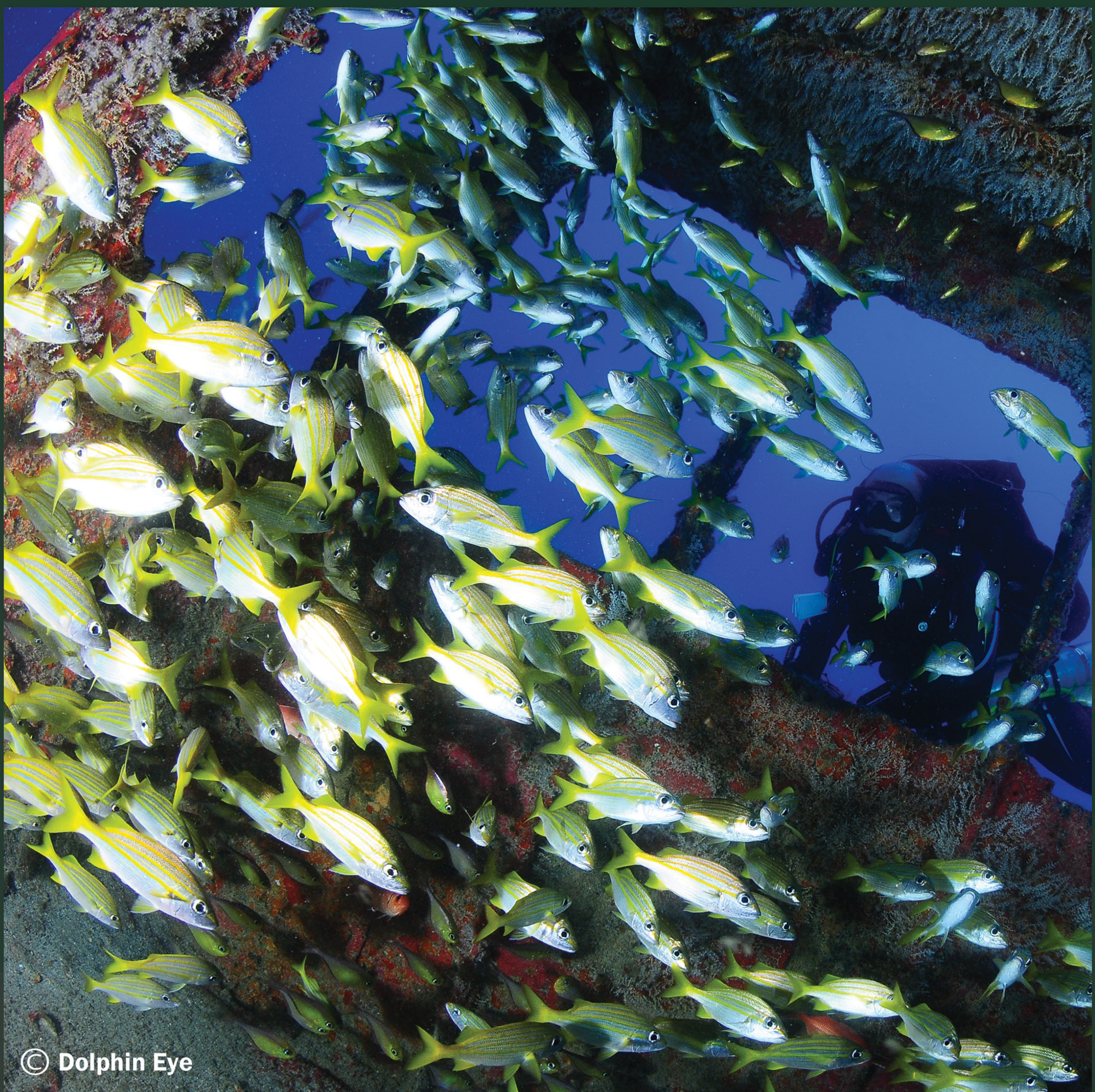
IANTD

International Association of Nitrox and Technical Divers

The leader in diver education



ENRICHED AIR NITROX DIVER

Student Manual by
Dick Rutkowski

Enriched Air Nitrox Diver

Student Manual

Disclaimer

Every effort has been made to ensure that this manual contains the most current, correct and clearly expressed information possible. Nevertheless inadvertent errors may occur. The authors, the Board of Directors, the Board of Advisors, nor any party associated with the International Association of Nitrox Divers, Inc. dba International Association of Nitrox and Technical Divers (IANTD) neither accepts any responsibility for accidents or injuries resulting from the use or misuse of the materials contained herein or from the activity of SCUBA diving, whether utilizing open, closed and/or semi-closed circuit equipment, and whether breathing compressed air or alternative breathing mixtures including combinations of Oxygen, Nitrogen and/or Helium and/or Neon.

SCUBA diving, including the use of compressed air and any gas mixture underwater, is an activity that has inherent risks. An individual may experience injury resulting in disability or death. Variations in individual physiology and medical fitness can lead to serious injury or death, even with adherence to accepted standards of performance, specified Oxygen limits and the correct use of dive tables and computers. All persons who wish to engage in SCUBA diving must receive instruction from a certified instructor and complete nationally recognized requirements in order to be certified as a SCUBA Diver. The use of alternative breathing mixtures, such a combinations of Oxygen, Nitrogen and/or Helium and/or Neon, requires additional instruction beyond that offered in traditional SCUBA courses.

Trained and certified SCUBA Divers, whether using compressed air or alternative breathing mixtures, are informed of the risks associated with SCUBA diving and with utilizing breathing mixtures as described above and, as such, ultimately bear responsibility for their own actions. Persons must not engage in SCUBA diving and the use of compressed air or alternative breathing mixtures unless they are willing to complete a course of instruction, pass certifying examinations and evaluations, maintain their skills and knowledge through active participation in diving activities and accept responsibility for any injury or death that may occur when participating in SCUBA diving activities.

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INTERNATIONAL ASSOCIATION OF NITROX AND TECHNICAL DIVERS

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by Dick Rutkowski

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CHAPTER 1 -CONTINUING YOUR JOURNEY...

WELCOME

Congratulations on completing your Open Water Diver program and for choosing to continue your diving journey. To be a successful, safe diver requires patience. You must allow yourself the time to improve. It will take time to acquire the educational background, skills, and equipment to properly execute your dives.

The materials are only a part of the educational system. You are an important part, as is your instructor. In this course, as in all IANTD courses, you will be learning new skills and acquiring knowledge. This will help you move on in your journey. The skills and education are not enough. You must also obtain the tools to safely execute dives.

Education, training, and equipment are all components of a skilled diver. Like all IANTD courses, your instructor, with the assistance of the educational materials, will help you internalize the things you need to be successful. This will enable you to move on in your diving journey. Remember to be open to new ideas.

It was once said that, “A person who is ripe is dying.” Be green and growing. Listen to your instructor and ask questions.

THE NEXT STEPS

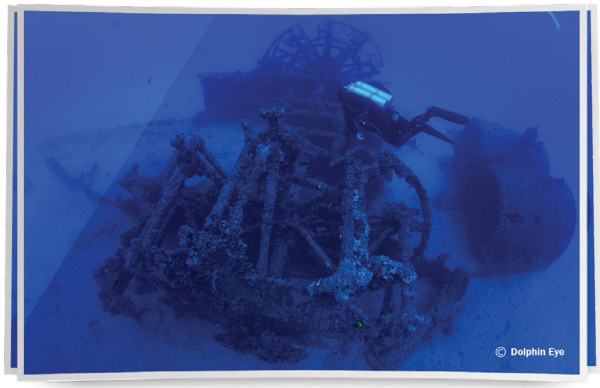
As you discovered, the Open Water Course was the beginning of a life-long journey. It is the key that opens the door to experiences you can only imagine. Where you go from here depends on you. There are a number of paths you can choose and experiences awaiting you.

Following the Open Water course is the Advanced Open Water Course. It is designed to provide you the essential knowledge and skills you will need in other IANTD courses. Tools such as navigation, dive planning for deep sport diving, and night diving are covered in this course.

Along with the Advanced Open Water Course, the Nitrox Diver Course rounds out the pre-requisite for the next level of diver education courses. It is the foundation for all of the IANTD advanced and technical courses. With the completion of these core courses, you are ready to open the door and explore

IANTD offers the most complete training programs in the world and has developed programs to help you reach your goals. Through its instructor base, IANTD offers a host of recreational and technical diving programs. These are designed to develop you into the diver you want to become.

Perhaps your sights are set on wreck diving. If so, your curriculum might include the Deep Diver Course, the Advanced Nitrox Diver Course, the Overhead Environment Program for Wreck Diving, a Normoxic Trimix or the Technical Diver Course. These would be followed by the Technical Wreck Diving Course, where you can incorporate all of the decompression diving and line skills from your other courses into a full penetration course. It will feature dives deep into sunken ships and safe staged decompression following the dives.



Perhaps you see yourself venturing into water filled holes, or as we all know them, caverns and caves. Again, your curriculum might include many of the courses that a wreck diver would take. These may include the Deep Diver Course, the Advanced Nitrox Diver Course, a Cavern Course, a Normoxic Trimix, or the Technical Diver course. The actual Cave Diving Course can be incorporated anywhere along the way, depending on where you want to take your diving.

Of course, there are always other pathways that you can take. You may want to incorporate rebreather diving into your dives, or you may feel that diving deeper in open water is a path for you. Wherever you want to go, IANTD and its instructors are here to help you reach your diving goals.

IANTD HISTORY

The International Association of Nitrox Divers, IAND, was formed in 1985 in response to the needs of the diving public. Up until that time, mixed gas diving and the use of decompression gasses was limited, in a formal way, to military and commercial divers. Sport divers were beginning to incorporate some of these methods into their diving, but planning was a free exchange of ideas, and sometimes these ideas were flawed.

In 1985, Dick Rutkowski, retired as the dive supervisor for the National Oceanographic and Atmospheric Administration, NOAA. Together, he and other leaders in the diving community, formed IAND. Dick's goal was to introduce the benefits of using Nitrox in many diving situations and to begin teaching safe decompression diving.

Under the leadership of Tom Mount, the organization grew into the leading technical training organization in the world, offering courses covering all aspects of sport diving. At the same time, the name was changed to the International Association of Nitrox and Technical Divers, IANTD. This better reflects the organization's additional emphasis technical diving

Today, IANTD has offices in over twenty-one countries and instructors in all major diving locations around the world. These instructors represent the "who's-who" of diving in both the traditional recreational diving arena and the technical diving arena.

IANTD continues to set the standard for both recreational and technical diving education. With the help of its International Licenses and International Board of Advisors, IANTD monitors the quality of its instructors and the educational programs in an effort to maintain the high-quality standards set by its founding members.

THE FUTURE

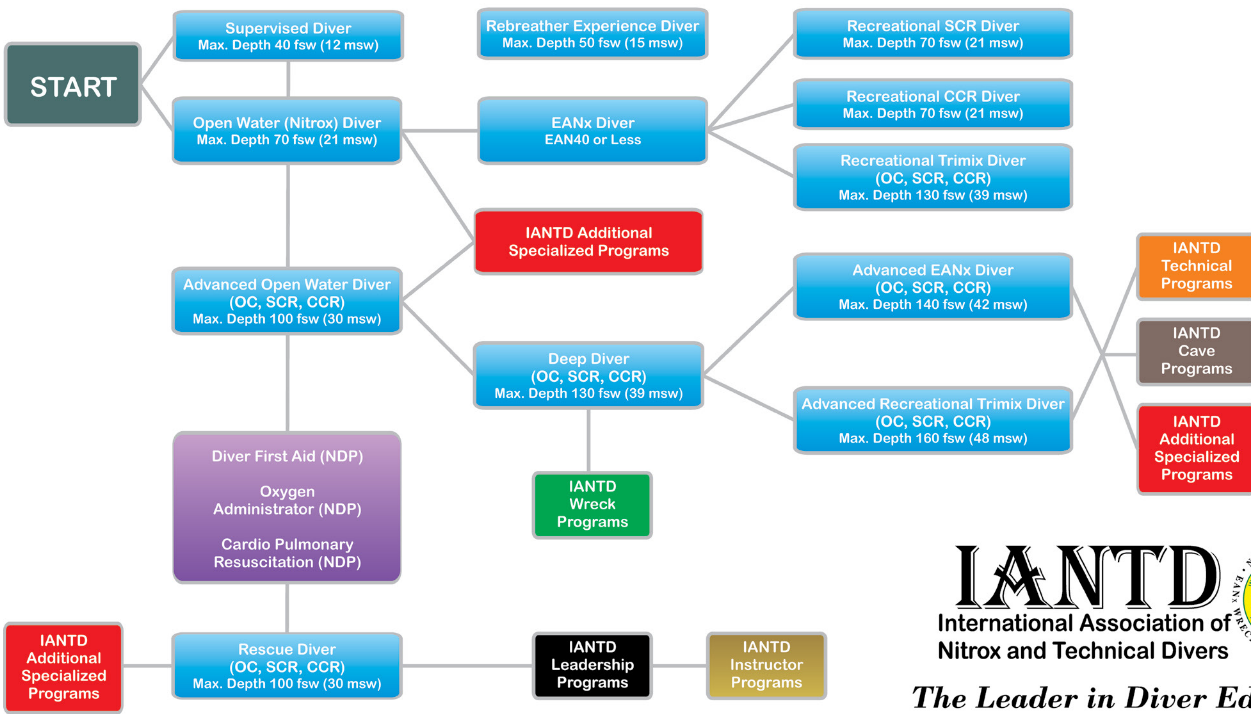
As technology improves, diving changes. With those changes, the accompanying education and skills development must change. IANTD is committed to maintaining its lead in the diving education industry by adapting its course offerings to the shifts in technology, hyperbaric medicine, research and environmental changes.

Our divers and instructors are some of the most well-trained and knowledgeable in the world. Through continuing diver education, in formal training sessions and through publications like Nitrox Diver - The IANTD Journal, IANTD is dedicated to making the diving community safer and more responsible to the environment in which we play and work.

All of us have in our veins the exact percentage of salt in our blood that exists in the ocean, and, therefore, we have salt in our blood, in our sweat, in our tears.
We are tied to the ocean.
And, when we go back to the sea
— whether it is to sail or watch it —
we are going back from whence we came.

