Nitrox Diver Manual

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Special thanks to our friends at Maxtec, who generously provided us with oxygen analyzers and analyzer photos for this manual

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Contents

⚠ WARNING

Nitrox divers use gas mixtures containing elevated oxygen levels, beyond the 20.9 percent found in normal atmospheric air. Doing so involves risks that go beyond those normally associated with recreational scuba diving. These risks include:

- Divers who breathe Nitrox under water are subject to a risk of oxygen toxicity, which can result in visual and hearing disturbances, irritability, nausea, dizziness, and convulsions. Disturbances in vision and hearing, as well as irritability, can cause divers to make poor choices in emergency and other situations. Nausea and dizziness may cause vomiting under water, which in turn can cause drowning and death. Suffering convulsions under water almost always leads to drowning and death.
- Handling or using gas mixtures containing more than 40 percent oxygen may subject those in the immediate vicinity to increased risk of fire or explosion. Even though you may not use gas mixtures with such a high concentration of oxygen, you may be exposed to this risk simply by being present at fill stations where such blending and storage is taking place.
- Nitrox divers and those who supply Nitrox are only human, and can make mistakes or misunderstand one another. These mistakes and misunderstandings can cause additional risk.
- This book is designed to be used as part of a complete Nitrox Diver course conducted by a qualified NASE instructor. It covers the use of Nitrox mixtures containing concentrations of oxygen up to and including 40 percent. Do not attempt to use Nitrox without the benefit of this instructor-supervised training; as doing so can lead to substantial additional risk.

As a Nitrox diver, or a student undertaking Nitrox Diver training, you need to understand and accept these risks, and assume full responsibility for your actions and for the risks you are undertaking.

Introduction

Read This First

Here are four things you will likely never hear fellow divers say:

- "I sure wish my computer would give me *less* bottom time..."
- "I wish I didn't get to make *so many dives* in a single day..."
- "It would be nice to have to wait *longer* before being able to make another dive..."
- "Getting bent sounds like fun. I wish there was a way I could come even closer to the no-decompression limits..."

If you understand why you will most likely never hear divers say anything like this, you also understand the popularity of Enriched Air Nitrox.

Nitrox in a Nutshell

- Enriched Air Nitrox (EAN*x*) is a gas mixture consisting primarily of oxygen and nitrogen — just like the air we breathe at the surface. The difference is, EAN*x* has *more* oxygen and *less* nitrogen.
- Nitrox exposes divers to less overall nitrogen and can result in longer no-stop bottom times, shorter surface intervals and greater safety margins.
- Exposure to higher concentrations of oxygen poses a risk of *oxygen toxicity* that is not present when diving air at recreational depths.
- Learning to use Nitrox involves mastering some simple concepts and spending time with a qualified instructor, where you will learn how to analyze tanks for oxygen content.

Becoming a Certified Nitrox Diver

Becoming a certified Nitrox Diver involves two steps:

- Mastering the knowledge and understanding every Nitrox Diver needs. You do this through self study.
- Attending a short orientation session with your instructor, during which he will answer any questions you may have, administer a short exam and demonstrate and have you practice the steps involved in analyzing Nitrox tanks, recording data in a fill-station log and programming your computer.

Owning a personal dive computer is strongly recommended for every diver. *For Nitrox Divers, however, it is essential.* Without a Nitrox computer to track your exposure to elevated partial pressures of nitrogen and oxygen, you have to perform a series of *Equivalent Air Depth* and "CNS Clock" calculations.

> It's not that these calculations are all that difficult, but rather that, the more math you have to do, *the greater the likelihood of making mistakes.*

Additionally, in so far as you dive Nitrox chiefly to maximize bottom time and shorten surface intervals, to *not* have a Nitrox computer at your disposal means that you may end up with *less* bottom time, not more. That doesn't exactly make sense.

IMPORTANT

Can you rent Nitrox dive computers? Sometimes — but you can't rely on them always being available. Additionally, you should *never dive any computer without first reading and thoroughly understanding the owners manual.* Do you really want to do that every time you rent a dive computer?

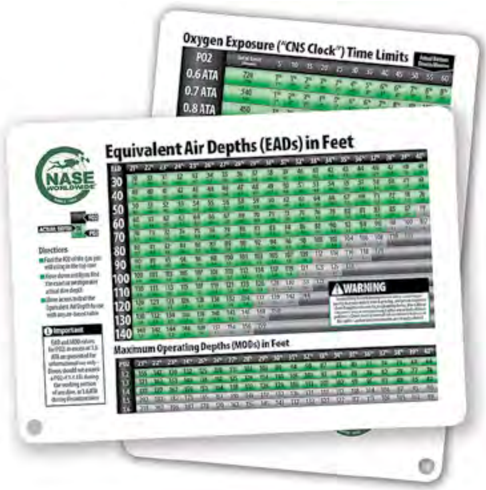
The good news is, Nitrox dive computers are more affordable than ever. A basic wrist-mounted Nitrox computer may cost no more than a quality set of mask and adjustable scuba fins. With this in mind, does it make any sense to *not* own a Nitrox computer?

About This Course

The NASE Nitrox Diver I course covers what you need to know to dive Nitrox, using a personal Nitrox dive computer to track your exposure to both oxygen and nitrogen. While this is all most recreational divers really need to know, some divers like to know more. For example:

- Some divers want to know what they would have to do to continue diving if a Nitrox dive computer was not available, due to loss, damage or failure.
- Just as some people are not happy driving a car unless they understand what is happening under the hood, some divers want to understand Nitrox in even greater depth.
- Still other divers have an interest in one day progressing on to technical diving — an activity that requires a much greater understanding of concepts such as Equivalent Air Depths, preventing oxygen toxicity by precisely tracking oxygen exposure and the mathematics that underlie much of what you will read here.

For these divers, there is a second, optional part to this course, contained in Part 2 of this book. It gets into tracking oxygen and nitrogen exposure in much greater depth, including how to use the NASE Equivalent Air Depth (EAD) and Oxygen Exposure tables. Completing this section, and the corresponding Study Questions and Final Exam, can result in NASE Nitrox Diver II certification. If you one day plan to progress to technical diver training, the information covered in this section is essential.



How to Use This Manual

The NASE Nitrox Diver Manual is designed to be used in one of two ways:

- *If you are taking the NASE Nitrox Diver course on line:* The manual serves as a convenient reference for when you are not able to look up information on line, or when it is simply faster to look up information in the Table of

Contents than it is to flip through pages in the online course. If you take the online course, you do not need to complete the Study Questions mentioned at the end of each unit.

- *If you are not taking the course on line:* The manual is designed to work with the NASE Nitrox Diver course Study Questions (i.e., “the homework”) in ways that will help ensure the best comprehension and retention of critical information.

Strategies for Using the Manual

Different people learn best in different ways. The manual and Study Questions accommodate a variety of learning styles. In so far as repetition is key to learning, these materials work together to enable you to go through the same information several times — but always in different ways.

Outlined below is a method we recommend. You can modify it, as needed, to meet your own individual needs.

Unit 2.2

Tracking Exposure to Oxygen

Without a computer, divers using air have their hands full just planning for and tracking their exposure to elevated partial pressures of nitrogen. When you add Nitrox to the equation, this process becomes even more complex. Fortunately, there is at least one alternative that can greatly simplify things.

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *If unable to use a dive computer to track exposure to oxygen, what is the simplest and easiest-to-use alternative?*
- *What must divers who cannot use a dive computer to track exposure to oxygen, or remain within a Limiting PO_2 of 1.4 ATA, be able to do to accurately track their exposure to oxygen?*
- *How do you perform "CNS Clock" calculations using the NASE Oxygen Exposure Table?*

If you can answer these questions, and master the associated knowledge and skills, the lack of a Nitrox-compatible dive computer may make life more complicated — but it won't necessarily prevent you from getting everything Nitrox can offer you.

The Easiest Way to Track Oxygen Exposure

As long as you remain within a limiting PO_2 of 1.4 ATA, there is a simple method that can make staying within safer oxygen limits easy. If you consult the NOAA Oxygen Time Limits table, you will see that the single-dive limit for a PO2 of 1.4 ATA is 150 minutes. *That's two and a half hours.*

PO2s	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Single-Dive Limit	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	150	[illegible]	[illegible]
24-Hour Limit	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Go through the manual: Rather than simply reading the manual from cover to cover, as you would a novel, we recommend the following:

- *Begin by flipping through the section or unit you wish to read:* Look at pictures, captions, chapter headings and subheadings. Doing so will give you a better feel for the section's organization and structure, and an overview of what you are about to learn.
- *Identify the learning goals:* At the start of each section, you will find a list of questions entitled *What to Look*

For. These will help you identify the most important information in each section.

- *Highlight important information:* As you read through each section in depth, highlight or underline the information that specifically answers the learning goal questions asked at the beginning of the section (as well as any other information you think is important). Doing so will help you when you come back and answer the Study Questions later on.

Complete the Study Questions: Yes, there is homework associated with the course — but it's homework that will not only help you pass the final exam the first time you try, it will also ensure you achieve the highest possible comprehension and retention of critical knowledge and skills.

The Study Questions are an Adobe Acrobat PDF. Your instructor will either give you a printed or electronic version, or you can download it from the NASE student website (*ScubaNASE.com*).

The electronic version of the Study Questions employs the latest Adobe Acrobat technology. This means you can complete them on your computer, then save and email the results back to your instructor. Not only is this easier and more legible than writing out answers by hand, it helps the environment by saving paper. And, the sooner your instructor can determine what you know, and what you may need a little help with, the better.

Whether you use the method outlined here, or another one better suited to your individual learning style, it is very, very important you have all the Study Questions completed and ready to turn in (or, better still, *turned in*) prior to the start of class. Your instructor will not allow you to participate if you do not.

Need to Know, Nice to Know

Throughout this manual, you will find snippets of information in boxes such as this one. These boxes denote *nice to know* as opposed to *need to know* information.


Trans
Pac
PINNACLE

Part 1

Computer Nitrox Diving

As you know from the Introduction, this first part of the book covers everything you need to know about how to dive Nitrox while using a Nitrox-capable dive computer. Part 1 is divided into five sections. These are:

- The What and Why of Nitrox
- The Science of Nitrox
- Equipment for Nitrox Diving
- Diving Nitrox
- Applying What You Have Learned

As you can see, we start with the theoretical and move, very quickly, to the practical.

Section 1.1

The What and Why of Nitrox

This first chapter addresses what Nitrox is and why divers use it. It covers:

- What is Nitrox?
- The Benefits and Drawbacks of Nitrox
- Alternate Terms and Abbreviations for Nitrox

What is Nitrox?

As a starting point for discussion, we will address the most basic question of all: *What exactly is Nitrox?*

What to Look For

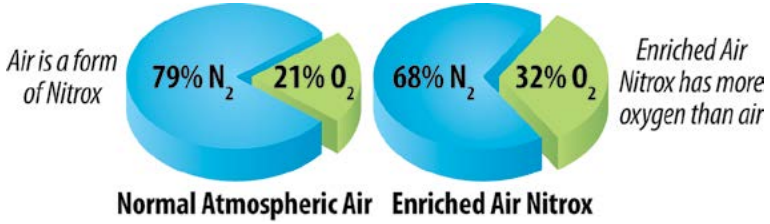
As you read through this section, highlight or underline the answers to the following:

- *What does the term Nitrox mean?*
- *What is Enriched Air Nitrox? How does it differ from air and other forms of Nitrox?*

If you can answer these two questions, you will be in a better position to understand what comes next.

Nitrox

The term *Nitrox* refers to any gas mixture consisting primarily of nitrogen and oxygen, in any quantity. By this definition, the air you are breathing right now is technically a form of Nitrox. You could also theoretically have a Nitrox mixture that contained *more* nitrogen and *less* oxygen than normal atmospheric air (although there would be no benefit in using such a mixture for diving).



Enriched Air Nitrox

The term *Enriched Air Nitrox* refers to any Nitrox mixture in which the concentration of oxygen is *greater* than the roughly 21 percent found in air. This is the Nitrox that offers the benefits of longer bottom times, shorter surface intervals, etc. When you hear divers talking about *Nitrox*, what they really mean is *Enriched Air* Nitrox. For simplicity, however, we will use the term *Nitrox* solely to refer to Enriched Air Nitrox throughout the balance of the course.

Those Pesky Trace Elements

As any student of science knows, air contains more than just oxygen and nitrogen. Roughly one percent of air is a mixture of argon, carbon dioxide and a handful of other elements. Fortunately, at their normal concentration in air, none of these elements have any significant impact on divers. For simplicity, we just lump these trace elements in with the roughly 79 percent of normal air we consider to be nitrogen.

Key Points to Remember From This Section

- *Nitrox* is any gas mixture consisting primarily of nitrogen and oxygen.
- The term *Enriched Air Nitrox* refers to any Nitrox mixture in which the concentration of oxygen is greater than the 20.9 percent found in air.

The Benefits and Drawbacks of Nitrox

In an ideal world, Nitrox would offer us nothing but benefits and have no offsetting drawbacks. Unfortunately, we have to deal with the fact that there are both pluses and minuses to using EAN*x*. That's what we will discuss next.

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *What is the chief benefit divers enjoy by diving Nitrox?*
- *What additional benefits might divers enjoy when using Nitrox?*
- *What is the chief drawback associated with diving Nitrox?*
- *What additional drawbacks might divers experience when using Nitrox?*
- *What are some common misconceptions regarding Nitrox?*

If you can answer these questions, you will have a better understanding of when it makes sense to dive Nitrox, and when it does not.

Nitrox's Chief Benefit

When you dive Nitrox, your body is exposed to less nitrogen and, as a consequence, *your tissues absorb less nitrogen* than they would on a comparable air dive. This translates directly into longer no-stop bottom times.

Depth (m)	15	18	21	24	27	30
Depth (ft)	50	60	70	80	90	100
NDL (Air)	70	50	40	30	25	20
NDL (EAN32)	130	70	50	40	30	25

The accompanying table compares the no-decompression limits for air with those for a nitrox mixture containing 32 percent oxygen. As you can see, the Nitrox advantage can be substantial.

Additionally, because you finish Nitrox dives with less nitrogen in your system than you would have after comparable air dives, it will require less time on the surface to reach a particular level of residual nitrogen than it would after diving air. In other words, you enjoy shorter surface intervals.

Additional Nitrox Benefits

The limiting factor on many deeper dives is not available bottom time but, rather, available gas. For example:

- You are making a dive to a wreck in 29 m/98 feet of water, using an 11-liter/80-cubic-foot tank filled to 207 bar/ 3,000 psi.
- To ensure you have sufficient gas for a slow ascent, a safety stop and an adequate reserve, you plan to begin your ascent at 70 bar/1,000 psi.
- Your suface air consumption (SAC) rate is 24 liters/0.85 cubic feet per minute.

If you do the math, you will discover that you will hit your safe ascent point roughly 15 minutes into the dive. That's five minutes *less* than the single-dive no-decompression limit for air at this depth. So, as you can see, air volume really is the controlling factor on many dives.

Consider this, however: If diving air, your dive would take you within five minutes of the no-deco limit. If, on the other hand, you were diving a Nitrox mixture with an oxygen

Fresh Versus Salt

Throughout this manual, any time you see a depth listed in meters or feet, be aware that we are talking about meters or feet *of salt water*. Equivalent depths in fresh water would be slightly deeper; however, what really matters is the ratio between ambient pressure at depth and ambient pressure at the surface. No matter what the actual linear distance from the surface, two atmospheres is still two atmospheres.

concentration of 32 percent, you would be *15 minutes* inside the no-deco limit — a substantially greater safety margin.

On repetitive dives, this additional safety margin may or may not be as pronounced. Also, if you "push" the no-deco limits on Nitrox, you can be at as much risk of DCS as you are when pushing the limits on air.

Still, given a series of dives with comparable depths and bottom times, *you are at less risk of DCS when diving Nitrox than you would be when diving air*. This may be an important advantage when divers have additional risk factors for DCS, such as a prior history of decompression sickness.

Nitrox's Chief Drawback

When you think about it, the term *Enriched Air* Nitrox is somewhat misleading. "Enriching" air with additional oxygen offers no direct benefit in and of itself — other than the fact doing so dilutes the concentration of nitrogen in the mix. In other words, the extra oxygen does nothing for you.

If anything, the additional oxygen presents a significant *disadvantage*, as it can put divers at risk for *oxygen toxicity*, something that is not an issue when diving air at recreational depths. We will discuss oxygen toxicity at length in the next section.

Additional Nitrox Drawbacks

Everything comes with a price. In the case of Nitrox, there is a price to pay for longer bottom times and shorter surface intervals.

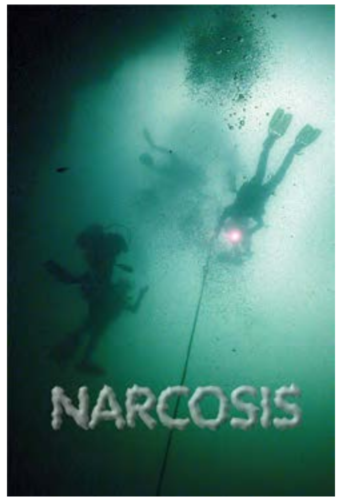
- *Nitrox generally costs more:* It can cost you twice as much (or more) than a comparable air fill.
- *Nitrox is not always available:* Some dive stores and resorts do not offer Nitrox as there may be no economic benefit for them to do so.
- *Getting Nitrox may require additional time:* Especially if your dive operation cannot dispense pre-mixed Nitrox.
- *Nitrox diving requires special training and certification:* Okay, you are getting that training right now. Bear in mind, however, that you may not always have dive buddies who are certified to dive Nitrox — a limitation that may rob *you* of some of Nitrox's benefits.
- *Nitrox may put some restrictions on the equipment you use:* Tanks and regulators used with Nitrox may need to meet special requirements.

Obviously, none of these drawbacks are insurmountable; nevertheless, they are things you need to be aware of.

Common Misconceptions

Over the years, Nitrox has been the subject of considerable mythology. In the early 1990s, prominent dive industry leaders were labeling it *Voodoo Gas* and *snake oil*. Mention or display of Nitrox was even banned at some trade and consumer dive shows.

