Irish Underwater Council

Comhairle Fó-Thuinn

EXTENDED RANGE

Extended Range

Training Programme

STUDENT HANDOUTS

COMHAIRLE FO-THUINN

IRISH UNDERWATER COUNCIL

EXTENDED RANGE TRAINING PROGRAMME

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Introduction

Course Aims

Extended range diving may involve

- Mandatory decompression
- Use of decompression nitrox mixtures up to 80%
- Dives to a maximum depth of 50 meters

Any type of diving involves a certain degree of risk. The important factors to remember are the degree of risk involved and the ability to cope with this risk.

Up until now your diving has allowed a 'direct' route to the surface where, if a problem arose, aborting the dive and ascending directly to the surface was an option. Undertaking extended range diving removes this option from the diver. A diver must prepare for extended range diving by learning the skills required, using the right equipment and being mentally prepared.

The diver must accept the greater potential risk of narcosis, hypercapnia, decompression illness and oxygen toxicity.

The Extended Range Diver course aims to provide the diver with the knowledge and basic skills to carry out this type of diving safely and competently.

Safety and competence are gained through practise, practise and practise.

Equipment Requirements

The minimum requirements to begin extended range diving are:

- Secondary buoyancy device e.g. dry-suit
- Nitrox cylinder and regulator, both oxygen clean and compatible, for decompression mixes
- Secondary timer and depth gauge
- Secondary cutting device
- Reel and S.M.B

Extended Range Diving – General Requirements

Attitude

It has been said that the sport of diving is 40% physical fitness and 60% mental fitness. Mental preparation for the planned dive is vital; there is no room for recklessness. A diver should be able to identify the reason for the dive, plus accept the risks that the dive involves.

Equipment

Each dive requires an appropriate set of equipment to carry out the dive safely. A diver must be able to identify these requirements.

Knowledge

A diver must possess the knowledge to complete the dive safely, without it there is no solution when a problem occurs. Emergency procedures should be reviewed and practised until they become second nature.

Training

Training gives a diver the skills to complete necessary tasks required for the dive to be conducted safely; these skills should be practised until they are instinctive. Always be trained for the planned dive.

Experience

Experience takes time to acquire, and is extremely valuable in learning to cope with new situations. Experience in a certain type of diving does not necessarily qualify when a different environment is encountered.

Extended Range – Diver Preparation

Breathing Techniques

Proper breathing techniques (diaphragm breathing) will greatly help in controlling the level of stress. Inadequate ventilation of the lungs may result in retention of carbon dioxide. This has an effect on a diver's decompression strategy, susceptibility to nitrogen narcosis, oxygen toxicity and more. The response of the body is to modify the breathing pattern by becoming shallower and rapid; this begins a vicious cycle. If the breathing pattern cannot be controlled, panic may well set in.

Practising proper breathing techniques will improve a diver's chance of reacting correctly in a stressful situation.

Goals

The confidence of a diver is greatly increased if goals are set, and then achieved. Any goals should be attainable, measurable and enforced. In this way the divers' ability will improve. Goals should be not be unrealistic; they are better achieved if they are set in steps and are relatively simple.

Pre dive visualisation

Visualising the actual dive in the planning stages helps to identify any potential problems and emergencies that may occur. This is a very helpful aid in discovering how to respond to these problems or emergencies. This reinforces diver confidence and also enables the diver to react more efficiently and quickly.

Solo diving philosophy

A dive should be planned with the knowledge that, if required, each diver is equipped to be self-sufficient in an emergency, as if diving solo. This gives each buddy confidence to have the ability to cope with any problem that might present itself. A good ethos to follow is: if a diver is not happy getting into the water alone, do not dive.

Stress management

While a small amount of stress (eustress) can be good, too much stress can have a very negative impact during the course of a dive. During stressful situations breathing tends to become shallow and rapid – causing increased levels of carbon dioxide, and all associated dangers soon follow.

A simple but effective response to high stress levels is:

Stop – Breathe – Think – Act

Regaining control over breathing gives a diver a much better chance of a successful outcome to the situation.

Continuous training

Training should be seen as a continuous event. The more you practise a skill the more natural it becomes. A good guide is to practise a skill on every dive. The skill need not be complicated; often the simple ones give the most confidence – e.g. mask clearing, regulator switching.

Complacency

Complacency must be avoided at all costs, no matter how qualified or experienced a diver is, complacency in any part of the dive – planning or in water – will eventually lead to problems. Pre dive planning and preparation is vital for all dives to ensure a successful outcome.

Nitrox Overview

Introduction

This is a review of the material covered in the Nitrox course. We will revise the pressure 'T'; physiology associated with nitrox diving; EAD theory; nitrox dive tables and then broaden knowledge of balancing oxygen clocks and the use of higher oxygen mixtures.

The Pressure 'T'

pPg = Fg x P

	pPg	
Fg = pPg / P	**Fg | P**	P = pPg / Fg

P = Pressure
Fg = Decimal fraction gas in mix
pPg = partial Pressure gas

This can be used to determine any of the unknown elements.

Nitrox Physiology

Oxygen partial pressure

Below pPO_2 0.16 bar hypoxia can develop, a pPO_2 of 0.21 bar is normoxic, and any mixes above pPO_2 0.50 bar must be considered for tracking oxygen loading to prevent hyperoxia.

There are recommended partial pressure levels for diving.

CFT recommendations:

1.4 bar – maximum partial pressure of oxygen for recreational diving

1.6 bar – maximum partial pressure of oxygen for decompression schedules. This is used to determine the Maximum Operating Depth for a decompression gas.

1.4 bar is used to determine the MOD of a bottom gas mix.

For example:
Dive to 30m on EAN 34
pPO_2 = 0.34 x 4
pPO_2 = 1.36
The partial pressure of any mix for a given depth can be determined using the Partial Pressure Table in Appendix 1

MOD of EAN 34 $= \frac{1.4}{0.34}$
= 4.1 bar or 31m

Oxygen Toxicity

There are two types:

1. Central nervous system (CNS) oxygen toxicity – the onset is sudden and can occur after short exposures to high partial pressures of oxygen. Symptoms as per acronym:

ConVENTID
Con = Convulsions
V = Visual disturbances
E = Ears -e.g. tinnitus (ringing in ears).
N = Nausea
T = Twitching of muscles, especially mouth and lips.
I = Irritability.
D = Dizziness, including a lack of coordination.

2. Pulmonary oxygen toxicity – breathing oxygen at elevated pressures affects the body over a period of time causing difficulty in breathing, a sore chest and throat.

Tolerance to oxygen exposure is dependant on the partial pressure and the duration of the exposure.

For CNS toxicity the exposure time is taken at each pPO_2 and compared to the maximum allowed, then expressed as a percentage (CNS%).

For pulmonary toxicity Units of Oxygen Tolerance are calculated for each pPO_2 and compared to a daily total (OTU's).

Use of Nitrox

Using nitrox mixes does not affect recompression treatments. Where oxygen loading has been tracked correctly all maximum daily allowances permit a complete therapeutic treatment to be undertaken.

Carbon Dioxide

As we know carbon dioxide is a by-product of metabolism and has to be expired by the body. Circumstances that lead to CO_2 build up can predispose a diver to decompression illness, narcosis and oxygen toxicity.

Equivalent Air Depth (EAD)

The equivalent air depth concept allows you, when using a nitrox mix, to use the equivalent depth of the dive as if you were breathing air. This enables you to use air decompression tables. In a nitrox mix the percentage of nitrogen will be lower, the equivalent depth of air will be deeper to achieve the same nitrogen partial pressure.

To work out the EAD use:
1. The EAD formula (expressed in Bar - convert to metres):

$$\text{EAD (expressed in Bar)} = \left(\frac{FN_2 \text{ in mix x P}}{FN_2 \text{ in air}} \right)$$

FN_2 = the decimal fraction of nitrogen
P = pressure of the dive in bars

For example
Dive to 30m on EAN 34

$$\text{EAD} = \frac{0{,}66 \times 4}{0.79}$$

= 3.34 bar or 23.4m - Use Air Table for 24m

2. Equivalent Air Depth Table as shown in Appendix 2. In this table, all the EAD calculations have been done, and the EAD's rounded off to the next 3-metre air table increment where necessary.

To find the EAD for a particular nitrox mix:

1. Find the percentage mix along the mixture row at the top of the table
2. Go down that column to the exact or next greater depth of the planned dive
3. Move across left to find the EAD of the planned dive

Oxygen Tracking

CNS Toxicity Tracking

To avoid CNS oxygen toxicity the diver needs to stay within the recommended exposure times, depending on the pPO_2. The recommended limits are set out in NOAA Table 1.

Rules for this table:

1. When one or more dives in a 24-hour period reach the maximum single exposure limit a break of 2 hours must be taken.
2. If one or more dives in a 24-hour period reach the maximum daily exposure, a 12-hour break must be taken.
3. Air must be breathed during these breaks.