John F. Kennedy

IANTD Sport Diver Programs



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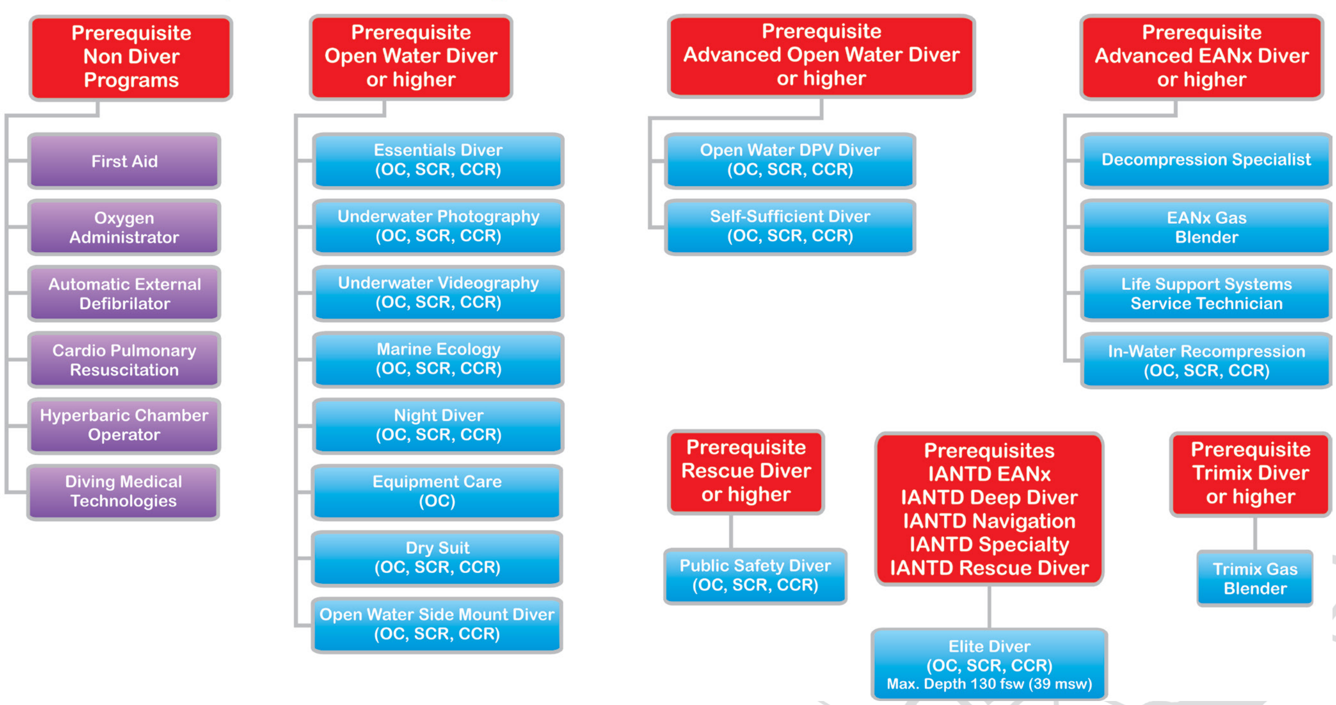
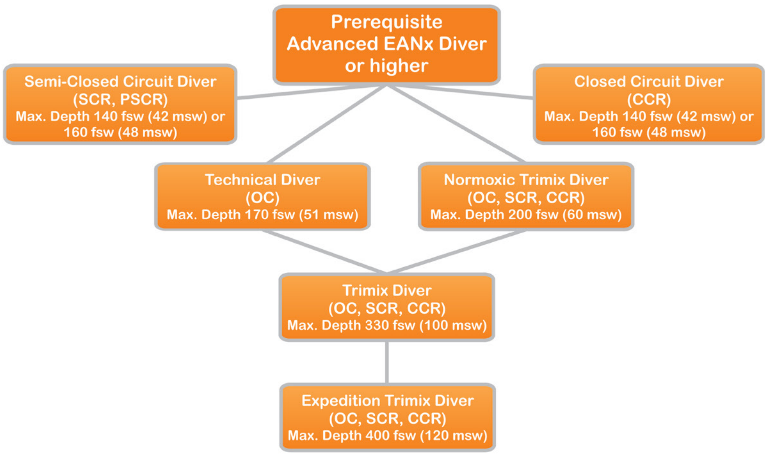
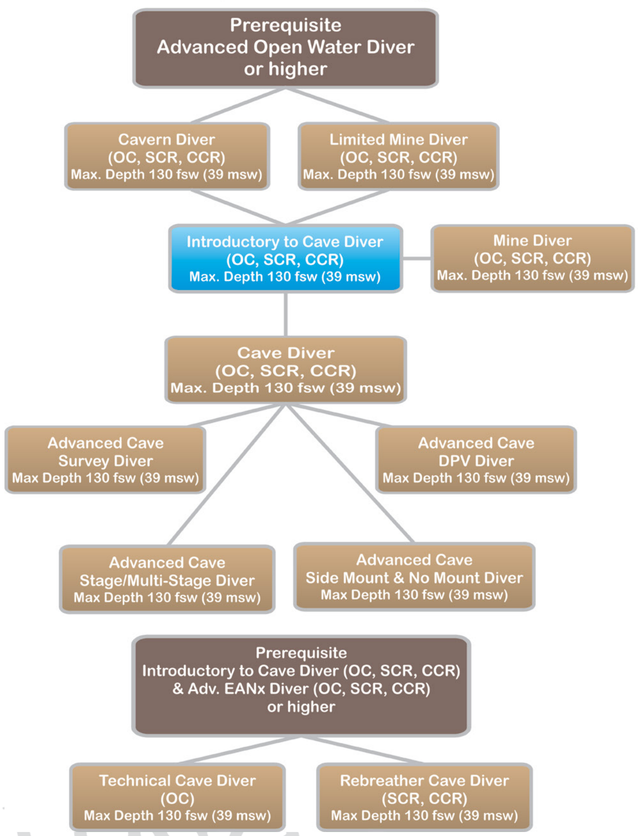
IANTD Additional Specialized Diver Programs *(Specialty programs do not have a chronological order.)*



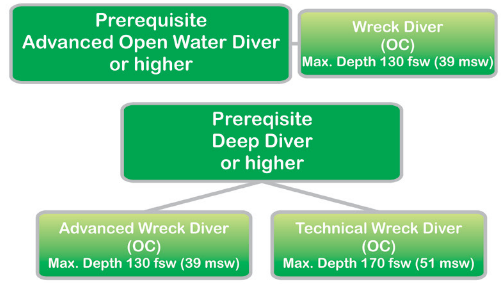
IANTD Technical Diver Programs



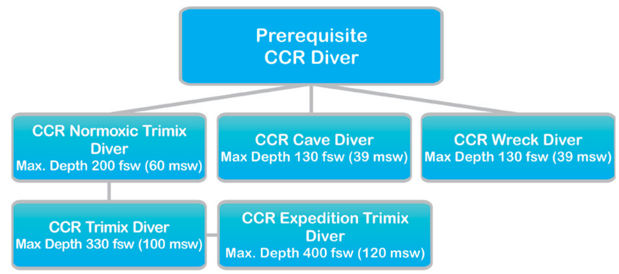
IANTD Cave, Mine Diver Programs



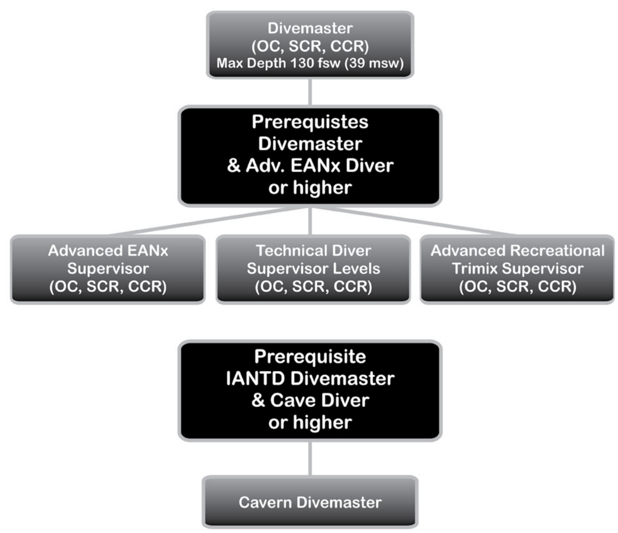
IANTD Wreck Diver Programs



IANTD CCR Programs



IANTD Leadership Programs



CHAPTER 1

THE BENEFITS & CONCERNS OF NITROX DIVING

INTERNATIONAL ASSOCIATION OF NITROX AND TECHNICAL DIVERS

The Leader in Diver Education

SECTION 1: THE BENEFITS & CONCERNS OF NITROX DIVING

INTRODUCTION

Did you know you have been breathing a form of Nitrox all of your life? Simply stated, Nitrox is any combination of oxygen and nitrogen. So, since the air we breath is approximately 21% oxygen and 79% nitrogen, it is a Nitrox blend. We could call this Natural Nitrox or Normoxic Nitrox. However, the use of this natural Nitrox was covered in your Open Water Diver course. In this course, our focus is using "Enriched Air Nitrox" (abbreviated EANx, where the x designates the oxygen percentage in the mixture).

Therefore, looking at our basic definition, Enriched Air Nitrox is a breathing gas blend with the oxygen content of the mixture higher than 21%. The traditional Nitrox blends are EAN 32, 32% oxygen, and EAN 36, 36% oxygen. As an IANTD Nitrox Diver, you will be certified to use oxygen/nitrogen mixtures from 21% to 40% oxygen.

TRADITIONAL NITROX MIXTURES ARE
EAN 32 AND EAN 36

Of course, the big question in your mind is probably "why?" Why do I want to use Nitrox? Why is it different to use than air? Why do I have to take an additional course to use it? The answers to these questions will be covered in more detail later in this manual. Suffice it to say that your body will appreciate the use of Nitrox, and your dive partner will appreciate the added time you both can spend underwater.

In the first instance, your body will appreciate the use of Nitrox because, by increasing the oxygen content of the mixture. Observing Dalton's Law, you automatically lower the nitrogen content. This, in turn, means that you are not exposing your tissues to as much nitrogen. Also, if you continue to use your air computer or the air tables, you are introducing more safety into your dives.

Secondly, the dive tables and computer algorythms are models used to calculate the amount of nitrogen being added to the body tissues. By lowering the nitrogen levels in the breathing gas, you are effectively adding less nitrogen to the tissues. Your body will "feel" as though it is diving shallower than you really are. This process is explored later in the Planning Nitrox Dives section. However, this equivalent nitrogen concept allows you to stay underwater longer.

So, if Nitrox is so wonderful, why do divers not use it all of the time? Because, with the benefits, there are some trade-offs. Remember that we mentioned that, traditionally, there are two mixtures? This indicates that there are some decisions to make when selecting Nitrox blends. As you will discover in later chapters, all dives require some choices, and using Nitrox is no different. The depth of your dive, the type of diving, and the equipment you will be using all affect the gas mixture you select.

HISTORY

If you have been diving for a long time, you may think diving with Nitrox is new. In a way it is, and in other ways it is not. In 1912, Germans were diving using mixtures of 45% oxygen and 55% nitrogen to a maximum depth of 100 feet (30 meters). Later, they developed equipment designed to use a mixture of 30% oxygen and 70% nitrogen down to 200 feet (60 meters).

Little was done with these gas mixtures, over the years, in favor of using air and open circuit scuba because of ease and availability. However, hardhat divers in the 1950's began using various Nitrox blends to extend their working safety.

In the 1970's, using data developed by commercial divers, as well as other research, the United States National Oceanographic and Atmospheric Administration (NOAA), under the direction of Morgan Wells and Dick Rutkowski, introduced Nitrox to divers working with the agency. NOAA allowed open circuit research divers to use mixtures NOAA termed NOAA I. These contained 32% oxygen, and later NOAA II, containing 36% oxygen.

In 1985, the International Association of Nitrox and Technical Divers, IANTD, taught it's first Nitrox course in the Bahamas. It would be ten years before the other training agencies began teaching Nitrox diving.

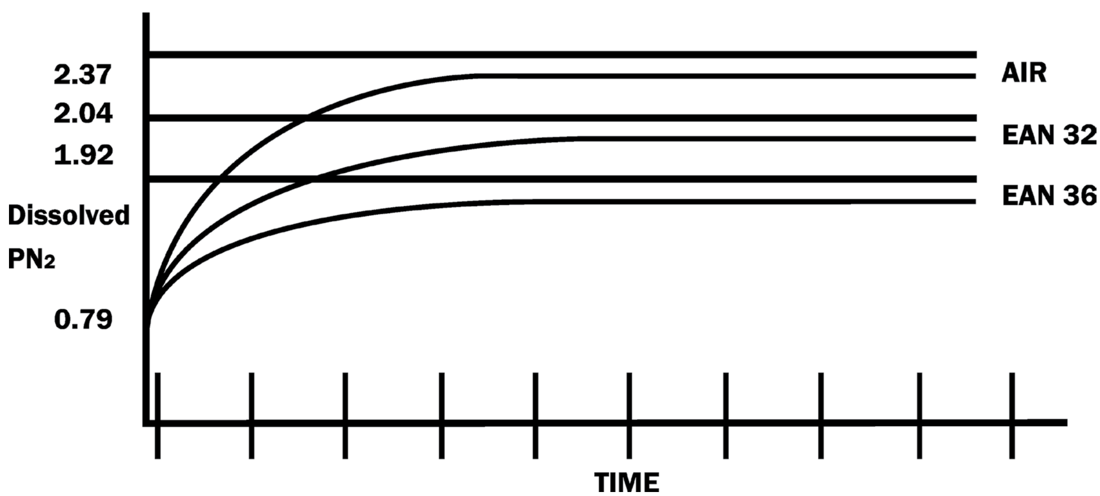


Figure 1-1: Typical nitrogen uptake curve based on a dive to 66 fsw/20 msw.

BENEFITS OF NITROX

As we alluded earlier, your body may appreciate the use of Nitrox. As you dive, your tissues absorb nitrogen while processing the oxygen. Your tissues load or absorb nitrogen in their cells, hence we use the term "tissue loading." As you ascend, the nitrogen stored in the tissues is removed from the body as a part of the normal respiration cycle. By reducing the amount of nitrogen in the breathing mixture, you expose your tissues to less nitrogen. Since the quantity of nitrogen in the cells is reduced, you get less tissue fatigue and increased safety.

Looking at this concept in more detail, the decompression obligation is dependent on the quantity of nitrogen absorbed by the body during the course of a dive. Both the rate of the nitrogen absorption and the total quantity of nitrogen which can be absorbed by the body are determined by the partial pressure of nitrogen in the breathing gas mixture. When you reduce the nitrogen content of the gas mixture and replace it with oxygen, which the body can use in metabolism, you reduce the absorption of nitrogen in the cell tissues.