Today we accept Nitrox as a certification every diver should have, and as a gas mixture every diver should breathe when it is beneficial to do so. Nevertheless, a few of the myths persist. Here are some of the most popular:



- *Nitrox reduces nitrogen narcosis:* This would seem to make sense. After all, you are breathing less nitrogen…right? Actually, what we have learned is that the additional oxygen in Nitrox has the potential to be at least *as narcotic* as the nitrogen it replaces. Oh, well…
- *Nitrox is a special gas mixture for technical deep diving:* If anything, Nitrox has more severe depth limitations than air does, due to the risk of oxygen toxicity. Unfortunately, uninformed divers sometimes mistake Nitrox for *Trimix*, a gas mixture containing oxygen,

What is Technical Diving?

In simplest terms, *technical diving* is any type of sport diving that takes divers beyond the normal recreational limits.
This may include:

- Depths greater than 40 m/130 ft.
- Use of gas mixtures with oxygen concentrations greater than 40 percent.
- Use of multiple gas mixes on the same dive.
- Dives requiring mandatory deco stops.

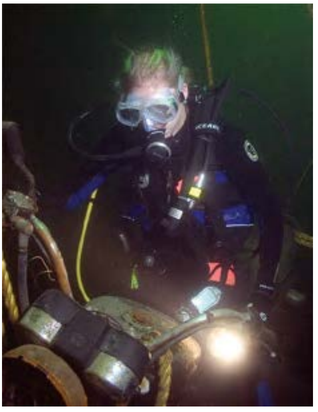
As you can imagine, tech diving entails risks that vastly eclipse those encountered by divers who remain within recreational limits. These risks can be managed, but doing so requires *a lot* of specialized training and equipment. Your instructor can tell you more.

nitrogen and helium. Helium mitigates narcosis, making it a highly desirable gas for technical diving at depths beyond 40 m/130 ft.

- *Nitrox divers cannot be treated for decompression sickness (DCS):* Fortunately, this was among the first myths to be debunked. Not only can you still be treated for DCS, you may be at less risk of needing that treatment.
- *Nitrox leads to a greater overall feeling of well-being:* This oft-repeated claim may well be wishful thinking. There is no evidence to support this contention (nor is there any evidence to disprove it).

Key Points to Remember From This Section

- The chief benefit of Nitrox is that, because it exposes divers to less overall nitrogen, they can enjoy longer bottom times and shorter surface intervals.



- In so far as available gas volume is generally the limiting factor on deeper dives, divers breathing Nitrox are likely to remain further inside the applicable no-decompression limits than divers breathing air. Also, Nitrox may well be the gas of choice for those at greater risk of DCS.
- The higher concentrations of oxygen in Nitrox puts divers at greater risk of *oxygen toxicity* and limit the depths to which divers can safely use Nitrox.
- Nitrox generally costs more to use than air, may not be as readily available (or take longer to get), requires special training and certification, and may put some restrictions on the equipment used.
- Common misconceptions regarding Nitrox include: That Nitrox is a special gas mixture for technical deep diving; that Nitrox reduces nitrogen narcosis; that Nitrox divers cannot be treated for decompression sickness (DCS); and, that Nitrox leads to a greater overall feeling of well being. None of these are true.

Alternate Terms and Abbreviations

Nitrox can go by many names. There is even a protocol for abbreviating *Enriched Air Nitrox* in its various flavors. You should know all of them.

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *What terms and abbreviations do divers use when referring to Enriched Air Nitrox?*
- *How can you incorporate oxygen percentage values into the acronym* EANX*?*

When you can talk intelligently about Nitrox, using the correct terminology, friends will consider you a gentleperson and a scholar. (No, seriously, they will. We promise…)

Common Nitrox Terminology

As we've already discussed, when you hear divers use the term *Nitrox*, they really mean *Enriched Air* Nitrox, a mixture in which the concentration of oxygen is greater than the 21 percent found in normal atmospheric air. Other terms you may hear include:

Who is Norm Oxic?

There is no such person. Nevertheless, a term you will hear quite frequently in conjunction with Nitrox and technical diving is *normoxic* air or *normoxic* Trimix. Any gas mixture referred to as being normoxic will have the same concentration of oxygen (20.9 percent) as normal atmospheric air does.

We tend to avoid the use of the term *normoxic* in this book, relying instead on the term *normal atmospheric air*. Nevertheless, when you hear others talk about normoxic air, they are referring to plain old atmospheric air with its normal oxygen content of 20.9 percent.

- *Enriched Air (without the "Nitrox" at the end):* As we mentioned earlier, this term is somewhat misleading, as adding oxygen to normal atmospheric air does nothing to "enrich" it in a way that is directly beneficial to divers. Nevertheless, you will see and hear this term from time to time.
- *SafeAir©:* This is one company's registered trade name for Nitrox (*yes*, you can register a name, you just can't patent the concept). This name is also somewhat misleading in that there is nothing inherently *unsafe* about diving normal atmospheric air within its limitations. Ironically, if you mis-use Nitrox, the resulting risk of oxygen toxicity can make it decidedly *unSafe* air.

The *x* in EAN*x*

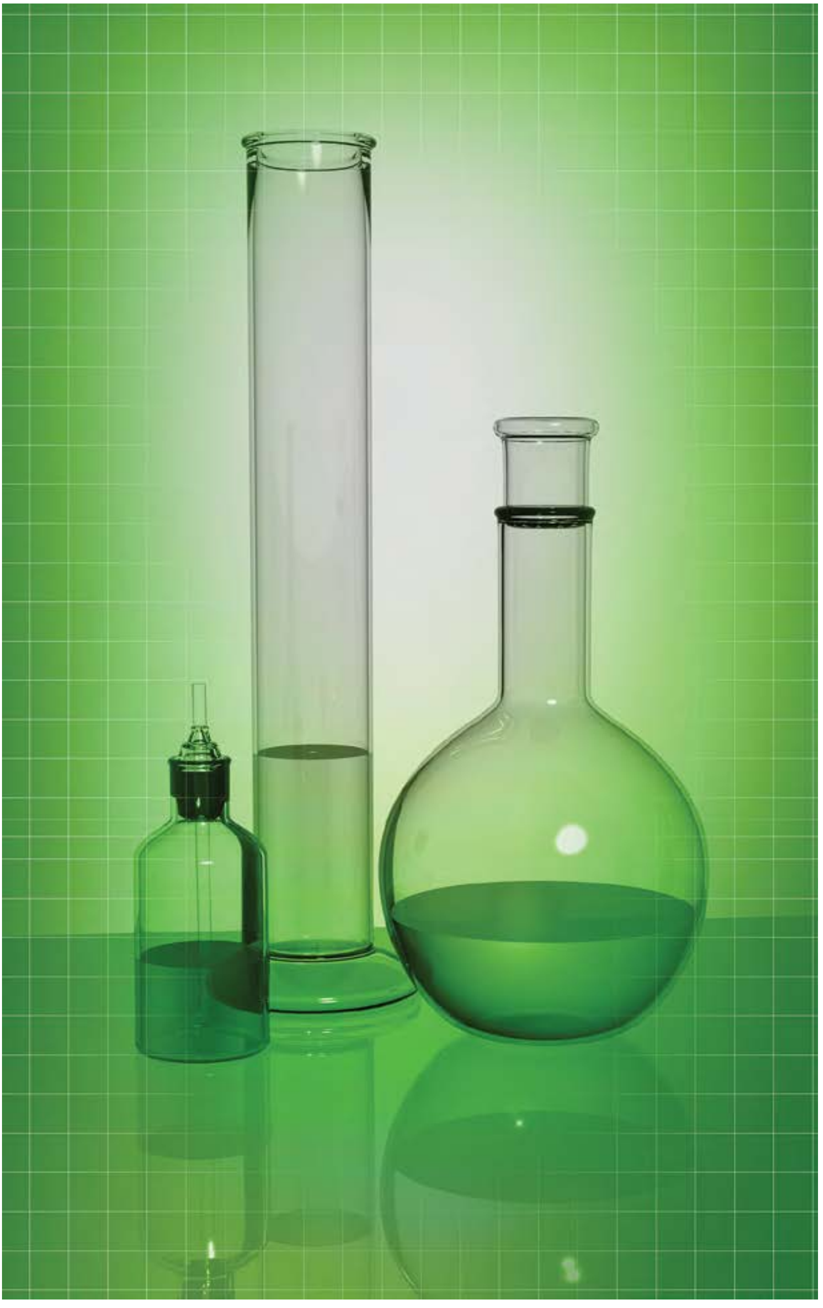
Enriched Air Nitrox is commonly abbreviated EAN*x*. As you no doubt guessed, *EAN* stands for *Enriched Air Nitrox;* the *x* is a variable that can be replaced by a numeric value representing the concentration of oxygen in the mixture (i.e., EAN32 is a Nitrox mixture containing 32 percent oxygen).

Occasionally, you will see the abbreviation depicted as EAN*x32*, EAN*x36* (or some other oxygen value). Strictly speaking, that is a bit of an oxymoron. What you are in essence saying is that, "This is Enriched Air Nitrox. We don't really know what the concentration of oxygen is (hence the *x*) — but, no, wait! We *do* know. It's 32 percent! Yippee!"

Please don't embarrass your friends and loved ones by making this common mistake.

Key Points to Remember From This Section

- Common terms for Nitrox include *Enriched Air* and *SafeAir*®. The most common abbreviation is EAN*x*.
- The *x* in EAN*x* is a variable that can be replaced by the concentration of oxygen in the mixture.



Section 1.2

The Science of Nitrox

"She blinded me with science." — *Thomas Dolby*

Well, you can relax. This science of Nitrox isn't all that complicated…or blinding, for that matter. Nevertheless, these are important things to know and will not only help you in your understanding of Nitrox, but several other aspects of diving as well.

In this section, we will look at:

- Oxygen Toxicity
- FO_2 and PO_2
- Oxygen Exposure Limits
- Equivalent Air Depths (EADs)

When we are done, you will be able to blind fellow divers with your intellectual brilliance.

Oxygen Toxicity

We tend to think of oxygen as a good thing. (After all, we couldn't live without it.) Well, have you heard the expression, *too much of a good thing?*

> This is the case with oxygen. In moderation, it's great. In excess, it can literally poison you.

In the words of Douglas Adams, *don't panic*. This risk is small and easily managed (at least at the recreational level). We'll show you how.

What to Look For

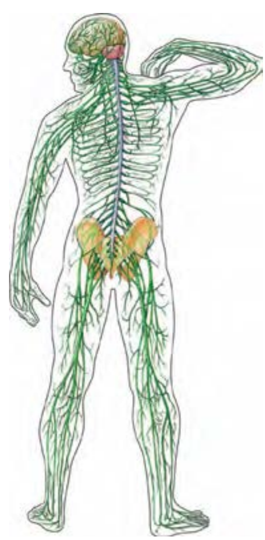
As you read through this section, highlight or underline the answers to the following:

- *What is the chief concern with breathing higher concentrations of oxygen under water?*
- *How do pulmonary oxygen toxicity and Central Nervous System (CNS) oxygen toxicity differ from one another?*
- *What additional factors may contribute to the onset of CNS oxygen toxicity?*
- *What are the signs and symptoms of CNS oxygen toxicity?*
- *What steps should you take if the signs or symptoms of CNS oxygen toxicity manifest themselves in you or a buddy?*
- *What is more important than simply being able to recognize and respond to the signs and symptoms of CNS oxygen toxicity?*

Obviously, oxygen toxicity is something you would really rather avoid. Being able to answer these questions will help you do just that.

Oxygen Toxicity: It Comes in Flavors

Earlier you read how there is *no* direct benefit in being exposed to the additional oxygen in Enriched Air Nitrox. If anything, this additional oxygen is a significant drawback, in that it puts divers at risk of *oxygen toxicity*. Oxygen toxicity comes in two flavors:



- Central Nervous System (CNS) Oxygen Toxicity.
- Pulmonary (Whole Body) Oxygen Toxicity.

Central Nervous System (CNS) Oxygen Toxicity: Exposure to high *partial pressures of oxygen* (something we will discuss shortly) can trigger a response in the central nervous system that can cause divers to convulse. While these convulsions are not necessarily fatal on the surface, under water a CNS "hit" could cause loss of motor control, leading to loss of mouthpiece and airway control and, consequently, drowning.

Pulmonary Oxygen Toxicity: This type of oxygen toxicity generally results from long-term exposure to elevated oxygen levels and is unusual in recreational diving. Pulmonary oxygen toxicity is of greater concern to technical and rebreather divers, who may be exposed to high levels of oxygen over multiple days of diving.

Risk Factors: Susceptibility to oxygen toxicity can vary widely from person to person and day to day. The two primary factors that lead to CNS oxygen toxicity incidents are the intensity of the exposure and its length. As a generalization, the more intense the exposure, the less time before CNS symptoms appear. (We will discuss Oxygen Time Limits in an upcoming segment.)

Additional factors that may contribute to CNS oxygen toxicity are cold, exertion (leading to high CO_2 levels) and certain drugs, including insulin, high blood pressure medication, decongestants and several others. This is one more reason why it is important that anyone taking prescription medication (other than birth control pills) seek a physician's approval for diving.

Fortunately, the risk CNS oxygen toxicity poses to recreational Nitrox divers is relatively small — particularly if divers remain well within the No-Decompression Limits and the Maximum Operating Depth (MOD) of the gas they are breathing. (MODs are yet another concept we will cover later in this section.)

OxTox Signs and Symptoms

The chief sign of oxygen toxicity that you might see other divers exhibiting is convulsions; the chief symptoms you might experience yourself include visual distortion, euphoria, nausea, twitching/tingling, irritability and dizziness. Of course, by the time any of these signs and symptoms manifest themselves, it will most likely be too late.

CONvulsions
Visual distortions
Euphoria
Nausea
Twitchiness/tingling
Irritability
Dizziness

⚠ WARNING

If you see or experience any signs or symptoms of oxygen toxicity, you and your buddies need to ascend immediately. *Remaining at depth may prove fatal.*

What is Even More Important Than a Fast Response

In so far as it will most likely be too late to respond to CNS oxygen toxicity once signs and symptoms manifest themselves, it is more important to be able to *prevent* them in the first place. Fortunately, this is easy to do — especially if remaining within recreational dive limits. It involves staying within your gas mixture's *Maximum Operating Depth (MOD)*, as well as staying well within the *Oxygen Time Limit* for your maximum *PO_2*. These are all terms we will discuss later in this unit.

Key Points to Remember From This Section

- While not necessarily fatal on the surface, under water a CNS "hit" can cause convulsions and loss of motor control, leading to loss of mouthpiece and airway control and, therefore, drowning.

- Pulmonary oxygen toxicity generally results from long-term exposure to elevated oxygen levels and is unusual in recreational diving.
- In addition to elevated exposure to oxygen, other contributing factors may include high carbon dioxide levels (work load) and use of certain drugs.
- The chief sign one may see in others is convulsions; the chief symptoms you may experience yourself include visual distortion, euphoria, nausea, twitching/tingling, irritability and dizziness/dyspnea (ConVENTID).
- If you see or experience any signs or symptoms of CNS oxygen toxicity, you and your buddies need to surface immediately.
- In so far as it will most likely be too late to respond to CNS oxygen toxicity once signs and symptoms manifest themselves, it is more important to be able to *prevent* them in the first place.

FO_2 and PO_2

We measure our exposure to oxygen while diving Nitrox in two ways. One deals with the *concentration* of oxygen in our breathing mixture; the other with the overall *intensity* of that exposure, based on depth. The two terms we use to do so are:

- Fraction of Oxygen (FO_2).
- Partial Pressure of Oxygen (PO_2 — also abbreviated ppO_2).

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *What do we mean when we refer to* Fraction of Oxygen (FO2)?
- *What are the* FO_2 *values of air and the most common Nitrox mixture?*
- *What do we mean when we refer to* Partial Pressure of Oxygen (PO2)?
- *How do you calculate* PO_2*, given* FO_2 *and depth?*
- *How does the effect of exposure to a particular* PO_2 *under water relate to breathing on the surface?*

This NOAA Didn't Build an Ark

Much of the pioneering work in the development of Nitrox was done by the National Oceanographic and Atmospheric Administration (NOAA — pronounced like the name *Noah*). NOAA is the USA government agency that operates the National Weather Service, the National Marine Fisheries Service and the National Ocean Service. If you have used a marine chart of USA waters, or consulted a weather forecast for the United States, you most likely have NOAA to thank for it.

Less well known is the fact NOAA operates several research vessels and has an extensive program of scientific and research diving. Such activities often involve long dives in relatively shallow (30 m/100 ft or less) water. Wanting to keep their divers as safe as possible during these activities, NOAA pioneered the use of Nitrox.

Many of the procedures for using Nitrox in recreational diving are based on NOAA's Nitrox policies. This includes how we mark Nitrox tanks and procedures for dispensing Nitrox.

Among the things NOAA is responsible for is the practice of using EAN32 and EAN36 as "standard" Nitrox mixtures. Originally known as *NOAA Nitrox I* and II, these mixes are now known as *NOAA Nitrox 32* and *Nitrox 36*.

Your understanding of FO_2 and PO_2 are essential to grasping the concepts of Maximum Operating Depths (MODs), Oxygen Time Limits and Equivalent Air Depths (EADs) — all factors which are essential to your safety.

Fraction of Oxygen

We express the *concentration* of oxygen in a gas mixture by using the term *Fraction of Oxygen (FO_2)*. In other words, a gas mix containing 50 percent oxygen has an FO_2 of 50 percent. Air has an FO_2 of 20.9 percent; The most common Nitrox mixture has an FO_2 of 32 percent (EAN32). Another common Nitrox mixture you hear about is EAN36; however, its actual use is nowhere near as common as EAN32.

