divers condition may prevent the performance of one or more of these tests. Record the omitted tests and reason. The neurological exam should be repeated every hour. Record the results and report to medical personnel. Practice the neurological examination frequently to become proficient.

ACCIDENT MANAGEMENT FLOW CHART

Mild signs/symptoms immediate evacuation not necessary

1. Fatigue
2. Skin rash
3. Weakness
4. Indifference
5. Personality change

Yes

FIRST AID

1. Administer oxygen for 30 minutes
2. Head and chest inclined on left
3. Observe for onset of more serious symptoms
4. Administer oral fluids
5. Administer 2 aspirins

Yes Relief

Keep patient under prolonged observation and have them consult a diving physician as soon as possible

No more relief symptoms

No relief

Severe signs/symptoms immediate evacuation to a recompression chamber

1. Joint pains
2. Dizziness
3. Paralysis of face
4. Visual disturbances
5. Feeling of blow on chest
6. Chest pain
7. Severe hacking cough
8. Shortness of breath
9. Bloody, frothy mouth
10. Staggering
11. Difficulty telling direction
12. Paralysis or weakness of extremities
13. Collapse or unconcsciouness
14. Convulsions
15. Cessation of breathing

Did patient take a breath underwater regardless of depth (1M or deeper) from a scuba tank or any other form of contained gas

Yes

1. CPR if necessary to restore breathing and or heart function.
2. Trendelenberg position
A. Lying on left side
B. Place patient on oxygen and ensure that they remain on oxygen until taken off by a physician.
3. IV fluids
4. 2 aspirins if conscious

No

If patient was not underwater during the past 24 hours.
1. Begin CPR if needed
2. Administer oxygen
3. Evacuate to nearest medical facility

UK coast guard
Phone:0831 151523

DAN Europe
Phone:01224 585747

At sea call coast guard on channel 16

Evacuate directly to a recompression facility:
1. Lying on left side
2. Transport below 250M
3. Forward complete history of all events leading up to accident

Insert information for your dive area:

Chamber________________

Coast guard________________

Diving physician____________

____

Notes: Oxygen begins to off load bubbles and delivers a greater supply to areas cut from oxygen.
Aspirin helps prevent platelet clumping.
Fluids help balance blood electrolytes

An unconscious diver must go immediately and directly to a recompression chamber regardless of diving depth.

If in doubt about divers condition call DAN:
01224 585747

PSA TRIMIX DECOMPRESSION TABLE I

(For TRIMIX 19/30, One Gas Switch Required)

The following TRIMIX Decompression Tables were produced with the assistance of ABYSS Advanced Dive Planning software. The 150 Algorithm was chosen for increased conservatism. **However, using this set of tables cannot guarantee the prevention of DCS!**

These tables are intended for planning dives to 60 metres. One gas switch to EAN50 is required, a second gas switch to O2 is optional. Note the following:

- Descent Rate is 15 metres per minute, Ascent rate is 10 metres per minute
- Trimix 19/30 is the bottom gas, for a max END of 40 MSW and PO2 of 1.4 bar
- One gas switch to EAN50 must be made during the ascent at a depth of 21 metres
- Trimix 19/30 is used for descent, EAN50 may be used as a travel gas to 21 metres depth
- 100% O2 may be used at the 6 metre and 3 metre stops without exceeding the CNS limits.

TRIMIX 19/30 EAN50 @ 21m or Less
Descent @ 15m per min Ascent @ 10m / min

Depth (metres)	Time (mins)	STOPS					
		18m	15m	12m	9m	6m	3m
24m	10						5
	15						5
	20						5
27m	10						5
	15						5
	20						5
30m	10						5
	15						5
	20						7
33m	10						5
	15						5
	20					2	9
36m	10						5
	15					1	6
	20					3	11
39m	10						5
	15					2	8
	20				1	4	13
42m	10						5
	15					4	9
	20				2	5	15

Note - Do not plan repetitive dives with this table.
O2 must be 19% - 20% He must be 28% - 30%.
No table can guarantee the prevention of DCS.

TRIMIX 19/30 EAN50 @ 21m or Less
Descent @ 15m per min Ascent @ 10m / min

Depth (metres)	Time (mins)	STOPS					
		18m	15m	12m	9m	6m	3m
45m	10					1	5
	15				1	4	11
	20			1	3	6	16
48m	10					2	6
	15				2	5	12
	20			2	3	7	18
51m	10					3	7
	15			1	3	4	14
	20		1	2	4	8	19
54m	10				1	3	8
	15			2	3	5	15
	20		2	2	5	9	21
57m	10				2	3	10
	15		1	2	3	6	17
	20	1	2	3	5	9	24
60m	10			1	2	3	11
	15		1	3	3	7	18
	20	1	2	4	6	10	25
63m **	10			1	2	4	12
	15		2	2	5	7	20
	20	2	3	3	7	11	27

Note - Do not plan repetitive dives with this table.
O2 must be 19% - 20% He must be 28% - 30%.
No table can guarantee the prevention of DCS.