Depth Feet	Depth Meters	NDL Air	NDL EAN28	NDL EAN32	NDL EAN36	NDL EAN40
40	12	125	125	154	154	154
50	15	75	75	125	125	154
60	18	51	35	75	75	125
70	21	35	35	51	75	75
80	24	25	35	35	51	51
90	27	20	24	25	35	51
100	30	17	19	20	25	35
110	33	14	17	20	20	*
120	36	12	14	17	*	*
130	39	10	12	*	*	*
* Exceeds the maximum PO_2 limit.						

Figure 1-2: Comparison of the no-stop dive time limits using the IANTD Dive Tables for the appropriate mixtures.

The dive tables and computer models use mathematical models to determine the amount of nitrogen absorbed by the body's tissues. As Figure 1-1 illustrates, at any time during a dive with Nitrox, the nitrogen absorbed by the body is less than for air.

Taking the safety factor further, it stands to reason, if we are reducing the nitrogen absorbed in the body, we should be able to reduce the interval between our last dive and the time we can fly. While there are some methods for calculating this reduced period, IANTD still recommends a twelve to twenty-four hour surface interval before flying. You should also be aware that this surface interval can increase to as much as forty-eight hours after some very long decompression dives.

A third benefit of using Nitrox is that you can use Nitrox to extend your bottom time by equating the amount of nitrogen in your breathing mixture to that of air. By using this ratio, your bottom time will increase.

USING NITROX HAS THE FOLLOWING ADVANTAGES:
- LONGER NO-STOP DIVE TIMES
- REDUCED INTERVAL BETWEEN DIVING AND FLYING
- ADDED CONSERVATISM WHEN USING AIR COMPUTERS OR TABLES

The relative time increases are shown in Figure 1-2. We will examine how to do this in the dive planning section using the Equivalent Nitrogen (Air) Depth formula, and the IANTD EAD/MOD Table.

PO_2 ATA	Oxygen limits and physiological implications
3.00	50/50 Nitrox Therapy Oxygen
2.80	100% Oxygen Therapy
2.50	Maximum Decompression For Op Diving
2.40	60/40 Nitrox Therapy Gas at 6 ATA
2.00	USN Exceptional Exposure Working Limit
1.60*	Maximum Exposure - Recreational Divers
1.50	Maximum Technical Nitrox Exposure
1.40	Maximum Heavy Exertion Recommended Limit
0.50**	Maximum Saturation Exposure
0.35	Normal Saturation Eposure
0.21	Normoxic - Normal Environment
0.16	Begin Minor Symptoms of Hypoxia
0.12	Serious Signs of Hypoxia
0.10	Unconsciousness
Coma or Death	

* CNS O_2 Toxicity (Paul Bert Effect)

** Pulmonary O_2 Toxicity (Lorraine Smith Effect)

Figure 1-3: Oxygen limits and physiological implications.

Depth FSW	Depth MSW	Pressure ATA	AIR	EAN28	EAN32	EAN36	EAN40
0	0	1.0	0.21	0.28	0.32	0.36	0.40
10	3	1.3	0.27	0.36	0.42	0.47	0.52
20	6	1.6	0.34	0.45	0.51	0.58	0.64
30	9	1.9	0.40	0.53	0.61	0.69	0.76
33	10	2.0	0.42	0.56	0.64	0.72	0.80
40	12	2.2	0.46	0.62	0.71	0.80	0.88
50	15	2.5	0.53	0.70	0.80	0.91	1.00
60	18	2.8	0.59	0.79	0.90	1.01	1.13
66	20	3.0	0.63	0.84	0.96	1.08	1.20
70	21	3.1	0.66	0.84	1.00	1.12	1.25
80	24	3.4	0.72	0.96	1.10	1.23	1.37
90	27	3.7	0.78	1.04	1.19	1.34	1.49
99	30	4.0	0.84	1.12	1.28	1.44	1.60
100	33	4.3	0.85	1.13	1.29	1.45	1.61
110	33	4.3	0.91	1.21	1.39	1.56	1.73
114	34.7	4.4	0.94	1.25	1.43	1.60	1.78
120	36	4.6	0.97	1.30	1.48	1.67	1.86
130	39	4.9	1.04	1.38	1.58	1.78	1.98
132	40	5.0	1.05	1.40	1.60	1.80	2.00
155	47	5.7	1.20	1.60	1.82	2.05	2.28
165	50	6.0	1.26	1.68	1.92	2.16	2.40
218	66	7.6	1.60	2.13	2.43	2.74	3.04

Exceeds the maximum recreational PO_2 limit.

Figure 1-4: Depth, pressure and patial pressure of oxygen relationships for vatious EANx mixtures.

CONCERNS WITH NITROX

While Nitrox is beneficial to divers, it does not eliminate nitrogen completely from the mix. This means that we are still concerned with excess nitrogen and the resulting decompression illness. Additionally, Enriched Air Nitrox fosters concerns with oxygen toxicity, which because of sport diving depth limitations, is not a concern for air divers.

Another concern for Nitrox divers is inaccurate gas analysis. If you are diving a mixture that you believe is EAN 28, and it is actually EAN 32, the higher oxygen level could lead to an oxygen toxicity issue. If the reverse were true, you believed you had a EAN 32, and it was actually EAN 28, the oxygen toxicity issue is eliminated, but you have introduced a possible decompression violation into your dive. As such, you will want to learn to analyze your gas properly. Never dive an unanalyzed Nitrox mixture. Most Nitrox divers carry their own oxygen analyzer for this reason.

OXYGEN & THE HUMAN BODY

Humans require oxygen to sustain life. Unfortunately, oxygen is probably the most misunderstood gas. If you have too little, you suffer from hypoxic symptoms including sleepiness and unconsciousness. With too much oxygen, we tend toward hyperoxic symptoms, including visual disturbances, nausea and convulsions. Because of this, for normal diving operations, the oxygen partial pressures must be maintained between 0.16ATA and 1.6ATA. As thermal stress (cold water) and/or the work load of a dive increases, the maximum oxygen partial pressure should be reduced. Additionally, exercise greatly reduces a diver's tolerance to oxygen. Heavy work loads and improperly maintained equipment can lead to increased levels of carbon dioxide, CO2, which can precipitate the onset of CNS oxygen toxicity.

We compute the partial pressures of oxygen by applying Dalton's law, which will be discussed further in the dive planning section. We can use the formula to compute the partial pressures of oxygen at depth. Figure 1-4 shows the partial pressure of oxygen at various depths for some of the common Nitrox mixtures.

HYPOXIA – TOO LITTLE OXYGEN

HYPEROXIA – TOO MUCH OXYGEN

THE OXYGEN EXPOSURE RANGE IS FROM
0.16ATA TO 1.6ATA

IT IS IMPORTANT NOT TO EXCEED THE
1.6ATA OXYGEN LIMIT!

OXYGEN TOXICITY

There are two types of oxygen toxicity of which divers need to be aware. The first, pulmonary or whole body toxicity, is not generally a concern for recreational divers. It is covered in more detail in the IANTD Advanced EANx and the Technical Diver courses. Central Nervous System Oxygen Toxicity, CNS Toxicity, can be a concern to recreational divers.

In the Nitrox Diver program we are primarily concerned with CNS Toxicity. While most people can tolerate partial pressures of oxygen of 2.0ATA or greater, while at rest, this rarely happens in an aquatic environment. As such, it is important not to exceed the 1.6ATA oxygen limit.

EANX DIVERS ARE PRIMARILY CONCERNED WITH CNS TOXICITY.
PULMINARY OXYGEN TOXICITY IS RARELY A CONCERN
FOR RECREATIONAL DIVERS

The symptoms of CNS toxicity can be described using the acronym CONVENTID, which stands for:

- CONvulsion - This is the most serious consequence of CNS toxicity because the diver may drown during the seizure or experience a gas embolism while being brought to the surface.
- Vision Visual - abnormalities, such as tunnel vision, which is a contraction of the normal field of vision (like looking through a tube).
- Ears/Euphoria - Abnormalities in hearing, such as ringing in the ears (i.e. tinnitus). Also, the sensation of well-being.
- Nausea - Sudden nausea which may be intermittent.
- Twitching/Tingling - This usually appears first in the lips or other facial muscles, but it may also affect any muscle. You may also experience tingling in the extremities. This is the most frequent and clear warning of CNS toxicity.
- Irritability - Any change in behavior, including anxiety, confusion and/or unusual fatigue.
- Dizziness - Vertigo during the dive.

Additional symptoms may include difficulty in taking a full breath, an apparent increase in breathing resistance, noticeable clumsiness, or lack of coordination.

Your tolerance is dependent on the oxygen partial pressure and time. It is reduced considerably with increased exercise. Additionally, while using high partial pressure oxygen mixtures at depth may increase the nitrogen elimination, it also increases a diver's risk of CNS toxicity if used in excess. Using Nitrox in this manner is covered in the IANTD Advanced EANx and the Technical Diver courses.

POINTS TO REMEMBER

EXERCISE INCREASES A DIVERS RISK OF CNS OXYGEN TOXICITY. THIS IS WHY IT IS IMPORTANT TO OBSERVE THE 1.6ATA MAXIMUM EXPOSURE LIMIT. FURTHER, IT IS IMPORTANT TO MONITOR YOUR CONDITION DURING THE DIVE FOR SYMPTOMS OF CNS TOXICITY, ESPECIALLY AS YOU NEAR THE 1.6ATA LIMIT.

In studies conducted by the NOAA, divers were considered at low risk for CNS Toxicity when the maximum exposure was limited to 1.6ATA for 45 minutes. Figure 1-5 shows the maximum time limits for various oxygen partial pressure exposures.

Because the exposure is cumulative over successive dives, we need to track the exposure not only on the first dive but also on repetitive dives. We do this by taking our actual dive time and dividing it by the maximum exposure limit. Multiplying this result by 100 gives us the percentage of the "oxygen clock" we used on that dive. For most recreational dives, you should keep this percentage below eighty percent.

ATA	Single Exposure Limit		24 hr Maximum Exposure	
	Minutes	Hours	Minutes	Hours
1.6	45	0.75	150	2.50
1.5	120	2.00	180	3.00
1.4	150	2.50	180	3.00
1.3	180	3.00	210	3.50
1.2	210	3.5	240	4.00
1.1	240	4.00	270	4.50
1.0	300	5.00	300	5.00
0.9	360	6.00	360	6.00
0.8	450	7.50	450	7.50
0.7	570	9.50	570	9.50
0.6	720	12.00	720	12.00

Figure 1-5: Partial Pressure and Exposure Time Limits for Nitrogen/Oxygen Divers (NOAA).

Additionally, in order to prevent potential problems, you need to apply the following rules to your dive planning:

1. If one or more dives within a twenty-four hour period (i.e. a repetitive dive) reach or exceed the single exposure limit, you will need to spend a minimum of two hours on the surface, breathing air, before diving again.
2. If one or more dives within a twenty-four hour period (i.e. a repetitive dive) have reached the maximum exposure limit for twenty-four hours, you will need to spend a minimum of twelve hours on the surface breathing air before diving again.

As divers we are the ambassadors for the sea.
Dr. Sylvia Earl

SECTION 1 - STUDY QUESTIONS

1. Traditional Nitrox blends have what percentage of oxygen?
   a. 21% and 32%
   b. 32% and 36%
   c. 36% and 40%
   d. 40% and 45%
2. As an IANTD Nitrox diver, you can use mixtures up to what percentage of oxygen?
   a. 32%
   b. 34%
   c. 36%
   d. 40%
3. Which of the following is not a benefit of diving with Nitrox?
   a. Reduced fatigue due to a reduction in tissue loading
   b. Longer non-stop time when compared to air
   c. Reduced interval between the last dive and the time you can fly
   d. Eliminates the risk of decompression illness
4. Which of the following are not concerns for Nitrox divers?
   a. Decompression illness
   b. Oxygen toxicity
   c. Inaccurate gas analysis
   d. Increases risk of the pulmonary disease
5. Hypoxic symptoms are caused by:
   a. Too little oxygen.
   b. Too much oxygen
   c. Too little nitrogen
   d. Too much helium
6. Hyperoxic symptoms are caused by:
   a. Too much oxygen.
   b. Too little oxygen
   c. Too much nitrogen
   d. Too little helium
7. Recreational Nitrox divers are primarily concerned with what form of oxygen toxicity?

a. Pulmonary Oxygen Toxicity

b. Cardiac Oxygen Toxicity

c. Lympthphatic Oxygen Toxicity

d. Central Nervous System Oxygen Toxicity

8. The maximum oxygen exposure for recreational Nitrox divers is:

a. PO2 = 1.2 ATA

b. PO2 = 1.4 ATA

c. PO2 = 1.6 ATA

d. PO2 = 2.0 ATA

9. The term CONVENTID is an acronym for:

a. CON ____________________

b. V ____________________

c. E ____________________

d. N ____________________

e. T ____________________

f. I ____________________

g. D ____________________

10. Tolerance to elevated levels of oxygen is dependent on:

a. the partial pressure of the oxygen

b. the quantity of cylinders

c. the time of exposure

d. both a and c

11. For recreational Nitrox divers, the term “oxygen clock” refers to:

a. the amount of oxygen tolerance units consumed on a dive

b. the amount of the NOAA single exposure limit used by a diver

c. how much time is left for a dive using the IANTD Air Decompression tables

d. the surface interval required for another dive

CHAPTER 2

PLANNING NITROX DIVES

The Leader in Diver Education

SECTION 2: PLANNING NITROX DIVES

PRESSURE RELATIONSHIP

Before we look at planning Nitrox dives, we need to understand the basic relationship between depth and the pressure exerted on the body. Living at mean sea level, we are subjected to one atmosphere of pressure which can be expressed as 760 mm of mercury, 29.95 inches of mercury, or 14.7 pounds per square inch. To keep things simple and understandable, we refer to this pressure as one atmosphere absolute, and it is the total pressure surrounding us as the direct result of the weight of the gasses in motion above and around us. These gasses include oxygen (O2), nitrogen (N2), carbon dioxide (CO2), argon (Ar), carbon monoxide (CO) and other trace gasses.