Partial Pressure of Oxygen

Where FO_2 refers to the *concentration* of oxygen in a mixture, PO_2 measures the *intensity* of that exposure, expressed in *Atmospheres Absolute* (ATA). Ultimately, it is not the concentration of oxygen that affects you under water as much as the PO_2 does. For example, you could breathe 100 percent O_2 (PO_2 of 1.0 ATA) at the surface for several hours with little or no ill effect. However, were you to take a mix containing just 50 percent O_2 to a depth of four atmospheres (PO_2 of 2.0 ATA), you could find yourself seriously dead in less than an hour.

Calculating PO_2: PO_2 values can be obtained by multiplying the FO_2 of a gas mixture by ambient pressure in Atmospheres Absolute. For example, at a depth of 2.0 ATA (10 m/33 ft), air has a PO_2 of 0.42 ATA (0.21 x 2.0 = 0.42).

PO_2's Impact on Divers: As we mentioned earlier, it is PO_2 that ultimately has the greatest impact on divers. For example, being exposed to a PO_2 of, say, 1.0 ATA at depth has largely the same overall effect as breathing a gas mixture containing 100 percent oxygen at the surface.

Key Points to Remember From This Section

- We express the *concentration* of oxygen in a gas mixture by using the term *Fraction of Oxygen (FO_2)*.
- Air has an FO_2 of 20.9 percent; the most common Nitrox mixture, EAN32, has an FO_2 of 32 percent.
- Where FO_2 refers to the *concentration* of oxygen in a mixture, PO_2 measures the *intensity* of that exposure in Atmospheres Absolute (ATA).

- PO_2 values can be obtained by multiplying the FO_2 of a gas mixture by depth in Atmospheres Absolute (ATA).
- Being exposed to a PO_2 of, say, 1.0 ATA at depth has largely the same effect as breathing a gas mixture containing 100 percent oxygen at the surface.

Math? Oh, No!

Relax, there is not a single math formula you need to memorize or use to be able to dive Nitrox safely. Any data you can deduce from a formula you can more easily look up on a chart or table. (Using a personal dive computer generally eliminates the need to do even this much.)

Nevertheless, some divers actually enjoy being able to "do the math." If you aspire to become a divemaster, instructor or technical diver, this need becomes more critical.

If you are going to commit just one single formula to memory, it should be the one shown here. This is the formula for converting depth in meters or feet to ambient pressure in Atmospheres Absolute (ATA).

$$\text{Absolute Pressure in Atmospheres} = \frac{D + \text{A depth of 10 m/33 ft}}{\text{A depth of 10 m/33 ft}}$$

$$P_t = \frac{D+10}{10}$$

Metric

$$P_t = \frac{D+33}{33}$$

Imperial

Pressure in ATA is like a magic number. It is not only integral to Nitrox diving, enabling us to find PO_2s, MODs and EADs, it is also instrumental in calculating Surface Air Consumption (SAC) rates and most diving physics problems.

You will see the PO_2 formula integrated into other mathematical formulas that appear throughout this manual. As with this one, these formulas are all *nice to know* as opposed to *need to know* information. For future reference, all of these formulas are compiled in a single location in Appendix 3.

Oxygen Exposure Limits

"A man has got to know his limitations." — *Inspector Harry Calahan*

We said earlier that oxygen toxicity is something you can avoid. It's all a matter of knowing your limits.

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *What do we mean by the term* Oxygen Time Limit?
- *What are the oxygen time limits most Nitrox divers rely on?*
- *What do we mean by the term* Limiting PO_2?
- *What value do most divers consider to be the absolute Limiting PO_2 during the active (working) phase of any dive?*
- *What do we mean by the term* Maximum Operating Depth *(MOD)?*
- *How can you determine MOD for any particular depth?*

Everything in this book is important. The ability to answer these six questions, however, may well be the most important.

Oxygen Time Limits

To help minimize the risk of oxygen toxicity, Nitrox divers remain within certain time limits. These limits will vary, depending on PO_2. The accompanying chart shows the Oxygen Time Limits recommended by NOAA.

PO2s	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Single-Dive Limit	720	540	450	360	300	240	210	180	150	120	45
24-Hour Limit	720	540	450	360	300	270	240	210	180	180	150

These are the ones most divers follow. Note that there are exposure limits for both single dives and 24-hour periods. And, in part because you do not "off gas" oxygen the way you do nitrogen, the 24-hour limits are not much greater.

⚠ WARNING

Susceptibility to O_2 toxicity can vary widely from person to person, and day to day. As with the no-deco limits, staying within the NOAA Oxygen Time Limits cannot guarantee absolute safety.

Use caution, stay well within these limits and be especially careful if you have predisposing factors for O_2 toxicity.

Limiting PO_2

A *Limiting PO_2* is a value, in Atmospheres Absolute (ATA), that determines the deepest you can use a particular gas mixture without incurring significant risk of O_2 toxicity. Recreational and technical divers stay within a maximum Limiting PO_2 of 1.4 ATA. Technical divers may increase this to 1.6 ATA during decompression. Due to their lengthier exposure to high PO_2s, on the other hand, rebreather divers often limit themselves to a maximum PO_2 of 1.3 or 1.2 ATA.

What is a Rebreather?

Recreational divers use what is known as *open-circuit* scuba. Each time we take a breath, our exhaled air is vented out into the water. Thus, we use the oxygen in only two to four percent of the gas we inhale; the rest is wasted. Not exactly efficient — but nevertheless cost effective for recreational diving.

Rebreathers are what is known as *closed-* or *semi-closed-circuit* scuba. Exhaled air recirculates through the system. A CO_2 scrubber removes the carbon dioxide and a manual or automatic mechanism replaces any oxygen consumed. As little or no gas is wasted, rebreathers are highly efficient.

Unfortunately, they are also expensive and *very, very* complicated. They can also kill you without warning if you don't know what you are doing.

What makes rebreathers worth mentioning is the fact that most models allow divers to maintain a constant PO_2. This means that where, on open circuit, you might hit your maximum PO_2 only periodically during the dive, a rebreather may allow you to be at your max PO_2 for almost the entire dive. This increases the risk of oxygen toxicity, and helps explain why rebreather divers generally use a PO_2 set point of less than the 1.4 ATA that defines the Limiting PO_2 for recreational diving.

You can learn more about rebreathers from your NASE Instructor.

Maximum Operating Depth

Maximum Operating Depth (MOD) refers to the deepest depth a diver can reach, using a particular gas mixture, without exceeding his or her Limiting PO_2. Assuming a Limiting PO_2 of 1.4 ATA, the MOD for EAN32 is 34 m/111 ft.

You can calculate this value using a formula; however, it is easier to simply consult the NASE Equivalent Air Depth table, which lists these values for gas mixtures ranging from air to EAN40.

MODs in Meters

PO2	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
1.2 ATA	47	44	42	40	38	36	34	32	31	30	28	27	26	25	24	23	22	21	20	20
1.3 ATA	51	49	46	44	42	40	38	36	34	33	31	30	29	28	27	26	25	24	23	22
1.4 ATA	56	53	50	48	46	43	41	40	38	36	35	33	32	31	30	28	27	26	25	25
1.5 ATA	61	58	55	52	50	47	45	43	41	40	38	36	35	34	32	31	30	29	28	27
1.6 ATA	66	62	59	56	54	51	49	47	45	43	41	40	38	37	35	34	33	32	31	30

The MOD Formula

Here is a forumla you can use to calculate MODs. It is the same formula we use to generate the NASE MOD table.

$$MOD = \left(\text{A depth of } 10\text{ m}/33\text{ ft} \times \frac{(\text{Limiting } PO_2)}{(FO_2)}\right) - \text{A depth of } 10\text{ m}/33\text{ ft}$$

$$MOD = \left(10 \times \frac{(PO_2)}{(FO_2)}\right) - 10 \qquad MOD = \left(33 \times \frac{(PO_2)}{(FO_2)}\right) - 33$$

Metric Imperial

If you have sufficient time to kill, you could use this formula to generate your own MOD table. (You would have to remember, however, to round fractional depth values up to the next shallower whole integer for safety.)

Of course, there is no real reason to do this math, as the values on the table never change.

MODs in Feet

PO2	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
1.2 ATA	155	147	139	132	125	119	113	108	103	99	94	90	87	83	80	77	74	71	68	66
1.3 ATA	171	162	153	145	138	132	125	120	114	110	105	101	97	93	89	86	82	79	77	74
1.4 ATA	187	177	167	159	151	144	138	132	126	121	116	111	107	102	99	95	91	88	85	82
1.5 ATA	202	192	182	173	165	157	150	143	137	132	126	121	117	112	108	104	100	97	93	90
1.6 ATA	218	207	196	187	178	170	162	155	149	143	137	132	127	122	117	113	109	105	102	99

One of the cardinal rules of Nitrox diving is that you never dive a gas mixture without first analyzing its contents, determining its FO_2, then identifying (and staying within) the MOD for that mixture.

EAN32 is an ideal gas for recreational divers. It has an MOD of 33 m/111 ft. This allows divers to reach the recommended recreational depth limit of 30 m/100 ft and still have a comfortable safety margin.

Key Points to Remember From This Section

- The term *Oxygen Time Limit* refers to the maximum time, in minutes, that a diver can be exposed to a particular PO_2 and not incur a significant risk of CNS oxygen toxicity.
- Most divers rely on the Oxygen Time Limits established by NOAA.
- A *Limiting PO_2* is a value, in Atmospheres Absolute (ATA), that determines the deepest you can use a particular gas mixture without incurring significant risk of O_2 toxicity. Recreational and technical divers generally stay within a maximum Limiting PO_2 of 1.4 ATA.
- *Maximum Operating Depth (MOD)* refers to the deepest depth a diver can reach, using a particular gas mixture, without exceeding his or her Limiting PO_2.
- You can calculate MODs using a formula; however, it is easier to simply consult the NASE Equivalent Air Depth table, which lists these values for gas mixtures ranging from air to EAN40.

Equivalent Air Depths

Just exactly how is it that Nitrox gives you all that extra bottom time? This is what we cover next.

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *What do we mean by the term* Equivalent Air Depth *(EAD)?*
- *What is the easiest way to determine the EAD for FO_2s from 21 to 40 percent?*

If you can grasp the concept of Equivalent Air Depth, you will finally understand where all the extra bottom time Nitrox provides comes from.

What Are EADs?

Equivalent Air Depth (EAD) is a way of comparing a depth reached while diving Nitrox to a depth reached while diving air that would expose divers to the same overall level of nitrogen absorption. For example, a diver breathing EAN32 at a depth of 29 m/98 ft is exposed to the same overall level of nitrogen as he or she would at 24 m/80 ft while breathing air. This means that the No-Decompression Limit (NDL) for an EAN32 dive to 29 m/98 ft is the

The EAD Formula

Here is the forumla we used to generate the NASE EAD table.

$$EAD = \frac{\left(\text{Fraction of Nitrogen in the Gas Mix}\right) \times \left(\text{Acutal Depth} + \text{A depth of 10 m/33 ft}\right)}{\text{The Fraction of Nitrogen in Air}} - \text{A depth of 10 m/33 ft}$$

$$EAD = \frac{(1-FO_2) \times (D+10)}{0.79} - 10$$

Metric

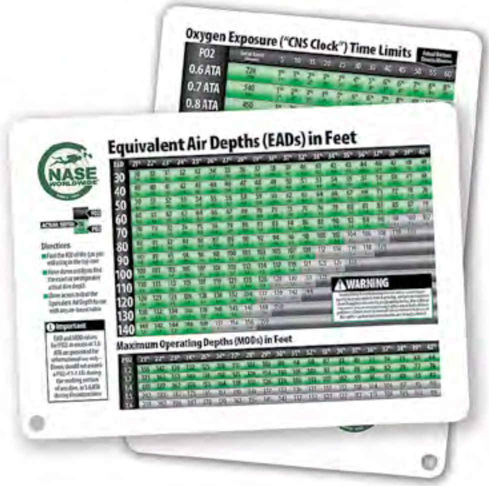
$$EAD = \frac{(1-FO_2) \times (D+33)}{0.79} - 33$$

Imperial

Again, if you want to experience and create your own table, you have to remember to round fractional depth values up the the next shallower whole integer.

same as the NDL for an air dive to 24 m/80 ft. This is why Nitrox divers enjoy longer bottom times.

Finding EADs



The easiest way to determine the EAD for FO_2s of up to 40 percent is to consult the NASE Equivalent Air Depth table. (You can also work a formula to arrive at this answer — but it will not differ from what you can more easily look up on the table.) You will find this table included with your course materials.

EADs (Meters)

EAD	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
9	9	9	9	9	10	10	10	10	11	11	11	12	12	12	13	13	13	14	14	15
12	12	12	12	12	13	13	13	14	14	14	15	15	15	16	16	17	17	18	18	18
15	15	15	15	15	16	16	17	17	17	18	18	19	19	19	20	20	21	21	22	22
18	18	18	18	19	19	19	20	20	21	21	22	22	23	23	24	24	25	25	26	26
21	21	21	21	22	22	23	23	24	24	24	25	26	26	27	27	28	28	29	30	30
24	24	24	24	25	25	26	26	27	27	28	28	29	30	30	31	31	32	33		
27	27	27	27	28	28	29	30	30	31	31	32	32	33	34	34	35				
30	30	30	31	31	32	32	33	33	34	35	35	36	37	37	38					
33	33	33	34	34	35	35	36	37	37	38	39	39	40							
36	36	36	37	37	38	39	39	40	41	41	42	43								
39	39	39	40	40	41	42	43	43	44	45										
42	42	42	43	44	44	45	46	47	47											

EADs (Feet)

EAD	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
30	30	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	46	47	48	49
40	40	40	41	42	43	44	46	47	48	49	50	51	53	54	55	57	58	60	61	63
50	50	51	52	53	54	55	56	58	59	60	62	63	64	66	67	69	71	72	74	76
60	60	61	62	63	64	66	67	69	70	71	73	75	76	78	80	81	83	85	87	89
70	70	71	72	74	75	76	78	80	81	83	84	86	88	90	92	94	96	98	100	102
80	80	81	82	84	86	87	89	90	92	94	96	98	100	102	104	106	108	110	113	
90	90	91	93	94	96	98	100	101	103	105	107	109	112	114	116	118	121			
100	100	101	103	105	107	108	110	112	114	117	119	121	123	126	128					
110	110	111	113	115	117	119	121	123	126	128	130	133	135							
120	120	121	123	126	128	130	132	134	137	139	142	144								
130	130	132	134	136	138	141	143	145	148	150										
140	140	142	144	146	149	151	154	156	159											

Key Points to Remember From This Section

- *Equivalent Air Depth (EAD)* is a way of comparing a depth reached while diving Nitrox to a depth reached while diving air that would expose divers to the same overall level of nitrogen absorption.
- The easiest way to determine the EAD for FO_2s of up to 40 percent is to consult the NASE Equivalent Air Depth table.

Section 1.3

Equipment for Nitrox Diving

Equipment can play a significant role in Nitrox diving, especially items such as tanks and regulators, which come into direct contact with high concentrations of oxygen. Computers also play a significant role in Nitrox diving; however, we'll talk about them in the next section. In this section, we discuss:

- How O_2 Affects Dive Gear
- Cylinder Markings

How O_2 Affects Dive Gear

"This is the captain. We are having a little problem with our entry sequence so we may experience some slight turbulence…and then explode." — *Nathan Fillion (as Captain Malcolm Reynolds)*

No one wants to blow up. Or replace unnecessarily damaged equipment. Or deal with any hassles that are otherwise avoidable. Fortunately, the potential problems associated with exposure to high concentrations of oxygen are, in fact, easily avoidable. That's what we cover in this section. Topics for discussion include:

- How Blending Methods Impact Dive Equipment
- The Problem with Oxygen
- Preventing Oxygen-Related Problems
- When Does Equipment Require O_2 Cleaning?
- Maintaining O_2 Cleanliness

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *What blending method exposes cylinders and valves to pure oxygen?*
- *What potential problems does exposure to elevated levels of oxygen create for dive equipment?*
- *What two conditions must dive equipment meet before it can be considered O_2 service rated?*
- *What additional factors may dictate that an equipment item, such as a regulator or valve, must be O_2 clean and service rated?*
- *What do we mean by the term* 40 Percent Rule?
- *What procedures must divers follow to ensure that an equipment item maintains its oxygen service rating?*
- *What Nitrox blending method requires that cylinders and valves be O_2 clean and service rated?*

Your dive equipment most likely represents a substantial investment. Understandably, you want it to last. What you *don't* want is for it to be damaged or destroyed unnecessarily. This is where a little common sense and an understanding of how oxygen can affect your equipment comes in.

How Blending Methods Impact Dive Equipment

The process by which dive operators create Nitrox is called *blending*. Blending methods fall into two categories, *pre-mixing* and *partial pressure blending*.

Pre-Mixing: There are several ways in which a dive operator can pre-mix Nitrox. The end result, however, is the same: The Nitrox blend attains its final concentration of oxygen (seldom more than 40 percent) *before* it goes into divers' tanks.

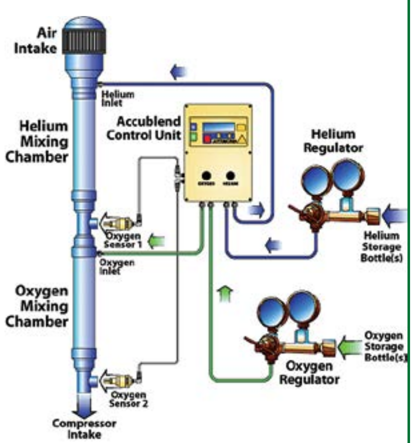
Partial Pressure Blending: This is the simplest but most time-consuming method of making Nitrox. The blender starts with an empty (or mostly empty) tank and fills it part way with pure oxygen. The tank is then topped off with air, causing the oxygen and air to mix inside the cylinder.

The Critical Difference: The chief difference between blending methods is that, when using pre-mixed Nitrox, the concentration of oxygen inside the cylinder and valve seldom exceeds 40 percent. When using partial-pressure blending, the inside of the tank and valve are exposed to pure oxygen during the mixing process. This can cause additional problems, as you are about to see.

