The Ocean Diver Nitrox Workshop

Student Workbook

The British Sub Aqua Club BS·AC

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Ocean Diver Supplementary Training

The Nitrox Workshop

The primary aim of the workshop is to update existing BSAC divers already qualified as Ocean Diver (or equivalent) and above who have not covered the nitrox component in the revised diver training programme (DTP) introduced in January 2007.

Aims

Unless you have attended a skill development course in the use of nitrox, you will not have access to breathing gases where the oxygen content is greater than air (Nitrox 21).

The key aims of this workshop are to enable BSAC Ocean Divers (or similar) to:

Appreciate the benefits of diving on nitrox

Dive safely in open water using nitrox 32 and nitrox 36 for no stop dives

Plan nitrox dives using BSAC 88 Tables or an air computer

Understand potential equipment implications

Understand the methodology for analysing a blended nitrox mix

What is nitrox?

A breathing gas usually having more than 21% O_2

Nitrox is fundamentally a gas containing any combination of nitrogen and oxygen. Today, in the UK, the gas should be blended according to British Standards. It should be noted that the breathing air standard (BS EN 12021) is applicable to all EU member countries. The new BS7478:2006 standard defines 'breathing gases for diving and hyperbaric applications'. Outside of the EU, blending may or may not be covered by local legislation.

The gas composition is defined by the nitrogen and oxygen gas fractions

The gas fractions do not take into account the trace gases (which are ignored primarily for simplicity of understanding).

- **Nitrox 21 (Air) = 21% oxygen + 79% nitrogen**
- **Nitrox 32 = 32% oxygen + 68% nitrogen**
- **Nitrox 36 = 36% oxygen + 64% nitrogen**

As the percentage of oxygen in the nitrox mix is increased, consequently the percentage of nitrogen is reduced

Why nitrox?

Advantages of nitrox – less nitrogen means

- **Increased safety factor when used with air table or computer**

  An air computer or table computes a diver's decompression assuming that they are breathing 79% nitrogen, so if the breathing gas is nitrox it assumes that the diver's tissues contain a higher percentage of absorbed nitrogen than they actually do. The difference in absorbed nitrogen, between the assumed and actual builds in a real margin of safety for the nitrox diver.

- **Reduced risk of DCI**

  One of the most important benefits of nitrox is a reduction in the probability of a diver experiencing an incident of DCI.

Disadvantages of nitrox

- **Nitrox divers can still suffer DCI**

  There will always be an element of risk. Nitrox diving minimises the risk, but does not completely protect the diver from DCI. Staying down too long, rapid ascents, being unfit, drug/alcohol abuse, dehydration and all other normal causes of DCI cannot be ignored.

- **Certain equipment must be dedicated to the use of nitrox**

  There is an additional cost for making diving equipment compatible with nitrox diving, i.e., putting it in 'oxygen service'. Care needs to be exercised that the dedicated equipment is not accidentally contaminated.

- **Some methods of cylinder filling can expose cylinders to oxygen**

  The most common method of blending nitrox is a technique called partial pressure mixing. This exposes the cylinder to pure oxygen which is a recognized fire risk. Equipment exposed to oxygen must be in 'oxygen service'.

- **Oxygen toxicity (explained later)**

  Increased percentage of oxygen in the breathing gas, may lead to oxygen toxicity.

Ocean Diver Qualification

It is very important that you clearly understand what Ocean Divers are allowed to do following this workshop. There are limitations on your use of nitrox.

An Ocean Diver is allowed to dive to a maximum depth of 20 metres

Ocean Diver training is limited by definition to a maximum depth of 20 metres. This workshop does not enable any further increase in depth.

