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Nitrox Diver

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Why Nitrox Diver?

This course will prepare you to safely use oxygen-enriched air up to EAN40 to **extend your dive time** at depth.

Course Overview

- Tonight’s lecture (~2 hours)
- Gas analysis and labeling session
- Planning and executing 2 dives using Nitrox

Overview

Introduction

Physics of Gases

Oxygen Toxicity

Best Mix, EAD, and MOD

Safely Handling Oxygen

Analyzing and Labeling Gas

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What is Nitrox?

- Any mix of oxygen and nitrogen - this includes Earth's air!
- Practically, this means any blend of gas where oxygen has been **added** to reduce the relative amount of nitrogen.

What is Nitrox?

- Nitrox is also called:
  - Oxygen-enriched air
  - Enriched air nitrox
  - EANx - where x is the percentage of oxygen in the blend, such as EAN32 or EAN40

Why Dive with Nitrox?

- The nitrogen in the air you are breathing limits the **depth to which you can dive**, the **time you can stay at depth**, and the **number of dives** you can make in a day.
- Adding oxygen (an inexpensive and metabolically well-understood gas) allows us to absorb less nitrogen.

Why Dive with Nitrox?

Maximum Dive Time (min)			
Depth (fsw)	Air	EAN32	EAN36
60	55	100	100
70	45	60	60
80	35	50	60
90	25	40	50
100	22	30	-
110	15	25	-

Why Dive with Nitrox?

- Anecdotally, many divers claim that they are less physically tired after a series of dives on nitrox.
- This has not been conclusively studied.

Benefits of Nitrox

- There is a misconception that “nitrox is for deep dives”.
- Nitrox is a **mid-range** breathing gas and provides the greatest advantages for dives in the **50- to 110-foot** depth range.

History of Enriched Air Diving

- 1878 - Paul Bert shows nitrogen to be cause of DCS.
- 1908 - J. S. Haldane publishes first diving decompression tables.
- 1935 - Behnke et al. attribute narcosis to nitrogen.
- 1959 - U.S. Navy Diving Manual introduces oxygen-enriched air.

History of Enriched Air Diving

- 1979 - NOAA Diving Manual publishes NOAA Nitrox I as standard mix.
- 1985 - IAND formed. Rutkowski expands nitrox to recreational diving.
- 1992 - NAUI sanctions teaching enriched air nitrox.

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Earth's Air

- The air we breathe has:
  - 21% Oxygen
  - 78% Nitrogen
  - 1% Argon
  - <1% other miscellaneous gases
- Review: What would be the EAN designation of air?

O_2 - Oxygen

- One of the most abundant elements on Earth.
- Much of what you will learn in this course is about oxygen:
  - Adding oxygen to gas blends
  - Avoiding oxygen toxicity
  - Care of equipment exposed to high concentrations of oxygen
- Necessary for life (anoxia/hypoxia), but toxic in excess (hyperoxia/ox-tox).

N_2 - Nitrogen

- Largely inert.
- Colorless, odorless, and tasteless.
- When breathed at higher pressures, it has a pronounced anesthetic effect referred to as **nitrogen narcosis**.

Partial Pressure

- The pressure of a gas dramatically changes its effect on our physiology or in chemical reactions.
- More specifically, the **partial pressure** of a gas allows us to consider the impact of an individual gas in a blend.
- Denoted Px or PPx, e.g. PO2 or PPN2.

Dalton's Law

- The partial pressure of any component gas in a mixture is the fraction of that gas in the mixture times the total gas pressure.

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

Dalton's Law: Practice

- PN2 of air at 5 atm?
- PN2 of EAN40 at 5 atm?

- PO2 of air at 5 atm?
- PO2 of EAN40 at 5 atm?

Dalton's Law: Practice

- PN2 of air at 5 atm? 78% x 5 atm = 3.90 atm
- PN2 of EAN40 at 5 atm?

- PO2 of air at 5 atm?
- PO2 of EAN40 at 5 atm?

Dalton's Law: Practice

- PN2 of air at 5 atm? 78% x 5 atm = 3.90 atm
- PN2 of EAN40 at 5 atm? 60% x 5 atm = 3.00 atm

- PO2 of air at 5 atm?
- PO2 of EAN40 at 5 atm?

Dalton's Law: Practice

- PN2 of air at 5 atm? 78% x 5 atm = 3.90 atm
- PN2 of EAN40 at 5 atm? 60% x 5 atm = 3.00 atm

- PO2 of air at 5 atm? 21% x 5 atm = 1.05 atm
- PO2 of EAN40 at 5 atm?