More on Blending Methods

In the early days of Nitrox, EAN*x* was only available one way: partial pressure blending. This is a labor-intensive and time-consuming process, and often requires that divers drop their tanks off for filling and pick them up later. Soon, however, a variety of pre-mixing methods evolved, among them:

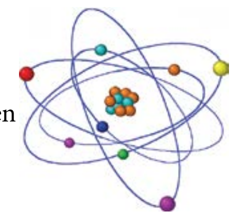
- **Large-Scale Partial Pressure Blending:** Nitrox is pre-mixed ahead of time in large storage cylinders, usually arranged in a *cascade*. This is a low-tech/low-cost approach that nevertheless saves divers time at the fill station.
- **Membrane Systems:** Popular on liveaboard dive vessels, these systems "denitrogenate" normal air by passing it through a special membrane. This method does not require separate oxygen cylinders, which may not be readily available in remote areas.
- **Mixing Sticks:** Also known as *continuous blending* systems, these blend oxygen, air (and sometimes helium) in a special mixing chamber, prior to being fed through a compressor.



For dive operations that do a sufficient volume of Nitrox, pre-mixing systems offer economy of scale. They save money in the long run, especially in terms of employee time. A qualified blender needs to do the pre-mixing, but does not have to be on hand to dispense gas. This translates into savings and convenience for customers, who do not have to wait for partial-pressure fills.

The Problem with Oxygen

Exposure to higher concentrations of oxygen can cause a variety of problems for dive equipment. Chief among them:



- Neoprene diaphragms and O-rings can deteriorate as much through oxidation as through wear (if not more so). Exposure to higher concentrations of oxygen can greatly accelerate the oxidation process, causing O-rings, in particular, to wear out prematurely.
- Despite the fact scuba air is vastly cleaner than what we normally breathe, carbon and other contaminants can build up on the interior surfaces of regulator first stages, tanks and tank valves. This, as well as certain non-oxygen-compatible lubricants used in regulator and valve service can *spontaneously combust* when exposed to high concentrations of oxygen under pressure.

Preventing Oxygen-Related Problems

To help prevent the problems oxygen can cause dive equipment, tanks, tank valves and regulators can undergo a process known as *O_2 cleaning* and be made O_2 service rated. This involves:

- Any regulator or valve surfaces exposed to high concentrations of oxygen under pressure must be thoroughly cleaned and free of grease, carbon and other contaminants.
- As the O_2-cleaned components are being reassembled, only oxygen-compatible O-rings and lubricants may be used.
- To maintain oxygen compatibility, tank and regulator surfaces can only come in contact with what is known as *oxygen-compatible air*. This is a standard of cleanliness that goes well beyond that normally required for scuba tanks. Not all fill stations meet this requirement.

When Does Equipment Require O_2 Cleaning?

Some dive equipment may require O_2 cleaning in order to be used with Nitrox. Other equipment does not. The equipment that *may* require O_2 cleaning includes:

- Tanks.
- Tank valves.
- Regulator first and second stages.

⚠ WARNING

Because tanks and valves are exposed to pure oxygen during partial-pressure blending, any Nitrox cylinders filled this way *must* be O_2 cleaned and service rated. *No exceptions.*

As far as tank valves that will be filled with pre-mixed Nitrox, and regulator first and second stages, there is a hierarchy of rules to determine whether or not O_2 cleaning is required.

"Real" O_2 Cleaning

The term *oxygen clean* as we use it in diving is actually a bit of an overstatement. "Real" O_2 cleaning, as it is practiced in, say, the aerospace industry, is actually much more involved.

- To start, the cleaning process must take place in a hermetically sealed clean room, in which the atmosphere is entirely free of potential contaminants.

- To maintain its oxygen-service rating, the O_2 clean component *cannot* come in contact with normal atmospheric air, or any gas that does not meet the same standards of cleanliness as the chamber in which the cleaning took place.

This is a standard of cleanliness that scuba equipment, by the vary nature of its use, cannot meet. Thus, what we in diving call *O_2 clean* and *O_2 service rated* wouldn't cut it in a lot of other industries. Fortunately, this doesn't matter. Time has shown that the standards of practice we follow for O_2 cleanliness in diving have proved adequate.

- At the top of this hierarchy are local laws, regulations and standards of practice among dive operators. In some areas, there is simply a blanket rule (or law) in effect that says that any equipment that comes into contact with gas mixtures other than air must be O_2 clean/service rated.
- Following this are manufacturer specifications. Most manufacturers state that tanks, valves and regulators *do not* need to be O_2 cleaned unless they will come into contact with gas mixtures with oxygen concentrations in excess of 40 percent. A few manufacturers, however, state that any such equipment used with gas mixtures other than air *must* be O_2 clean and exposed to gases made with oxygen-compatible air. This is common when working with titanium regulator first stages.

Don't Sweat the Small Stuff

Throughout this discussion of O_2 cleaning, you may have been wondering, "What about my high- and low-pressure hoses? What about my BC? They can come into contact with high concentrations of oxygen as well…" *Don't sweat it.*

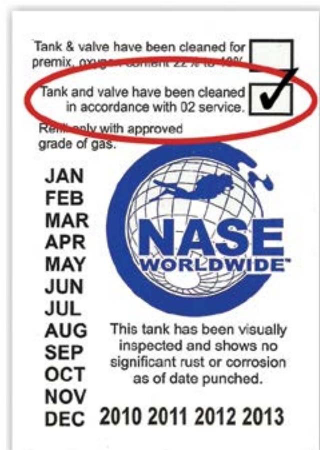
- As part of its O_2 service, your regulator technician will replace the neoprene O-rings in your regulator hoses with ones made from Viton® or similar materials. He or she will also lubricate these O-rings with the same oxygen-compatible lubricant as was used on the first and second stages.
- While it is true that neoprene is a major component in most high- and low-pressure hoses (as well as first-stage diaphragms), the thickness of these materials tends to mitigate any concerns over excess oxidation.
- As far as your BC goes, *yes*, it will be exposed to higher concentrations of oxygen — but under such low pressures that this really won't be a concern.

- Unless superseded by manufacturer specifications and/or local regulations or standards of practice, the general rule is that tanks, valves and regulators *do not* need to be O_2 clean and service rated unless they will be exposed to oxygen concentrations greater than 40 percent (the "40 Percent Rule").

It never hurts to err on the side of caution. Other than time and expense, there is no downside to O_2 cleaning, and many experts recommend O_2 cleaning Nitrox tanks, valves and regulators regardless.

Maintaining O_2 Cleanliness

If you have tanks, valves or regulators that have been O_2 cleaned, it is important you remember that, to maintain its oxygen service rating, these items must *only* be exposed to oxygen-compatible air or gas mixtures made using oxygen-compatible air.



Unfortunately for dive operators, there is no easy way to tell whether a tank that was O_2 cleaned, even just a few days ago, has been filled at any time with non-oxygen-compatible air. This is why so many operators are converting to pre-mixed Nitrox systems. Doing so helps reduce the risks involved in partial pressure blending in cylinders that are marked as being "O_2 clean" — but have been filled once or more with normal scuba air, thus voiding the O_2 service rating.

Key Points to Remember From This Section

- Partial-pressure blending exposes tanks and valves to pure oxygen during the filling process. Pre-mixing generally does not expose tanks and valves to oxygen concentrations in excess of 40 percent.
- Exposure to elevated levels of oxygen may cause neoprene diaphragms and O-rings to oxidize and, thus, wear out faster. Additionally, if non-oxygen-compatible lubricants are used, or there is a build up of carbon, grease or other contaminants on valve or regulator surfaces, the presence of high concentrations of oxygen under pressure can result in fire or explosion.

- Any regulator or valve surfaces exposed to high concentrations of oxygen (more than 40 percent) under pressure must be thoroughly cleaned and free of grease, carbon and other contaminants. Oxygen-compatible O-rings and lubricants must also be used.

- Because tanks and valves are exposed to pure oxygen during partial-pressure blending, they *must* first be O_2 clean and service rated.
- Manufacturer specifications and/or local regulations or standards of practice may require that *any* equipment exposed to oxygen concentrations greater than that of air be O_2 clean and service rated.
- Unless superseded by manufacturer specifications and/or local regulations or standards of practice, the general rule is that tanks, valves and regulators *do not* need to be O_2 service rated unless it will be exposed to oxygen concentrations greater than 40 percent (the "40 Percent Rule").
- To maintain its oxygen service rating, tanks, valves and regulators must only be exposed to oxygen-compatible air or gas mixtures made using oxygen-compatible air.

Cylinder Markings

Consider the following:

> A diver mistakenly picks up a cylinder containing EAN36, thinking it is air. He makes a dive to 39 m/128 ft, where the ambient pressure is 4.9 ATA. At this depth, his PO_2 will be 4.9 ATA times an FO_2 of 36 percent or almost *1.8 ATA*. Twelve minutes into the dive, he convulses and drowns, not knowing what was happening to him.

Pretty scary, isn't it? Ironically, had this diver been breathing air, he most likely would have been fine.

To prevent situations just like this one, NOAA developed a set of protocols for marking Nitrox cylinders, not only so that divers would not mistake a Nitrox tank for an air tank, but also to better identify exactly what the tank's contents are. These protocols are largely the same as the ones most recreational Nitrox divers follow today. In this section, we will look at these procedures in greater depth.

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *What is the most common method used to indicate that tanks may contain Nitrox mixtures with FO_2s greater than 21 percent?*
- *What does the presence of a Nitrox tank decal mean and, equally important, what does it not mean?*
- *What data should a Nitrox contents label list?*
- *What must you do to ensure that the data appearing on a Nitrox contents label is correct?*

Given the potential consequences of *not* knowing what is in your scuba tank, it makes sense to have a fairly bulletproof way of alerting others to the fact a cylinder *may* contain a gas mixture other than air and must be analyzed prior to use. Nitrox divers use two different types of markings to accomplish this: Nitrox tanks wraps and Nitrox contents labels.

Nitrox Tank Wraps

The most common means of marking Nitrox tanks is with a distinctive green-and-yellow Nitrox tank decal (also known as a *tank wrap*).

Doing so allows divers to instantly recognize the fact a tank *may* contain something other than air. Tank wraps are available from a variety of sources, but generally contain the words *Nitrox, Enriched Air* or EAN*x* in large letters.

Another less-common (but still used) method of marking Nitrox cylinders is to paint the body of the cylinder yellow and the very top portion green. You are most likely to see this in dive operations that must manage a large quantity of Nitrox cylinders.

WARNING

It is important to understand that a Nitrox tank decal means that a tank *may* contain a gas mixture other than air and must be analyzed prior to use. It *does not,* however, signify that the cylinder contains gas at any particular FO_2, such as 32 percent.

Divers frequently re-fill Nitrox cylinders with air for use on dives where Nitrox isn't necessary, or available (although re-filling a tank with non-oxygen-compatible air will invalidate the cylinder's oxygen-clean status). Thus, seeing a Nitrox tank wrap *doesn't* necessarily mean that the tank contains EAN*x* at any particular percentage; just that it must be analyzed before use. Technical divers, who may use stage and deco cylinders for a variety of different gas mixtures, may use a distinctive *Gas Mixture Other Than Air* decal in lieu of the standard Nitrox tank wrap.

Nitrox Contents Labels

While Nitrox tank decals alert divers to the fact a cylinder *may* contain Nitrox, the contents decal testifies to the specific FO_2 and MOD of the tank's contents, based on analysis. There is no standard format for such decals, other than the fact they contain, as a minimum, the FO_2, MOD, date of analysis and the initials of the person who analyzed the mixture.

Commercially made Nitrox contents labels are available from a variety of sources. Unfortunately, these tend to have numbers that are hard to read, and the decals themselves can be difficult to remove after use. (They can also sometimes come off during use and end up littering the bottom.)

An emerging standard of practice, adopted from the technical diving community, is to use a brightly colored piece of duct tape and a large permanent marker to label tank contents. This is not only more cost effective, it results in numbers that are easier to read, and markings that stay in place during the dive, yet come off easily when needed.

The accompanying photo shows one way to label tank contents. Notice that the FO_2, MOD, date of analysis and the initials of the person who analyzed the gas are easy to read.

> Be aware that the standard of practice in Nitrox diving is that you must either personally analyze the tank yourself, or you must witness the gas blender do it. After analysis, you must also maintain control over the tank so that there is no possibility of it being refilled without your knowledge.

Key Points to Remember From This Section

- The most common means of marking Nitrox tanks is with a distinctive green-and-yellow Nitrox tank decal (tank wrap).
- A Nitrox tank decal means that a tank *may* contain a gas mixture other than air and must be analyzed prior to use. It *does not,* however, signify that the cylinder contains gas at any particular FO_2, such as 32 percent.
- After analyzing, mark the cylinder with FO_2, MOD, date and the initials of the person who analyzed the mixture.
- You must either personally analyse the tank yourself, or you must personally witness the gas blender do it.

Section 1.4

Diving Nitrox

The experience of diving Nitrox is really no different from diving air. The differences come in how you prepare for your dive, and how you track your exposure to nitrogen and oxygen under water. In this section we look at:

- Obtaining Nitrox Tanks and Fills
- Planning and Making Nitrox Dives

Obtaining Nitrox Tanks and Fills

This is your starting point. You can't make a Nitrox dive unless you have Nitrox to dive with. Over the next few pages, we will look at:

- Completing the Fill Station Log
- Understanding Oxygen Analyzers
- Analyzing Cylinder Content

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *What may a fill station operator want you to do when obtaining Nitrox tanks or fills?*
- *What features do O_2 analyzers typically have in common?*
- *Why do you need to calibrate a gas analyzer's oxygen sensor prior to use?*
- *What steps should you follow when using an oxygen analyzer?*

If you can answer these questions, you will not only be able to get Nitrox tanks and fills, you will also know the correct FO_2 value to enter into your dive computer.

Completing the Fill Station Log

Understandably, dive operators who provide Nitrox rental tanks and Nitrox fills want to protect themselves as much as possible. One way dive operators do this is by insisting on proof of Nitrox Diver training and certification. Another way is by having customers who obtain Nitrox complete what is known as a *fill station log*. You will generally be required to complete such a log when renting or filling Nitrox tanks.

When you fill out and sign the fill station log, you are testifying to several things, including:

- The fact you have personally analyzed (or witnessed the analysis of) the Nitrox tank or tanks you will be using.
- The FO_2 and, more importantly, the MOD of those cylinder(s).

Not every dive operator requires use of a fill station log; however, most do, and it is something you should expect to complete when obtaining Nitrox.

Understanding Oxygen Analyzers

Before you can enter data in the fill log, before you can program your Nitrox dive computer, before you can plan your dive and determine your safe Maximum Operating Depth (MOD), you need to know exactly what is in your tank. For that, you will need an oxygen analyzer.

It's Seldom Perfect

You're planning a dive on a wreck in 27 m/90 ft of water. You plan to use EAN32 as this dive will be well within EAN32's MOD of 33 m/111 ft. (Besides, this is what you always dive.)

You drop your tank off at the dive center the night before, so that they will have time to partial pressure blend it. The next morning you are running late — but still have time to pick up your tank on the way to the boat.

When you get to the dive center, you analyze your tank and find the oxygen content to be *33.8* percent. *Now what do you do?*

- The generally acceptable margin of error for Nitrox fills is ±1.0 percent. This means that, as long as the gas analyzes at between 31.0 and 33.0 percent, you can safely consider it EAN32. Unfortunately, this is not the case here, as the gas is closer to EAN34.
- The gas blender offers to re-mix the tank for you. Unfortunately, this will take several minutes — and you are already running late.

What do you do? The answer is, *don't sweat it.* EAN34 has an MOD of 31 m/102 ft, which provides a comfortable safety margin over and above your planned maximum depth of 27 m/90 ft. You just set your computer for 34 percent and enjoy the fact you now have a few more minutes of bottom time than you would have had on EAN32.

The fact is, gas blending is as much an art as it is a science, and while blenders generally hit within the allowable target range of ±1.0 percent, they don't do so 100 percent of the time. As long as the resulting mix does not put you uncomfortably close to your Maximum Operating Depth (MOD), don't sweat a percentage point or two.

This is yet another example of why computers provide the best possible means of planning and making Nitrox dives. No matter what your actual FO_2 ends up being, your computer can still accurately track your exposure to both oxygen and nitrogen.

This is in contrast to the early days of Nitrox diving, when many students only learned how to use dedicated EAN32 and EAN36 tables. Unless your gas mix ended up within ±1.0 percent of these values, you were (to paraphrase Clint Eastwood) "a victim of fecal misfortune."

Oxygen analyzers come in a wide variety of sizes and shapes. All analyzers will have the following features in common:

- *A power supply:* This is almost always a battery. Some are user-replaceable; others are designed to last the life of the analyzer.
- *A digital display:* This will generally be designed to display oxygen content in tenths of a percent (i.e., *32.6%, 36.1%*, etc.).
- *An oxygen sensor:* This may be internal or external.
- *A calibration button or dial:* This allows you to *calibrate* the analyzer against what is known as a *reference gas* (calibration is something we will discuss next).

Some analyzers are designed to be held directly against the orifice of your tank's valve, while you allow a small stream of gas to flow from the tank into the analyzer. Other analyzers will have a fitting at the end of a flexible hose that allows you to attach the analyzer directly to your tank or BC low-pressure hose. Of the two types, the latter is the more accurate as:

- The connector helps ensure that gas flows over the sensor at a constant rate (and, thus, pressure). This is important as fluctuations in flow rate can affect accuracy.
- The gas flow to the sensor takes place within a closed environment and is less likely to be affected by outside factors such as moisture.

Obviously, the type of analyzer you hold directly against the tank valve may be slightly easier to use; however, you may pay for that convenience in accuracy — although the variance is seldom more than ±0.2 percent. Still, as no analyzer is ever 100 percent accurate, anything you can do to increase the accuracy of the analysis helps.

Analyzing Cylinder Content

We considered condensing this section to a single sentence: *Read, understand and follow your oxygen analyzer's owner's manual*. Then we thought you

Should You Own Your Own Analyzer?