Participate only in “No-Stop” dives using Air, Nitrox 32 or Nitrox 36

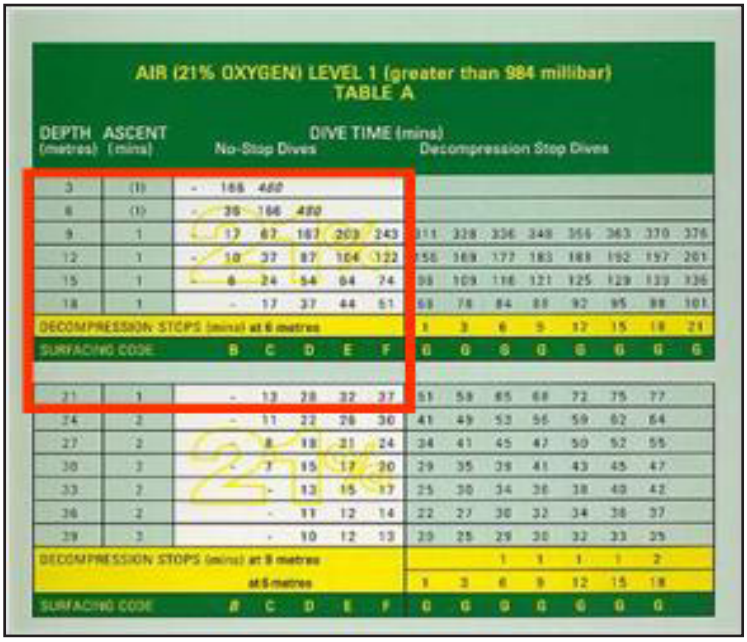
Ocean Divers can choose to dive with any one of three breathing gas mixes. You will need to obtain a nitrox certificate from BSAC HQ to enable you to purchase nitrox from dive shops.

Plan dives using an air table or air computer

Dive planning for the Ocean Diver is limited to the use of ‘air’ (Nitrox 21) tables or dive computers. If you already own a nitrox computer you should not set the gas mix to match the nitrox mix until you have completed Sports Diver training. You should use your computer with the air model only.

For example, an Ocean diver who has not dived in the past 24 hours is able to dive within the illustrated no-stop dive envelope

The graphic clarifies the operational envelope for Ocean Divers highlighted by the red box. Ocean Divers should not be straying outside this diving envelope.



AIR (21% OXYGEN) LEVEL 1 (greater than 984 millibar)
TABLE A

DEPTH (metres)	ASCENT (mins)	DIVE TIME (mins) No-Stop Dives					Decompression Stop Dives							
3	(1)	-	166	480										
6	(1)	-	36	166	480									
9	1	-	17	67	167	203	243	311	328	336	348	356	363	370	376
12	1	-	10	37	87	104	122	156	169	177	183	188	192	197	201
15	1	-	6	24	54	64	74	98	109	116	121	125	129	133	136
18	1	-	-	17	37	44	51	68	78	84	88	92	95	98	101
DECOMPRESSION STOPS (mins) at 6 metres								1	3	6	9	12	15	18	21
SURFACING CODE			B	C	D	E	F	G	G	G	G	G	G	G	G
21	1	-	-	13	28	32	37	51	58	65	68	72	75	77	
24	2	-	-	11	22	26	30	41	49	53	56	59	62	64	
27	2	-	-	8	18	21	24	34	41	45	47	50	52	55	
30	3	-	-	7	15	17	20	29	35	39	41	43	45	47	
33	2	-	-	-	13	15	17	25	30	34	36	38	40	42	
36	2	-	-	-	11	12	14	22	27	30	32	34	36	37	
39	3	-	-	-	10	12	13	20	25	29	30	32	33	35	
DECOMPRESSION STOPS (mins) at 9 metres										1	1	1	1	2	
at 6 metres								1	3	6	9	12	15	18	
SURFACING CODE			B	C	D	E	F	G	G	G	G	G	G	G	

Oxygen Toxicity

Although oxygen toxicity is unlikely to affect Ocean Divers, the following explains what it is. There are actually two types of oxygen toxicity, but this section is concerned only with the most hazardous type for divers, Central Nervous System (CNS) toxicity, and only discusses the effect of oxygen toxicity in general terms.

Oxygen can be toxic depending upon:

- **The operating depth (pressure) of the dive**
- **Time of exposure at the operating depth**
- **The fraction of oxygen in the blended mix**

Signs

The following recognisable signs do not necessarily happen in this order and some may not happen at all.

- **Visual or auditory disturbances**
- **Muscular twitching**
- **Convulsions**

Highly unlikely occurrence for Ocean Divers

Breathing the standard gas mixes of Nitrox 32 or Nitrox 36 and operating within the 20 metre depth limit, it is highly unlikely that any Ocean Diver would experience the effects of oxygen toxicity.

Oxygen Toxicity

Resolution

If you experience any of the described signs you should immediately:

- **Abort the dive and return to surface**

Prevention

The nitrox mixes have been chosen to minimise risk and build in a significant safety margin.