CFT recommend that no more than 80% of the limit be used.

For no stop diving the oxygen time can be based on the pPO_2 at the maximum depth of the dive and the NOAA single exposure time limit.

For extended diving, possibly involving the use of different gas mixes where increased time may be spent on higher oxygen mixes cumulative oxygen exposures must be tracked.

The oxygen clock continues to run at decompression depths, and as the effects of oxygen are cumulative, strict rules must be followed in order to prevent acute oxygen toxicity

To calculate CNS% for each mix on the dive you can use the following:

$$\text{CNS\%} = \frac{\textbf{(Bottom Time at depth)}}{\textbf{(NOAA Single Exposure Time for } pPO_2 \textbf{ at specific depth)}} \times 100$$

(Using the NOAA exposure times from Table 2: NOAA Oxygen Partial Pressure and Exposure Limits) Appendix 3a

Alternatively see Appendix 3: Oxygen Partial Pressure and CNS% per minute. The table shows the CNS% exposure per minute at each pPO_2. Use the CNS% figure and multiply by the total exposure time at that partial pressure of oxygen.

Using either technique you can calculate the CNS% at each depth; the sum of these values is equal to your oxygen exposure for that dive.

Any pPO_2 0.5 bar or less may be ignored for oxygen tracking purposes as it does not add to oxygen loading.

The oxygen limits must be strictly adhered to, and minimum surface intervals may be required depending on the cumulative CNS%:

CFT Recommendations

For the Single Exposure time: If CNS% > 80% the minimum SI = 2 hours.

For Maximum Exposure time in 24 hours: If CNS% > 80% the minimum SI = 12 hours.

A maximum CNS% of 80% should not be exceeded for a single or multiple dives.

Diving with nitrox does not affect possible recompression treatment. All limits and recommendations are set with the possibility of treatment being required.

Surface Intervals

Having calculated the total for the dive, we can reduce this figure by 50% for each 90 minutes spent on the surface following the dive. If the complete 90 minutes has not been reached then no reduction is allowed. The CNS% at the end of the surface interval is the oxygen loading at the start of the next dive. This must be added to the CNS% for the second dive, and so the accumulation goes on. (This is similar to Residual Nitrogen Times, RNT, for repetitive dives).

Example:
If a dive to 30m for 50 minutes on EAN 34 requires a decompression schedule of 13 minutes at 4.5m on EAN 50. Then a second dive is done after a 2-hour surface interval. What is the CNS% for the dive and after the surface interval?

CNS% at 30m
pPO_2 = 1.36
CNS% per min @ pPO_2 1.36 = 0.62
Total CNS% for bottom = 0.62 x 50
= 31%
CNS% at 4.5m
pPO_2 = 1.45 x 0.5
= 0.725
CNS% per min @ pPO_2 0.725 = 0.19
Total CNS% for deco = 0.19 x 13
= 2.47%
Total CNS% for dive = 31 + 2.47
= 33.47%

After a 2 hour (120 minutes) surface interval we can reduce the CNS% by one half = 16.74%

Here we have dealt with tracking CNS% oxygen to ensure acute toxicity is not a danger on the dive.

Pulmonary Toxicity Tracking

To prevent pulmonary oxygen toxicity, also known as whole body or chronic oxygen toxicity, we need to assess the effects of long exposure to oxygen on the body. We do this by calculating the tolerance of the body to oxygen exposure, using Oxygen Tolerance Units, (OTU). In the past this has also been calculated as the Unit Pulmonary Toxicity Dose (UPTD), and for our purposes they can be interchanged.

To calculate OTU's for each mix on the dive you can use the following:

$$OTU = t \; \frac{[\,(pPO_2 - 0.5)\,]^{0.83}}{0.5}$$

where t is time of exposure and pPO_2 is in bar.

Pulmonary tracking can also be calculated using the table in Appendix 4: Oxygen Partial Pressure and OTU dose per minute.

The table is based on breathing 100% oxygen at 1 bar, which would accumulate 1 OTU per minute. The accepted maximum limit for medical treatment with 100% oxygen is 1425 OTU's per day.

Using either of these methods you can calculate the OTU exposure at each depth; the sum of these values gives you the total units for the dive. Each dive total is added together to give a daily total. This is accumulative and there is assumed no surface reduction.

There are daily maximum allowable OTU doses for divers, depending on the number of consecutive days of diving.

See Appendix 5: Maximum OTU Exposure per day.

These daily allowances account for the possible requirement of recompression treatment ensuring the diver stays within the maximum daily total of 1425 OTU's. The aggressive US Navy Treatment Table 6A accumulates about 650 OTU's. For this reason you are guided towards not exceeding a daily total of 300 OTU's. It is recommended that two full days should be allowed before you can consider being clear of the daily allowances.

Example:
If a dive to 30m for 50 minutes on EAN 34 requires a decompression schedule of 13 minutes at 4.5m on EAN 50. Then a second dive is done after a 2-hour surface interval. What is the OTU for the dive and after the surface interval?

OTU at 30m
pPO_2 = 1.36

OTU per min @ pPO_2 1.36 = 1.63
Total OTU for bottom = 1.63 x 50
= 81.5

OTU at 4.5m on EAN 50
pPO_2 = 1.45 x 0.5
= 0.725
OTU per min @ pPO_2 0.725 = 0.56
Total OTU for deco = 0.56 x 13
= 7.3
Total OTU for dive = 81.5 + 7.3
= 88.8

OTU after the surface interval = 88.8. There is no surface reduction.

This is well within the daily recommendations, even with the possibility of a second dive.

On completing the two calculations you will find that the CNS% is nearly always the limiting factor in open circuit diving.

Equipment

Introduction

Your equipment is your life support system underwater; it needs to be the best possible, well maintained and appropriate for use in extended range diving.

The configuration of your dive equipment is the secret of successfully completing the planned dive, especially as there are some extra items required. All your primary (essential) dive equipment should now have a back up. Primary life saving equipment should be carried in your primary triangle. This is a triangle from your chin covering your chest area where essential items i.e. dry-suit inflation, back-up regulator, BCD inflator, can be accessed with little effort.

We will look first at the individual items of equipment and then move on to kit configuration. We will also look at setting up a decompression station.

Air Source - Cylinders and Regulators

You must have a dual air source – either manifold or dual outlet valve on main cylinder or a pony cylinder. Each air source must have a separate regulator plus a pressure gauge. Manifold cylinders with an isolation valve would only require one pressure gauge.

Cylinders

Cylinders can be aluminium or steel, however aluminium cylinders sometimes become positively buoyant at the end of a dive; this may cause problems with buoyancy on the shallower stops.

DIN valves are preferable, as they tend to be mechanically stronger than the yoke fitting.

The working pressure of a cylinder can be either 232 or 300 Bar. The 300 Bar cylinders are more streamlined and compact. A 12 litre cylinder @ 300 Bar contains more gas than a 15 litre cylinder @ 232 Bar. Not all compressors can fill to 300 Bar; this will need to be taken into account when assessing gas availability. The size and numbers of the cylinders will be dependant on the type of dive and the gas required for the dive. Carrying extra-unwanted cylinders will reduce streamlining and increase the workload, so gas management is important to optimise the cylinders needed.

The use of cylinder boots or guards is a matter of personal choice. Cylinder guards fitted to neck protect the first stages and can prevent the cylinder being accidentally turned off; they also provide useful handles for carrying.

If the main cylinders are manifold type, it is important that the isolation valve can be reached. A remote isolation valve can be fitted to simplify this. Steel bands must be used for a manifold cylinder system, and are preferable for twinning cylinders, to give a more secure fitting.

Stage cylinders should be attached using only piston clips to avoid lines being snagged (as can happen with karabiners). The use of piston clips also allows for easier removal underwater if necessary.

Each cylinder must have a pressure gauge and be **CLEARLY** marked with the gas content and maximum operating depth. If cylinders are used with over EAN 40 they must be oxygen clean and oxygen compatible, i.e. in oxygen service. Remember silicon grease is not oxygen compatible.

Cylinders should only be used if suitable for the purpose, ie valve type is nitrox compatible. CFT recommendations must be followed for cylinder testing and oxygen cleaning.

All nitrox mixes MUST be analysed before use

Regulators

All regulators must be serviced, well maintained and rated for the environments that they will be exposed to.

First stage regulators with DIN fittings are preferable as the yoke fittings are susceptible to 0-ring failures and dislodging due to accidental bumping. The first stage should allow for hoses to be routed vertically downwards avoiding looping of hoses.

The main cylinder should have two regulators, one with a second stage hose of 1.5m to 2m in length to facilitate air sharing. This used as the primary second stage. The second stage back up should be held around the neck with tubing to allow quick and easy access.

Second stages that can be routed either left or right are useful for setting up the configuration of the equipment.

Hoses should be streamlined as much as possible, try to use interstage hoses with the same fittings, e.g. for BCD and dry-suit.