If at all possible, you should own your own oxygen analyzer and take it with you every time you get Nitrox fills or rent Nitrox cylinders. This is for several reasons:

- To start, every analyzer works slightly differently. To use an analyzer correctly, you need to read and understand the owner's manual and practice with the unit. This is tough to do if you are using an analyzer other than your own.
- If you own and use your own analyzer, you never have to worry about whether the sensor is still good, or the unit is faulty. (Unless, of course, you slack off on maintenance, in which case you will only have yourself to blame.)

- By having your own analyzer, you will not be inconvenienced if the fill station's analyzer has become lost or damaged, or is "temporarily" off with someone else.

Owning your own analyzer is a small investment that brings peace of mind. And that can be priceless.

might be more impressed if we rambled on a bit. (Okay, these are things all Nitrox divers should know, regardless of which analyzer they use.)

The need to calibrate: Try this experiment some time.

- Turn your analyzer on and expose the sensor to normal, atmospheric air.
- Adjust (calibrate) the sensor as outlined in the owner's manual to read the 20.9 percent oxygen normally found in air.
- Turn the analyzer off and leave it overnight.
- In the morning, turn the analyzer on and, without changing anything, look at the display.

Odds are it will not read the same 20.9 percent it did the day before. *Why is that?*

WARNING

Oxygen sensors can be affected by a wide variety of factors, including sensor age, temperature, pressure and humidity. As these factors are almost never the same, each time you use your analyzer, you need to *calibrate* (reset) it so that its readings match those of a known *reference* gas — usually air.

If you do not calibrate, you won't get an accurate reading.

Using oxygen analyzers: Ultimately, you are going to have to consult your oxygen analyzer's owner's manual for the specific instructions on how to use your analyzer. Here are some general guidelines, though, on the steps you will likely follow. Let's start with the most ideal situation:

- You have a tank of normal scuba air for calibration, which you know unequivocally to have an FO_2 of 20.9 percent.
- Your analyzer is designed to plug directly into your tank valve or BC low-pressure inflator hose, so that there is little chance of humidity affecting the analysis, and you will be calibrating at the same flow rate as you will be using when analyzing your target gas.
- Your analyzer has a dial that allows you to precisely adjust the display.

With these resources at your disposal, here are the steps you would most likely follow:

Why Use Air as a Reference Gas?

There are two basic principles you should adhere to when selecting a *reference* gas (the gas against which you calibrate the analyzer):

- The oxygen content of the reference gas must be known *unequivocally*.
- The reference gas should be as close in oxygen content to that of the target gas (the gas you will be analyzing) as possible.

In theory, the ideal reference gas to use when analyzing a tank that is *supposed* to contain EAN32 is another cylinder of EAN32 whose oxygen content has been established beyond a shadow of a doubt. Unfortunately, because of the inherent inaccuracies in analyzers, you can never be certain that a gas that analyzes as EAN32 has exactly 32 percent O_2 in it.

Even the oxygen bottles you get from the gas company may not be pure O_2. The only readily available gas whose oxygen content is unequivocal is normal, atmospheric air. There is an additional reason for choosing air instead of pure oxygen.

> 100 percent is a long way from 32 percent. Thus, if your analyzer was off by, say, three percent of the displayed value, gas that analyzed as EAN32 could, in fact, be anything from EAN29 to EAN35. That's enough to cause serious problems.

In contrast, if you calibrate against air, an error of three percent will mean that a gas that analyzes as EAN32 will only be off by, at most, around 0.9 percent. That's a lot safer.

Bear in mind, if you calibrate against a scuba cylinder containing air (which is ideal, as it *theoretically* has the same moisture content as the gas you are analyzing), you must be 100 percent certain your "air" tank cannot possibly contain any additional oxygen.

> This means that your calibration tank *cannot* have been used for Nitrox since it was last completely drained. Additionally, it must be filled from an air source that is *only used to fill air*, and which has never been used to fill Nitrox (in which case there could be some additional oxygen trapped in the lines).

If you can't be certain that your calibration tank contains no additional oxygen, you will need to calibrate against outside or room air (despite its potential moisture content).

- Start by attaching the analyzer connection to the tank valve or BC inflator hose coming from your calibration tank. Turn the analyzer on.

Note that, even though the sensor is being exposed to normal atmospheric air, the display will most likely *not* read 20.9 percent.

- Turn the calibration tank on.

The 0_2 reading may increase slightly, as the pressure on the sensor increases.

- Allow the air to flow until the display reading stabilizes (usually 30 seconds or more).
- Once the display reading has stabilized, slowly turn the calibration dial on the analyzer until it reads exactly 20.9 percent. Your analyzer is now calibrated.
- Without turning the analyzer off or touching the calibration dial, disconnect it from your calibration tank and reconnect the analyzer to the tank you will be analyzing.
- Turn the tank on and allow the gas to continue flowing until the display reading stabilizes (usually 30 seconds or more).

When the display stabilizes, the number shown will be the oxygen concentration (FO_2) of the gas mixture in the tank. Round this to the nearest integer and put this percentage on the contents label and in the fill log. This is the value you will program into your Nitrox dive computer.

Here are some variations on the steps outlined above, which you may need to use depending on circumstances.

- If your analyzer is the kind that is designed to be held against the tank valve orifice, calibrate and analyze by turning the calibration tank on “just a crack,” and then adjusting the gas flow to the smallest amount of flow possible. Hold the analyzer tightly against the valve orifice, so that there is as little chance as possible of contaminating the analyzer with gas other than what is coming from the tank.
- If you don’t have access to a calibration cylinder that you know, *unequivocally*, contains nothing but normal atmospheric air, you will need to calibrate against ambient air. Follow the manufacturer’s recommendations, These generally include using a calibration setting of slightly less than 20.9 percent. If no such instructions are provided, use a setting of between 20.7 and 20.8 percent. This compensates for the difference in readings caused by the increased flow of gas across the sensor when held up to a tank.
- Some analyzers can only be calibrated to 20.9 percent.

Key Points to Remember From This Section

- Most fill station operators will expect you to: personally analyze (or witness the analysis of) Nitrox cylinder content; and, record this data, along with MOD and other information, in a fill station log.
- Most O_2 analyzers will have some or all of the following: a power supply (typically a battery); a means of connecting to the cylinder valve orifice or a regulator low-pressure inflator hose; a means of controlling gas flow; a sensor element; a digital display; and, a means of calibrating the analyzer.
- You need to calibrate the analyzer to account for variations caused by the presence of moisture and changes in temperature, sensor age, etc.
- The steps in analyzing your tank may include: connecting your analyzer system to its calibration source; open the source and adjust flow as needed; turn the calibration dial to read 20.9 percent for air (it may be a lower value if not using a closed system); disconnect from the calibration source and reconnect to the tank being analyzed; allow gas to flow for at least 30 seconds or until the analyzer reading stabilizes.

Planning and Making Nitrox Dives

Now we will look at:

- Computers: The Best Nitrox Planning/Tracking Tools
- Using Nitrox Dive Computers

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *Why do Nitrox dive computers provide the best way to plan for and monitor Nitrox divers' exposure to nitrogen and oxygen?*
- *What are the most important things you should do before using any Nitrox dive computer under water?*
- *How can you use your Nitrox computer to plan upcoming Nitrox dives?*
- *What should you be monitoring on your Nitrox dive computer while under water?*

Armed with the answers to these questions, you will be able to make actual Nitrox dives (which is the whole point of this course…right?).

Computers: The Best Nitrox Planning/Tracking Tools

If you had to, you could plan and track Nitrox dives by using regular dive tables in conjunction with Equivalent Air Depth (EAD) and "CNS Clock" tables (in fact, you can learn how to do this in Part 2). Nevertheless, the fact remains it is not only easier, but very possibly safer to do so using a Nitrox dive computer. This is for several reasons:

- Making Nitrox dives *without* a computer involves looking up information on several tables and doing a fair amount of math. The more of this you have to do, the more likely you are to make mistakes.
- Dive computers adjust for the multilevel nature of most dives, allowing you to achieve all of the benefits Nitrox offers.
- Your Nitrox computer doesn't care whether you are using EAN32, EAN36 — or anything else between air and EAN40. Just set the FO_2 correctly; the computer will take care of tracking your exposure to both oxygen and nitrogen.

Using Nitrox Dive Computers

The Nitrox Diver course is among the few Specialty Diver programs that do not have required dives. This is because the experience of diving Nitrox is no different from diving air. You don't feel any different; you won't breathe any different.

The only real "skill" in diving Nitrox (outside of learning to analyze tanks), is learning how to program your Nitrox dive computer, and understanding what it is telling you under water.

As we've mentioned previously, we could probably condense this entire section into a single sentence: *Read and make certain you thoroughly understand and follow your dive computer's owner's manual.* This is the single most important thing you can do when diving Nitrox.

IMPORTANT

Dive computers can be complex. You should *never* use any dive computer without reading the owner's manual. This is why relying on rental computers *is not* a good idea: Each time you rent a different computer, you will have to learn yet another owner's manual.

Nitrox dive computers are more affordable than ever. Inexpensive wrist-top models are available for about the cost of a good set of mask, snorkel and fins. It just plain makes sense to own your own.

Setting FO_2: If there is anything about diving Nitrox that rivals reading your computer's owner's manual in importance, it is setting the correct FO_2. Exactly how you do so will vary by make and model. It is important you understand not only how to set this on your dive computer, but also how to check this setting before and between dives.

Additional Computer Settings: Your computer may allow you to control a number of other settings, such as various alarms. Here are some common ones:

- *Limiting PO_2 Warning*: Most dive computers, by default, assume a Limiting PO_2 of 1.4 ATA. Some computers will allow you to adjust this warning upward or

Set for a Different FO_2?

You sometimes hear that, if you have risk factors for decompression sickness (DCS), you should set your computer for air, or for an FO_2 significantly lower than that of the gas mixture you will be breathing. *Think carefully before doing so.*

- If you set your computer for anything other than the gas mixture you are actually breathing, you will rob the computer of its ability to accurately track your exposure to elevated partial pressures of oxygen (PO_2s). Your computer will also not display accurate PO_2 values at depth.
- If you do suffer from DCS, the physicians at the recompression chamber are going to rely on your computer to paint an accurate picture of your dive history. Your computer can't do that unless it was set to the exact gas mixture you were using.

Most computer manufacturers will allow you to set additional conservatism factors, should you feel the need for additional protection from DCS. Doing so will enable the computer to accurately track your nitrogen and oxygen exposure while providing you with shorter no-stop dive times. This is a far better choice than lying to your computer.

downward. You may choose to set a more conservative PO_2 warning than 1.4 ATA. You *should not*, however, set the warning greater than this value.

- *Depth Warning:* Some computers allow you to set a depth warning. If you exceed this depth, an alarm will sound or display. In so far as the MOD for EAN32 is 33 m/111 ft, you may want to set a depth alarm for the recommended recreational depth limit of 30 m/100 ft. This will give you an additional safety margin.

- *Conservatism Factor:* If you think you may have a greater susceptibility to decompression sickness (DCS), many computers will allow you to set a conservatism factor that creates shorter no-stop dive times than those the computer uses by default.
- *Multiple Gas Mixes:* If you think you may one day want to venture into technical diving, you will want to purchase a computer that can track exposure to multiple gas mixtures on the same dive. As a recreational diver, however, you will only be using a single gas mixture. Therefore, you need to learn how to either set all of the gas mixtures to your current FO_2 or lock out the gas mixtures you will not be using.

Know How Your Computer Defaults: Among the most common errors divers make when using Nitrox computers is failing to set the correct FO_2 prior to the dive. Most dive computers will try to protect you from the consequences of such an error in one or both of two ways:

- On many computers, an alarm may sound or display if you enter the water with the FO_2 not set.
- If you have not reset the FO_2 on most computers, they will *default* to a set of values designed to keep you as safe as possible. A typical set of default values might be a nitrogen concentration of 79 percent and an oxygen concentration of 50 percent. Depending on the make and model, your computer may default anywhere from ten minutes to several hours following a prior dive.

IMPORTANT

It's important you understand when and how your particular computer defaults. Even more importantly, you need to get in the habit of checking your computer's FO_2 setting before you enter the water and again immediately upon submerging.

Planning Nitrox Dives: You plan Nitrox dives much the same as you would an air dive — the exception, of course, being that you need to know the Maximum Operating Depth (MOD) for your gas mixture and plan to stay well within it. If diving EAN32, or any mixture with a lower FO_2, this pretty much takes care of itself, as long as you stay within the recommended depth limit for recreational diving (30 m/100 ft).

As it does when you dive air, your computer will allow you to enter a *Plan* mode on the surface, in which you can scroll through projected no-stop dive times for upcoming dives, based on depth. When using Nitrox, these times will be greater than they would be on air. Also, given the multilevel nature of recreational dives, your actual no-stop dive times may exceed what you see while in *Plan* mode.

What to Monitor Under Water: As with any dive, you will want to monitor your Nitrox dive computer for current depth, maximum depth reached during the dive, Actual Bottom Time and no-stop dive time remaining. You also need to know what your computer will display if you accidentally exceed your no-stop dive time and have to make a mandatory decompression stop.

No-Stop Dive Time vs. NDL

When discussing what your computer displays under water, you will notice we tend to use the term *no-stop dive time* as opposed to *No-Decompression Limit*. What's the difference?

- *No-Decompression Limits* are fixed values, such as you would find on a dive table or see on your computer when it is in *Plan* mode.
- *No-stop dive times* are what your computer displays during the dive, and are constantly changing, depending on factors such as current depth, Actual Bottom Time, etc.

It's a small distinction, but one that more accurately conveys what your computer is telling you.

When diving Nitrox, there are some additional things your computer may display that you will need to pay attention to. These include:

- *FO_2:* Most computers will display the FO_2 value you have programmed into them throughout the dive. It is particularly important to double check this when first entering the water.
- *PO_2:* Nearly all Nitrox computers will display your current PO_2. This will vary depending on depth. Remember that your computer can only display an accurate PO_2 value if you have programed the right FO_2 into it.

- *Oxygen Exposure Bar Graph:* Much like the nitrogen exposure bar graph you are used to, this additional display, found on most Nitrox computers, provides a visual representation of the percentage of your Oxygen Exposure Limit you have consumed.
- *Nitrox-Related Warnings:* These may include PO_2 and depth warnings. You need to know how your computer will display these warnings, and whether or not an audible alarm will sound as well.

Key Points to Remember From This Section

- Nitrox dive computers eliminate the need for divers to use special tables or to calculate Equivalent Air Depths, and reduce the likelihood of mathematical or other errors. They automatically adjust for varying nitrogen exposures, based on the FO_2 you program into them. They also track exposure to oxygen and eliminate the need for complex "CNS Clock" calculations.
- The most important things you need to do before using any Nitrox dive computer under water are: read and make sure you thoroughly understand the owner's manual; and, set your computer for the correct FO_2.
- After setting the computer for the FO_2 of the gas mixture you will be using, you can put the computer in *Plan* mode and scroll through the list of available depths and NDLs, the same as you would if diving air.
- As with an air computer, you should continuously monitor current depth, maximum depth, Actual Bottom Time and remaining no-stop dive time. Additionally, you should also monitor the computer's oxygen-exposure bar graph (if so equipped), as well as your current $PO_{2.}$

Don’t Forget the Homework

Hopefully, you’ve been completing the homework as you were working through each section of the book. If not, it’s time to go back and do so not. Remember, if you don’t have a copy of the Study Questions, you can download them from *ScubaNASE.com*.

Section 1.5

Applying What You Have Learned

As we mentioned at the beginning, the majority of the Nitrox Diver I course consists of self study — which you have now completed. (Congratulations!) All that remains is for you to complete a short practical application session with a qualified NASE Instructor. During that session, you will:

- Review any homework questions you don't understand.
- Take the NASE Nitrox Diver I course final exam.
- See a demonstration of how to use an oxygen analyzer — and then get hands-on experience doing it yourself.
- Practice completing a fill station log.
- See a demonstration of how to set FO_2 on a typical Nitrox dive computer — and then get hands-on experience doing so yourself.
- See and practice how to put a Nitrox dive computer into *Plan* mode and scroll through the display of upcoming no-stop dive time values.

Although it is not a requirement, your instructor may also provide you with the opportunity to make one or more Nitrox dives. (This is often done in conjunction with other NASE Advanced or Specialty Diver course activities.)

> If you are going for the NASE Nitrox II Diver certification, you will also need to read Part 2 of this manual and complete the corresponding homework.

Other than that, you will be ready to start enjoying the longer bottom times, shorter surface intervals and potentially greater safety margins Nitrox provides. Enjoy.

Part 2

Understanding Nitrox in Depth

As we said at the beginning of this book, dive computers provide what is not only the most convenient but, arguably, the best way for recreational Nitrox divers to plan for and track their exposure to elevated partial pressures of nitrogen and oxygen.

- The ability to accurately track multi-level dive profiles enables dive computers to provide divers with the longest bottom times and shortest surface intervals.
- Dive computers eliminate the need for divers to perform a number of complex and time-consuming nitrogen- and oxygen-exposure calculations and, in so doing, help reduce the likelihood of mathematical or other errors.

What would you do, however, if you did not have access to a dive computer? In the early days of Nitrox, dive computers were prohibitively expensive and none but the most costly models could track exposure to gas mixtures other than air. Back then, dive computers were not an option for many Nitrox divers.

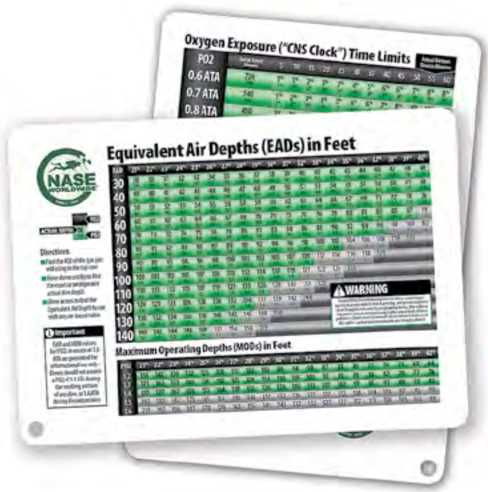
Today, a highly capable Nitrox computer can cost no more than a quality set of mask and fins ("air only" dive computers have all but vanished). So there is really no excuse for being a Nitrox diver and *not* owning at least one Nitrox-capable dive computer.