- **Each mix has a defined "Maximum Operating Depth" (MOD), which exceeds the Ocean Diver depth limit of 20 metres:**

  The following statements are only applicable to no-stop decompression diving: planning decompression dives on nitrox is part of the Sports Diver syllabus.

  - **Nitrox 32 - 35 metres for NO-STOP dives**
  - **Nitrox 36 - 30 metres for NO-STOP dives**

- **Always analyse the nitrox mix before use**

  Blenders are required to demonstrate that the gas supplied

is what was requested, within specification. It is important to reconfirm the mix prior to the dive.

- **Always clearly label the cylinder with:**
    - **Oxygen percentage**
    - **MOD**

  It is essential to document the cylinder's contents and operational parameters on the cylinder itself to prevent accidents. Old labels should be removed prior to filling to avoid any confusion.

- **Do NOT exceed the MOD for the gas mix**

  For Ocean Divers this should not be an issue, but it could happen if, for example, a cylinder containing the wrong gas is chosen or an incident occurs on the dive and the divers are forced to dive deeper than planned.

    - **Further considerations need to be understood as you progress through higher levels of training**

BSAC 88 Tables - Planning a No-Stop Dive

BSAC '88 Tables have always been part of Ocean Diver training, so you will be familiar with the material in the following section. Nevertheless, it is essential that the rules, procedures and definitions contained within the BSAC '88 Tables are fully understood. If you have purchased the BSAC Nitrox tables for level 1, note that the air (21%) table is the one to be used by Ocean Divers. It is identical to the BSAC '88 Table for level 1. The rules, procedures and definitions utilised in the BSAC Nitrox decompression tables are identical to those used for the BSAC '88 Tables:

- No-stop diving.
- Ascent rates.
- Dive profiles.
- Table procedures and usage.
- Altitude diving above level 1 is not currently catered for in the BSAC Nitrox Tables. However, the considerations regarding

decompression and flying in aircraft before or after a dive remain the same.

- Recommended safe diving.

The white area/zone on the 21% table is what Ocean Divers may use, as this indicates no-stop dives.

You must understand the basic definitions prior to working through the following example.

Dive to 20 m for 30 minutes

It is the first dive so CTC=A. Remember that 20 metres is the maximum allowable depth for an Ocean Diver.

Depth and/or time is 'in between' values

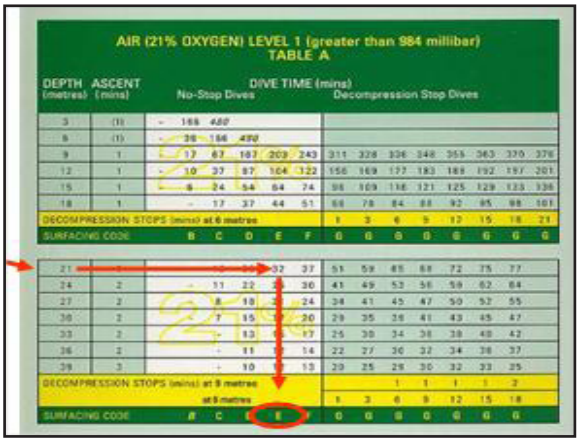
Remember that the table increments in 3 metre intervals, so when planning dives, always be cautious, i.e.,

- **Use next greater depth**

  21 metres is the closest incremental depth for dive planning purposes in this case.

- **Use next longer time**

  32 minutes is the closest and safest option to the original planned 30 minutes.



Surface Code is E

The intersection of 21 metres at 32 minutes identifies the surfacing code as E.

Planning Two Dives

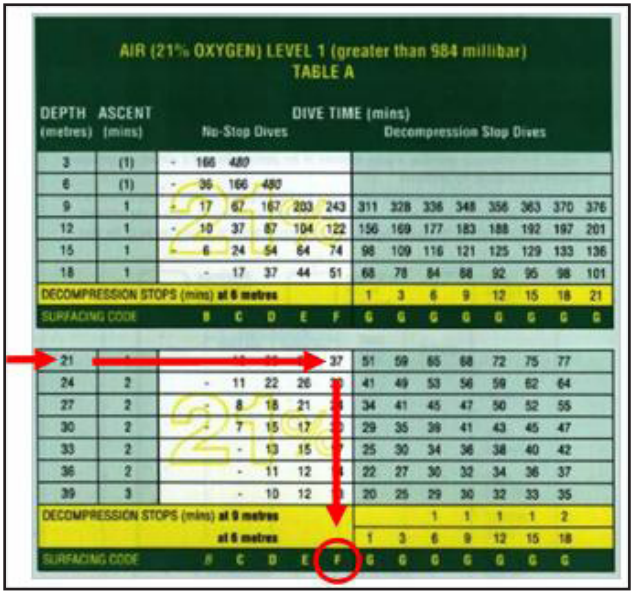
Example

You could use either BSAC '88 or BSAC Nitrox tables to work through this dive example. The procedures for using the tables are identical.