Decompression nitrox regulators must be identifiable to prevent incorrect gas switching at depth. The use of a mouth guard/ isolation device is ideal; colour coding is often difficult to distinguish at depth. Divers must ensure that when switching regulators at depth they are easily indentifiable for both diver and buddy. The wrong mix breathed at depth can be fatal.

Regulators being used with nitrox must be nitrox compatible and if used with nitrox mixtures above 40% they must be in oxygen service.

Regulators should be used according to the manufacturers recommendations, including servicing and oxygen cleaning.

Gauges and Timers

Gauges on consoles tend to hang down and can be a hazard. It is better to have wrist-mounted gauges where possible and stud type pressure gauges on side-mounted cylinders. The pressure gauge for your main back mounted cylinder will have to be on a hose, but it should be as compact as possible and clipped onto the BCD.

Two depth gauges and two timers are required; the extra act as your back up. A diver must always carry a compass; ensure other equipment does not impede its function.

A hard copy of the dive tables used to plan the dive must be taken.

The dive plan, including run times, must be written on a slate. The slate must also show the over-run times and loss of decompression gas scenarios. Dive computers should not be relied on for decompression information. They are battery operated and can be prone to failure. They can be used for depth and time, but must never be allowed to control the dive. The dive must follow the pre-dive plan as recorded on the slates.

Buoyancy Control Device (BCD)

The BCD is the foundation of your diving equipment; it has to carry your backpack, main cylinder, stage cylinders, reels, S.M.B's, lights, lifting bags, cutting devices and any other equipment that the dive may require.

A BCD can be either wings or jacket variety. The wings type can have either a single or dual bladder. The jacket BCD usually only has one bladder. If the single bladder wings or jacket type BCD is used a dry-suit can act as a back-up BCD.

The BCD must provide adequate lift taking into account the extra equipment being carried, a minimum of 25kgs is recommended. It must also provide an adequate number of D-rings in suitable places – it is not a good idea to attach equipment to D-rings on cylinders. You must be able to attach and secure all the equipment so the risk of entanglement is reduced.

The jacket type of BCD is more comfortable, but can carry less; the wings type carries more but can be difficult to remove.

Many manufacturers now make modular systems, which can be added to and improved over time.

Suits

Hypothermia is a real threat with extended range diving; your suit and under-suit must therefore provide adequate thermal insulation. The type of suit you use, either neoprene or membrane, will affect the type of under-suit you will require. Ensure your under-suit does not hinder the dump valve on your dry-suit; a piece of webbing over the inside of the dump valve can alleviate this problem.

Latex wrist and necks seals should be left long to ensure a good seal.

The dry-suit must have flexibility to allow gas switches and shutdowns if necessary. Depending on the duration of the dive or the trip provision may be necessary for a toilet facility – either nappy or leg/ pee valve.

Gas used for dry-suit inflation must be less than EAN40, to meet the in service oxygen requirements. An alternative is the use of argon. Argon has excellent thermal properties but it must be used with care, as it is extremely narcotic. It should be provided in 1-2 litre back mounted cylinders, and must not have a second stage fitted to the regulator (to avoid asphyxiation).

A semi-dry or wet suit is not suitable for extended range diving.

Hood

The hood should have 10mm holes punched in the top and at both ears. This improves your hearing, prevents pressure buffeting around the ears and stops gas build up inside the hood. The holes will take very little away from the thermal qualities of the hood.

Weight Systems

Standard belts with blocks or shot can be used; a second buckle will help to prevent slippage.

An alternative to the standard belt is a harness system using blocks or shot. The use of a harness is a very comfortable option.

Some jacket BCD's have integrated weights, but these tend to be cumbersome and make the equipment very heavy.

Remember carrying stage cylinders will require a weight adjustment; this can be awkward with shot weight.

If weights are carried in quick release pouches care should be taken that toggles do not hang down and the weights cannot become loose while underwater. Quick release weights are really only of benefit for surface rescue, as a diver should have enough redundant buoyancy on the dive.

Mask/Fins/Snorkel

There are no special types of fins and masks required.

The mask strap can be worn inside the hood to prevent it being lost and a spare mask should be carried.

Short wide fins are often more suitable for this type of diving.

Mask and fins must have good quality straps; the condition of these should be checked before each dive. A spare fin and mask strap should be available in the spares bag.

The snorkel is of no importance in extended range diving, so it should be carried in a more streamlined position i.e. inside of leg (outside the primary triangle).

Reels

Two reels are required, one with approximately 100m of line used to reel off the shot-line. The second reel, with approximately 30m of line will be used to deploy your SMB and act as a back up. Reels with clutches or ratchets can be awkward to deploy, a simple lock on or off is much easier to use. In some types of diving different coloured lines can be used, but the colours are not always easy to distinguish at depth. The line should be as strong as possible.

Ideally two reels shuold be used to deploy an SMB, if the first becomes snagged, the second can be used to complete the deployment. Under no circumstances should a reel be attached to your dive gear whilst you are deploying an SMB.

If you become separated from your buddy while using a line, you should cut the line and leave it for your buddy.

Reels can be prone to snagging if not wound up correctly, this should be checked prior to each dive.

Reel deployment is a skill that takes time to master and requires constant practise.

Surface Marker Buoys (SMB)

An SMB is your contact with the surface. Two are required, one red and one yellow.

The red colour indicates the diver is OK – has missed the shot-line and therefore is off the decompression station (if the dive was on a shot-line), but has enough gas to complete the required decompression times.

The yellow SMB indicates the diver has missed the shot-line and requires gas to complete the decompression obligation.

The storage location of an SMB requires careful consideration, as it may well be your only method of communicating with the surface.

An SMB with an attached pony bottle for inflation, instead of using a second stage, removes the possibility of causing a regulator free-flow. The pony bottle should be filled prior to every dive.

Jonline

A Jon line is a length of strong line (usually 2 meters in length) with a piston clip at one end and an open ring on the other (this end for attaching to a shot-line). The use of a Jonline will smooth out the effects of any swell on a decompression station and can be extremely useful when decompressing on a crowded shot-line or decompression station.

Cutting Tools

A diver would normally carry some sort of cutting device. There are various options available but you should carry two cutting tools, including a 'J' type net cutter and scissors (medical plaster scissors are a good option). The blades should be kept rust free and sharp.

The cutting tools should be located in the primary triangle for easy access with either hand.

Light Systems

There are numerous types of lights available, handheld, umbilical, head mounted etc. The extended range diver should carry two (for cave diving three is the minimum).

The important considerations are power, battery duration and bulb type. They should be chosen to be as streamlined as possible, again avoiding anything that will hang down.

Lights are prone to failure, but if they are checked before each dive and well maintained the likelihood of both lights failing is minimal.

Strobes

Strobes are useful in low visibility or when diving with a Closed Circuit Rebreather diver as there are no bubbles.

Extra Equipment

EPIRB (Emergency Position Indicating Radio Beacon)

Some divers carry an EPIRB in case of losing boat on the surface. There should be very little chance of this happening if divers return to decompression station.

Helmets:

The use of a helmet offers head protection plus it can be used to mount light systems.

Lifting bags

There are various types and sizes available depending upon the requirement. You must consider storage and lift capacity.

Diver Propulsion Vehicles/Scooters

All diver propulsion vehicles are expensive; there are different types and depth ratings available. You should consider the depth rating, battery duration and power before purchase. Diver propulsion vehicles or scooters used correctly can greatly reduce gas usage.

In Water Spares:
You should make up a small bag of in water spares containing: straps; string; slates; clips, etc.

Kit Configuration

Once you have assembled the extra equipment requirements you have to consider how to attach it all without looking like a Christmas tree. This is best done as a practical exercise as it varies from person to person. Kit configuration is something that you can refine over a period of time, until you find what works best for you.

1. Identify what needs to be in your primary triangle, and work from there. These items need to be readily available and identifiable.
2. Some items require redundancy depending on the type of diving.
3. The configuration must be balanced to distribute weight evenly and streamlined to minimize drag.

Factors to consider

1. Cylinder options
   i. Twin back-mounted with manifold and isolator
   ii. Twin back-mounted with manifold and no isolator (not desirable)
   iii. Twin back-mounted no manifold
   iv. Single back mounted and One side mount
2. Cylinder and BCD should fit comfortably. Should not float away from the body when inflated
3. BCD hoses should be secured and accessible, not floating above the diver.
4. Redundant regulator located on a neck strap, easily visible on the diver's chest.
5. Avoid anything dangling below the diver, damage could occur to equipment or environment.
6. Cutting instruments should be accessible with either hand. Sited on the lower leg is not desirable.

The important factor is STREAMLINE.

Good kit configuration will have the following

- Comfort and balance
- Reliability and touch identification.
- Streamlining with minimum drag
- Rescue capability
- Self sufficiency & redundancy
- All cylinders correctly labelled

If you don't need it don't bring it!

Always try a new piece of equipment in shallow water first, assess the effect it has on your existing set-up and its importance, i.e. is it a life saving item needing to be in your primary triangle. Always perform a bubble check at 6m before continuing your descent.