Still, circumstances can arise in which a Nitrox diver might not have a computer at his or her disposal. Batteries can die. Computers can go missing or become damaged. If something like this happens in the middle of a week-long dive vacation, you *are not* going to want to simply stop diving.

Of course, you can help avoid problems such as these by changing batteries preemptively and carrying a backup dive computer. Still, it is conceivable that, despite these precautions, you could find yourself in a situation where, in order to keep diving, you would need to be able to track exposure to nitrogen and oxygen *without* the aid of a dive computer.

Another reason you might want to know more about the underlying principles behind Nitrox diving is if you one day choose to progress to NASE technical diver training. Your entry-level tech instructor will most likely want you to have a more in-depth understanding of diving gas mixtures than is covered in the typical recreational Nitrox Diver course. He may not only expect you to be able to correctly use Equivalent Air Depth (EAD) and "CNS Clock" Exposure tables, but also be able to work a variety of mathematical formulas involving things such as MODs, best gas mix, etc.

Yet another reason you might want to know more about Nitrox diving is that you are the kind of person who simply isn't comfortable unless he knows everything there is to know about the gas he is breathing. A good analogy is that, while no one really needs to know how an internal combustion engine works in order to drive a car, a lot of us just aren't happy unless we can look at the instrument panel and understand what all of those gauges are telling us.



In this section, we get into two areas that, while not something recreational Nitrox divers using computers *need* to know, many students may find nice to know — particularly if they one day plan to get into technical diving. These are:

- Planning for and tracking exposure to elevated partial pressures of nitrogen without a dive computer.
- Doing the same thing in regard to elevated partial pressures of oxygen.

Following this section, you will find an Appendix in which we have collected all of the tables, charts and formulas you have seen throughout this manual — as well as some you may not have seen.

Section 2.1

Tracking Exposure to Nitrogen

Given a series of comparable dives, Nitrox divers are at less risk of suffering decompression sickness (DCS) than divers making the same dives on air. *Why?* Nitrox divers simply absorb less nitrogen.

This does not, however, mean that diving Nitrox eliminates all risk of DCS. In the absence of a functioning dive computer, you need to be able to track your exposure to elevated partial pressures of nitrogen using nothing more than a depth gauge, timer and dive tables.

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *What additional methods, beyond just using dive computers, are available to help Nitrox divers plan for and track their exposure to nitrogen?*
- *What limitations are associated with dedicated EAN32 and EAN36 dive tables?*
- *How do you use the NASE Equivalent Air Depth (EAD) table with air-based dive tables?*

If you can answer these questions, and master the associated knowledge and skills, you will be better prepared to dive Nitrox than divers who are utterly computer dependent.

Alternate Means of Tracking Nitrogen

If your primary dive computer fails, goes missing or is damaged, there are several fallback procedures that *may* allow you to continue diving. These include:

- *Use a back-up dive computer*: This is arguably the best option. To be able to use it, however, you not only need to have a backup computer, but take it with you on every dive, so that it is able to track the amount of residual nitrogen present in your body from prior dives. If you have access to a backup computer, but it has not been with you on every dive, you will need to wait at least twelve hours before re-entering the water.

- *Use an air-based dive table or computer:* As far as tracking exposure to nitrogen goes, using an air-based dive table or computer will not only work, it builds in a very substantial safety margin (while at the same time robbing users of Nitrox's chief benefit — longer bottom times and shorter surface intervals). Unlike most Nitrox dive computers, air computers do not track exposure to elevated partial pressures of oxygen.
- *Use the EAN32 values on the NASE Recreational Dive Tables:* Assuming you have access to a breathing mixture that is always within ±1 percent of EAN32, you can use the depth values appearing in the EAN32 column on the standard NASE Recreational Dive Table. (This will not help you, however, if your breathing mixture is substantially richer or leaner than 32 percent.)

* Start Here (Depths in Feet) Air	EAN32	A	B	C	D	E	F
40	51	5	15	25	30	40	50
50	63		10	15	25	30	40
60	75		10	15	20	25	30
70	86		5	10	15	20	30
80	98		5	10	15	20	25
90	109		5	10	12	15	20
100			5	7	10	15	20
110				5	10	13	15
120				5	10		
130				5			

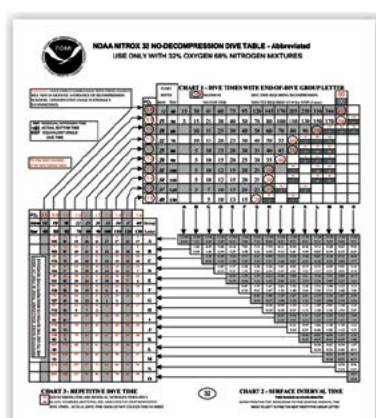
- *Use other dedicated EAN32 or EAN36 dive tables:* These are available from several sources. Using them, however, subjects you to some very serious limitations, which we will discuss in greater detail shortly.
- *Use the NASE Equivalent Air Depth (EAD) chart in conjunction with any air-based dive table:* Of all the methods outlined thus far (other than having a backup Nitrox computer), this is the most flexible. It works with any gas mix from EAN22 to EAN40. It also works with any air-based dive table, so you don't need to re-learn a new air table to use it. We will discuss using the EAD table in greater depth shortly.
- *Use desktop decompression software:* Desktop decompression software is a staple in technical diving. Many technical diving courses revolve around its proper use. Among other things, desktop deco software can generate custom dive tables to cover a variety of gas mixtures and situations. Its use, however, is much more suited to technical than recreational diving. For now it is enough to simply know that this software exists, and that it is something you needn't concern yourself with unless you one day progress to technical diver training.

Things to bear in mind when switching *from* a Nitrox dive computer to another method: The chief reason you, as a recreational Nitrox diver, would likely need to use any of the methods outlined above is that you are dealing with primary dive computer loss or failure. If this is the case, there are some things you need to keep in mind:

- *Unless a minimum of twelve hours has passed since your last dive, you need to be able to track exposure to residual nitrogen:* In other words, if you are switching to a dive table, you need to be able to go back, see where your previous dives would put you on the dive table you are switching to, and continue from there. Bear in mind, if you were using a dive computer, your prior dives may not fall within dive table limits (even though they were well within the computer's no-stop dive times). If this is the case, or you simply don't have a record of the precise starting times, ending times and depths of your prior dives, you are going to have to wait twelve or more hours for all residual nitrogen to clear from your system. Similarly, if switching to another computer, you will also have to wait at least twelve hours unless that computer has been with you on every dive.
- *You also need to be able to track your prior and continuing exposure to elevated partial pressures of oxygen:* How you can do so is covered in the next section.

Using Dedicated EAN32/EAN36 Dive Tables

You may have seen dedicated EAN32 or EAN36 dive tables that are available from a variety of sources. (NASE does not have a dedicated EAN32 table, but rather includes an EAN32 column on its regular Recreational Dive Tables.) As long as your breathing mix is within ±1 percent of either of these values, you can theoretically use these tables to plan for and track nitrogen exposure. Doing so, however, may present you with some serious limitations.



- *They only work for specific gases:* If your gas is not within ±1 percent of EAN32 or EAN36, neither of these tables will do you any good.
- *They may not be based on dive tables you already know:* If the dedicated EAN32/EAN36 tables are not based on

an air dive table with which you are already familiar, they may be confusing.

- *They may have issues with accuracy:* Many dedicated Nitrox dive tables are based on the decades-old NOAA Nitrox I and II tables. These were created in an era before digital gauges, and have values that have been forcibly rounded to the next deeper 3 m/10 ft increment, leading to NDLs that may be overly conservative at some depths, but not so at others. These tables, however, do not have the overall conservatism built into them that most recreational dive tables.

Old Gauges Calibration in Ten-Foot increments

The better, more accurate choice is to use the NASE Equivalent Air Depth (EAD) Table in conjunction with whatever air dive table you already know and are comfortable using.

Using the NASE Equivalent Air Depth (EAD) Table

The NASE Equivalent Air Depth (EAD) Table offers three distinct advantages over most dedicated EAN32 and EAN36 dive tables.

- It works with any recreational Nitrox mixture: EAN22 through EAN40.
- It contains additional information generally not found on dedicated EAN32/EAN36 tables: This includes PO_2s, MODs and "CNS clock" data.
- You can use the EAD table with any air-based dive table; there is no need to learn a brand-new set of air dive tables.

Using the NASE EAD Table is easy:

- *Start with the top row:* Find the FO_2 column that corresponds to the gas mixture used.
- *Find your depth:* Move down the column until you find the exact or next greater depth reached during the dive.
- *Find the Equivalent Air Depth:* Read across to the far left-hand column to find the Equivalent Air Depth you will use in conjunction with your air-based dive tables.

EAD	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
30	30	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	46	47	48	49
40	40	40	41	42	43	44	46	47	48	49	50	51	53	54	55	57	58	60	61	63
50	50	51	52	53	54	55	56	58	59	60	62	63	64	66	67	69	71	72	74	76
60	60	61	62	63	64	66	67	69	70	71	73	75	76	78	80	81	83	85	87	89
70	70	71	72	74	75	76	78	80	81	83	84	86	88	90	92	94	96	98	100	102
80	80	81	82	84	86	87	89	90	92	94	96	98	100	102	104	106	108	110	113	
90	90	91	93	94	96	98	100	101	103	105	107	109	112	114	116	118	121			
100	100	101	103	105	107	108	110	112	114	117	119	121	123	126	128					
110	110	111	113	115	117	119	121	123	126	128	130	133	135							
120	120	121	123	126	128	130	132	134	137	139	142	144								
130	130	132	134	136	138	141	143	145	148	150										
140	140	142	144	146	149	151	154	156	159											

Key Points to Remember From This Unit

- If you can't use a dedicated Nitrox computer as your primary dive planning tool (or that computer fails or goes missing), you can, as an alternative: track your exposure to nitrogen using a backup Nitrox computer; an air-based dive table or computer; dedicated EAN32/36 dive tables; or, the NASE Equivalent Air Depth Table.
- Remember that dedicated EAN32/EAN36 dive tables: may only work with with specific gas mixes; may not be based on air tables you are familiar with; may not be totally accurate; and, may not have any overall built-in conservatism.
- To use the NASE Equivalent Air Depth (EAD) table: find the column for the gas mixture used; move down to find the exact or next deeper maximum dive depth; move across to find the Equivalent Air Depth (EAD) value to use with the air dive table of your choice.

Section 2.2

Tracking Exposure to Oxygen

Without a computer, divers using air have their hands full just planning for and tracking their exposure to elevated partial pressures of nitrogen. When you add Nitrox to the equation, this process becomes even more complex. Fortunately, there is at least one alternative that can greatly simplify things.

What to Look For

As you read through this section, highlight or underline the answers to the following:

- *If unable to use a dive computer to track exposure to oxygen, what is the simplest and easiest-to-use alternative?*
- *What must divers who cannot use a dive computer to track exposure to oxygen, or remain within a Limiting PO_2 of 1.4 ATA, be able to do to accurately track their exposure to oxygen?*
- *How do you use the NASE Oxygen Exposure Time Limits table to perform a series of "CNS Clock" calculations?*

If you can answer these questions, and master the associated knowledge and skills, the lack of a Nitrox-compatible dive computer may make life more complicated — but it won't necessarily prevent you from getting everything Nitrox can offer you.

The Easiest Way to Track Oxygen Exposure

As long as you remain within a limiting PO_2 of 1.4 ATA, there is a simple method that can make staying within safer oxygen limits easy. If you consult the NOAA Oxygen Time Limits table, you will see that the single-dive limit for a PO2 of 1.4 ATA is 150 minutes. *That's two and a half hours.*

PO2s	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Single-Dive Limit	720	540	450	360	300	240	210	180	150	120	45
24-Hour Limit	720	540	450	360	300	270	240	210	180	180	150

Not only is it extremely unlikely that you would make a single dive that would exceed this limit, it's almost equally as unlikely that any series of no-decompression dives with PO_2s greater than 0.5 ATA would exceed 150 minutes of Actual Bottom Time (ABT) in any 24-hour period.

PO2s	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Single-Dive Limit	720	540	450	360	300	240	210	180	150	120	45
24-Hour Limit	720	540	450	360	300	270	240	210	180	180	150

The bottom line is that, as long as you remain within a limiting PO_2 of 1.4 ATA, stay within the no-decompression limits (NDLs) and make no more than the generally recommended three to four dives a day (with the latter dives being noticeably shallower), you will have little to worry about.

Manually Tracking "CNS Clock" Exposures

Among the many arguments for staying well within a limiting PO_2 of 1.4 ATA is the fact that, once you exceed this value, your oxygen time limit decreases sharply. As an example, the NOAA single-dive time limit for 1.6 ATA is just 45 minutes — less than a third of the limit for a PO_2 of 1.4 ATA.

Technical divers routinely use a limiting PO_2 of 1.6 ATA for decompression. A recreational diver could conceivably exceed a limiting PO_2 of 1.4 ATA accidentally. In either instance, unless you have a Nitrox-capable dive computer that can track your oxygen exposure for you, you are going to need a means to do so manually.

> The good news here is that, unless you get into multi-day technical and/or rebreather diving, you will not have to track what are known as *Oxygen Tolerance Units* or *OTU*s. These are used to help technical divers prevent pulmonary or "whole body" oxygen toxicity — which fortunately, is of little concern to recreational divers.

What recreational divers need to concern themselves with is preventing Central Nervous System (CNS) oxygen toxicity. To do so, we use what are commonly called "CNS Clock" calculations. You can do this using the NASE CNS Clock table.

Using the NASE CNS Clock Table: The CNS Clock table is designed to help you determine what percentage of your theoretical single-dive exposure limit you consumed on any individual dive. Using the table is easy:

- Start by finding the maximum PO_2 reached during the dive in the left-hand column.
- Read across until you find a column whose time meets or just exceeds the Actual Bottom Time (ABT) for the dive.

In this box you will find two values:

- The topmost and larger number will be the percentage of your single-dive oxygen exposure limit you consumed during the dive.
- The smaller number at the bottom will be the percentage of your 24-hour oxygen exposure limit you consumed.

Oxygen Exposure ("CNS Clock") Time Limits

Actual Bottom Time in Minutes

PO2	Total Limit (Minutes)	5	10	15	20	25	30	35	40	45	50	55	60
0.6 ATA	720 / 720	1% / 1%	1% / 1%	2% / 2%	3% / 3%	3% / 3%	4% / 4%	5% / 5%	6% / 6%	6% / 6%	7% / 7%	8% / 8%	8% / 8%
0.7 ATA	540 / 540	1% / 1%	2% / 2%	3% / 3%	4% / 4%	5% / 5%	6% / 6%	6% / 6%	7% / 7%	8% / 8%	9% / 9%	10% / 10%	11% / 11%
0.8 ATA	450 / 450	1% / 1%	2% / 2%	3% / 3%	4% / 4%	6% / 6%	7% / 7%	8% / 8%	9% / 9%	10% / 10%	11% / 11%	12% / 12%	13% / 13%
0.9 ATA	360 / 360	1% / 1%	3% / 3%	4% / 4%	6% / 6%	7% / 7%	8% / 8%	10% / 10%	11% / 11%	13% / 13%	14% / 14%	15% / 15%	17% / 17%
1.0 ATA	300 / 300	2% / 2%	3% / 3%	5% / 5%	7% / 7%	8% / 8%	10% / 10%	12% / 12%	13% / 13%	15% / 15%	17% / 17%	18% / 18%	20% / 20%
1.1 ATA	240 / 270	2% / 2%	4% / 4%	6% / 6%	8% / 7%	10% / 9%	13% / [illegible]	15% / 13%	17% / 15%	19% / 17%	21% / 19%	23% / 20%	25% / 22%
1.2 ATA	210 / 240	2% / 2%	5% / 4%	7% / 6%	10% / 8%	12% / 10%	14% / [illegible]	17% / 15%	19% / 17%	21% / 19%	24% / 21%	26% / 23%	29% / 25%
1.3 ATA	180 / 210	3% / [illegible]	6% / [illegible]	8% / 7%	11% / 10%	14% / [illegible]	17% / 14%	19% / 17%	22% / 19%	25% / 21%	28% / 24%	31% / 26%	33% / 29%
1.4 ATA	150 / 180	3% / 3%	7% / 6%	10% / 8%	13% / 11%	17% / 14%	20% / 17%	23% / 19%	27% / 22%	30% / 25%	33% / 28%	37% / 31%	40% / 33%

Do this for every dive in which you exceed a limiting PO_2 of 0.5 ATA. The total percentage consumed during any 24-hour period should not be allowed to exceed 100 percent.

What about surface interval credit? It's important to understand that, unlike nitrogen and other inert gases, your body does not "in gas" oxygen during dives and "off gas" it during surface intervals. What does happen during surface intervals is that your body recovers, at least somewhat, from the adverse chemical effects of exposure to elevated partial pressures of oxygen.

A widely-held assumption is that the cumulative effect of oxygen exposure reduces itself by one half for every 90 minutes of surface interval. In other words, if you had consumed 50 percent of your theoretical "CNS Clock" at the end of a particular dive, then waited at least 90 minutes before making another dive, it would be as though you'd only consumed 25 percent of your single-dive oxygen exposure limit.

The table shown here depicts a theoretical "CNS Clock" Surface Interval Credit table. Technical divers use tables like this one when planning and making a series of dives with high PO_2 levels.