** Contingency Depth

Repetitive Dives

Limited testing suggests that one repetitive dive per day may be made with the following provisions:

- A minimum surface interval of 4 hours is ensured
- A Residual inert Gas time of 5 minutes is added to the actual Bottom time for decompression planning purposes.

PSA TRIMIX DECOMPRESSION TABLE II

(For TRIMIX 17/42, Two Gas Switches Required)

The following TRIMIX Decompression Tables were produced with the assistance of ABYSS Advanced Dive Planning software. The 150 Algorithm was chosen for increased conservatism. **However, using this set of tables cannot guarantee the prevention of DCS!**

These tables are intended for planning dives to 72 MSW. Note the following:

- Descent Rate is 15 metres per minute, Ascent rate is 10 metres per minute
- EAN36 shall be used as a travel gas to 30m depth
- Trimix 17/42 is the bottom gas, for a max END of 40 MSW and PO2 of 1.4 ATA
- Ascent requires a gas switch to EAN36 at a depth of 30 metres
- Deco requires a gas switch to100% O2 at 6 metres.

TRIMIX 17/42 EAN36 ≤ 30m 100% O2 ≤ 6m
Descent @ 15m per min Ascent @ 10m / min

Depth (metres)	Time (mins)	STOPS								
		27m	24m	21m	18m	15m	12m	9m	6m	3m
57m	10							3	3	8
	15					1	3	4	6	13
	20				1	3	3	7	9	18
60m	10						1	3	3	9
	15					2	3	4	7	14
	20				2	3	4	8	9	20
63m	10						2	3	4	9
	15				1	2	3	5	7	16
	20			1	2	3	5	8	10	22
66m	10					1	2	3	4	11
	15				2	2	3	6	8	17
	20		1	1	2	4	5	9	11	23
69m	10					2	2	3	5	13
	15			1	2	2	4	7	9	18
	20		1	2	2	4	7	9	12	25
72m	10				1	1	2	4	6	13
	15			2	1	3	4	8	9	20
	20	1	1	2	3	4	7	10	12	27
75m **	10				1	2	2	5	6	14
	15		1	1	2	3	5	8	10	21
	20	1	2	2	3	5	7	12	13	29

Note - Do not plan repetitive dives with this table.
O2 must be 16.5% - 17.5% He must be 40% - 42%.
No table can guarantee the prevention of DCS.

** Contingency Depth

Repetitive Dives

Limited testing suggests that one repetitive dive per day may be made with the following provisions:

- A minimum surface interval of 4 hours is ensured
- A Residual inert Gas time of 5 minutes is added to the actual Bottom time for decompression planning purposes.

PSA Gas Management Worksheet Metric

Maximum Depth __________ Rated Cylinder Capacity __________

Bottom Time __________

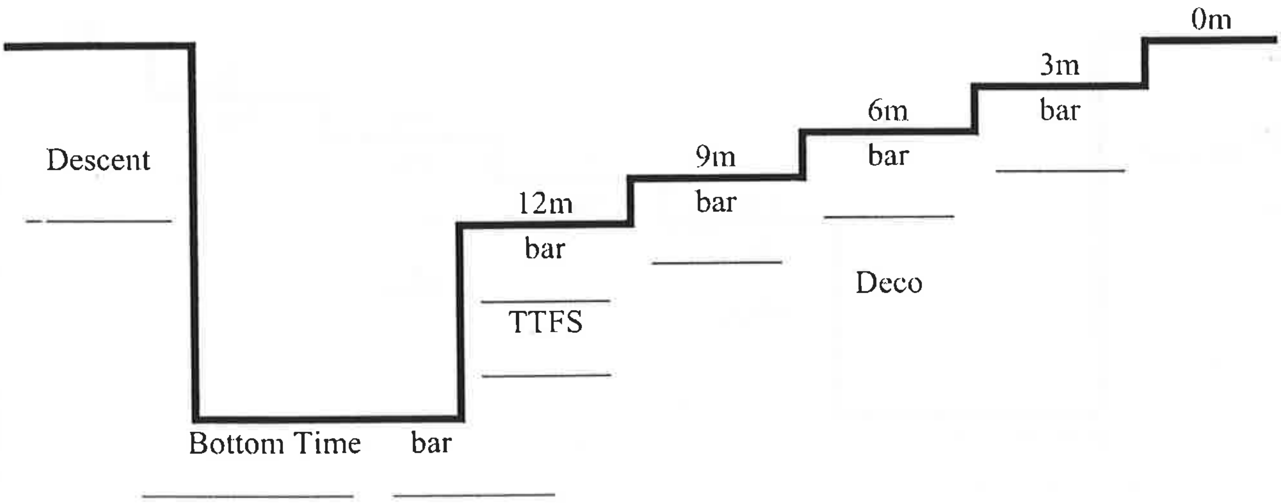
SCR in Litres / Min __________ Starting Cylinder Pressure __________