Dalton's Law: Practice

- PN2 of air at 5 atm? 78% x 5 atm = 3.90 atm
- PN2 of EAN40 at 5 atm? 60% x 5 atm = 3.00 atm

- PO2 of air at 5 atm? 21% x 5 atm = 1.05 atm
- PO2 of EAN40 at 5 atm? 40% x 5 atm = 2 atm

Dalton's Law: Practice

- PN2 of air at 5 atm? 78% x 5 atm = 3.90 atm
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- PO2 of air at 5 atm? 21% x 5 atm = 1.05 atm
- PO2 of EAN40 at 5 atm? 40% x 5 atm = 2 atm

Conclusions?

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Central Nervous System Toxicity

- Has a wide range of signs and symptoms, the most dramatic being epilepsy-like convulsions
- CNS toxicity can result from relatively short exposures to high partial pressures of oxygen
- The seizure itself is not likely to cause lasting damage - the danger is drowning.

Ox-tox Limits

- For recreational diving, the generally accepted PO2 exposure limit is **1.4 atm**, with 1.6 atm reserved for contingencies.

Ox-tox Risk Factors

- Among the many factors that can increase your susceptibility to CNS oxygen toxicity are:
  - heavy exercise
  - increased carbon dioxide build-up from whatever cause
  - chilling or hypothermia

Ox-tox Signs and Symptoms

- The most obvious signs and symptoms of CNS oxygen toxicity are:
  - Convulsions
  - Visual disturbances
  - Nausea or dizziness
  - Twitching
  - Tingling extremities
  - Irritability
  - Labored breathing

Ox-tox First Aid

- If your buddy shows signs of ox-tox, ascend immediately and get them out of the water
- If possible, switch them to a lower PPO2 gas as soon as possible

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Converting Depth to Pressure

- At the surface, atmospheric pressure is 1 atm.
- Every 33 fsw we descend, we gain an additional 1 atm.
- Therefore, the pressure at a given depth is:

$$P = 1\ atm + (depth / 33\ fsw/atm)$$

- Since this pressure is absolute, we denote it with ATA instead of atm

Converting Depth to Pressure: Practice

- Convert the following depths to ATA:
  - 0 fsw (surface)
  - 33 fsw
  - 100 fsw

- At which depths would you achieve the following pressures?
  - 1 ATA
  - 3 ATA
  - 5 ATA

Converting Depth to Pressure: Practice

- Convert the following depths to ATA:
  - 0 fsw (surface) - 1 ATA
  - 33 fsw
  - 100 fsw

- At which depths would you achieve the following pressures?
  - 1 ATA
  - 3 ATA
  - 5 ATA

Converting Depth to Pressure: Practice

- Convert the following depths to ATA:
  - 0 fsw (surface) - 1 ATA
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  - 100 fsw

- At which depths would you achieve the following pressures?
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  - 3 ATA
  - 5 ATA

Converting Depth to Pressure: Practice

- Convert the following depths to ATA:
  - 0 fsw (surface) - 1 ATA
  - 33 fsw - 2 ATA
  - 100 fsw - 4.03 ATA

- At which depths would you achieve the following pressures?
  - 1 ATA
  - 3 ATA
  - 5 ATA

Converting Depth to Pressure: Practice

- Convert the following depths to ATA:
  - 0 fsw (surface) - 1 ATA
  - 33 fsw - 2 ATA
  - 100 fsw - 4.03 ATA

- At which depths would you achieve the following pressures?
  - 1 ATA - 0 fsw
  - 3 ATA
  - 5 ATA

Converting Depth to Pressure: Practice

- Convert the following depths to ATA:
  - 0 fsw (surface) - 1 ATA
  - 33 fsw - 2 ATA
  - 100 fsw - 4.03 ATA

- At which depths would you achieve the following pressures?
  - 1 ATA - 0 fsw
  - 3 ATA - 66 fsw
  - 5 ATA

Converting Depth to Pressure: Practice

- Convert the following depths to ATA:
  - 0 fsw (surface) - 1 ATA
  - 33 fsw - 2 ATA
  - 100 fsw - 4.03 ATA

- At which depths would you achieve the following pressures?
  - 1 ATA - 0 fsw
  - 3 ATA - 66 fsw
  - 5 ATA - 132 fsw

Maximum Operating Depth

The **Maximum Operating Depth** (MOD) for a gas blend is the depth below which we exceed our PO2 limits.

Maximum Operating Depth

To calculate the MOD of a gas, first find the pressure that gives us a PO2 of 1.4.

Then, we convert that pressure to a depth.

Maximum Operating Depth: Practice

What is the MOD of EAN40?
What is the MOD of EAN36?
What is the MOD of air?

MOD Tables

It’s very easy to make a table for MOD in a spreadsheet program!