First Dive

- **20 m for 33 min**

  This is the first dive in the past 24 hours. As the graphic illustrates, you must apply the principle of next greater depth of 21 metres and next longest time of 37 minutes to correctly identify the surfacing code.



AIR (21% OXYGEN) LEVEL 1 (greater than 984 millibar)
TABLE A

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SURFACING CODE		B	C	D	E	F		G	G	G	G	G	G	G	G
21	1	-	-	-	-	-	37	51	59	65	68	72	75	77	
24	2	-	-	11	22	26	30	41	49	53	56	59	62	64	
27	2	-	-	8	18	21	24	34	41	45	47	50	52	55	
30	2	-	-	7	15	17	20	29	35	39	41	43	45	47	
33	2	-	-	-	13	15	17	25	30	34	36	38	40	42	
36	2	-	-	-	11	12	14	22	27	30	32	34	36	37	
39	3	-	-	-	10	12	13	20	25	29	30	32	33	35	
DECOMPRESSION STOPS (mins) at 9 metres										1	1	1	1	2	
at 6 metres								1	3	6	9	12	15	18	
SURFACING CODE		B	C	D	E	F		G	G	G	G	G	G	G	

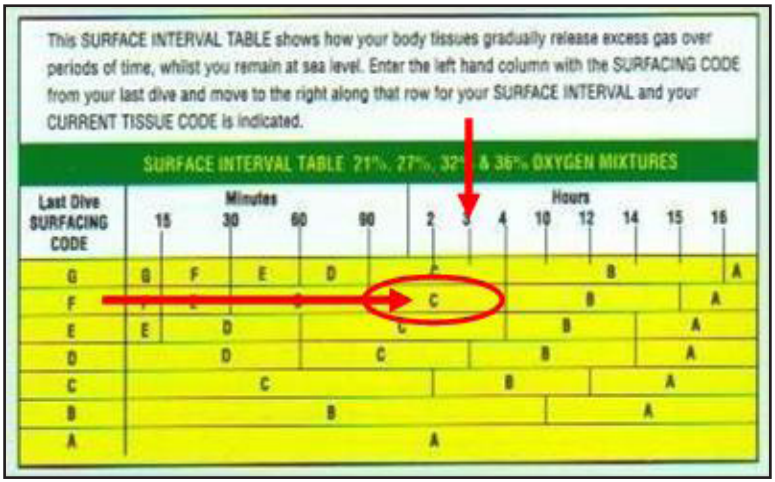
- **Surfacing Code = F**

Surface Interval Table

The example continues. The next step is to work out the current tissue code.

Surface Interval 3 hours

The divers had a surfacing code of F after the first dive. The Surface Interval Table is used to find the new surface code in preparation for dive two.



Second Dive CTC = C

Planning - dive two

Second Dive

- **Table C**

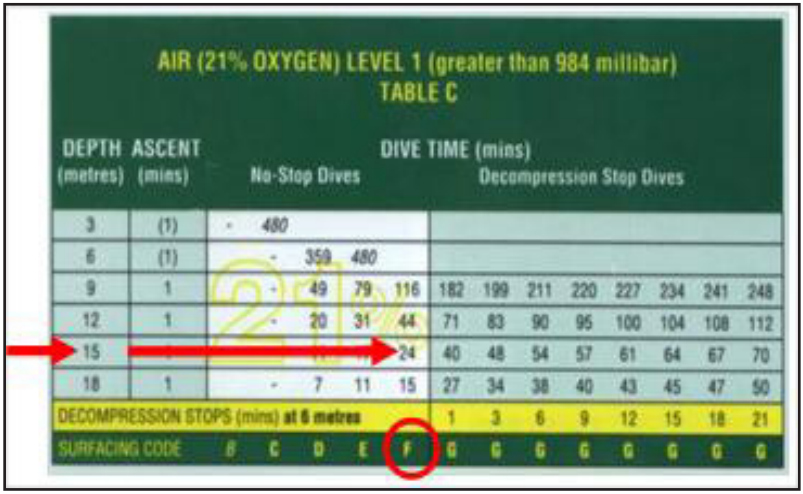
  The CTC was C which means that you must use Table C of the air tables to plan the second dive.