When we dive, our instrumentation shows depth in feet or meters and pressure in pounds per square inch (psi) or bar. However, to keep the units uniform in the computations, we generally work with units of atmospheric pressure absolute (ATA) which includes the surface pressure. As such, we need a method to convert between our instruments and atmospheres. To do that we use the following formula:

$$P_{(ata)} = \left[\frac{D_{(fsw)}}{33_{(fsw)}}\right] + 1 \qquad P_{(ata)} = \left[\frac{D_{(msw)}}{10_{(msw)}}\right] + 1$$

Feet of Seawater	Meters of Seawater	Pressure ATA	Pressure PSIG	Pressure BAR
0	0	1	0.0	1.013
33	10	2	14.7	2.026
66	20	3	29.4	3.039
99	30	4	44.1	4.052
132	40	5	58.8	5.065
165	50	6	73.5	6.078
198	60	7	88.1	7.091
218	66	7.6	97.0	7.699

Figure 2-1: Relationship between depths and pressures.

If we look at Figure 2-1 we will see this relationship between our instruments and ATA. We can also take this one step further and look at the pressure for a given depth, see Figure 2-2.

Now that we have a basic understanding of the pressure relationships used in diving, we need to look at them in relation to planning our dives. As we noted in the previous section, one of our concerns in diving is the amount of oxygen in our breathing mixture. We noted that if it drops too low we have a hypoxic situation and conversely, if it gets too high we are placed in a hyperoxic situation. And as noted, either of these extremes can lead to serious consequences underwater.

Feet of Seawater	Meters of Seawater	Pressure ATA	Feet of Seawater	Meters of Seawater	Pressure ATA
0	0	1.00	120	36	4.60
10	3	1.30	130	39	4.90
20	6	1.60	140	42	5.20
30	9	1.90	150	45	5.50
40	12	2.20	160	48	5.80
50	15	2.50	170	51	6.10
60	18	2.80	180	54	6.40
70	21	3.10	190	57	6.70
80	24	3.40	200	60	7.00
90	27	3.70	210	63	7.30
100	30	4.00	218	66	7.60
110	33	4.30			

Figure 2-2: Depths and the calculated absolute pressures.

DALTON'S LAW

A British chemist, John Dalton, determined that the total pressure exerted by a mixture of gasses is the sum of the pressures that would be exerted by each gas if it were present and occupied the total volume.

Depth FSW	Depth MSW	Pressure ATA	AIR	EAN28	EAN32	EAN36	EAN40
0	0	1.0	0.21	0.28	0.32	0.36	0.40
10	3	1.3	0.27	0.36	0.42	0.47	0.52
20	6	1.6	0.34	0.45	0.51	0.58	0.64
30	9	1.9	0.40	0.53	0.61	0.69	0.76
33	10	2.0	0.42	0.56	0.64	0.72	0.80
40	12	2.2	0.46	0.62	0.71	0.80	0.88
50	15	2.5	0.53	0.70	0.80	0.91	1.00
60	18	2.8	0.59	0.79	0.90	1.01	1.13
66	20	3.0	0.63	0.84	0.96	1.08	1.20
70	21	3.1	0.66	0.84	1.00	1.12	1.25
80	24	3.4	0.72	0.96	1.10	1.23	1.37
90	27	3.7	0.78	1.04	1.19	1.34	1.49
99	30	4.0	0.84	1.12	1.28	1.44	1.60
100	33	4.3	0.85	1.13	1.29	1.45	**1.61**
110	33	4.3	0.91	1.21	1.39	1.56	**1.73**
114	34.7	4.4	0.94	1.25	1.43	1.60	**1.78**
120	36	4.6	0.97	1.30	1.48	**1.67**	**1.86**
130	39	4.9	1.04	1.38	1.58	**1.78**	**1.98**
132	40	5.0	1.05	1.40	1.60	**1.80**	**2.00**
155	47	5.7	1.20	1.60	**1.82**	**2.05**	**2.28**
165	50	6.0	1.26	**1.68**	**1.92**	**2.16**	**2.40**
218	66	7.6	1.60	**2.13**	**2.43**	**2.74**	**3.04**

(Red) Exceeds the maximum recreational PO_2 limit.

Figure 2-3: Depth, pressure and partial pressure of oxygen relationships for various mixtures.

Dalton's Law can be expressed as :

Pressure = P1 + P2 + P3+ Pn

where P1, P2, P3, Pn, etc. is the absolute pressure of that gas in the mixture. Put another way, the pressure of a given gas can be determined by multiplying the total pressure by the fraction of the gas in the mixture or:

$$P_g = P_{ATA} \times F_g$$

Using this formula we can determine the partial pressure of oxygen at depth, or:

$$PO_2 = P_{ATA} \times FO_2$$

As we discussed in the previous section, while we need oxygen to live, too much oxygen can lead to serious consequences underwater. As such, we can use Dalton's Law to determine our oxygen exposure for various Enriched Air Nitrox blends, see Figure 2-3.

Looking at the table, we notice that the oxygen exposure, or PO2 increases with depth. This is true for all open-circuit SCUBA and semi-closed circuit SCUBA systems.

NO MATTER HOW MUCH GAS IS IN THE CYLINDER, THE FRACTION OF THE GAS (E.G. OXYGEN) REMAINS THE SAME, REGARDLESS OF THE DEPTH

BEST EANX MIXTURE

When we plan a dive using Nitrox, we often want to use the best or optimal mixture for our planned depth. We said earlier, the maximum oxygen exposure is limited to 1.6ATA. For dive planning purposes, we reduce this number to 1.5ATA or even 1.4ATA. This gives us a cushion between our maximum depth and our planned or target depth. We can use Dalton's Law to compute the optimal mixture for a dive. The formula is expressed as:

$$FO_2 = \frac{\text{Desired Oxygen Level } (PO_2)}{\text{Depth in Atmospheres } (P_{ATA})}$$

As we discovered in the previous section, we have to be aware of the oxygen clocks. As such, we may want to reduce the partial pressure of the oxygen to extend the time we can breath that mixture underwater. Using the best mix formula above, we can determine the optimal breathing mix at various oxygen levels or, as commonly noted, the partial pressure of oxygen, PO2. Figure 2-4 shows the optimal mixes for various depths and partial pressure of oxygen levels.

Depth FSW	Depth MSW	PO_2				
		1.20 ATA	1.3 ATA	1.4 ATA	1.5 ATA	1.6 ATA
40	12	54	59	63	68	72
50	15	48	52	56	60	64
60	18	43	46	50	53	57
70	21	38	42	45	48	51
80	24	35	38	41	44	47
90	27	32	35	38	40	43
100	30	30	32	35	37	40
110	33	28	30	32	35	37
120	36	26	28	30	32	35
130	39	24	26	28	30	32

(Red) EANx Divers are limited to mixtures from EAN22 to EAN40

Figure 2-4: Best EANx mixtures for a given PO2

MAXIMUM DEPTH

As part of the dive planning process, we need to compute the maximum depth an EANx mixture can be used. We refer to this as the maximum operating depth or MOD and it is computed using the following formula fsw or msw:

$$MOD_{(fsw)} = \left[\frac{\text{Maximum Oxygen Exposure } (PO_2)}{\text{Fraction of Oxygen } (FO_2)}\right] - 1 + 33 \text{ fsw}$$

OR

$$\underset{(msw)}{MOD} = \left[\frac{\text{Maximum Oxygen Exposure } (PO_2)}{\text{Fraction of Oxygen } (FO_2)}\right] - 1 + 10\ \text{msw}$$

However, we rarely want to dive at the maximum depth. We can use the same formula to compute a planned depth or a target operating depth. You will need to compute the MOD and the TOD every time you rent or use a EANx cylinder so it is important that you understand this formula.

POINTS TO REMEMBER

THE MAXIMUM OPERATING DEPTH IS DETERMINED USING A MAXIMUM OXYGEN EXPOSURE OR PO2 OF 1.6ATA.
THE TARGET OR PLANNED DEPTH SHOULD BE COMPUTED USING A LOWER OXYGEN EXPOSURE SUCH AS 1.4ATA TO 1.2ATA.

EQUIVALENT DEPTH

If you remember, we discussed two advantages of Nitrox in relation to nitrogen absorption. First, if we use an air table or air computer, we introduce more safety using EANx, because we reduce the nitrogen in the breathing mixture. Secondly, we discussed that by using EANx, we could extend our bottom time.

The extension of bottom time is explained by the equivalent air depth or equivalent nitrogen depth concept. Since we are replacing some of the nitrogen with oxygen in our breathing mixture, it is as if "physiologically" we are diving at a shallower depth. Furthermore, if we are physiologically diving at a shallower depth, we should, in theory, have more time at depth.

The equivalent nitrogen depth concept equates the inspired nitrogen in an EANx mixture at one depth to that of air at another depth (i.e. END). This procedure has been used for over forty years, and references to it can be found in the United States Navy Diving Manual as early as 1959.

The basic formula for computing the equivalent nitrogen depth is:

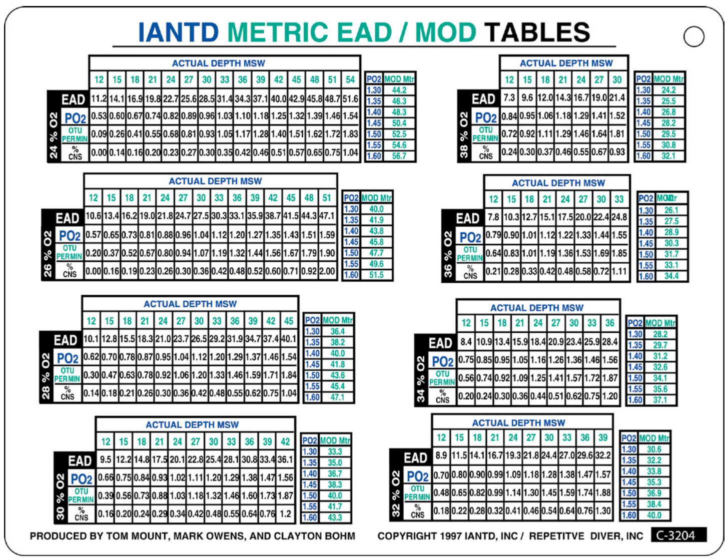
$$\underset{(fsw)}{END} = \left[\frac{FN_2 \text{ (Fraction of Nitrogen on Mixture) x } (D_{fsw} + 33_{fsw})}{0.79 \text{ (Fraction of Nitrogen on Air)}}\right] + 33\ \text{fsw}$$

OR

$$END_{(msw)} = \left[\frac{FN_2 \text{ (Fraction of Nitrogen on Mixture) x } (D_{msw} + 10_{msw})}{0.79 \text{ (Fraction of Nitrogen on Air)}} \right] + 10 \text{ msw}$$

EAD/MOD TABLE

Now, before you go totally insane trying to memorize the formulas we have discussed thus far, relax and take a breath. We have, for our use, a table. See Figure 2-5, that contains all of this data for EANx mixtures from EAN 24 - 100% oxygen. This table simplifies EANx diving and should be placed in your logbook.



IANTD METRIC EAD / MOD TABLES

24 % O2

ACTUAL DEPTH MSW	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
EAD	11.2	14.1	16.9	19.8	22.7	25.6	28.5	31.4	34.3	37.1	40.0	42.9	45.8	48.7	51.6
PO2	0.53	0.60	0.67	0.74	0.82	0.89	0.96	1.03	1.10	1.18	1.25	1.32	1.39	1.46	1.54
OTU PER MIN	0.09	0.26	0.41	0.55	0.68	0.81	0.93	1.05	1.17	1.28	1.40	1.51	1.62	1.72	1.83
% CNS	0.00	0.14	0.16	0.20	0.23	0.27	0.30	0.35	0.42	0.46	0.51	0.57	0.65	0.75	1.04

PO2	MOD Mtr
1.30	44.2
1.35	46.3
1.40	48.3
1.45	50.4
1.50	52.5
1.55	54.6
1.60	56.7

26 % O2

ACTUAL DEPTH MSW	12	15	18	21	24	27	30	33	36	39	42	45	48	51
EAD	10.6	13.4	16.2	19.0	21.8	24.7	27.5	30.3	33.1	35.9	38.7	41.5	44.3	47.1
PO2	0.57	0.65	0.73	0.81	0.88	0.96	1.04	1.12	1.20	1.27	1.35	1.43	1.51	1.59
OTU PER MIN	0.20	0.37	0.52	0.67	0.80	0.94	1.07	1.19	1.32	1.44	1.56	1.67	1.79	1.90
% CNS	0.00	0.16	0.19	0.23	0.26	0.30	0.36	0.42	0.48	0.52	0.60	0.71	0.92	2.00

PO2	MOD Mtr
1.30	40.0
1.35	41.9
1.40	43.8
1.45	45.8
1.50	47.7
1.55	49.6
1.60	51.5

28 % O2

ACTUAL DEPTH MSW	12	15	18	21	24	27	30	33	36	39	42	45
EAD	10.1	12.8	15.5	18.3	21.0	23.7	26.5	29.2	31.9	34.7	37.4	40.1
PO2	0.62	0.70	0.78	0.87	0.95	1.04	1.12	1.20	1.29	1.37	1.46	1.54
OTU PER MIN	0.30	0.47	0.63	0.78	0.92	1.06	1.20	1.33	1.46	1.59	1.71	1.84
% CNS	0.14	0.18	0.21	0.26	0.30	0.36	0.42	0.48	0.55	0.62	0.75	1.04

PO2	MOD Mtr
1.30	36.4
1.35	38.2
1.40	40.0
1.45	41.8
1.50	43.6
1.55	45.4
1.60	47.1

30 % O2

ACTUAL DEPTH MSW	12	15	18	21	24	27	30	33	36	39	42
EAD	9.5	12.2	14.8	17.5	20.1	22.8	25.4	28.1	30.8	33.4	36.1
PO2	0.66	0.75	0.84	0.93	1.02	1.11	1.20	1.29	1.38	1.47	1.56
OTU PER MIN	0.39	0.56	0.73	0.88	1.03	1.18	1.32	1.46	1.60	1.73	1.87
% CNS	0.16	0.20	0.24	0.29	0.34	0.42	0.48	0.55	0.64	0.76	1.2

PO2	MOD Mtr
1.30	33.3
1.35	35.0
1.40	36.7
1.45	38.3
1.50	40.0
1.55	41.7
1.60	43.3

38 % O2

ACTUAL DEPTH MSW	12	15	18	21	24	27	30
EAD	7.3	9.6	12.0	14.3	16.7	19.0	21.4
PO2	0.84	0.95	1.06	1.18	1.29	1.41	1.52
OTU PER MIN	0.72	0.92	1.11	1.29	1.46	1.64	1.81
% CNS	0.24	0.30	0.37	0.46	0.55	0.67	0.93