Good configuration requires time, effort and experimentation.

Decompression station

A shot line and detachable decompression station should be used on all decompression dives.

Shot-line
The shot-line should be able to support the entire dive group. It should be made up of 2 x A3 or A4 buoys, polypropylene line at least 20 mm thick and approximately 30kgs of weight. The length of the shot-line should be 1 metre in excess of the greatest depth expected. For wreck diving a Paracord and or chain can be used for securing the shot-line to the wreck.

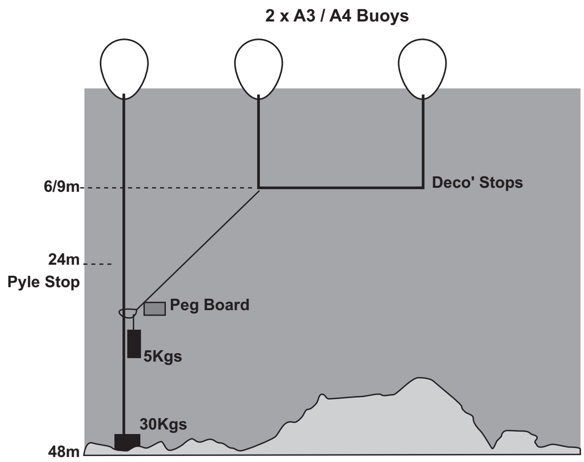
Decompression station
The decompression station consists of:

- At least 2 x A3 or A4 buoys,
- Polypropylene line at least 20 mm thick,
- 2 x 2 metre length's of shock cord {bungie},
- 2 meter length of scaffold tube or similar.

An attachment line joins the shot-line to the decompression station. It should be 12mm thick polypropylene line, long enough to attach to the shot-line 3m below the deepest stop and weighted with a 5kg sinker. The line uses a karabiner to attach to the shot-line to facilitate quick release once all the divers are on the decompression station.

A pegboard is attached near the end of the attachment line to enable the divers to check in and out. This will show if there are divers still to ascend to the decompression station, the last diver is then able to release the station from the shot-line.

An example of a Decompression Station



Nitrogen and Decompression

Introduction

We know the role nitrogen plays in governing our diving. We need to, in this lecture, revise this role and look at how decompression schedules for extended range diving are planned. There are two new concepts to bring into the dive plan – run times and Pyle stops, plus we will look at computer software for dive planning.

Nitrogen

When undertaking extended range diving we are knowingly putting ourselves at increased risk of problems associated with the uptake of nitrogen in our bodies.

The two problems we must concern ourselves with are:

- Narcosis
- Decompression Sickness (DCS)

1. Narcosis

Narcosis is caused by an increased partial pressure of nitrogen and is well known to create symptoms similar to alcohol intoxication. To a diver within the no-stop range, although still at danger, the option of ascending directly to the surface is available to reduce or remove the symptoms of narcosis. To an extended range diver with a decompression schedule to meet narcosis can quickly become a serious problem.

Narcosis affects a divers' ability to perform simple motor and mental tasks. Unless the skills required have been well practised the diver is in danger of not being able to complete these straightforward tasks.

Narcosis can to some extent be controlled by acclimatisation or adaptation, but the effects of acclimatisation are thought to reduce in about a week.

There are some predisposing factors that may increase a divers' susceptibility including rapid compression, the use of alcohol and/or social drugs. The retention of carbon dioxide, caused by any number of factors such as hard work or fatigue, increases the likelihood of narcosis.

Fortunately mild symptoms appear before the onset of critical impairment. This does allow a diver time to react to the situation, with the only option being to ascend to a shallower depth to reduce the effects.

In the same manner that people can perform some tasks adequately under the influence of alcohol, divers can ascend safely after completing a deep dive under varying levels of nitrogen impairment.

2. Decompression Sickness (DCS)

DCS, as we know, is caused by a rapid reduction in ambient pressure leading to the localised formation of bubbles in body tissues. These bubbles can occur in the circulating blood as well as in any tissue or organ in the body. Rapid reduction in pressure causes the bubbles to grow, and the symptoms produced vary widely, according to the location and the size of the bubbles. Every dive is shown to produce micro-bubbles in the diver; the important consideration here is to prevent the growth of these bubbles, keeping them a-symptomatic, by following decompression schedules.

The common manifestations of DCS are extreme fatigue, dizziness, headaches, numbness, joint pain, tingling and weakness.

There are a number of predisposing factors to DCS that must be considered: age, obesity, heavy workload (before, during and after the dive), poor fitness, alcohol consumption and dehydration. It is thought that dehydration may well be the most significant predisposing factor in DCS. Drinking plain water works wonders.

The extended range diver is put at greater risk of DCS, but if the planned decompression obligations are strictly kept, allowing for predisposing factors, the probability is no higher than the no-stop diver.

Divers can reduce the risk of DCS in a number of ways including: diving conservatively; using EANx mixtures with air tables; reducing dive times with each attributable predisposing factor; sticking within the limits of the dive plan.

Decompression Schedules

Decompression diving is a planned event. The extended range diver needs to plan the dive profile deciding on the depth, time, gas mix and decompression obligation.

The decompression schedules are based on the standard Buehlmann Air Diving Tables. When decompression diving with EANx mixtures the EAD concept is used, the tables being identical in format and use to the Buehlmann Tables. The tables have been computed for comparable EAD's. The decompression times are given for using either air or 50% nitrox as the decompression mix.

See:
Appendix 6A: EAD Dive Tables with Surface Interval and Repetitive Dive Table
Appendix 6B: EAD Tables with 50% Nitrox Decompression or Air Decompression Times

Example:
Dive to 30m for 50 minutes on EAN 34. What is the required decompression schedule and repetitive group (RG) at the end of the dive, plus after a 2-hour surface interval?

EAD 30m on EAN34 = 23.4 or 24m (as calculated before)

See Appendix 6B

24m for 50 minutes requires a decompression schedule of

4.5m for 19 minutes on air **OR**

4.5m for 13 minutes on EAN50

In both cases RG = G

After 2-hour surface interval - see Appendix 6A

RG = B

For extended air diving we use our standard Buehlmann air tables to determine our decompression obligations. See Appendix 7: Air Diving Decompression Tables. The table in Appendix 6B can be used to determine the decompression schedules for times not shown on the standard tables.

Example:
Dive to 30m for 50 minutes on air. What is the required decompression schedule and RG at the end of the dive, plus after a 2-hour surface interval?

(Use Appendix 6B to find the decompression schedule)

30m for 50 minutes requires a decompression schedule of:

9m for 4 minutes

6m for 4 minutes

4.5m for 35 minutes

RG = H

At the end of the 2-hour surface interval RG = E

The difference in residual nitrogen time (RNT) penalty to carry to a repetitive dive between the above two dives highlights the benefit of using a higher EANx mix.

Safety Planning

For each dive the profile must be worked out for (i) the planned dive; (ii) one depth increment deeper and one time increment longer; (iii) the loss of decompression gas. The different dive profiles must be recorded on the divers slate

Dive time management

This is based on Run Times, and a deep dive profile will include the use of Pyle Stops.

Run Times

Run times identify key time marks in a dive plan. These marks indicate to the diver the time to move to the next stage, whether that be the turn of a dive, (i.e. the furthest point out, where the diver begins the return leg of the dive), or the ascent to the next decompression depth. By using run times the diver always knows the time to make the next move. This also means that the surface support knows the exact time divers should be surfacing, as the run times include the decompression obligations. The surface support will be immediately aware of the possibility that increased decompression is being carried out or the extended time may be as a result of a more serious situation. In either scenario the support team can prepare for an emergency.

Pyle Stops

Pyle stops were named after Richard Pyle, who used to collect fish at depths between 54m to 68m and bring them to the surface (hopefully alive). To achieve this it was necessary on his ascent to pause at depths deeper than his scheduled decompression stops to release expanding gas in the swim bladders of the fish. He discovered, on these dives, a reduction in his fatigue on surfacing. Despite this relatively unscientific hypothesis there is now evidence to back up his findings.

By reducing the rate of decompression from deep dives any bubbles formed are kept to a minimum size. When Richard Pyle stopped to release the gas from his fish he was inadvertently preventing bubble growth in his tissues, thus lessening the size, number and effects of bubbles in his system on surfacing. This is the aim of decompression schedules, preventing the formation of bubbles, reducing their expansion if present and allowing tissues to off-gas. So the extended range diver now includes modified Pyle Stops in the dive plan to help achieve these aims.

To incorporate Pyle stops:

1. Calculate the decompression profile
2. Take the distance between the bottom depth (at the point you start your ascent) and the first decompression stop. Find the mid point – the linear midpoint is close enough – and this is your first Pyle stop for one minute.
3. Recalculate your run time at the start of the ascent (this Pyle stop is added to bottom time; in the same manner as a slowed ascent is).
4. If the distance between your Pyle stop and the first decompression stop is greater than about 10m find the midpoint between these two, and include a second Pyle stop for one minute.
5. Recalculate the run time in the same manner as step 3; again this Pyle stop will be added to your bottom time.