Formulae

Rated Cylinder Capacity ÷ Rated Cylinder Pressure = Litres / Bar Value __________

Starting Cylinder Pressure x Rated Cylinder Capacity = Starting Cylinder Volume __________

1. (Depth + 10) ÷ 10 = ATA
2. Starting Cylinder Volume (or previous Litres remaining) - Litres Used = Litres Remaining
3. Litres Used ÷ Rated Cylinder Capacity = Bar Used
4. Litres Remaining ÷ Rated Cylinder Capacity = Bar Remaining



Formula No			1		2	3	4
PHASES	Time X	SCR (Litres/Min)	X bars =	Litres Used	Litres Remaining	Bar Used	Bar Remaining
Descent							
Bottom							
TTFS							
Deco 1							
Deco 2							
Deco 3							
Deco 4							
Deco 5							
Deco 6							

PSA Gas Management Worksheet Metric

Maximum Depth ________ Rated Cylinder Capacity ________

Bottom Time ________

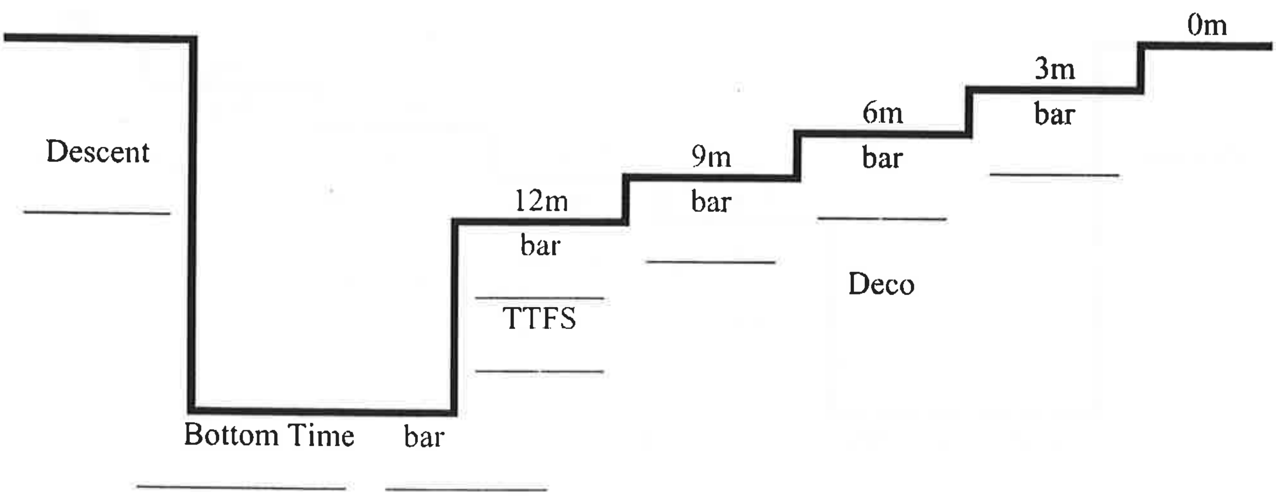
SCR in Litres / Min ________ Starting Cylinder Pressure ________

Formulae

Rated Cylinder Capacity ÷ Rated Cylinder Pressure = Litres / Bar Value ________

Starting Cylinder Pressure x Rated Cylinder Capacity = Starting Cylinder Volume ________

1. (Depth + 10) ÷ 10 = ATA
2. Starting Cylinder Volume (or previous Litres remaining) - Litres Used = Litres Remaining
3. Litres Used ÷ Rated Cylinder Capacity = Bar Used
4. Litres Remaining ÷ Rated Cylinder Capacity = Bar Remaining



Formula No			1		2	3	4
PHASES	Time X	SCR (Litres/Min)	X bars =	Litres Used	Litres Remaining	Bar Used	Bar Remaining
Descent							
Bottom							
TTFS							
Deco 1							
Deco 2							
Deco 3							
Deco 4							
Deco 5							
Deco 6							