PO2	MOD Mtr
1.30	24.2
1.35	25.5
1.40	26.8
1.45	28.2
1.50	29.5
1.55	30.8
1.60	32.1

36 % O2

ACTUAL DEPTH MSW	12	15	18	21	24	27	30	33
EAD	7.8	10.3	12.7	15.1	17.5	20.0	22.4	24.8
PO2	0.79	0.90	1.01	1.12	1.22	1.33	1.44	1.55
OTU PER MIN	0.64	0.83	1.01	1.19	1.36	1.53	1.69	1.85
% CNS	0.21	0.28	0.33	0.42	0.48	0.58	0.72	1.11

PO2	MOD Mtr
1.30	26.1
1.35	27.5
1.40	28.9
1.45	30.3
1.50	31.7
1.55	33.1
1.60	34.4

34 % O2

ACTUAL DEPTH MSW	12	15	18	21	24	27	30	33	36
EAD	8.4	10.9	13.4	15.9	18.4	20.9	23.4	25.9	28.4
PO2	0.75	0.85	0.95	1.05	1.16	1.26	1.36	1.46	1.56
OTU PER MIN	0.56	0.74	0.92	1.09	1.25	1.41	1.57	1.72	1.87
% CNS	0.20	0.24	0.30	0.36	0.44	0.51	0.62	0.75	1.20

PO2	MOD Mtr
1.30	28.2
1.35	29.7
1.40	31.2
1.45	32.6
1.50	34.1
1.55	35.6
1.60	37.1

32 % O2

ACTUAL DEPTH MSW	12	15	18	21	24	27	30	33	36	39
EAD	8.9	11.5	14.1	16.7	19.3	21.8	24.4	27.0	29.6	32.2
PO2	0.70	0.80	0.90	0.99	1.09	1.18	1.28	1.38	1.47	1.57
OTU PER MIN	0.48	0.65	0.82	0.99	1.14	1.30	1.45	1.59	1.74	1.88
% CNS	0.18	0.22	0.28	0.32	0.41	0.46	0.54	0.64	0.76	1.30

PO2	MOD Mtr
1.30	30.6
1.35	32.2
1.40	33.8
1.45	35.3
1.50	36.9
1.55	38.4
1.60	40.0

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Figure 2-5: EAD / MOD Table.

PUTTING IT ALL TOGETHER

With all of these concepts, formulas and tables you are probably wondering if using EANx is really worth all of the detailed planning and math. Hang on and keep reading. You are about to find out just how simple it is to add Nitrox to your dive.

Planning dives using Nitrox only adds a few steps to your dive planning process. If you use the IANTD EAD/MOD table, they are pretty painless steps. After you decide where you want to dive and how deep you want to go, the rest of the Nitrox portion of you dive plan falls into place.

By starting with the depth you want to visit, we can determine the best Nitrox mixture for your dive. Remember there is a trade-off between nitrogen absorption (no-stop time on your computer or dive tables) and the oxygen clocks (using the NOAA CNS oxygen exposure chart, see Figure 1-5). Of course at this point, your breathing rate and that of your buddy will also play a role in your dive planning.

Once you have selected your EANx blend, you can look up the maximum operating depth for the mixture (i.e. the maximum floor of your dive). Also, look at the deepest depth you want to dive to (i.e. your target operating depth). Then, it is time to find the equivalent nitrogen depth and the percentage of the CNS oxygen clock you plan on using. Both of these are on the IANTD EAD/MOD Table, see Figure 2-5. Plan your dive using the appropriate dive table. Better yet, program the EANx blend into your dive computer and get ready to go into the water.

Want an example that ties it all together? Okay, let's fly off to a South Pacific island, Kosrae perhaps. The dive operator regularly supplies EAN 32 and EAN 36. You want to explore the deeper parts of the reef on the first dive and a shallow site on the second dive. As such, you request EAN 32 for the first dive and EAN 36 for the second dive.

IANTD DIVE TABLES

The IANTD Dive Tables were derived using the Bühlmann ZH-L16 model, which is among the most widely tested and used decompression models in use today. This model is used to calculate both staged and continuous decompression. It is also programmed into many of today's dive computers.

When using these tables the following definitions apply:

- Depths listed are the maximum depth reached during the dive.
- Bottom Time is the time you left the surface until you begin your direct ascent to the surface or any decompression stops.
- Decompression stop time is the time required to stay at that stop. It does not include the time required to ascend to the stop.
- Repetitive group is a measure of excess nitrogen remaining in the body after a dive.
- Surface interval is the time beginning after surfacing from a dive until beginning the next descent.
- Residual nitrogen time is a measure of the amount of excess nitrogen still in the body at the end of the surface interval. It is the time you must consider that is already spent at the planned depth of the repetitive dive.

The following rules must be applied when using the dive tables:

- The ascent rate must not exceed 33 feet per minute (10 meters per minute).
- Use the exact or next greater dive depth and time when using the table (i.e. round to the next deepest depth or time).
- For strenuous dives, use the prescribed decompression for the next time increment (i.e. use the next longer time).
- Repetitive dives require additional time to be added to the actual bottom time.
- A safety stop of 3 minutes at 15 fsw (4.5 msw) is required during an ascent from any no-stop dive (up to an altitude of 1000 ft/300 m).

Dive 1: Looking at the IANTD EAD/MOD Table, see figure 2-6, you see that at 1.6ATA the maximum operating depth for EAN 32 is 132 fsw (39 msw).

32 % O2	ACTUAL DEPTH FSW									
	40	50	60	70	80	90	100	110	120	130
EAD	30	38	47	56	64	73	81	90	99	107
PO2	0.71	0.80	0.90	1.00	1.10	1.19	1.29	1.39	1.48	1.58
OTU PER MIN	0.48	0.66	0.83	1.00	1.16	1.31	1.46	1.61	1.75	1.90
% CNS	0.18	0.22	0.28	0.33	0.41	0.47	0.54	0.64	0.79	1.47

PO2	MOD FSW
1.30	101
1.35	106
1.40	111
1.45	117
1.50	122
1.55	127
1.60	132

Figure 2-6: EAN32 Maximum Operation Depth at a PO2 of 1.6 ata.

You want to be a little conservative and leave plenty of time on your oxygen clock, so you plan the dive to 100 fsw (30 msw), which yields a PO2 of 1.29ATA, see Figure 2-7.

32 % O2	ACTUAL DEPTH FSW									
	40	50	60	70	80	90	100	110	120	130
EAD	30	38	47	56	64	73	81	90	99	107
PO2	0.71	0.80	0.90	1.00	1.10	1.19	1.29	1.39	1.48	1.58
OTU PER MIN	0.48	0.66	0.83	1.00	1.16	1.31	1.46	1.61	1.75	1.90
% CNS	0.18	0.22	0.28	0.33	0.41	0.47	0.54	0.64	0.79	1.47

PO2	MOD FSW
1.30	101
1.35	106
1.40	111
1.45	117
1.50	122
1.55	127
1.60	132

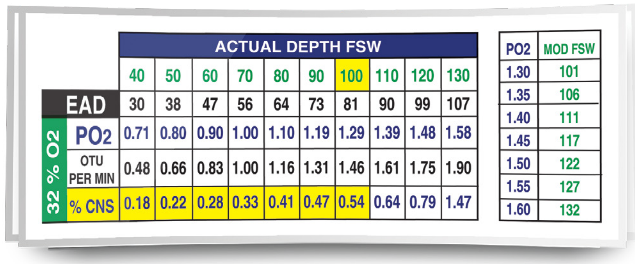
Figure 2.7: EAN32 Equivalent Air Depth for 100 feet.

Still looking at the cheat sheet, you find your equivalent air depth, EAD, is 81 fsw (27 msw), see Figure 2-8.

32 % O2	ACTUAL DEPTH FSW									
	40	50	60	70	80	90	100	110	120	130
EAD	30	38	47	56	64	73	81	90	99	107
PO2	0.71	0.80	0.90	1.00	1.10	1.19	1.29	1.39	1.48	1.58
OTU PER MIN	0.48	0.66	0.83	1.00	1.16	1.31	1.46	1.61	1.75	1.90
% CNS	0.18	0.22	0.28	0.33	0.41	0.47	0.54	0.64	0.79	1.47

PO2	MOD FSW
1.30	101
1.35	106
1.40	111
1.45	117
1.50	122
1.55	127
1.60	132

Figure 2-8: EAN32 Partial Pressure of Oxygen at 100 feet.

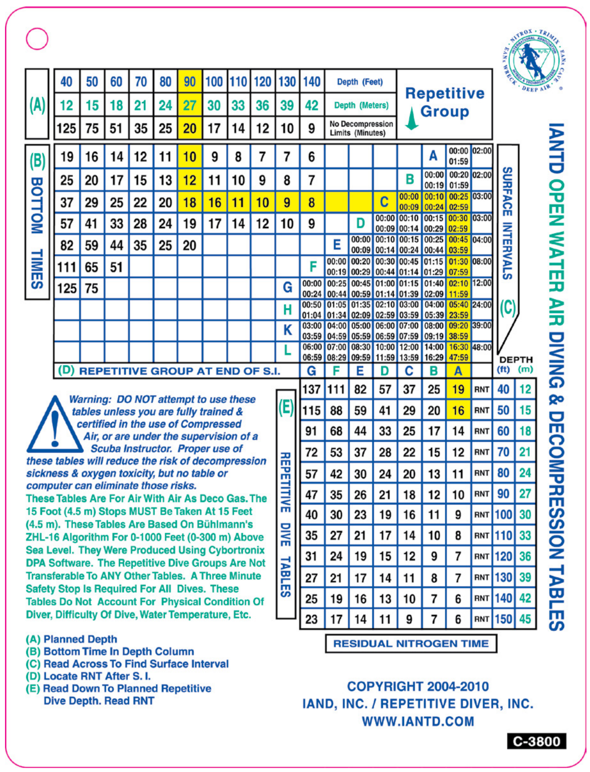


32 % O2	ACTUAL DEPTH FSW									
	40	50	60	70	80	90	100	110	120	130
EAD	30	38	47	56	64	73	81	90	99	107
PO2	0.71	0.80	0.90	1.00	1.10	1.19	1.29	1.39	1.48	1.58
OTU PER MIN	0.48	0.66	0.83	1.00	1.16	1.31	1.46	1.61	1.75	1.90
% CNS	0.18	0.22	0.28	0.33	0.41	0.47	0.54	0.64	0.79	1.47

PO2	MOD FSW
1.30	101
1.35	106
1.40	111
1.45	117
1.50	122
1.55	127
1.60	132

Figure 2-9: EAN32 CNS% per minute at 100 feet.

Now it is time to pull out your IANTD Air Diving & Decompression Tables, Figure 2-10 and decide how long you can stay, assuming your breathing rate will let you stay the maximum time. You find that the no-stop limit is 20 minutes (remember the EAD is 81 fsw or 27 msw). If you stay the 15 minutes, looking at the table, figure 2-10, your repetitive group designation will be C.



IANTD OPEN WATER AIR DIVING & DECOMPRESSION TABLES

(A)	40	50	60	70	80	90	100	110	120	130	140
Depth (Feet)	40	50	60	70	80	90	100	110	120	130	140
Depth (Meters)	12	15	18	21	24	27	30	33	36	39	42
No Decompression Limits (Minutes)	125	75	51	35	25	20	17	14	12	10	9

(B) BOTTOM TIMES

Repetitive Group	40	50	60	70	80	90	100	110	120	130	140
A	19	16	14	12	11	10	9	8	7	7	6
B	25	20	17	15	13	12	11	10	9	8	7
C	37	29	25	22	20	18	16	11	10	9	8
D	57	41	33	28	24	19	17	14	12	10	9
E	82	59	44	35	25	20					
F	111	65	51								
G	125	75									
H											
K											
L											

(C) SURFACE INTERVALS — (D) REPETITIVE GROUP AT END OF S.I.

Group	G	F	E	D	C	B	A	
A							00:00 01:59	02:00
B						00:00 00:19	00:20 01:59	02:00
C					00:00 00:09	00:10 00:24	00:25 02:59	03:00
D				00:00 00:09	00:10 00:14	00:15 00:29	00:30 02:59	03:00
E			00:00 00:09	00:10 00:14	00:15 00:24	00:25 00:44	00:45 03:59	04:00
F		00:00 00:19	00:20 00:29	00:30 00:44	00:45 01:14	01:15 01:29	01:30 07:59	08:00
G	00:00 00:24	00:25 00:44	00:45 00:59	01:00 01:14	01:15 01:39	01:40 02:09	02:10 11:59	12:00
H	00:50 01:04	01:05 01:34	01:35 02:09	02:10 02:59	03:00 03:59	04:00 05:39	05:40 23:59	24:00
K	03:00 03:59	04:00 04:59	05:00 05:59	06:00 06:59	07:00 07:59	08:00 09:19	09:20 38:59	39:00
L	06:00 06:59	07:00 08:29	08:30 09:59	10:00 11:59	12:00 13:59	14:00 16:29	16:30 47:59	48:00

(E) REPETITIVE DIVE TABLES — RESIDUAL NITROGEN TIME

G	F	E	D	C	B	A		DEPTH (ft)	DEPTH (m)
137	111	82	57	37	25	19	RNT	40	12
115	88	59	41	29	20	16	RNT	50	15
91	68	44	33	25	17	14	RNT	60	18
72	53	37	28	22	15	12	RNT	70	21
57	42	30	24	20	13	11	RNT	80	24
47	35	26	21	18	12	10	RNT	90	27
40	30	23	19	16	11	9	RNT	100	30
35	27	21	17	14	10	8	RNT	110	33
31	24	19	15	12	9	7	RNT	120	36
27	21	17	14	11	8	7	RNT	130	39
25	19	16	13	10	7	6	RNT	140	42
23	17	14	11	9	7	6	RNT	150	45

Warning: DO NOT attempt to use these tables unless you are fully trained & certified in the use of Compressed Air, or are under the supervision of a Scuba Instructor. Proper use of these tables will reduce the risk of decompression sickness & oxygen toxicity, but no table or computer can eliminate those risks.

These Tables Are For Air With Air As Deco Gas. The 15 Foot (4.5 m) Stops MUST Be Taken At 15 Feet (4.5 m). These Tables Are Based On Bühlmann's ZHL-16 Algorithm For 0-1000 Feet (0-300 m) Above Sea Level. They Were Produced Using Cybortronix DPA Software. The Repetitive Dive Groups Are Not Transferable To ANY Other Tables. A Three Minute Safety Stop Is Required For All Dives. These Tables Do Not Account For Physical Condition Of Diver, Difficulty Of Dive, Water Temperature, Etc.