NB Some software calculations may be based on the pressure mid point between the stops, instead of the linear.

Example of Run Times incorporating Pyle Stops

Dive Profile:
Dive 30m for 50 minutes

Deco schedule:
4.5m for 13 minutes

Pyle Stops:
(30 – 4.5) / 2 = 13
30 – 13 = 17m
First Pyle Stop at 17m
17 to 4.5 is greater than 10m so second Pyle stop is required at:
(17 – 4.5) / 2 = 6.25
17 – 6.5 = 10.75m
Second Pyle stop at 11m

To calculate Run Times for Dive Slate:
Bottom time is now 48 minutes (two Pyle stops = 2 minutes), so for your ascent your slate would show this:

Depth	Stop	Run Time
30m		48 min
17m	1 min	50 min
11m	1 min	52 min
4.5m	13 min	66 min
Surface		67 min

You can see from this schedule that the ascent rate, Pyle stops and decompression times are all included and you know the time to move on to the next stage.

You need to also calculate over-run times, i.e. going deeper and also staying longer, to give you a back up plan.

Decompression Software

There are a number of software packages that will perform all the calculations we have looked at: decompression times, Pyle stops, gas use, MOD's, run times, CNS%, plus all the others, and probably a few more. There are some programs that allow an element of conservatism to be entered for the specific dive, a useful tool for cold or working dives. These programs allow you to look at every aspect of the dive, incorporating several scenarios, plus performing the calculations means that the element of human error is reduced.

Most programs will print out a report detailing the dive depths and times, gas usage, oxygen dosages, time-to-fly and oxygen partial pressures. These can then easily be reviewed to ensure that any limitations have not been exceeded.

These programs are often the best tools to make full advantage of using decompression gases.

Example of Decompression Software –The example of the dive worked through in the lecture as calculated by dive planning software:

EXAMPLE DIVE – EXTENDED RANGE DIVER:
Dive number:1

Atmospheric pressure= 1000mBar Safety factor=0%

Depth1= 30msw: 50mins 34%O2 Run Time= 50mins

DIVE 1 DECOMPRESSION REQUIREMENTS
Stop= 17msw: 1mins 34%O2 Run Time= 52mins
Stop= 10msw: 1mins 34%O2 Run Time= 54mins
Stop= 6msw: 1mins 50%O2 Run Time= 55mins
*Stop= 4.5msw: 13mins 50%O2 Run Time= 69mins

Total time to surface=19mins
Time to first stop=3mins
CNS exposure: 33%peak, 33%dive end
CNS exposure= 33%
Max PPO2=1.36bar
OTU=95units; OTU total=95
Dive Start: Day 1 Time 00:00
Dive Finish: Day 1 Time 01:10
Flight Time: Day 1 Time 02:27
Surface gas=21%O2
Surface interval= 0mins

Depth1= 30msw: 50mins 34%O2 Run Time= 50mins

Depth	Gas	Stop	RT
4.5	50	13	69
6	50	1	55
10	34	1	54
17	34	1	52

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Completing the Decompression Schedules

It is important that each diver has complete control over buoyancy and ascent rates. You can see from the theory and looking at dive run times the strict discipline that must be applied to both the planning work prior to the dive and on the dive itself.

The secret here, as with any new skill, is to practise in a safe environment. It is better to perfect a skill, e.g. gas switching, at a time it is not required, rather than be in trouble on a dive when the skill is necessary for the safe completion of the dive.

All the theory on this course is focused towards enabling you to complete decompression diving in a safe manner; the skills must be practised by you.

Shortened or Omitted Decompression

Any shortened or omitted decompression stops are treated in the same manner as they would in no-stop diving. The consequences in extended range diving can be more serious. Planned decompression stops are likely to be longer than those incurred by overstaying on a no-stop dive. The procedure to follow:

Remain calm and avoid emotional distress

Avoid physical exertion

Lie down and breathe 100% oxygen (if available)

Drink non-alcoholic, non-caffeine fluid

Monitor for symptoms of decompression illness

If symptoms appear follow first aid procedures and contact the nearest chamber

If no symptoms appear, refrain from diving for at least 24 hours

Summary

This lecture has reviewed nitrogen and the effect on us as extended range divers. Decompression diving is a planned event; strict decompression schedules including Pyle stops must be calculated, using the proprietary tables or proven software, giving the diver a complete profile of run times. This must cover not only the planned dive, but also what the schedule will be if the time or depth is over-run. Shortened or omitted decompression, when involved in this type of diving, can have more serious consequences than an unintentional decompression obligation that may occur in no-stop diving.

Gas Management

Introduction

Extended diving requires a more disciplined approach to gas management than previously required. We are all familiar with the basic calculation:

Gas required = Time (min) x Breathing rate (l/min) x Ambient pressure (bar)

For the first time you will dispense with the "50 bar" reserve, as now you are in the situation of not having a direct route to the surface.

We will look at determining your personal gas use – surface gas consumption, gas rules for bottom and decompression mixes, what to do in an emergency and type of gas.

Personal Gas Consumption

To enable you to calculate your gas usage on any dive it is important to know your gas consumption in water. You need to determine your surface gas consumption; this will allow you to calculate your Respiratory Minute Volume (RMV), which is your rate of gas consumption per minute at the surface.

Gas consumption is calculated by finning at a constant depth for a specific time noting cylinder pressure at start and end of the time. The reduction in pressure multiplied by the cylinder size gives total gas used for the time period. This is then adjusted back to surface pressure to give your surface gas consumption. Divide this by the time (in minutes) gives you your Respiratory Minute Volume on which all gas consumption calculations are based.

For example:

Fin at 10m (2 bar) for 10 minutes with contents reading 202 bar at start, 175 bar at end using a 12 litre cylinder.

Gas Consumption = $\frac{\text{27 bar drop x 12 litre cylinder size}}{\text{2 bar pressure}}$

= 162

Divide by the time = 162/10

Respiratory Minute Volume = 16.2 litres per minute

To calculate gas consumption for a dive multiply Respiratory Minute Volume (RMV) by the pressure of the planned depth.

For example:
Dive to 30m: 4 bar pressure x RMV 16.2 litre = 64.8 litres per minute.

RMV will vary enormously depending upon the individual and the level of activity, ranging from 6 litres/minute at rest to 60 litres/minute when swimming hard. An average RMV for an individual would be approximately 20-25 litres/minute.

Under stress RMV can increase several times, so using the above example under normal conditions a 12-litre cylinder filled to 232 bar would provide enough gas for 42 minutes. In a stressful situation this time could be reduced to 10 minutes. This highlights the importance of gas management.

Rules for Gas Management

For dives deeper than 40m, dives involving decompression and any dive involving an overhead environment the Rule of Thirds is used to determine the bottom mix gas requirements.

The bottom mix is the gas used on the descent to first decompression stop.

The decompression mix is the gas used for decompression stops.

Rule of Thirds - definition

The outward leg of the dive is ended (turned) when one third of the gas is used, leaving one-third for the exit (the return), and one-third as reserve. This ensures that the divers could make a safe exit in the event of a catastrophic gas loss from one of the divers. Where the dive involves decompression "exit" is regarded as reaching the first decompression stop.

Decompression Gas

Where decompression is planned the amount of decompression gas required should be calculated with at least one-half extra as a reserve, i.e. 1.5 x planned usage.

If the bottom mix and the decompression mix are the same gas, the redundant gas supply should provide your decompression requirements. In the event of gas loss from the main cylinder your decompression obligations can still be met from your redundant gas supply.

For divers with differing RMV's and cylinder sizes, the diver with the highest RMV determines the gas consumption, and the diver with the least litres of air determines the available gas.

It is best to carry all the gas you require for a dive, unless it can be safely and reliably staged. This will depend upon the type of dive and the environment. In open water it is important to be self-sufficient, whereas a wreck dive on a shot-line can be reliably staged.

Example:
Dive 30m for 50 minutes; deco schedule - 4.5m for 13 minutes

RMV = 16.2 l/min

Bottom Mix:
At 30m = 4bar
RMV at depth = 16.2 x 4
= 64.8 l/min
Descent – take average of linear descent
Ascent - take average of linear ascent between stops
Descent 2 mins = 2 x 64.8 / 2
= 64.8 litres
Bottom 46 mins = 46 x 64.8
= 2980.8 litres
Ascent to 4.5m = 5 x 64.8 / 2 (Ascent 3 mins + Pyle Stops 2 mins)
= 162 litres
Total gas on bottom mix = 3208 litres

Apply Rule of Thirds

Two thirds = 3208 litres

Total gas required = 4812 litres

Requires 2 x 12litre cylinders @ 201 bar each

The dive should be turned when 1604 litres of gas used. When using twin cylinders each one should be used equally, i.e. 67 bar from each cylinder. At the first decompression stop the remaining gas = 134 bar.