- **15 metres**

  This is the planned maximum depth for the second dive.

- **20 min**

  This is the planned maximum dive time for the second dive.



AIR (21% OXYGEN) LEVEL 1 (greater than 984 millibar)
TABLE C

DEPTH (metres)	ASCENT (mins)	DIVE TIME (mins) No-Stop Dives			Decompression Stop Dives							
3	(1)	480										
6	(1)	359	480									
9	1	49	79	116	182	199	211	220	227	234	241	248
12	1	20	31	44	71	83	90	95	100	104	108	112
15	1	11	17	24	40	48	54	57	61	64	67	70
18	1	7	11	15	27	34	38	40	43	45	47	50
DECOMPRESSION STOPS (mins) at 6 metres					1	3	6	9	12	15	18	21
SURFACING CODE		B	C	D	E	F	G	G	G	G	G	G	G	G

- **Surface Code = F**

An Ocean Diver could make these dives using Nitrox 21, Nitrox 32 or Nitrox 36. The higher the percentage of oxygen in the nitrox mix, the lower the probability of experiencing DCI.

Good practice to increase oxygen % for the second dive

It is good practice to increase the oxygen (or keep the same) in the mix for subsequent dives as this will help to minimise the risk of DCI.

Dive Planning - Computers

Dive computers can be used in exactly the same way as for diving using air:

You should be able to simply use any recognised dive computer out of the box (provided you read the manual) and be able to go diving safely, without any need to alter the dive parameters.

- **Plan the dive, dive the plan**

  It is importance to use your dive computer to plan your dive in advance. You should find out the maximum no stop times for your chosen dive based on your computer's air model.

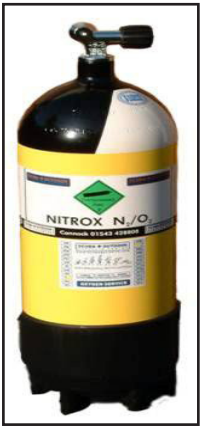
- **Use of nitrox 32 & nitrox 36 at Ocean Diver level requires no changes to:**
  - **Use of the dive planning function**
  - **Use of the computer during the dive**
  - **Access to post dive information**

An Ocean Diver's computer should be in default mode, i.e. set as an air diving computer. The fact that you may be breathing Nitrox 32 or Nitrox 36 has no impact on your computer's functions, or the way that it is used.

Some computers can be programmed for different nitrox mixes:

- **While you remain an Ocean Diver keep your computer set to air**
- **Other mixes, and their implications, are covered during training for higher qualifications**

The Nitrox Cylinder



Different labels for "Breathing Air" and "Nitrox"

The graphic shows the current British Standard, but within the UK, older British Standard markings may still be encountered. If you are taking this workshop outside the EU, ask your instructors about the corresponding local requirement.

Cylinders used for nitrox need to be periodically cleaned & certified

In the EU, cylinders should always be labelled to show the gas they contain. Additionally, cylinders used for nitrox mixes need to be cleaned and certified for use annually. The certification period is continually being reviewed.

N.B. if filling by premix or continuous blending below 40% O_2, cleaning and certification is not necessary.

Nitrox – Practices

Cleaning of equipment

All equipment should be free of contaminates thereby preventing a fire or explosion.

- **Oxygen supports combustion**

  The fire triangle consists of three key components; oxygen, fuel and an ignition source when combined lead to a fire. Enriched oxygen mixes increase the potential for a fire incident.

- **Materials and greases must be safe with higher oxygen percentages**

  Materials or greases coming into contact with enriched oxygen sources should always be compatible with oxygen. Always seek advice when assembling equipment for use with nitrox.

- **Cylinders exposed to oxygen must be cleaned either periodically removing combustible contaminants or if the cylinder is knowingly exposed to a contaminate**

  When nitrox is produced by the usual process of partial pressure filling, oxygen is added to the cylinder under pressure. If the oxygen comes into contact with a combustible contaminate such as oil, there is a possibility of a fire or explosion.

- **Some regulators do not require cleaning if used with less than Nitrox 40 (confirm with the manufacturer).**

  There are a number of manufacturers who produce regulators that are compatible with nitrox mixes containing up to 40% oxygen. Confirm the compatibility of your personal regulator(s) with enriched nitrox mixes.