(A) Planned Depth
(B) Bottom Time In Depth Column
(C) Read Across To Find Surface Interval
(D) Locate RNT After S. I.
(E) Read Down To Planned Repetitive Dive Depth. Read RNT

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C-3800

Figure 2-10: IANTD Air Dive Table for Dive 1.

Going back to the EAD/MOD Table, you find your CNS exposure is 15 minutes x 0.54 or 8.1%, and you're done with this dive. So let's recap this dive:

EAN Mixture: EAN 32

MOD: 132 fsw

Planned Depth: 100 fsw

Planned PO2: 1.29ATA

EAD: 81 fsw

Bottom Time: 15 min.

Reptitive Group: C

CNS%: 8.1%

Time to eat a healthy lunch and do not forget to re-hydrate yourself. Relax and enjoy the scenery and ocean while discussing your dive and getting ready for the next dive. The surface interval is an hour and a half.

Dive 2: Ok, lunch is done, and it is time to plan the second dive. Remember you selected EAN 36 for the second dive. Checking your handy EAD/MOD Table, see Figure 2-11.

36 % O2	ACTUAL DEPTH FSW 40	50	60	70	80	90	100	110
EAD	26	34	42	50	59	67	75	83
PO2	0.80	0.91	1.01	1.12	1.23	1.34	1.45	1.56
OTU PER MIN	0.65	0.84	1.02	1.20	1.37	1.54	1.70	1.87
% CNS	0.22	0.28	0.34	0.43	0.50	0.60	0.74	1.19

PO2	MOD FSW
1.30	86
1.35	91
1.40	95
1.45	100
1.50	105
1.55	109
1.60	114

Figure 2-11: EAN36 Equivalent Air Depth for 60 feet.

You see that at 1.6ATA the maximum operating depth for EAN 36 is 114 fsw (38 msw), see figure 2-12. The reef was so spectacular on your way up that you want to maximize your time underwater. A 60 fsw (18 msw) dive yields a PO2 of 1.01ATA, see Figure 2-13.

36 % O2	ACTUAL DEPTH FSW 40	50	60	70	80	90	100	110
EAD	26	34	42	50	59	67	75	83
PO2	0.80	0.91	1.01	1.12	1.23	1.34	1.45	1.56
OTU PER MIN	0.65	0.84	1.02	1.20	1.37	1.54	1.70	1.87
% CNS	0.22	0.28	0.34	0.43	0.50	0.60	0.74	1.19

PO2	MOD FSW
1.30	86
1.35	91
1.40	95
1.45	100
1.50	105
1.55	109
1.60	114

Figure 2-12: EAN36 Maximum Operation Depth at a PO2 of 1.6 ata.

36 % O2	ACTUAL DEPTH FSW	40	50	60	70	80	90	100	110
	EAD	26	34	42	50	59	67	75	83
	PO2	0.80	0.91	1.01	1.12	1.23	1.34	1.45	1.56
	OTU PER MIN	0.65	0.84	1.02	1.20	1.37	1.54	1.70	1.87
	% CNS	0.22	0.28	0.34	0.43	0.50	0.60	0.74	1.19

PO2	MOD FSW
1.30	86
1.35	91
1.40	95
1.45	100
1.50	105
1.55	109
1.60	114

Figure 2-13: EAN36 Partial Pressure of Oxygen at 60 feet.

Still looking at the EAD/MOD Table, you find your equivalent air depth, EAD, is 42 fsw (32 msw). See Figure 2-14. You plan on staying underwater for 54 minutes.

36 % O2	ACTUAL DEPTH FSW	40	50	60	70	80	90	100	110
	EAD	26	34	42	50	59	67	75	83
	PO2	0.80	0.91	1.01	1.12	1.23	1.34	1.45	1.56
	OTU PER MIN	0.65	0.84	1.02	1.20	1.37	1.54	1.70	1.87
	% CNS	0.22	0.28	0.34	0.43	0.50	0.60	0.74	1.19

PO2	MOD FSW
1.30	86
1.35	91
1.40	95
1.45	100
1.50	105
1.55	109
1.60	114

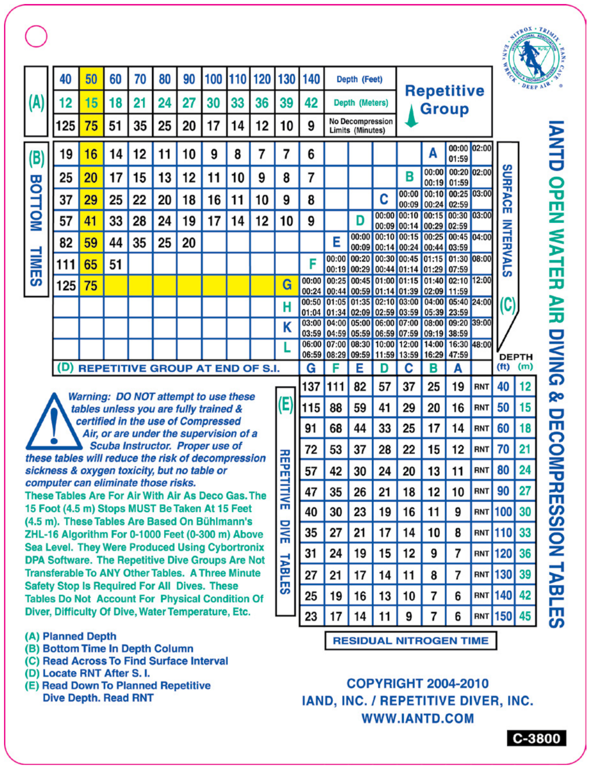
Figure 2-14: EAN36 Equivalent Air Depth for 60 feet.

36 % O2	ACTUAL DEPTH FSW	40	50	60	70	80	90	100	110
	EAD	26	34	42	50	59	67	75	83
	PO2	0.80	0.91	1.01	1.12	1.23	1.34	1.45	1.56
	OTU PER MIN	0.65	0.84	1.02	1.20	1.37	1.54	1.70	1.87
	% CNS	0.22	0.28	0.34	0.43	0.50	0.60	0.74	1.19

PO2	MOD FSW
1.30	86
1.35	91
1.40	95
1.45	100
1.50	105
1.55	109
1.60	114

FIgure 2-15: EAN36 CNS% per minute at 60 feet.

You pull out your IANTD Air Diving & Decompression Tables, Figure 2-16, and, looking at a repetitive group of C with a surface interval of one hour and a half, you find your new repetitive group designation is an A. An A diver going to 42 feet (remember that EAD) has a residual nitrogen time of 16 minutes. This yields a table bottom time of 70 minutes. Back to the top of the table, a dive to an EAD of 42 fsw (so you use the 50 fsw column) for 70 minutes makes us a G diver at the end of the dive, see Figure 2-15.



Depth (Feet)	40	50	60	70	80	90	100	110	120	130	140	Repetitive Group
Depth (Meters)	12	15	18	21	24	27	30	33	36	39	42	
No Decompression Limits (Minutes)	125	75	51	35	25	20	17	14	12	10	9	
	19	16	14	12	11	10	9	8	7	7	6	A
	25	20	17	15	13	12	11	10	9	8	7	B
	37	29	25	22	20	18	16	11	10	9	8	C
	57	41	33	28	24	19	17	14	12	10	9	D
	82	59	44	35	25	20						E
	111	65	51									F
	125	75										G

Group	G	F	E	D	C	B	A	
A							00:00 01:59	02:00
B						00:00 00:19	00:20 01:59	02:00
C					00:00 00:09	00:10 00:24	00:25 02:59	03:00
D				00:00 00:09	00:10 00:14	00:15 00:29	00:30 02:59	03:00
E			00:00 00:09	00:10 00:14	00:15 00:24	00:25 00:44	00:45 03:59	04:00
F		00:00 00:19	00:20 00:29	00:30 00:44	00:45 01:14	01:15 01:29	01:30 07:59	08:00
G	00:00 00:24	00:25 00:44	00:45 00:59	01:00 01:14	01:15 01:39	01:40 02:09	02:10 11:59	12:00
H	00:50 01:04	01:05 01:34	01:35 02:09	02:10 02:59	03:00 03:59	04:00 05:39	05:40 23:59	24:00
K	03:00 03:59	04:00 04:59	05:00 05:59	06:00 06:59	07:00 07:59	08:00 09:19	09:20 38:59	39:00
L	06:00 06:59	07:00 08:29	08:30 09:59	10:00 11:59	12:00 13:59	14:00 16:29	16:30 47:59	48:00

G	F	E	D	C	B	A		Depth (ft)	Depth (m)
137	111	82	57	37	25	19	RNT	40	12
115	88	59	41	29	20	16	RNT	50	15
91	68	44	33	25	17	14	RNT	60	18
72	53	37	28	22	15	12	RNT	70	21
57	42	30	24	20	13	11	RNT	80	24
47	35	26	21	18	12	10	RNT	90	27
40	30	23	19	16	11	9	RNT	100	30
35	27	21	17	14	10	8	RNT	110	33
31	24	19	15	12	9	7	RNT	120	36
27	21	17	14	11	8	7	RNT	130	39
25	19	16	13	10	7	6	RNT	140	42
23	17	14	11	9	7	6	RNT	150	45

Figure 2-15: IANTD Air Table for Dive 2.

Back on the EAD/MOD Table, Figure 2-13, you find your CNS exposure is 54 minutes x 0.34 or 18.4% for this dive and a total of 26.5% for the day. Okay, you're done with this dive. Let's recap this dive:

EAN Mixture: EAN 36

MOD: 118 fsw

Repetitive Group Start: C

Repetitive Group after surface interval: A

Planned Depth: 60 fsw

Planned PO2: 1.01ATA

EAD: 42 fsw

Bottom Time: 54 min.

Repetitive Group: G

CNS% this Dive: 18.4%

CNS% for Day: 26.5%

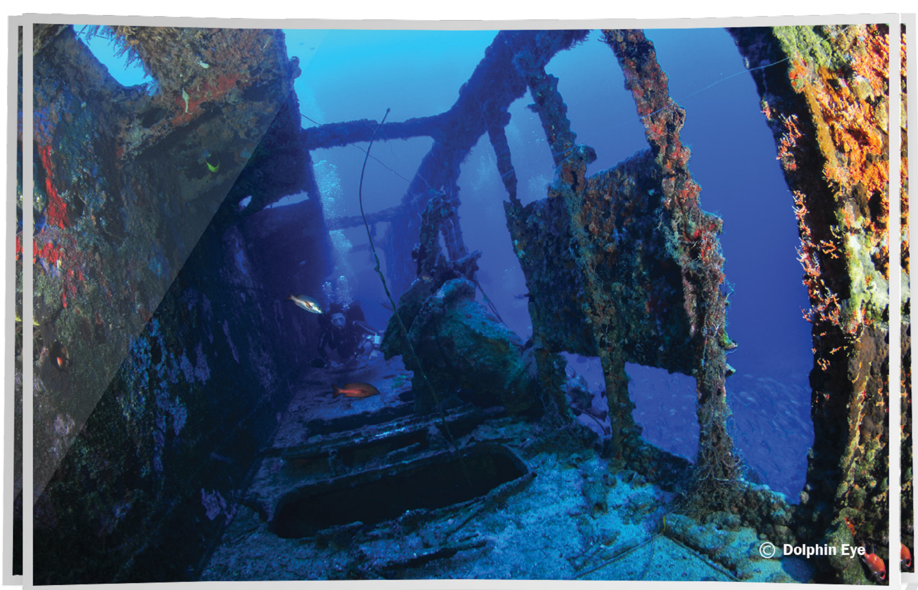
Now that you are back aboard your dive boat, it is time to head back to the dock, so the crew can clean your dive equipment and you can complete your logbook and relax before dinner. EANx diving is so easy!

REMEMBER THE CNS% ACCUMULATES ON EACH DIVE. YOU NEED TO CONSIDER THE TOTAL EXPOSURE.

SUMMARY

Now, advice on planning your dive. If you had brought your Nitrox dive computer, you could have bypassed consulting the IANTD Air Diving & Decompression Tables and programmed your EANx mixture in your dive computer. Additionally, the computer calculates the no-stop time based on your actual depth at the various phases of the dive rather than assuming you are at the maximum depth for the entire dive. Utilizing real-time data, your computer re-computes your no-stop and decompression times, thus allowing you to remain underwater for longer periods of time; assuming your gas consumption rate will let you stay longer. You still have to plan your dive, but the dive computer does much of the math for you. Remember it is important to plan your dive and dive your plan!

As you can see from this example, diving using EANx mixtures adds a few steps to your dive planning process, but by using the appropriate IANTD tables, they are relatively painless steps. As a matter of simplicity, if you have the IANTD EAN 32 and EAN 36 Tables, you need not calculate the END/EAD value. You would only have to use the appropriate table for mix and use the RNT from the table you will be using for the next dive. There are additional dive planning problems in the study questions that follow. You can also ask your IANTD Instructor for additional problems to work out at home.



SECTION 2 — STUDY QUESTIONS

1. One atmosphere is equivalent to which of the following?
   a. 14.7 psi
   b. 29.95 inches of mercury
   c. 33 fsw or 10 msw
   d. All of the above
2. According to Dalton's Law, the partial pressure of the oxygen can be determined using which of the following formulas?
   a. P1V1 = P2V2
   b. PO2 = PATA x FO2
   c. PO2 = PATA + FO2
   d. PO2 = PATA/FO2
3. No matter how much gas is in the cylinder, the fraction of the gas remains the same even at different depths.
   a. True
   b. False
4. Complete the following table:

Depth Feet	Depth Meters	Pressure ATA	Best EANx Mixture @ 1.4 ata
60	18		
70	21		
80	24		
90	27		
100	30		

5. The maximum operating depth is computed using which partial pressure of oxygen (PO2)?
   a. 1.2ATA
   b. 1.4ATA
   c. 1.5ATA

d. 1.6ATA

6. You can use the IANTD Air Diving & Decompression Tables for any Nitrox mixture if:

   a. You base your no-stop time as if you were doing an air dive and utilize the EANx mixture as a safety margin.

   b. You use the next shallower depth and compute the no-stop times using this number.

   c. You compute the equivalent nitrogen depth to determine the adjusted depth and plan your no-stop times using that depth.

   d. both a and c

7. Complete the following:

Depth Feet	Depth Meters	Pressure ATA	NDL Limit	Nitrox Mixture	PP02	EAD fsw/msw	Adjusted NDL	Maximum Single Expossure Limit
47	14			EAN30				
56	17			EAN36				
104	31			EAN36				
111	33			EAN32				
122	37			EAN28				
130	39			EAN24				

8. You are planning a dive to 75fsw (23msw) using EAN 32 for 35 minutes. You plan on taking a 2-hour surface interval and then a dive to 67fsw (20msw) using EAN 36. What is the maximum possible no-stop time for the second dive?

   a. 19 Minutes

   b. 55 Minutes

   c. 59 Minutes

   d. 24 Minutes

CHAPTER 3

THE OPERATIONAL ASPECTS OF NITROX DIVING

MAXIMUM OPERATION DEPTH

BEST MIX

NITROX

NOAA

OXYGEN LIMITS

EQUIVALENT AIR DEPTH

PAUL BERT

FO_2

N_2

IANTD

International Association of Nitrox and Technical Divers

SECTION 3: THE OPERATIONAL ASPECTS OF NITROX DIVING

OVERVIEW

Up to this point we have been talking about the benefits and concerns of Nitrox diving in relation to the diver. Now it is time to look at the operational side of Nitrox diving. Specifically, we need to discuss the equipment considerations and the preparation of Nitrox mixtures.