Decompression Mix:
Decompression stop at 4.5m
RMV at depth = 1.45 x 16.2
= 23.5 l/min
Stop = 13 min
Gas required = 13 x 23.5
= 306 litres
Gas rule - one-half extra = 306 x 1.5
= 459 litres
Require 3l cylinder @ 153 bar

Emergency Situations

There are two emergency scenarios that could occur. It is important to be able to communicate with the surface cover to indicate the nature of the emergency.

Firstly, in the event of missing the shot-line (if an ascent on a shot is expected) or simply ascending in open water you may still have sufficient gas to meet your decompression schedule. You must indicate this by deploying a **red** surface marker buoy. This informs the surface cover that you are completing your decompression, but in open water and to be aware of a potential emergency.

Secondly, if your ascent is in open water for any reason and you have insufficient gas to complete your decompression requirements you must deploy a **yellow** surface marker buoy. This indicates to the surface cover that you have an emergency situation. They will then be able to deploy the emergency decompression station with stage decompression cylinders.

Type of Gas

The safest possible mix should be used for the planned dive. Remember that a pPO_2 of 1.4 is used for the MOD of the bottom mix. Whereas for decompression schedules a pPO_2 of 1.6 determines the MOD of the mix used on the decompression stops.

CFT recommendations:

1.4 bar – maximum partial pressure of oxygen for recreational diving. This is the maximum allowed for the bottom gas mix.

1.6 Bar – maximum partial pressure of oxygen for decompression schedules. This is used to determine the MOD for a decompression gas.

Each mix must be analysed, and the regulators labelled in the event of more than one mix being used. The label will specify the type of gas and the MOD. It is important to identify any gas that could be potentially hyperoxic at any depth.

If there are different nitrox mixes being used in a group of the divers the following will apply:

- The richest nitrox mix must be used to determine the maximum operating depth for a dive.
- The least richest mix must be used to determine the decompression schedule.

The type of gas used will affect the CNS% and OTU's, and each should be calculated for all portions of the dive.

Different gas mixes should be worn in accordance with the generally accepted rule of:

LEFT : LEAN RIGHT : RICH

This means that a richer mix should be worn on the diver's right hand side and a less rich mix worn on the left.

All the dive information must be recorded on each individual divers' slate. This will enable a diver to react to an increase in gas consumption, for whatever reason.

Summary

Each diver has an individual gas consumption (RMV), which can be easily calculated on any dive. This simple exercise is the essential to safe extended diving.

The rules applied to gas calculations for extended diving are also straightforward; the rule of thirds to be used for the bottom mix and 1.5 times the planned usage for any decompression gas.

An “out of ordinary” ascent can be communicated to the surface cover using surface markers buoys.

The overall dive plan governs the type of gas that is used.

This is just a part of the dive planning required for extended diving. Each part is as important as the other. All need to be understood and practised many times until it becomes second nature. Never stop recording your gas consumption and analysing gas management.

Dive Planning

Introduction

In order for Extended Range diving to be carried out efficiently and safely, thorough dive planning is essential and this has to be meticulous in nature. All aspects of dive planning for recreational diving apply to extended range diving e.g. assessment of the site, weather, tides and emergency plans. These are well covered in previous modules. Here we will look at the extra needs of extended range diving.

Pre dive planning

Pre dive planning leads to the successful execution of an extended range dive. The format should be as follow:

1. Determine the depth and profile of the dive – including diver entry and exit points
2. Identify the ideal gas mixture with MOD – for both bottom and decompression gas, analyse gas. Use the richest mix to determine the MOD of the planned dive.
3. Decide decompression schedule. Use the least rich mix to determine the deco schedule.
4. Calculate CNS%, OTU's and gas requirements, including an allowance for safety. Use the least amount of gas available and the highest RMV to determine the gas requirements.
5. Assess equipment requirements – include individual requirements (e.g. thermal considerations) and equipment needed for the dive team.

Dive support platform

As can be seen from the equipment lecture each diver requires a large amount of equipment when carrying out extended range diving. There is also the spare gas required and decompression station so boat space may be a big consideration.

Depending on dive location, distance from shore etc, a hard boat may be a better and safer option.

Any boat must be checked for emergency equipment such as radios, oxygen and first aid etc.

Recovery of divers in an emergency must also be considered when assessing the support requirements.

Dive Group Selection

Divers must prepare themselves for the dive, both physically and mentally. Each diver should be fit – qualified, medically fit and dived up – and have the correct equipment for the planned dive. Any diver that does not fit this category should not dive.

Groups should be chosen on the basis of compatibility – similar equipment, gas mixes, gas consumption. Diver groups should work together as a team, despite being self-sufficient.

Gas availability

When the gas requirements, both mixes and quantity, have been decided the availability of gas may be a constraint on the extent of the dive. The fill requirements must be assessed; if 300 bar cylinders are used, they may require being full to complete the dive. The divers must be assured of the quality of gas available. There must also be provision to analyse the gas prior to the dive to make sure the analysis fits with the dive plan.

Emergency Planning

There are additional emergency procedures to be considered. Contingency plans need to be formulated for:

- Loss of gas – both bottom and decompression gas loss can precipitate an emergency situation. The decompression schedule for loss of decompression gas should be written on the diver's slate
- Loss of shot-line – divers unable to return to the shot-line, may be able to complete the dive safely, but this may put the boat cover in a difficult situation
- Dive team separation – buddy pairs becoming separated, the dive needs to be aborted and decompression schedules must be completed – surface support may not be aware of the separation until the divers surface
- Equipment failure – may occur at any stage of the dive and this will determine the seriousness of the failure; divers may not be able to complete the required decompression time.
- Change in dive profile - a deeper and longer dive will affect gas consumption and the decompression schedule. This should be written on the diver's slate in case the planned profile is exceeded.

Support divers

Support divers must be experienced divers in the type of diving undertaken. They should be dived up in the same manner as the dive team and qualified for the diving expected from them.

The support divers should be capable of setting up dive equipment, the decompression station and act as carriers for spare gas if it is needed.

Support divers should assist the dive team, prior to the dive, during decompression and during exit from the water.

It is important that the support divers are included in the pre-dive planning and be familiar with all aspects of the dive plan.

Practical Planning Workshop

We will now look at the practical calculations that form the pre-dive plan

Dive to 30m using EAN 34 with a bottom time of 50 minutes.

pPO_2 – 1.36
Bottom mix MOD – 31m
EAD – 23.4m use the 24m table.
Decompression – 13 minutes @ 4.5m using EAN 50
Decompression mix MOD – 22m

CNS Oxygen Tracking:
CNS% at 30m on bottom mix EAN 34
pPO_2 – 1.36
CNS% per min = 0.62 (Appendix 3)
Total CNS% = 0.62 x 50
= 31% for bottom mix
CNS% at 4.5m on deco mix EAN 50
pPO_2 – 0.725
CNS% per min = 0.19 (Appendix 3)
Total CNS% = 0.19 x 13
= 2.47% for deco mix
Total CNS% for dive = 31 + 2.47
= 33.47% OK

Pulmonary Oxygen Tracking:
OTU's at 30m on bottom mix EAN 34
pPO_2 – 1.36
OTU per min = 1.63 (Appendix 4)
Total OTU = 1.63 x 50
= 81.5 OTU for bottom mix
OTU's at 4.5m on deco mix EAN 50
pPO_2 – 0.725
OTU per min = 0.56 (Appendix 4)
Total OTU = 0.56 x 13
= 7.3 for deco mix
Total OTU for dive = 81.5 + 7.3
= 88.8 OTU's OK

Calculate Run Times for Dive
Ascent 30m to 4.5m
Pyle Stop – 17m for 1 min
Pyle Stop – 11m for 1 min
Bottom Time – 48 mins
Pyle Stops – 2 mins
Ascent – 3 mins
Decompression – 13 mins

Run Times on Dive Slate

Depth	Stop	RT
30m		48 mins
17m	1 min	50 mins
11m	1 min	52mins
4.5m	13 mins	66 mins
Surface		67 mins

Depth - 30m
BT - 50 mins (2 Pyle Stops)

Gas Management
RMV = 16.2 l/min
At 30m = 4bar
RMV at depth = 16.2 x 4 = 64.8 l/min
Descent – take average of linear descent
Ascent - take average of linear ascent between stops

Descent 2 mins = 2 x 64.8 / 2
= 64.8 litres
Bottom 46 mins = 46 x 64.8
= 2981 litres
Ascent to 4.5m = 5 x 64.8 / 2
= 162 litres
Total gas on bottom mix = 3208 litres

Apply Rule of Thirds
Two thirds = 3208 litres
Total gas required = 4812 litres
Require:
2 x 12 litre cylinders @ 201 bar