Starting CNS%	0:00 0:29	0:30 0:59	1:00 1:29	1:30 1:59	2:00 2:59	3:00 3:59	4:00 5:59	6:00 8:59
10%	10%	8%	6%	5%	4%	3%	2%	1%
20%	20%	16%	13%	10%	8%	5%	3%	1%
30%	30%	24%	19%	15%	12%	8%	5%	2%
40%	40%	32%	25%	20%	16%	10%	6%	2%
50%	50%	40%	32%	25%	20%	13%	8%	3%
55%	55%	44%	35%	28%	22%	14%	9%	3%
60%	60%	48%	38%	30%	24%	15%	10%	4%
65%	65%	52%	41%	33%	26%	16%	10%	4%
70%	70%	56%	44%	35%	28%	18%	11%	4%
75%	75%	60%	47%	38%	30%	19%	12%	5%
80%	80%	64%	50%	40%	32%	20%	13%	5%
85%	85%	68%	54%	43%	34%	21%	14%	5%
90%	90%	72%	57%	45%	36%	23%	14%	5%
95%	95%	76%	60%	48%	38%	24%	15%	6%
100%	100%	80%	63%	50%	40%	25%	16%	6%

You have probably noticed that, when talking about "CNS Clock" exposures, we use the word *theoretical* a lot. That's because the assumptions regarding oxygen exposure are just that — *theoretical*. They have not received the same level of empirical testing common to dive tables and decompression algorithms. Because of this, there are no guarantees. Use caution and avoid pushing limits.

Try This: Plan a series of three no-decompression dives in which you approach a limiting PO_2 of 1.4 ATA, such as you might make off a liveaboard dive vessel. See how much of your theoretical "CNS Clock" you consume on each dive, and what the total for the three dives would be. What you will discover is that, as long as you stay within a limiting PO_2 of 1.4 ATA, and don't exceed the no-decompression limits, it is almost impossible to exceed even your single-dive oxygen exposure limit.

Even if you could make three 50-minute dives in which you hit a maximum PO_2 exposure of 1.4 ATA, you would still only meet the single-dive oxygen exposure limit of 150 minutes. The only way you could do that without exceeding the no-deco limits is to make multilevel dives using a computer. In this case, your computer would give you credit for the shallower portions of each dive, during which your oxygen exposure would be reduced. The bottom line: It is almost impossible to exceed your CNS limits on recreational dives if you stay within a limiting PO_2 of 1.4 ATA.

In other words, everything we just covered in terms of using "CNS Clock" and CNS Surface Interval Credit tables really only applies to technical and/or rebreather divers. Recreational divers would only have to concern themselves with this if they accidentally exceeded a limiting PO_2 of 1.4 ATA and they lacked a dive computer to track their oxygen exposure.

Nevertheless, it is a nice thing to know, if only from a theoretical standpoint. And, if you one day progress to technical diving, this information is going to be much more important.

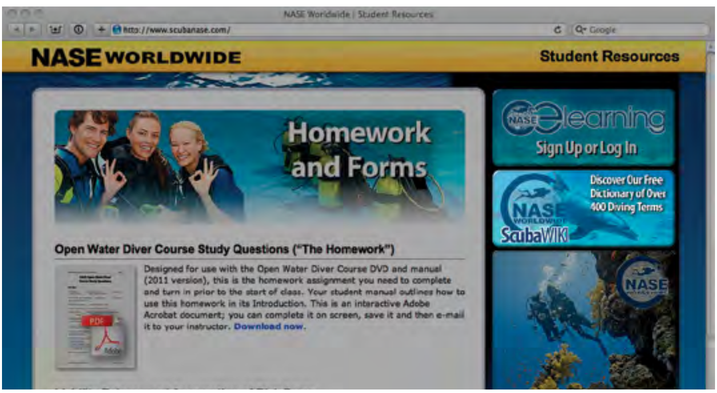
Key Points to Remember From This Section

- If you don't have access to a Nitrox-capable dive computer, the easiest way to stay within safer oxygen-exposure limits is to keep within a limiting PO_2 of 1.4 ATA and keep your accumulated Actual Bottom Times (ABTs) for any 24-hour period to 150 minutes or less.
- If you do exceed these limits, and don't have a computer tracking this for you, you are going to have to do a series of "CNS Clock" calculations.
- To do this, use the CNS Clock table to find out the percentage of your single-dive oxygen exposure limit consumed on each individual dive in a series, then make certain that the total for any 24-hour period does not exceed 100 percent.

Appendix I

Glossary and External Links

NASE Worldwide maintains a comprehensive glossary of scuba terminology — including all of the terms defined in this book — at *www.ScubaNASE.com*. When you arrive at the home page, you will see the link for the NASE ScubaWIKI.



Clicking on this link will take you to the Wiki.

You will also find links to information on DAN's and other websites that can provide you with even more information.

Appendix 2

Tables and Charts

In this Appendix, you will find a compilation of all of the tables and charts appearing throughout the book.

Partial Pressures of Oxygen

This table shows the Partial Pressures of Oxygen (PO_2) found at various depths, based on the concentration of oxygen (FO_2) in the breathing mixture.

M	Ft	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
9	30	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8
12	40	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.9	0.9
15	50	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0
18	60	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1
21	70	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.2
24	80	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4
27	90	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5
30	100	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.5	1.6	1.6
33	110	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.6	1.7	1.7
36	120	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9
39	130	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0
42	140	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1

Maximum Operating Depths (MODs) (Metric)

Based on the concentration of oxygen (FO_2) in the breathing mixture.

PO2	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
1.2 ATA	47	44	42	40	38	36	34	32	31	30	28	27	26	25	24	23	22	21	20	20
1.3 ATA	51	49	46	44	42	40	38	36	34	33	31	30	29	28	27	26	25	24	23	22
1.4 ATA	56	53	50	48	46	43	41	40	38	36	35	33	32	31	30	28	27	26	25	25
1.5 ATA	61	58	55	52	50	47	45	43	41	40	38	36	35	34	32	31	30	29	28	27
1.6 ATA	66	62	59	56	54	51	49	47	45	43	41	40	38	37	35	34	33	32	31	30

Maximum Operating Depths (MODs) (Imperial)

Based on the concentration of oxygen (FO_2) in the breathing mixture.

PO2	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
1.2 ATA	155	147	139	132	125	119	113	108	103	99	94	90	87	83	80	77	74	71	68	66
1.3 ATA	171	162	153	145	138	132	125	120	114	110	105	101	97	93	89	86	82	79	77	74
1.4 ATA	187	177	167	159	151	144	138	132	126	121	116	111	107	102	99	95	91	88	85	82
1.5 ATA	202	192	182	173	165	157	150	143	137	132	126	121	117	112	108	104	100	97	93	90
1.6 ATA	218	207	196	187	178	170	162	155	149	143	137	132	127	122	117	113	109	105	102	99

Oxygen Time Limits

Based on the NOAA *Oxygen Time Limits for Working Divers*.

PO2s	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Single-Dive Limit	720	540	450	360	300	240	210	180	150	120	45
24-Hour Limit	720	540	450	360	300	270	240	210	180	180	150

NASE “CNS Clock” Table (Next Page)

The percentage of single-dive and 24-hour time limits consumed on any given dive, based on PO_2.

Oxygen Exposure ("CNS Clock") Time Limits

Actual Bottom Time in Minutes

PO2	Total Limit (Minutes)	5	10	15	20	25	30	35	40	45	50	55	60
0.6 ATA	720 / 720	1% / 1%	1% / 1%	2% / 2%	3% / 3%	3% / 3%	4% / 4%	5% / 5%	6% / 6%	6% / 6%	7% / 7%	8% / 8%	8% / 8%
0.7 ATA	540 / 540	1% / 1%	2% / 2%	3% / 3%	4% / 4%	5% / 5%	6% / 6%	6% / 6%	7% / 7%	8% / 8%	9% / 9%	10% / 10%	11% / 11%
0.8 ATA	450 / 450	1% / 1%	2% / 2%	3% / 3%	4% / 4%	6% / 6%	7% / 7%	8% / 8%	9% / 9%	10% / 10%	11% / 11%	12% / 12%	13% / 13%
0.9 ATA	360 / 360	1% / 1%	3% / 3%	4% / 4%	6% / 6%	7% / 7%	8% / 8%	10% / 10%	11% / 11%	13% / 13%	14% / 14%	15% / 15%	17% / 17%
1.0 ATA	300 / 300	2% / 2%	3% / 3%	5% / 5%	7% / 7%	8% / 8%	10% / 10%	12% / 12%	13% / 13%	15% / 15%	17% / 17%	18% / 18%	20% / 20%
1.1 ATA	240 / 270	2% / 2%	4% / 4%	6% / 6%	8% / 7%	10% / 9%	13% / 11%	15% / 13%	17% / 15%	19% / 17%	21% / 19%	23% / 20%	25% / 22%
1.2 ATA	210 / 240	2% / 2%	5% / 4%	7% / 6%	10% / 8%	12% / 10%	14% / 13%	17% / 15%	19% / 17%	21% / 19%	24% / 21%	26% / 23%	29% / 25%
1.3 ATA	180 / 210	3% / 2%	6% / 5%	8% / 7%	11% / 10%	14% / 12%	17% / 14%	19% / 17%	22% / 19%	25% / 21%	28% / 24%	31% / 26%	33% / 29%
1.4 ATA	150 / 180	3% / 3%	7% / 6%	10% / 8%	13% / 11%	17% / 14%	20% / 17%	23% / 19%	27% / 22%	30% / 25%	33% / 28%	37% / 31%	40% / 33%
1.5 ATA	120 / 180	4% / 3%	8% / 6%	13% / 8%	17% / 11%	21% / 14%	25% / 17%	29% / 19%	33% / 22%	38% / 25%	42% / 28%	46% / 31%	50% / 33%
1.6 ATA	45 / 150	11% / 3%	22% / 7%	33% / 10%	44% / 13%	56% / 17%	67% / 20%	78% / 23%	89% / 27%	100% / 30%	33%	37%	40%

Directions

- This table allows you to determine the percentage of your total oxygen exposure limit you have used on any single dive.
- To do so, start by finding the partial pressure of oxygen (PO2) you experienced at the deepest point of your dive in the left-hand column (see the EAD table on the reverse side if you need to find the PO2 value).
- Move across horizontally until you find the column that meets or just exceeds the length of the dive, in minutes.
- The numbers in each box represent the percentage of the total time limit you used during the dive.

10% / 10%	Single Dive % / 24-Hour %

- You can combine percentage values from different columns to determine totals that exceed 60 minutes. For example, for a 65-minute dive, add the percentages from the 60 and 5 minute columns.
- The most common procedure for recreational divers is to ensure that the combined single-dive percentages of a series of dives within a 24-hour period does not exceed 100 percent (this will be easy if you remain within a limiting PO2 of 1.4 ATA).
- For dives separated by long surface intervals, it may be possible to reduce some of the oxygen time limit used on previous dives. Consult Part II of the NASE *Nitrox Diver* manual for more information.

⚠ WARNING

Susceptibility to both decompression sickness and oxygen toxicity may vary widely from day to day, and person to person • Even though used correctly, no planning device, dive table or computer can guarantee you won't suffer one or both of these problems • Divers must assume all risks associated with use of this table • Caution and conservatism are strongly advised

ℹ Important

EAD and MOD values for PO2s in excess of 1.6 ATA are presented for informational use only • Divers should not exceed a PO2 of 1.4 ATA during the working portion of any dive, or 1.6 ATA during decompression

NASE WORLDWIDE SINCE 1982

CNS Surface Interval Credit Table

Based on a theoretical half time of 90 minutes.

Starting CNS%	0:00 0:29	0:30 0:59	1:00 1:29	1:30 1:59	2:00 2:59	3:00 3:59	4:00 5:59	6:00 8:59
10%	10%	8%	6%	5%	4%	3%	2%	1%
20%	20%	16%	13%	10%	8%	5%	3%	1%
30%	30%	24%	19%	15%	12%	8%	5%	2%
40%	40%	32%	25%	20%	16%	10%	6%	2%
50%	50%	40%	32%	25%	20%	13%	8%	3%
55%	55%	44%	35%	28%	22%	14%	9%	3%
60%	60%	48%	38%	30%	24%	15%	10%	4%
65%	65%	52%	41%	33%	26%	16%	10%	4%
70%	70%	56%	44%	35%	28%	18%	11%	4%
75%	75%	60%	47%	38%	30%	19%	12%	5%
80%	80%	64%	50%	40%	32%	20%	13%	5%
85%	85%	68%	54%	43%	34%	21%	14%	5%
90%	90%	72%	57%	45%	36%	23%	14%	5%
95%	95%	76%	60%	48%	38%	24%	15%	6%
100%	100%	80%	63%	50%	40%	25%	16%	6%

Equivalent Air Depths (Metric)

Based on the concentration of oxygen (FO_2) in the breathing mixture.

EAD	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
9	9	9	9	9	10	10	10	10	11	11	11	12	12	12	13	13	13	14	14	15
12	12	12	12	12	13	13	13	14	14	14	15	15	15	16	16	17	17	18	18	18
15	15	15	15	15	16	16	17	17	17	18	18	19	19	19	20	20	21	21	22	22
18	18	18	18	19	19	19	20	20	21	21	22	22	23	23	24	24	25	25	26	26
21	21	21	21	22	22	23	23	24	24	24	25	26	26	27	27	28	28	29	30	30
24	24	24	24	25	25	26	26	27	27	28	28	29	30	30	31	31	32	33		
27	27	27	27	28	28	29	30	30	31	31	32	32	33	34	34	35				
30	30	30	31	31	32	32	33	33	34	35	35	36	37	37	38					
33	33	33	34	34	35	35	36	37	37	38	39	39	40							
36	36	36	37	37	38	39	39	40	41	41	42	43								
39	39	39	40	40	41	42	43	43	44	45										
42	42	42	43	44	44	45	46	47	47											

Equivalent Air Depths (Imperial)

Based on the concentration of oxygen (FO_2) in the breathing mixture.

EAD	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
30	30	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	46	47	48	49
40	40	40	41	42	43	44	46	47	48	49	50	51	53	54	55	57	58	60	61	63
50	50	51	52	53	54	55	56	58	59	60	62	63	64	66	67	69	71	72	74	76
60	60	61	62	63	64	66	67	69	70	71	73	75	76	78	80	81	83	85	87	89
70	70	71	72	74	75	76	78	80	81	83	84	86	88	90	92	94	96	98	100	102
80	80	81	82	84	86	87	89	90	92	94	96	98	100	102	104	106	108	110	113	
90	90	91	93	94	96	98	100	101	103	105	107	109	112	114	116	118	121			
100	100	101	103	105	107	108	110	112	114	117	119	121	123	126	128					
110	110	111	113	115	117	119	121	123	126	128	130	133	135							
120	120	121	123	126	128	130	132	134	137	139	142	144								
130	130	132	134	136	138	141	143	145	148	150										
140	140	142	144	146	149	151	154	156	159											

NASE Equivalent Air Depth and MOD Table (Metric)

Waterproof version available from NASE Worldwide.

NASE WORLDWIDE SINCE 1982

F02
ACTUAL DEPTH 00 0.0 P02

Directions

- Find the F02 of the gas you will using in the top row
- Move down until you find the exact or next greater actual dive depth
- Move across to find the Equivalent Air Depth to use with any air-based table

Important

EAD and MOD values for P02s in excess of 1.6 ATA are presented for informational use only • Divers should not exceed a P02 of 1.4 ATA during the working portion of any dive, or 1.6 ATA during decompression

Equivalent Air Depths (EADs) in Meters

EAD	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
9	9 0.4	9 0.5	9 0.5	9 0.5	10 0.5	10 0.6	10 0.6	10 0.6	11 0.7	11 0.7	11 0.7	12 0.8	12 0.8	12 0.8	13 0.9	13 0.9	13 0.9	14 1.0	14 1.0	15 1.0
12	12 0.5	12 0.5	12 0.6	12 0.6	13 0.6	13 0.6	13 0.7	14 0.7	14 0.7	14 0.8	15 0.8	15 0.8	15 0.9	16 0.9	16 1.0	17 1.0	17 1.0	18 1.1	18 1.1	18 1.2
15	15 0.6	15 0.6	15 0.6	15 0.6	16 0.7	16 0.7	17 0.8	17 0.8	17 0.8	18 0.9	18 0.9	19 1.0	19 1.0	19 1.0	20 1.1	20 1.1	21 1.2	21 1.2	22 1.3	22 1.3
18	18 0.6	18 0.7	18 0.7	19 0.7	19 0.8	19 0.8	20 0.9	20 0.9	21 0.9	21 1.0	22 1.0	22 1.1	23 1.1	23 1.2	24 1.2	24 1.3	25 1.3	25 1.4	26 1.5	26 1.5
21	21 0.7	21 0.7	21 0.8	22 0.8	22 0.8	23 0.9	23 0.9	24 1.0	24 1.0	24 1.1	25 1.1	26 1.2	26 1.2	27 1.3	27 1.3	28 1.4	28 1.5	29 1.5	30 1.6	30 1.6
24	24 0.8	24 0.8	24 0.8	25 0.9	25 0.9	26 1.0	26 1.0	27 1.1	27 1.1	28 1.2	28 1.2	29 1.3	30 1.4	30 1.4	31 1.5	31 1.5	32 1.6	33 1.7	34 1.8	34 1.8
27	27 0.8	27 0.9	27 0.9	28 1.0	28 1.0	29 1.1	30 1.1	30 1.2	31 1.2	31 1.3	32 1.4	32 1.4	33 1.5	34 1.5	34 1.6	35 1.7	36 1.8			
30	30 0.9	30 0.9	31 1.0	31 1.0	32 1.1	32 1.1	33 1.2	33 1.3	34 1.3	35 1.4	35 1.4	36 1.5	37 1.6	37 1.6	38 1.7	39 1.8				
33	33 1.0	33 1.0	34 1.1	34 1.1	35 1.2	35 1.2	36 1.3	37 1.4	37 1.4	38 1.5	39 1.6	39 1.6	40 1.7							
36	36 1.0	36 1.1	37 1.1	37 1.2	38 1.2	39 1.3	39 1.4	40 1.4	41 1.5	41 1.6	42 1.7	43 1.7								
39	39 1.1	39 1.1	40 1.2	40 1.2	41 1.3	42 1.4	43 1.5	43 1.5	44 1.6	45 1.7										
42	42 1.1	42 1.2	43 1.3	44 1.3	44 1.4	45 1.5	46 1.6	47 1.6	47 1.7											

WARNING

Susceptibility to both decompression sickness and oxygen toxicity may vary widely from day to day, and person to person • Even though used correctly, no planning device, dive table or computer can guarantee you won't suffer one or both of these problems • Divers must assume all risks associated with use of this table • Caution and conservatism are strongly advised

Maximum Operating Depths (MODs) in Meters

P02	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
1.2	47	44	42	40	38	36	34	32	31	30	28	27	26	25	24	23	22	21	20	20
1.3	51	49	46	44	42	40	38	36	34	33	31	30	29	28	27	26	25	24	23	22
1.4	56	53	50	48	46	43	41	40	38	36	35	33	32	31	30	28	27	26	25	25
1.5	61	58	55	52	50	47	45	43	41	40	38	36	35	34	32	31	30	29	28	27
1.6	66	62	59	56	54	51	49	47	45	43	41	40	38	37	35	34	33	32	31	30

NASE Equivalent Air Depth and MOD Table (Imperial)

Waterproof version available from NASE Worldwide.