In general, after research by various agencies, in both the government sector and the private sector, including NOAA, the United States Navy and the United States Coast Guard, mixtures containing oxygen below forty percent, do not require extra handling other than the routine maintenance recommended by the manufacturer of the equipment. Once we exceed the forty percent mark, however, special cleaning and preparation of the equipment is required. We call this special handling oxygen cleaning.

> POINTS TO REMEMBER
>
> AS LONG AS THE OXYGEN CONTENT OF THE BREATHING MIXTURE ENTERING THE CYLINDER OR AIR DELIVERY SYSTEM IS 40% OR LESS, THE SCUBA EQUIPMENT CAN BE USED WITHOUT SPECIAL OXYGEN CLEANING

Additionally, SCUBA equipment that is to be placed in oxygen service (i.e. equipment to be used with Nitrox blends over forty percent) must be reassembled after the oxygen cleaning, using oxygen compatible components and lubricants. However, you should check your equipment manufacturer's guide regarding the use of enriched air Nitrox mixtures. Some equipment manufacturers state that the use of non-air mixtures will void the warranty. Other manufacturers require special service before using the equipment with enriched air Nitrox mixtures.

> POINTS TO REMEMBER
>
> IN ORDER TO MAINTAIN THE OXYGEN SERVICE RATING OF YOUR DIVE CYLINDER, YOU MUST FILL IT WITH NITROX OR AIR THAT IS CONSIDERED NITROX COMPATIBLE. STANDARD BREATHING AIR MAY INTRODUCE CONTAMINANTS INTO THE CYLINDER. REMEMBER, NOT ALL DIVE SHOPS OFFER THIS GRADE OF AIR

As you will learn shortly, the only time an IANTD Nitrox Diver will need to place equipment in oxygen service is when the supplier of the gas uses partial pressure blending to produce the gas. In this instance, the cylinder must be cleaned, because during the filling process, it will contain one-hundred percent oxygen, which is then adjusted for the mix you requested.

So, what happens if your equipment is not oxygen cleaned and is exposed to high concentrations of oxygen? Quite simply, there is a high risk of an explosion and fire. For this reason, it is important that the cleanliness of oxygen clean components be maintained. For cylinders in oxygen service, this means filling them only with Nitrox, using Nitrox grade breathing gasses. Not all dive shops or gas blending facilities offer this higher standard of gas fills, so be sure to ask prior to having your cylinder filled.

Figure 3-1: Contaminated Nitrox Cylinder after an explosion.

LABELING

In the United States, the Compressed Gas Association, CGA, developed a standard set of cylinder colors for various gas mixtures. Other countries developed similar programs. However, divers have not really adhered to the color scheme, so a system for identifying Nitrox dive cylinders and segregating them from other breathing gas cylinders was needed.

The SCUBA diving industry, in conjunction with the CGA, came up with a method of identifying Nitrox cylinders. Figure 3-1 shows the standard cylinder labeling developed for Nitrox cylinders.

NITROX BLENDING

There are a number of ways to produce Nitrox. In resort areas or locations that fill large numbers of Nitrox cylinders, you will typically find a membrane system driven by a low pressure air compressor. These systems produce consistent Nitrox blends up to 40%. oxygen.

In smaller operations, where the demand for Nitrox is lower or where there is a demand for Nitrox blends over 40% partial pressure, blending methods are employed. The gas can either be blended in the individual cylinder or in a large bank cylinder from which the individual cylinder is filled.

If you want to learn more about blending Nitrox gasses, you may want to enroll in an IANTD Gas Blender Course.

ANALYSIS

Before using a cylinder of Nitrox it is important to test the gas in the cylinder. For this reason, IANTD gas blending facilities will require that you analyze each bottle of Nitrox and sign the appropriate Fill Station Log, see Figure 3-3.

Figure 3-2: Oxygen Analyzer

Divers who use Nitrox on a regular basis usually own their own oxygen analyzer. There are a number of different models on the market, see Figure 3-2, including some dive computers that can be used as oxygen analyzers. By owning your own analyzer you know the condition of the sensor and can get a reading independent of the test equipment used by the fill station.

If your reading is significantly different from the reading recorded by the gas blender, double check your calibration and perhaps ask the supplier for another analyzer. The oxygen sensor cells have a useful life of one to two years, depending on the environment and use of the cell. One of the analyzers may be giving inaccurate readings.

After testing your cylinders, record the mixture on the content sticker along with the maximum operating depth for the mixture. It is important to do this now and not wait until later. On dive boats and locations, cylinders may look similar, and you do not want to dive without knowing what gas mixture is in the cylinder you are using. Remember, there have been injuries resulting from diving with the incorrect gas mixtures. If you are in doubt, re-analyze the mixture at the dive site.

ALL NITROX GAS MIXTURES MUST BE ANALYZED PRIOR TO DIVING.
THERE ARE NO EXCEPTIONS!

Because analyzers have a margin of error, you may want to apply the one percent safety rule. For CNS oxygen toxicity purposes, add 1% to the reading you get from the analyzer (i.e. for a reading of 36% you would use 37%), and for nitrogen absorption purposes subtract one percent (i.e. for a reading of 36% you would use 35%). The IANTD Waterproof Nitrox Diving & Decompression Tables take this one-percent into account (i.e. for a reading of 36%, you can still use the 36% table). By applying this one-percent rule you have increased the safety margin of your dive.

USE THE 1% RULE FOR YOUR GAS READING FOR THE OXYGEN AND THE DECOMPRESSION CLOCKS

Oceanic Ventures, Inc.
Mix Gas Blend Log

Cylinder Serial Number / ID	Owners Name	Certification Type & Number	Gas Mixture Requested	Blender Analysis	Blender Signature	Blender Analysis Date	Store Personnel Signature	Store Personnel Date	User Analysis	User Signature	User Signature Date
OV13	Oceanic Ventures,Inc	EANx Diver #145254	32%	32.2%	Marcel Krammer	04/05/2015	Eric Keibler	04/10/2015	32.4%	F. Brown	04/10/2015
OV14	Oceanic Ventures, Inc	EANx Divers #658921	40%	39.5%	Marcel Krammer	05/02/2015	Eric Keibler	05/03/2015	39.9%	Margaret P.	05/03/2015
OV15	Oceanic Ventures, Inc	Adv. EANx Diver #254784	36%	36.8%	Marcel Krammer	05/15/2015	Eric Keibler	05/25/2015	36%	Hans W.	05/25/2015
LP112-IASC	Ann Keiblen	Technical Diver #362514	50%	50.1%	Marcel Krammer	06/18/2015	Eric Keibler	06/18/2015	49.7%	Mark L.	06/08/2015

Figure 3-3: Fill station log sheet.

SUMMARY

In general, the method of producing Nitrox breathing gasses is less important to the diver; what is more important is that you personally test the mixture in your bottle and record it on the content sticker. This way you will always know the oxygen content of the cylinder you are taking underwater with you.

SECTION 3 — STUDY QUESTIONS

1. As long as the oxygen content of the breathing gas mixture entering the cylinder is below ______________, you can use your equipment with it before it needs special oxygen cleaning?
   a. 50%
   b. 90%
   c. 40%
   d. 21%
2. It is not necessary to fill your oxygen/Nitrox ready cylinder with Nitrox compatible air when using it for air diving.
   a. True
   b. False
3. Nitrox cylinders must be labeled appropriately and the gas contents of the cylinder must be noted on a content sticker.
   a. True
   b. False
4. As long as you obtain your Nitrox fills from a reputable dive facility, there is no need to test the Nitrox gas mixture.
   a. True
   b. False
5. The advantage to owning your own oxygen analyzer is which of the following?
   a. You know the condition of the oxygen sensor.
   b. You are more familiar with the operation of your own equipment.
   c. It provides you with an independent measurement of the gas.
   d. All of the above.

APPENDIX

The Leader in Diver Education

Technical Diving Selected Planning Formulas

Absolute Presssure:

$$P_{ata} = \left[\frac{D_{fsw}}{33_{fsw}} \right] + 1$$

Oxygen Dose:

$$PO_2 = FO_2 \ X \ P_{ata}$$

Maximum Operation Depth:

$$MOD_{fsw} = \left[\left(\frac{PO_{2\ (ata)}}{FO_2} \right) - 1_{ata} \right] X \ 33_{fsw}$$

Best EANx Mix:

$$FO_2 = \frac{PO_{2\ (ata)}}{P_{ata}}$$

Equivalent Air Depth:

$$EAD_{fsw} = \left[\frac{(FN_2 \ X \ D_{fsw} + 33_{fsw})}{0.79} \right] - 33_{fsw}$$

Surface Air Consumption:

$$SAC = \frac{\text{Total Gas Consumed}}{D_{ata} \ X \ T_{(min.)}}$$

Respiratory Minute Volume:

$$RMV = \frac{SAC}{\left[\frac{\text{Rated Cylinder Working Pressure}}{\text{Rated Cylinder Volume}} \right]}$$

Available Gas Volume:

$$V_{available} = \left(\frac{P_{gauge}}{P_{rated}} \right) X \ V_{rated}$$

Central Nervous System O_2 Toxicity:

$$\%CNS = \frac{\text{Dive Time at } PO_2}{\text{NOAA Single Exposure Limit}}$$

Note: the %CNS exposure for all of the depths/mixtures must be computed separately and added together to arrive at the final %CNS amount for the dive.

Whole Body O_2 Toxicity:

$$OTU = T \ x \left[\frac{(PO_2 - 0.5)}{0.5} \right]^{0.83}$$

Note: the OTU exposure for all of the depths/mixtures must be computed separately and added together to arrive at the final OTU amount for the dive.

Inspired Oxygen:

$$\text{Inspired } O_2 = \frac{\left[(FO_2 \ X \ FR_{lpm} - VO_{2(lpm)}) \right]}{(FR_{lpm} - VO_{2(lpm)})}$$

Gas Supply Duration:

$$T_{min} = \frac{\left[(V \ X \ P_{fill} - \text{Reserve}) \right]}{FR_{lpm}}$$

APPENDIX B1: IANTD NO-STOP TABLES — AIR

IANTD OPEN WATER AIR DIVING & DECOMPRESSION TABLES

(A)

Depth (Feet)	40	50	60	70	80	90	100	110	120	130	140
Depth (Meters)	12	15	18	21	24	27	30	33	36	39	42
No Decompression Limits (Minutes)	125	75	51	35	25	20	17	14	12	10	9

(B) BOTTOM TIMES

40	50	60	70	80	90	100	110	120	130	140	Repetitive Group
19	16	14	12	11	10	9	8	7	7	6	A
25	20	17	15	13	12	11	10	9	8	7	B
37	29	25	22	20	18	16	11	10	9	8	C
57	41	33	28	24	19	17	14	12	10	9	D
82	59	44	35	25	20						E
111	65	51									F
125	75										G
											H
											K
											L

(C) SURFACE INTERVALS

Repetitive Group	G	F	E	D	C	B	A	
A							00:00 01:59	02:00
B						00:00 00:19	00:20 01:59	02:00
C					00:00 00:09	00:10 00:24	00:25 02:59	03:00
D				00:00 00:09	00:10 00:14	00:15 00:29	00:30 02:59	03:00
E			00:00 00:09	00:10 00:14	00:15 00:24	00:25 00:44	00:45 03:59	04:00
F		00:00 00:19	00:20 00:29	00:30 00:44	00:45 01:14	01:15 01:29	01:30 07:59	08:00
G	00:00 00:24	00:25 00:44	00:45 00:59	01:00 01:14	01:15 01:39	01:40 02:09	02:10 11:59	12:00
H	00:50 01:04	01:05 01:34	01:35 02:09	02:10 02:59	03:00 03:59	04:00 05:39	05:40 23:59	24:00
K	03:00 03:59	04:00 04:59	05:00 05:59	06:00 06:59	07:00 07:59	08:00 09:19	09:20 38:59	39:00
L	06:00 06:59	07:00 08:29	08:30 09:59	10:00 11:59	12:00 13:59	14:00 16:29	16:30 47:59	48:00
(D) REPETITIVE GROUP AT END OF S.I.	G	F	E	D	C	B	A	

(E) REPETITIVE DIVE TABLES

G	F	E	D	C	B	A		DEPTH (ft)	DEPTH (m)
137	111	82	57	37	25	19	RNT	40	12
115	88	59	41	29	20	16	RNT	50	15
91	68	44	33	25	17	14	RNT	60	18
72	53	37	28	22	15	12	RNT	70	21
57	42	30	24	20	13	11	RNT	80	24
47	35	26	21	18	12	10	RNT	90	27
40	30	23	19	16	11	9	RNT	100	30
35	27	21	17	14	10	8	RNT	110	33
31	24	19	15	12	9	7	RNT	120	36
27	21	17	14	11	8	7	RNT	130	39
25	19	16	13	10	7	6	RNT	140	42
23	17	14	11	9	7	6	RNT	150	45

RESIDUAL NITROGEN TIME

Warning: DO NOT attempt to use these tables unless you are fully trained & certified in the use of Compressed Air, or are under the supervision of a Scuba Instructor. Proper use of these tables will reduce the risk of decompression sickness & oxygen toxicity, but no table or computer can eliminate those risks.