Decompression stop at 4.5m
RMV at depth = 1.45 x 16.2
= 23.5 l/min
Stop 13 min = 13 x 23.5
= 306 litres
Gas rule 1.5x extra = 306 x 1.5
= 459 litres
Require: 3 litre cylinder @ 153 bar

Safety Planning
Calculate dive to one deeper depth increment and for one longer time increment
Calculate decompression schedule using bottom mix
This information must appear on the dive slate
Compare all your calculations with your buddy
Check all figures do not exceed recommended limits

Appendix 1

Partial Pressure of Oxygen for Depth and Fraction of Gas

DEPTH	PERCENTAGE OF OXYGEN IN MIX																			
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
11	0.44	0.46	0.48	0.5	0.53	0.55	0.57	0.59	0.61	0.63	0.65	0.67	0.69	0.71	0.73	0.76	0.78	0.8	0.82	0.84
12	0.46	0.48	0.51	0.53	0.55	0.57	0.59	0.62	0.64	0.66	0.69	0.7	0.73	0.75	0.77	0.79	0.81	0.84	0.86	0.88
13	0.48	0.51	0.53	0.55	0.58	0.6	0.62	0.64	0.67	0.69	0.71	0.74	0.76	0.78	0.8	0.83	0.85	0.87	0.9	0.92
14	0.5	0.53	0.55	0.58	0.6	0.62	0.65	0.67	0.7	0.72	0.74	0.77	0.79	0.82	0.84	0.86	0.89	0.91	0.94	0.96
15	0.53	0.55	0.58	0.6	0.63	0.65	0.68	0.7	0.73	0.75	0.77	0.8	0 .82	0.85	0.87	0.9	0.92	0.95	0.97	1
16	0.55	0.57	0.6	0.62	0.65	0.68	0.7	0.73	0.75	0.78	0.81	0.83	0.86	0.88	0.91	0.94	0.96	0.99	1.01	1.04
17	0.57	0.59	0.62	0.65	0.68	0.7	0.73	0.76	0.78	0.81	0.84	0.86	0.89	0.92	0.94	0.97	1	1.03	1.05	1.08
18	0.59	0.62	0.64	0.67	0.7	0.73	0.76	0.78	0.81	0.84	0.87	0.9	0.92	0.95	0.98	1.01	1.04	1.06	1.09	1.12
19	0.61	0.64	0.67	0.7	0.73	0.75	0.78	0.81	0.84	0.87	0.9	0.93	0.96	0.99	1.01	1.04	1.07	1.1	1.13	1.16
20	0.63	0.66	0.69	0.72	0.75	0.78	0.81	0.84	0.87	0.9	0.93	0.96	0.99	1.02	1.05	1.08	1.11	1.14	1.17	1.2
21	0.65	0.68	0.71	0.74	0.78	0.81	0.84	0.87	0.9	0.93	0.96	0.99	1.02	1.05	1.08	1.12	1.15	1.18	1.21	1.24
22	0.67	0.7	0.74	0.77	0.8	0.83	0.86	0.9	0.93	0.96	0.99	1.02	1.06	1.09	1.12	1.15	1.18	1.22	1.25	1.28
23	0.69	0.73	0.76	0.79	0.83	0.86	0.89	0.92	0.96	0.99	1.02	1.06	1.09	1.12	1.15	1.19	1.22	1.25	1.29	1.32
24	0.71	0.75	0.78	0.82	0.85	0.88	0.92	0.95	0.99	1.02	1.05	1.09	1.12	1.16	1.19	1.22	1.26	1.29	1.33	1.36
25	0.74	0.77	0.81	0.84	0.88	0.91	0.95	0.98	1.01	1.05	1.08	1.12	1.15	1.19	1.22	1.26	1.29	1.33	1.36	1.4
26	0.76	0.79	0.83	0.86	0.9	0.94	0.97	1.01	1.04	1.08	1.12	1.15	1.19	1.22	1.26	1.3	1.33	1.37	1.4	1.44
27	0.78	0.81	0.85	0.89	0.93	0.96	1	1.04	1.07	1.11	1.15	1.18	1.22	1.26	1.29	1.33	1.37	1.41	1.44	1.48
28	0.8	0.84	0.87	0.91	0.95	0.99	1.03	1.06	1.1	1.14	1.18	1.22	1.25	1.29	1.33	1.37	1.41	1.44	1.48	1.52
29	0.82	0.86	0.9	0.94	0.98	1.01	1.05	1.09	1.13	1.17	1.21	1.25	1.29	1.33	1.36	1.4	1.44	1.48	1.52	1.56
30	0.84	0.88	0.92	0.96	1	1.04	1.08	1.12	1.16	1.2	1.24	1.28	1.32	1.36	1.4	1.44	1.48	1.52	1.56	1.6
31	0.86	0.9	0.94	0.98	1.03	1.07	1.11	1.15	1.19	1.23	1.27	1.31	1.35	1.39	1.43	1.48	1.52	1.56	1.6	
32	0.88	0.92	0.97	1.01	1.05	1.09	1.13	1.18	1.22	1.26	1.3	1.34	1.39	1.43	1.47	1.51	1.55	1.6		
33	0.9	0.95	0.99	1.03	1.08	1.12	1.16	1.2	1.25	1.29	1.33	1.38	1.42	1.46	1.5	1.55	1.59			
34	0.92	0.97	1.01	1.06	1.1	1.14	1.19	1.23	1.28	1.32	1.36	1.41	1.45	1.5	1.54	1.58	1.63			
35	0.95	0.99	1.04	1.08	1.13	1.17	1.22	1.26	1.31	1.35	1.39	1.44	1.48	1.53	1.57	1.62				
36	0.97	1.01	1.06	1.1	1.15	1.2	1.24	1.29	1.33	1.38	1.43	1.47	1.52	1.56	1.61					
37	0.99	1.03	1.08	1.13	1.18	1.22	1.27	1.32	1.36	1.41	1.46	1.5	1.55	1.6						
38	1.01	1.06	1.1	1.15	1.2	1.25	1.3	1.34	1.39	1.44	1.49	1.54	1.58							
39	1.03	1.08	1.13	1.18	1.23	1.27	1.32	1.37	1.42	1.47	1.52	1.57	1.62							
40	1.05	1.1	1.15	1.2	1.25	1.3	1.35	1.4	1.45	1.5	1.55	1.6								
41	1.07	1.12	1.17	1.22	1.28	1.33	1.38	1.43	1.48	1.53	1.58									
42	1.09	1.14	1.2	1.25	1.3	1.35	1.4	1.46	1.51	1.56	1.61									
43	1.11	1.17	1.22	1.27	1.33	1.38	1.43	1.48	1.54	1.59										
44	1.13	1.19	1.24	1.3	1.35	1.4	1.46	1.51	1.57	1.62										
45	1.16	1.21	1.27	1.32	1.38	1.43	1.49	1.54	1.6											
46	1.18	1.23	1.29	1.34	1.4	1.46	1.51	1.57												
47	1.2	1.25	1.31	1.37	1.43	1.48	1.54	1.6												
48	1.22	1.28	1.33	1.39	1.45	1.51	1.57													
49	1.24	1.3	1.36	1.42	1.48	1.53	1.59													
50	1.26	1.32	1.38	1.44	1.5	1.56	1.62													
51	1.28	1.34	1.4	1.46	1.53	1.59														
52	1.3	1.36	1.43	1.49	1.56	1.61														
53	1.32	1.9	1.45	1.51	1.58															
54	1.34	1.41	1.47	1.54	1.61															
55	1.37	1.43	1.5	1.56																
56	1.39	1.45	1.52	1.58																
57	1.41	1.47	1.54	1.61																
58	1.43	1.5	1.56																	
59	1.45	1.52	1.59																	
60	1.47	1.54	1.61																	
61	1.5	1.56																		
62	1.51	1.58																		
63	1.53	1.61																		
64	1.5																			
65	1.58																			
66	1.6																			

DEPTH IN METRES	OXYGEN PERCENTAGE IN MIX					
O2	50	60	70	80	90	100
1	0.55	0.66	0.77	0.88	0.99	1.1
2	0.6	0.72	0.84	0.96	1.08	1.2
3	0.65	0.78	0.91	1.04	1.17	1.3
4	0.7	0.84	0.98	1.12	1.26	1.4
5	0.75	0.9	1.05	1.2	1.35	1.5
6	0.8	0.96	1.12	1.28	1.44	1.6
7	0.85	1.02	1.19	1.36	1.53	
8	0.9	1.08	1.26	1.44	1.62	
9	0.95	1.14	1.4	1.52		
10	1	1.2	1.47	1.6		
11	1.05	1.26	1.54			
12	1.1	1.32	1.61			
13	1.15	1.38				
14	1.2	1.44				
15	1.25	1.5				
16	1.3	1.56				
17	1.35	1.62				
18	1.4					
19	1.45					
20	1.5					
21	1.55					
22	1.6					

DEPTH AND OXYGEN PERCENTAGE VERSUS PARTIAL PRESSURE IN BAR

Read along the top column for the percentage of your mix, then down the side column for depth. Where the two intersect is the partial pressure of oxygen of that mix at that depth.