Emergency cylinders

- **Avoid filling with nitrox unless oxygen cleaned**

  The majority of emergency cylinders have been exposed to contamination by being left open. They are generally poorly maintained. The process of filling normally involves exposing the emergency cylinder to 200+ bar of direct gas pressure from the decanting cylinder, which leads to rapid increase in temperature. If contaminates are rapidly heated, there is a higher possibility of a fire or explosion, in the presence of enriched nitrox mixes.

Nitrox – Procedures

Percentages must be checked with an oxygen analyser before use

The percentage of oxygen should always be checked with an oxygen analyser when the diver receives the charged cylinder from the blender, and again just before diving.

- **Follow analyser manufacturer's guidance**

  The operation and maintenance of oxygen analysers vary from manufacturer to manufacturer. Read and follow the instructions for the calibration and measurement of oxygen.

- **Supplied gas should not vary more than ±1% from the desired mix**

  In September 2006, a new British Standard BS7486:2006 was introduced defining what diver grade oxygen and nitrox is and what the measurement tolerances should be for a particular range of nitrox breathing mixes. This defines the standard for

commercially supplied nitrox. For general measurements on site, it is acceptable that the tolerance of percentage of oxygen is within ±1%.

- **Diving beyond these conditions requires additional considerations (e.g. MOD adjustment)**

  If the fraction of oxygen is different from the expected mix, then you should recalculate the MOD.

- **All cylinders should be clearly marked with oxygen percentage and MOD**

  It is essential that all divers label their cylinders accurately. Many incidents could have been avoided if this simple discipline had been followed, for example, picking up the wrong cylinder. It also benefits the surface cover should they need to use enriched nitrox for oxygen therapy to treat DCI.

Nitrox – Using an analyser

There is a wide variety of oxygen analysers available on the market, and the methods of operation of each are likely to differ, however, there is an underlying generic principle of operation. The following is an example (by kind permission of Analox Instruments Ltd) of such a generic principle of operation. It is important therefore, to follow the manufacturer's instructions for the proper use of the instrument in each case.

In general, the basic steps are:

Step 1: Switch on the gas analyser.

Step 2: Air Calibration. This is essential before use.

Step 3: Very slowly open the cylinder valve until the gas is heard gently hissing out.

Step 4: Present the analyser to the cylinder valve outlet and hold firmly to prevent gas escaping.

Close the pillar valve after a short period (this will depend upon the analyser type).

Nitrox – Analysing a mix

Analysing the mix continued:

Step 5: Take a reading. Care must be taken here to ensure that the cylinder gas reading is taken and not the surrounding, ambient air.

Step 6: Record the analysis

Note: Although breathing gas suppliers are rigorous in controlling breathing gas mixtures, experience shows that it is possible for a mixture to be supplied which does not correspond to the cylinder markings or desired mix. All breathing gas mixtures should be checked on receipt and re-checked immediately prior to assembling aqua-lung kits.

Analysing essentials

Calibrate prior to use

Always calibrate the analyser prior to use.

Keep flow rate even and as low as possible

By keeping the flow rate slow and even ensures that the reading is consistently accurate. Some more sophisticated oxygen analysers have a flow restrictor to ensure the gas is metered to the oxygen sensor.

Erratic readings point towards analyser failure

An oxygen analyser reacts relatively slowly to change. Any strange effects or erratic readings should be regarded as a failure. Failures include the oxygen cell that should be replaced periodically; typically frequency of replacement is every three years.

Avoid windy conditions

The wind interferes by diluting the measured gas and provides a false reading.

Avoid moisture

Moisture interferes with the oxygen cell and causes a false reading.

At Ocean Diver level your analysis should be within ± 1% of target mix

Store analyser away from elevated oxygen levels

Elevated oxygen levels reduce the life of the oxygen cell. The oxygen cell effectively behaves as a battery.

Summary

This workshop has covered the material added to the DTP from January 2007 on nitrox for Ocean Divers. The topics were:

Nitrox gas composition

Benefits of nitrox

Ocean Diver qualification

- **Maximum operating depth of 20 metres**
- **For NO-STOP dives only**

Oxygen toxicity

Dive planning

- **BSAC 88 Tables**
- **Air (21%) only**

Equipment

- **Cylinders labelled with gas % and MOD**

Gas analysis