These Tables Are For Air With Air As Deco Gas. The 15 Foot (4.5 m) Stops MUST Be Taken At 15 Feet (4.5 m). These Tables Are Based On Bühlmann's ZHL-16 Algorithm For 0-1000 Feet (0-300 m) Above Sea Level. They Were Produced Using Cybortronix DPA Software. The Repetitive Dive Groups Are Not Transferable To ANY Other Tables. A Three Minute Safety Stop Is Required For All Dives. These Tables Do Not Account For Physical Condition Of Diver, Difficulty Of Dive, Water Temperature, Etc.

(A) Planned Depth
(B) Bottom Time In Depth Column
(C) Read Across To Find Surface Interval
(D) Locate RNT After S. I.
(E) Read Down To Planned Repetitive Dive Depth. Read RNT

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APPENDIX B2: IANTD NO-STOP TABLES — EAN 32

IANTD EAN 32% DIVING & DECOMPRESSION TABLES

(A)

Depth (Feet)	40	50	60	70	80	90	100	110	120
Depth (Meters)	12	15	18	21	24	27	30	33	36
No Decompression Limits (Minutes)	154	125	75	51	35	25	20	20	17

(B) BOTTOM TIMES

40	50	60	70	80	90	100	110	120	Repetitive Group
25	19	16	14	12	11	10	10	9	A
37	25	20	17	15	13	12	12	11	B
55	37	29	25	22	20	18	18	16	C
81	57	41	33	28	24	19	19	17	D
105	82	59	44	35	25	20	20		E
130	111	65	51						F
154	125	75							G
									H
									K
									L

SURFACE INTERVALS (C)

Repetitive Group	G	F	E	D	C	B	A	
A							00:00 01:59	02:00
B						00:00 00:19	00:20 01:59	02:00
C					00:00 00:09	00:10 00:24	00:25 02:59	03:00
D				00:00 00:09	00:10 00:14	00:15 00:29	00:30 02:59	03:00
E			00:00 00:09	00:10 00:14	00:15 00:24	00:25 00:44	00:45 03:59	04:00
F		00:00 00:19	00:20 00:29	00:30 00:44	00:45 01:14	01:15 01:29	01:30 07:59	08:00
G	00:00 00:24	00:25 00:44	00:45 00:59	01:00 01:14	01:15 01:39	01:40 02:09	02:10 11:59	12:00
H	00:50 01:04	01:05 01:34	01:35 02:09	02:10 02:59	03:00 03:59	04:00 05:39	05:40 23:59	24:00
K	03:00 03:59	04:00 04:59	05:00 05:59	06:00 06:59	07:00 07:59	08:00 09:19	09:20 38:59	39:00
L	06:00 06:59	07:00 08:29	08:30 09:59	10:00 11:59	12:00 13:59	14:00 16:29	16:30 47:59	48:00

(D) REPETITIVE GROUP AT END OF S.I.

(E) REPETITIVE DIVE TABLES

G	F	E	D	C	B	A		DEPTH (ft)	(m)
154	130	105	81	55	37	25	RNT	40	12
137	111	82	57	37	25	19	RNT	50	15
115	88	59	41	29	20	16	RNT	60	18
91	68	44	33	25	17	14	RNT	70	21
72	53	37	28	22	15	12	RNT	80	24
57	42	30	24	20	13	11	RNT	90	27
47	35	26	21	18	12	10	RNT	100	30
47	35	26	21	18	12	10	RNT	110	33
40	30	23	19	16	11	9	RNT	120	36

RESIDUAL NITROGEN TIME

Warning: DO NOT attempt to use these tables unless you are fully trained & certified in the use of Gas Mixtures Other Than Air, or are under the supervision of a Gas Mixtures Other Than Air Instructor. Proper use of these tables will reduce the risk of decompression sickness & oxygen toxicity, but no table or computer can eliminate those risks.

These Tables Are For EAN 32% With EAN 32% As Deco Gas. The 15 Foot (4.5 m) Stops MUST Be Taken At 15 Feet (4.5 m). These Tables Are Based On Bühlmann's ZHL-16 Algorithm For 0-1000 Feet (0-300 m) Above Sea Level. They Were Produced Using Software Available From IAND, Inc. The Repetitive Dive Groups Are Not Transferable To ANY Other Tables. A Three Minute Safety Stop Is Required For All Dives. These Tables Do Not Account For Physical Condition Of Diver, Difficulty Of Dive, Water Temperature, Etc.

(A) Planned Depth
(B) Bottom Time In Depth Column
(C) Read Across To Find Surface Interval
(D) Locate RNT After S. I.
(E) Read Down To Planned Repetitive Dive Depth. Read RNT

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APPENDIX B3: IANTD NO-STOP TABLES — EAN 36

IANTD EAN 36% DIVING & DECOMPRESSION TABLES

(A)

40	50	60	70	80	90	100	110	Depth (Feet)	Repetitive Group ↓
12	15	18	21	24	27	30	33	Depth (Meters)	
154	125	75	75	51	35	25	20	No Decompression Limits (Minutes)	

(B) BOTTOM TIMES — SURFACE INTERVALS (C)

40	50	60	70	80	90	100	110							
25	19	16	16	14	12	11	10					A	00:00 01:59	02:00
37	25	20	20	17	15	13	12				B	00:00 00:19	00:20 01:59	02:00
55	37	29	29	25	22	20	18			C	00:00 00:09	00:10 00:24	00:25 02:59	03:00
81	57	41	41	33	28	24	19		D	00:00 00:09	00:10 00:14	00:15 00:29	00:30 02:59	03:00
105	82	59	59	44	35	25	20	E	00:00 00:09	00:10 00:14	00:15 00:24	00:25 00:44	00:45 03:59	04:00
130	111	65	65	51			F	00:00 00:19	00:20 00:29	00:30 00:44	00:45 01:14	01:15 01:29	01:30 07:59	08:00
154	124	75	75			G	00:00 00:24	00:25 00:44	00:45 00:59	01:00 01:14	01:15 01:39	01:40 02:09	02:10 11:59	12:00
						H	00:50 01:04	01:05 01:34	01:35 02:09	02:10 02:59	03:00 03:59	04:00 05:39	05:40 23:59	24:00
						K	03:00 03:59	04:00 04:59	05:00 05:59	06:00 06:59	07:00 07:59	08:00 09:19	09:20 38:59	39:00
						L	06:00 06:59	07:00 08:29	08:30 09:59	10:00 11:59	12:00 13:59	14:00 16:29	16:30 47:59	48:00
(D) REPETITIVE GROUP AT END OF S.I.							G	F	E	D	C	B	A	

(E) REPETITIVE DIVE TABLES

G	F	E	D	C	B	A		DEPTH (ft)	(m)
154	130	105	81	55	37	25	RNT	40	12
137	111	82	57	37	25	19	RNT	50	15
115	88	59	41	29	20	16	RNT	60	18
115	88	59	41	29	20	16	RNT	70	21
91	68	44	33	25	17	14	RNT	80	24
72	53	37	28	22	15	12	RNT	90	27
57	42	30	24	20	13	11	RNT	100	30
47	35	26	21	18	12	10	RNT	110	33

RESIDUAL NITROGEN TIME

Warning: DO NOT attempt to use these tables unless you are fully trained & certified in the use of Gas Mixtures Other Than Air, or are under the supervision of a Gas Mixtures Other Than Air Instructor. Proper use of these tables will reduce the risk of decompression sickness & oxygen toxicity, but no table or computer can eliminate those risks.

These Tables Are For EAN 36% With EAN 36% As Deco Gas. The 15 foot (4.5 m) Stops MUST Be Taken At 15 Feet (4.5 m). TheseTables Are Based On Bühlmann's ZHL-16 Algorithm For 0-1000 Feet (0-300 m) Above Sea Level. They Were Produced Using Software available from IAND, Inc. The Repetitive Dive Groups Are Not Transferable To ANY Other Tables. A Three Minute Safety Stop Is Required For All Dives. These Tables Do Not Account For Physical Condition Of Diver, Difficulty Of Dive, Water Temperature, Etc.

(A) Planned Depth
(B) Bottom Time In Depth Column
(C) Read Across To Find Surface Interval
(D) Locate RNT After S. I.
(E) Read Down To Planned Repetitive Dive Depth. Read RNT

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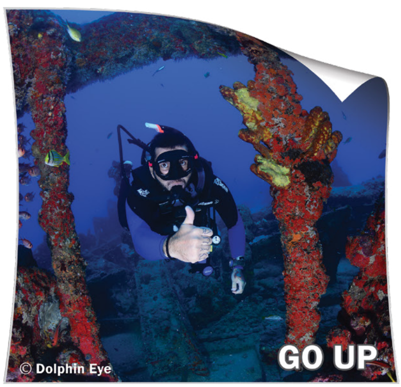
APPENDIX 1 - HAND SIGNALS

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Out of Gas


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COLD


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GET TOGETHER


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You Lead I'll Follow


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Turn Back


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BUBBLE


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DECOMPRESSION

APPENDIX C: STUDY QUESTION ANSWERS

SECTION 1: THE BENEFITS & CONCERNS OF NITROX DIVING—STUDY QUESTIONS

1. b
2. d
3. d
4. a
5. a
6. a
7. d
8. c
9. Convulsion, Visual, Ears/Euphoria, Nausea, Twitching/Tingling, Irritability, Dizziness
10. d
11. b

SECTION 2: PLANNING NITROX DIVES—STUDY QUESTIONS

1. d
2. b
3. a
4.

Depth Feet	Depth Meters	Pressure ATA	Best EANx Mixture @ 1.4 ata
60	18	2.8	40
70	21	3.1	40
80	24	3.4	40
90	27	3.7	38
100	30	4.3	33

5. d
6. c

7.

Depth Feet	Depth Meters	Pressure ATA	NDL Limit	Nitrox Mixture	PPO2	EAD fsw/msw	Adjusted NDL	Maximum Single Expossure Limit
47	14	2.4	75	EAN30	0.72	38/12	125	450
56	17	2.7	51	EAN36	0.97	39/12	125	300
104	31	4.1	35	EAN36	1.20	42/13	75	210
111	33	4.3	14	EAN32	1.49	77/23	25	120
122	37	4.7	14	EAN28	1.38	90/27	20	150
130	39	4.9	10	EAN24	1.32	108/33	14	150

8. c

SECTION 3: THE OPERATIONAL ASPECTS OF NITROX DIVING—STUDY QUESTIONS

1. c
2. b
3. a
4. b
5. d

APPENDIX D: REFERENCES AND FURTHER READING

Arntzen, A. J., Eidsvik S. - Modified air and NITROX diving and treatment tables. NUI Report 30-80 Bergen: Norwegian Underwater Institute, September 1980.

ASTM Document - G-88, Designing Systems for Oxygen Service.

ASTM Document - G-93, Cleaning Methods for Material and Equipment Used in Oxygen Enriched Atmospheres.

Bergllage T. E., McCracken TM., Equivalent Air Depth: Fact or Fiction. Undersea Biomed Res. G(4):379-384, 1979a.

Butler and Thalman, Oxygen exposure limit table (table 7) - 1986, adapted from data in the International Diving and Aerospace Data System, Institute for Environmental Medicine, University of Pennsylvania by C. J. Lambertsen and R. Peterson.

CCA Pamphlet : P-5, Suggestions for the Care of High Pressure Air Cylinder for Underwater Breathing.

CCA Pamphlet : G-4, Oxygen.

Clark, J.M., Oxygen tolerance in NITROX Diving: Hamilton RW, Hulbert AW, Crosson DJ, eds Harbor Branch Workshop on Enriched Air NITROX Diving. Tech. Report 89-1, Rockville, MD: NOAA Office of undersea Research, 1989

Dinsmore, David A., 1988. Use of optimal enriched air breathing mixtures to maximize dive time and operational flexibility. Advances In Underwater Science. Proceedings of the American Academy of Underwater Sciences. Eighth Annual Scientific Diving Symposium, La Jolla, Califomia :33-40.

Dinsmore, David A., 1989. Enriched Air Diving Safety Considerations. In: Oceans '89 Proceedings 89CH2780-5, 5: 1695-1697, September 18-21, Seattle, Washington.

R W., Hulbert, A. W., Crosson, D. J.: eds. Harbor Branch Workshop on Enriched Air NITROX Diving. Technical Report 89-1. Rockville, MD: NOAA Office of Undersea Research, 1989.

Lambertsen, C. J., Discussion: RW, Hulbert AW, Crosson DJ eds. Harbor Branch Workshop on Enriched Air NITROX Diving. Tech. Report 89-1 NOAA, Rockville, MD: Office of Undersea Research, 1989.

Leitch, D.R, Barnard E.E.P., Observations on No-Stop and Repetitive Air and Oxynitrogen Diving. Undersea Biomed Res. 9(2):113-129, 1982.

Logan, J.A., An Evaluation of the Equivalent Air Depth. NEDU Report 1-61. Washington, D.C.: USN Experimental Diving Unit, 1961.

Mastro, Steve J., Dinsmore, D.A., The Operational Advantages of Enriched Air NITROX Versus Air for Research Diving. Marine Technology Society Journal, Vol. 23, November 19, 1989.

Mastro, Steve J., 1989. Use of two primary breathing mixtures for enriched air diving operations. In: Diving for Science. (Lang and Jaap, ad.), pp. 241-247. American Academy of Underwater

Sciences, La Jolla, California.

Mastro, Steve J., 1989. Enriched Air Mixing Systems: Considerations and Practical Techniques. In: Oceans '89 Proceedings 89CH2780-5,1: 1706-1710, September 18-21, Seattle, Washington.

NOAA Diving Manual, Miller, J.W. ed., Second edition, Rockville, MD: NOAA, U. S. Department of Commerce, 1979.

NFPA 53-M, Manual on Fire Hazards in Oxygen Enriched Atmospheres.

U.S. Navy Diving Manual, Navships 250-538, Navy Dept. 1959, Section 3.6.

Vann, R D., The Physiology of NITROX Diving. Technical Report 89-1. NOAA.

Wells, J. M., The Use of Nitrogen-Oxygen Mixtures as Divers Breathing Gas.

Wells, J. M., NITROX Diving Within NOAA: History, Applications,and Future NOAA Tech Report 89-1.

Wells, J. M., Recent Developments in the Rise of Breathing Medias Other Than Air for Shallow-Diving Marine Technology. Society Journal, Vol. 23, No. 4,1989.

Wright, W., Use of the Pennsylvania, Institute of Environmental Medicine Procedure for Cumulative Pulmonary Oxygen Toxicity, U.S. Navy Exp. Diving Unit, Rep. NEDU 2-72, 1972.

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