NASE WORLDWIDE SINCE 1982

ACTUAL DEPTH 00 (F02) 0.0 (P02)

Directions

- Find the F02 of the gas you will using in the top row
- Move down until you find the exact or next greater actual dive depth
- Move across to find the Equivalent Air Depth to use with any air-based table

Important

EAD and MOD values for P02s in excess of 1.6 ATA are presented for informational use only • Divers should not exceed a P02 of 1.4 ATA during the working portion of any dive, or 1.6 ATA during decompression

Equivalent Air Depths (EADs) in Feet

EAD	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
30	30 0.5	30 0.5	31 0.5	32 0.5	33 0.5	34 0.6	35 0.6	36 0.6	37 0.7	38 0.7	39 0.7	40 0.8	41 0.8	42 0.8	43 0.9	44 0.9	46 0.9	47 1.0	48 1.0	49 1.0
40	40 0.5	40 0.5	41 0.6	42 0.6	43 0.6	44 0.7	46 0.7	47 0.7	48 0.8	49 0.8	50 0.8	51 0.9	53 0.9	54 0.9	55 1.0	57 1.0	58 1.1	60 1.1	61 1.2	63 1.2
50	50 0.6	51 0.6	52 0.6	53 0.7	54 0.7	55 0.7	56 0.8	58 0.8	59 0.9	60 0.9	62 0.9	63 1.0	64 1.0	66 1.1	67 1.1	69 1.2	71 1.2	72 1.3	74 1.3	76 1.4
60	60 0.6	61 0.7	62 0.7	63 0.7	64 0.8	66 0.8	67 0.9	69 0.9	70 1.0	71 1.0	73 1.0	75 1.1	76 1.1	78 1.2	80 1.2	81 1.3	83 1.4	85 1.4	87 1.5	89 1.5
70	70 0.7	71 0.7	72 0.8	74 0.8	75 0.9	76 0.9	78 1.0	80 1.0	81 1.1	83 1.1	84 1.1	86 1.2	88 1.3	90 1.3	92 1.4	94 1.4	96 1.5	98 1.6	100 1.6	102 1.7
80	80 0.8	81 0.8	82 0.9	84 0.9	86 1.0	87 1.0	89 1.0	90 1.1	92 1.1	94 1.2	96 1.3	98 1.3	100 1.4	102 1.4	104 1.5	106 1.6	108 1.6	110 1.7		
90	90 0.8	91 0.9	93 0.9	94 1.0	96 1.0	98 1.1	100 1.1	101 1.2	103 1.2	105 1.3	107 1.4	109 1.4	112 1.5	114 1.6	116 1.6	118 1.7				
100	100 0.9	101 0.9	103 1.0	105 1.1	107 1.1	108 1.2	110 1.2	112 1.3	114 1.3	117 1.4	119 1.5	121 1.5	123 1.6	126 1.7						
110	110 1.0	111 1.0	113 1.1	115 1.1	117 1.2	119 1.2	121 1.3	123 1.4	126 1.4	128 1.5	130 1.6	133 1.7								
120	120 1.0	121 1.1	123 1.1	126 1.2	128 1.3	130 1.3	132 1.4	134 1.5	137 1.5	139 1.6	142 1.7									
130	130 1.1	132 1.1	134 1.2	136 1.3	138 1.3	141 1.4	143 1.5	145 1.6	148 1.6	150 1.7										
140	140 1.2	142 1.2	144 1.3	146 1.4	149 1.4	151 1.5	154 1.6	156 1.7												

WARNING

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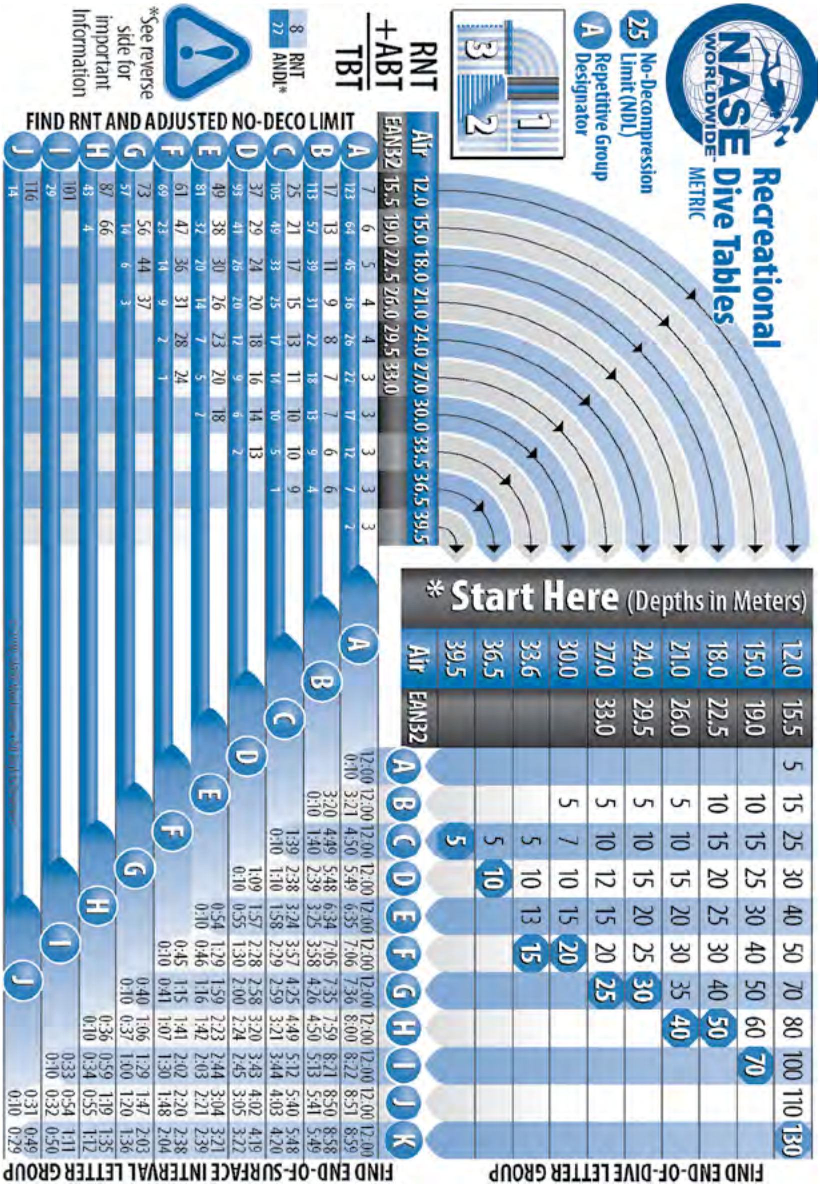
Maximum Operating Depths (MODs) in Feet

P02	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
1.2	155	147	139	132	125	119	113	108	103	99	94	90	87	83	80	77	74	71	68	66
1.3	171	162	153	145	138	132	125	120	114	110	105	101	97	93	89	86	82	79	77	74
1.4	187	177	167	159	151	144	138	132	126	121	116	111	107	102	99	95	91	88	85	82
1.5	202	192	182	173	165	157	150	143	137	132	126	121	117	112	108	104	100	97	93	90
1.6	218	207	196	187	178	170	162	155	149	143	137	132	127	122	117	113	109	105	102	99

NASE Recreational Dive Table (Metric)

Waterproof version available from NASE Worldwide.



NASE Recreational Dive Table (Imperial)

Waterproof version available from NASE Worldwide.

NASE Worldwide
Recreational Dive Tables
IMPERIAL

25 No-Decompression Limit (NDL)

A Repetitive Group Designator

* Start Here (Depths in Feet)

FIND END-OF-DIVE LETTER GROUP

Air	EAN32	A	B	C	D	E	F	G	H	I	J	K
40	51	5	15	25	30	40	50	70	80	100	110	130
50	63		10	15	25	30	40	50	60	70		
60	75		10	15	20	25	30	40	50			
70	86		5	10	15	20	30	35	40			
80	98		5	10	15	20	25	30				
90	109		5	10	12	15	20	25				
100			5	7	10	15	20					
110				5	10	13	15					
120				5	10							
130				5								

FIND END-OF-SURFACE INTERVAL LETTER GROUP

	A	B	C	D	E	F	G	H	I	J	K
A	12:00 0:10	12:00 3:21	12:00 4:50	12:00 5:49	12:00 6:35	12:00 7:06	12:00 7:36	12:00 8:00	12:00 8:22	12:00 8:51	12:00 8:59
B		3:20 0:10	4:49 1:40	5:48 2:39	6:34 3:25	7:05 3:58	7:35 4:26	7:59 4:50	8:21 5:13	8:50 5:41	8:58 5:49
C			1:39 0:10	2:38 1:10	3:24 1:58	3:57 2:29	4:25 2:59	4:49 3:21	5:12 3:44	5:40 4:03	5:48 4:20
D				1:09 0:10	1:57 0:55	2:28 1:30	2:58 2:00	3:20 2:24	3:43 2:45	4:02 3:05	4:19 3:22
E					0:54 0:10	1:29 0:46	1:59 1:16	2:23 1:42	2:44 2:03	3:04 2:21	3:21 2:39
F						0:45 0:10	1:15 0:41	1:41 1:07	2:02 1:30	2:20 1:48	2:38 2:04
G							0:40 0:10	1:06 0:37	1:29 1:00	1:47 1:20	2:03 1:36
H								0:36 0:10	0:59 0:34	1:19 0:55	1:35 1:12
I									0:33 0:10	0:54 0:32	1:11 0:50
J										0:31 0:10	0:49 0:29

RNT
+ABT
TBT

8 RNT
22 ANDL*

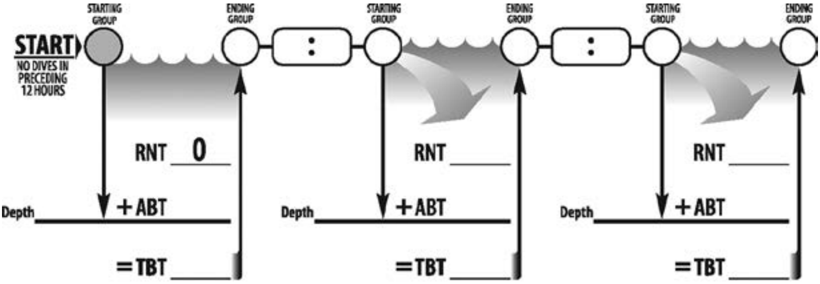
*See reverse side for important Information

FIND RNT AND ADJUSTED NO-DECO LIMIT

	Air 40 EAN32 51	50 63	60 75	70 86	80 98	90 109	100	110	120	130
A	7 123	6 64	5 45	4 36	4 26	3 22	3 17	3 12	3 7	3 2
B	17 113	13 57	11 39	9 31	8 22	7 18	7 13	6 9	6 4	
C	25 105	21 49	17 33	15 25	13 17	11 14	10 10	10 5	9 1	
D	37 93	29 41	24 26	20 20	18 12	16 9	14 6	13 2		
E	49 81	38 32	30 20	26 14	23 7	20 5	18 2			
F	61 69	47 23	36 14	31 9	28 2	24 1				
G	73 57	56 14	44 6	37 3						
H	87 43	66 4								
I	101 29									
J	116 14									

NASE Recreational Dive Table (Back)

Waterproof version available from NASE Worldwide.



Terminology

Single Dive: Any dive made at least 12 hours after a previous dive.

Repetitive Dive: Any dive made within 12 hours of a prior dive. *You must account for residual nitrogen when making repetitive dives.*

Actual Bottom Time (ABT): Time spent under water. Begins when you leave the surface; ends when you return.

Repetitive Group Designator (Letter Group): Equates the overall level of excess nitrogen left in your body from previous dives to a letter of the alphabet. The more nitrogen, the higher the letter. *Increases* with depth and time; *decreases* the longer you remain out of the water.

Residual Nitrogen Time (RNT): A way of equating your letter group to the number of minutes it would take at a particular depth to absorb an equivalent amount of excess nitrogen on a single dive.

Adjusted No-Decompression Limit (ANDL): The amount of time you can spend at a particular depth, allowing for residual nitrogen from prior dives, without exceeding the overall no-decompression limit (NDL) for that depth.

Total Bottom Time (TBT): The sum of ABT and RNT. TBT must not exceed the NDL for your maximum depth.

Rules for Use

- The NASE Recreational Dive Tables are based on the US Navy dive tables, and further modified based on Doppler bubble research conducted by the US Navy.
- Make no more than one single dive, followed by two repetitive dives in any 24-hour period.
- To maximize bottom time and safety margins, make each dive in a series to the same or a shallower depth than the previous dive (i.e., deepest dives first).
- Stay well inside any no-decompression limit (NDL).
- If you exceed any dive table depth or time value, round to the *next greater depth or time shown*.
- Ascend at a rate no greater than 10 m/30 ft per minute.
- End every dive with a precautionary decompression (safety) stop at 3-6 m/10-20 ft for from three to five minutes.
- If you accidentally exceed an NDL by *no more than five minutes*, remain five minutes at 3-6 m/10-20 ft (or until lack of breathing gas forces you to surface). Wait *at least 12 hours* before diving again.
- If you accidentally exceed an NDL by *more than five minutes*, stop for 15 minutes at 3-6 m/10-20 ft (or until lack of breathing gas forces you to surface). Wait *at least 12 hours* before diving again.
- Wait *at least 12 hours* after single dives before flying or driving to altitude.
- Wait *at least 24 hours* after repetitive dives or multiple days of diving before flying or driving to altitude.

Appendix 3

Formulas

As a recreational Nitrox diver, there is no need ffor you to memorize formulas. Any data you might need is more easily found in the tables appearing in Appendix 2. Nevertheless, you may find these formulas “nice to know” — particularly if you one day progress to technical or rebreather diving.

Depth in Atmospheres

If you are going to memorize just one formula, this is the one. It converts any depth in meters or feet to depth in Atmospheres Absolute (ATA). Useful not only in Nitrox and technical diving, it will also help you solve many of the physics questions you need to master as a Divemaster or Instructor.

$$\text{Absolute Pressure in Atmospheres} = \frac{D + \text{A depth of } 10\text{ m}/33\text{ ft}}{\text{A depth of } 10\text{ m}/33\text{ ft}}$$

$$P_t = \frac{D+10}{10}$$

Metric

$$P_t = \frac{D+33}{33}$$

Imperial

Depth in Meters or Feet From Depth in Atmospheres

The is the reverse of the previous formula. Its usefulness is limited.

$$D = \left(\text{Absolute Pressure in Atmospheres} + \text{A depth of 10 m/33 ft} \right) - \text{A depth of 10 m/33 ft}$$

$$D = (P_t + 10) - 10$$

Metric

$$D = (P_t + 33) - 33$$

Imperial

PO_2 From Depth and FO_2

This is the formula used to generate the PO_2 tables you see appearing throughout this manual.

$$\text{Partial Pressure of Oxygen } (PO_2) = \text{Depth in Atmospheres Absolute} \times \text{Fraction of Oxygen } (FO_2)$$

$$PO_2 = \left(\frac{D + 10}{10}\right) \times FO_2$$

Metric

$$PO_2 = \left(\frac{D + 33}{33}\right) \times FO_2$$

Imperial

Maximum Operating Depth (MOD)

This is the formula used to generated the MOD tables.

$$MOD = \left(\text{A depth of 10 m/33 ft} \times \frac{(\text{Limiting } PO_2)}{(FO_2)} \right) - \text{A depth of 10 m/33 ft}$$

$$MOD = \left(10 \times \frac{(PO_2)}{(FO_2)} \right) - 10$$

Metric

$$MOD = \left(33 \times \frac{(PO_2)}{(FO_2)} \right) - 33$$

Imperial

Equivalent Air Depth (EAD)

This is the formula used to generated the EAD tables.

$$EAD = \frac{\left(\text{Fraction of Nitrogen in the Gas Mix}\right) \times \left(\text{Acutal Depth} + \text{A depth of 10 m/33 ft}\right)}{\text{The Fraction of Nitrogen in Air}} - \text{A depth of 10 m/33 ft}$$

$$EAD = \frac{(1 - FO_2) \times (D + 10)}{0.79} - 10$$

Metric

$$EAD = \frac{(1 - FO_2) \times (D + 33)}{0.79} - 33$$

Imperial

Actual Depth from EAD

The reverse of the previous formula. (Its usefulness is rather limited.)

$$D = \left(\frac{0.79\,(EAD + 10)}{(1 - FO_2)} \right) - 10$$

Metric

$$D = \left(\frac{0.79\,(EAD + 33)}{(1 - FO_2)} \right) - 33$$

Imperial

Best Mix

If you know your maximum depth and the limiting PO_2 you want to remain within, this will tell you your theoretical "best mix" (although you can pretty much determine this simply by looking at the NASE EAD/MOD table).

$$\text{Best Mix} = \left(\frac{\text{Limiting PO2}}{\left(\text{MOD} + \text{A depth of 10 m/33 ft}\right) \div \text{A depth of 10 m/33 ft}} \right)$$

$$\text{FO2} = \left(\frac{\text{PO2}}{(\text{MOD}+10) \div 10} \right)$$

Metric

$$\text{FO2} = \left(\frac{\text{PO2}}{(\text{MOD}+33) \div 33} \right)$$

Imperial