Maximum Operating Depth	
Max PO2:	**1.4**
% of O2	MOD (fsw)
40%	82
39%	85
38%	88
37%	91
36%	95
35%	99
34%	102
33%	107
32%	111
31%	116
30%	121
29%	126
28%	132
27%	138
26%	144
25%	151
24%	159
23%	167
22%	177
21%	187

Best Mix

The **best mix** for a given dive or depth is the mix whose MOD is at the bottom of the dive. This minimizes nitrogen ongassing.

Best Mix: Practice

What is the best mix for 100 fsw?

What is the best mix for 60 fsw?

Equivalent Air Depth

Equivalent Air Depth for a given depth and gas blend is the depth at which the PN2 matches that of the nitrox. This allows you to use a dive table for air.

Equivalent Air Depth

What is the EAD for EAN32 at 60 fsw?

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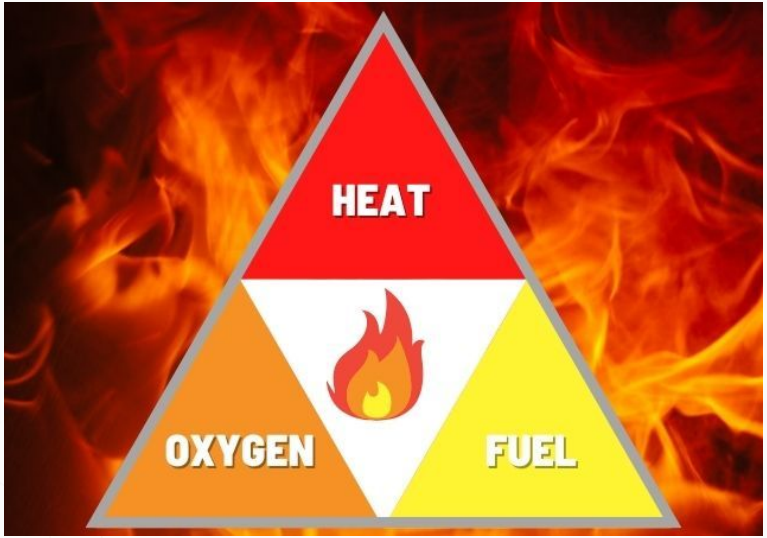
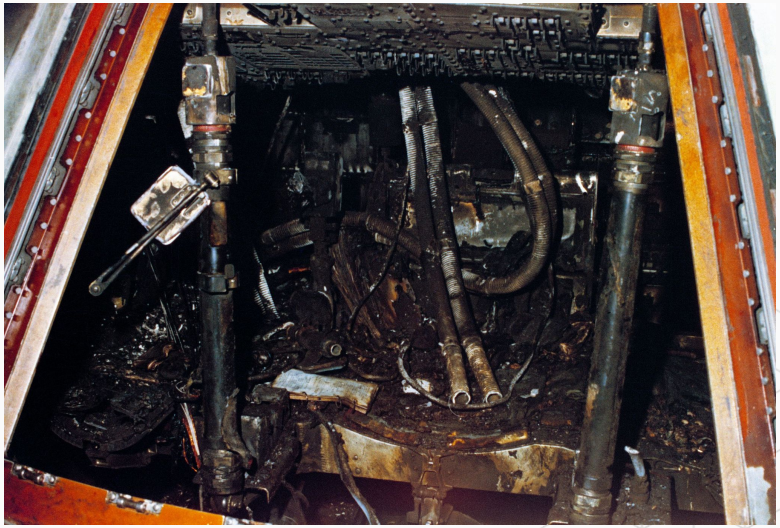
The Fire Triangle





The 40% Rule

If a tank/piece of equipment is going to see 40% O_2 or more, it should be **oxygen cleaned** and **oxygen compatible**.

- **O_2 cleaned: Scrubbing out hydrocarbons, metal shavings, and anything else flammable at elevated O_2 levels**
- **O_2 compatible: The equipment itself should not be made of flammable materials or materials that can spark**

Does that make EAN40 safe with dirty equipment?

Does that make EAN40 safe with dirty equipment?

No!

Let’s explore how we actually make Nitrox…

Partial Pressure Blending

- Very common, easiest way for most shops to start selling Nitrox
- Boost tank with oxygen, top with air
- Example for EAN32: 418 psi O_2, then 3000 psi of air

This exposes the tank and valve to 100% O_2

Continuous Flow Mixing

- Often called a “Nitrox stick”
- Mix oxygen in a premix chamber, then feed into compressor.
- Nothing gets exposed to higher concentrations of oxygen than the final mix, doesn’t require a booster.

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Field Trip!

Labeling A Nitrox Tank

- Follow local customs: regulations vary.
- Always required for YOUR SAFETY:
  - Near the tank valve: gas blend (to 1 decimal place), date of analysis, diver's name.
  - On side of tank: MOD, put in such a way that someone swimming next to you could read it.