Appendix 2

Equivalent Air Depths

EAD	***OXYGEN CONTENT OF MIXTURE BREATHED (%)***																			
(m)	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
12	12	12	12	13	13	13	14	14	14	15	15	15	16	16	17	17	17	18	18	19
15	15	15	16	16	16	17	17	17	17	18	19	19	19	20	20	21	21	22	22	23
18	18	18	19	19	19	20	20	21	21	22	22	22	23	23	24	24	25	26	26	27
21	21	21	22	22	23	23	24	24	24	25	25	26	26	27	28	28	29	29	30	30
24	24	24	25	25	26	26	27	27	28	28	29	29	30	31	31	32	33	32	31	
27	27	27	28	28	29	29	30	31	31	32	32	33	34	34	35	34	34			
30	30	31	31	32	32	33	33	34	34	35	36	36	37	37	36					
33	33	34	34	35	35	36	36	37	38	38	39	40	39							
36	36	37	37	38	38	39	40	40	41	42	42									
39	39	40	40	41	42	42	43	44	45	44										
42	42	43	43	44	45	45	46	47												
45	45	46	46	47	48	49	50													
48	48	49	49	50	51	52														
51	51	52	53	53	54															
54	54	55	56	57																
57	57	58	59																	
60	60	61																		
63	63																			
66	66																			

To use the Equivalent Air Depth Table:

Go across the top of the table until you reach the mix that you are using. Go down that column to find your exact or next greatest dive depth. Go across to the left hand column and read off your E.A.D. in metres.

Example: Using Nitrox 32% at 33 metres.

Go across to reach 32%.

Go down to 33 metres.

Follow the row across to the left, where the E.A.D. can be read: 27 metres.

Appendix 3

Oxygen Partial Pressure and CNS% per minute

PO_2	CNS%/min	PO_2	CNS%/min	PO_2	CNS%/min
0.6	0.14	1.02	0.35	1.42	0.68
0.62	0.14	0.04	0.36	1.44	0.71
0.64	0.15	0.06	0.38	1.46	0.74
0.66	0.16	1.08	0.4	1.48	0.78
0.68	0.17	1.1	0.42	1.5	0.83
0.7	0.18	1.12	0.43	1.52	0.93
0.72	0.18	1.14	0.43	1.54	1.04
0.74	0.19	1.16	0.44	1.56	1.19
0.76	0.2	1.18	0.46	1.58	1.47
0.78	0.21	1.2	0.47	1.6	2.22
0.8	0.22	1.22	0.48	1.62	5
0.82	0.23	1.24	0.51	1.65	6.25
0.84	0.24	1.26	0.52	1.67	7.69
0.86	0.25	1.28	0.54	1.7	10
0.88	0.26	1.3	0.56	1.72	12.5
0.9	0.28	1.32	0.57	1.74	20
0.92	0.29	1.34	0.6	1.77	25
0.94	0.3	1.36	0.62	1.78	31.25
0.96	0.31	1.38	0.63	1.8	50
0.98	0.32	1.4	0.65	1.82	100
1	0.33				

Notes: Calculate the PO_2 for the depth and mix and using the table find the CNS%/minute. Multiply this time by time of exposure at each partial pressure (bottom and decompression gas) to find the total for the dive.

Exposure time is taken as decompression bottom time from the tables and time at each decompression stop where a high FO_2 decompression gas is employed.

Appendix 3a

Table 2. NOAA Oxygen Partial Pressure Table

Exposure Limits for Divers		
Oxygen Partial Pressure	Maximum Duration for Single Exposure	Maximum Total Duration
(Bar)	(Minutes)	(Minutes)
1.6	45	150
1.5	120	180
1.4	150	180
1.3	180	210
1.2	210	240
1.1	240	270
1.0	300	300
0.9	360	360
0.8	450	450
0.7	570	570
0.6	720	720

Appendix 4

Oxygen Partial Pressure and OTU dose per minute

pO_2 (Bar)	OTU/minute	pO_2 (Bar)	OTU/minute
0.55	0.15	1.10	1.16
0.60	0.26	1.15	1.24
0.65	0.37	1.20	1.32
0.70	0.47	1.25	1.40
0.75	0.56	1.30	1.48
0.80	0.65	1.35	1.55
0.85	0.74	1.40	1.63
0.90	0.83	1.45	1.70
0.95	0.92	1.50	1.78
1.00	1.00	1.55	1.85
1.05	1.08	1.60	1.93

Appendix 5

Maximum OTU Exposure per day

Oxygen Exposure Limits	
Number of Days	Daily Limit (OTU)
1	850
2	700
3	620
4	525
5	460
6	420
7	380
8	350
9	330
10	310

Appendix 6a

Dive Tables with Surface Intervals and Repetitive Dive Times

TABLE A Surface Interval and Repetitive Dive Table

BOTTOM TIMES

12	15	18	21	24	27	30	33	36	39	42	Depth in metres			Repetitive Group				SURFACE INTERVAL (C)
125	*75*	*51*	*35*	*25*	*20*	*17*	*14*	*12*	*10*	*9*	*No Deco. Limits*							
19	16	14	12	11	10	9	8	7	7	6					A	00:00 01:59	02:00	
25	20	17	15	13	12	11	10	9	8	7				B	00:00 00:19	00:20 01:59	02:00	
37	29	25	22	20	18	16	11	10	9	8			C	00:00 00:09	00:10 00:24	00:25 02:59	03:00	
57	41	33	28	24	19	17	14	12	10	9		D	00:00 00:09	00:10 00:14	00:15 00:29	00:30 02:59	03:00	
82	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	
111	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	
125	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 DIVE AT END OF S.I.

(E) REPETITIVE DIVES

G	F	E	D	C	B	A	0	Depth
137	111	82	57	37	25	19	RNT	12
115	88	59	41	29	20	16	RNT	15
91	68	44	33	25	17	14	RNT	18
72	53	37	28	22	15	12	RNT	21
57	42	30	24	20	13	11	RNT	24
47	35	26	21	18	12	10	RNT	27
40	30	23	19	16	11	9	RNT	30
35	27	21	17	14	10	8	RNT	33
31	24	19	15	12	9	7	RNT	36
27	21	17	14	11	8	7	RNT	39
25	19	16	13	10	7	6	RNT	42
23	17	14	11	9	7	6	RNT	45

Residual Nitrogen Times

1. Find depth & BT from Table B (no stop) or Table A.
2. Find RG
3. Find Re-entry code after Surface Interval (C).
4. Find new dive depth and RNT using Re-entry code (E).
5. Add RNT to planned bottom time or subtract from No stop time to give schedule.

The tables are based on the Buhlmann ZHL16 system with an option to use EAN50 or greater as a decompression gas. The repetitive dive groups are not transferable to any other table. A three minute safety stop is recommended on all dives. These tables do not take into account the physical condition of the diver or water temperature, dive difficulty etc.

Appendix 6b

EAD Dive Tables with Decompression Times for Air or 50% Nitrox

TABLE B IANTD Air Tables with 50% Nitrox Decompressions or Air Decompressions

Depth	Mins	Air Stops 9	Air Stops 6	Air Stops 4.5	50/50 6	50/50 4.5	RG
12	150			1		1	G
15	90			5		3	G
	120			19		12	H
18	60			6		5	F
	70			11		7	G
	80			16		11	G
	90			24		15	H
	100			31		20	H
	110			37		24	H
	120			45		27	K
21	50			10		7	F
	60			17		11	G
	70			24		16	H
	80			35		22	H
	90			43		28	H
	100		1	52	1	32	H
	110		3	71	2	38	K
	120		5	87	4	46	K
24	40			11		8	F
	50			19		13	G
	60		1	28	1	18	G
	70		3	38	2	25	G
	80		5	46	4	30	H
	90	1	7	64	5	34	K
	100	3	9	84	7	44	K
	110	6	9	101	7	54	K
	120	8	12	114	9	62	L
27	30			9		7	F
	40			17		13	G
	50		3	26	3	17	G
	60	2	4	38	3	24	H
	70	4	6	47	5	30	H

Depth	Mins	Air Stops 15	Air Stops 12	Air Stops 9	Air Stops 6	Air Stops 4.5	50/50 6	50/50 4.5	RG
27	80			7	8	69	6	35	H
	90			10	9	92	7	49	K
	100			14	11	108	8	59	K
	110			17	14	129	10	68	K
	120		1	21	14	151	10	77	L
30	25					9		7	E
	30				1	12	1	9	F
	40			1	3	22	3	14	G
	50			4	4	35	3	22	H
	60			7	6	46	5	29	H
	70			11	8	68	6	34	H
	80		2	13	10	94	7	50	K
	90		4	16	13	112	9	62	K
	100		6	20	14	140	10	72	K
	110		9	24	14	171	10	85	L
33	25				1	11	1	8	F
	30			1	2	16	2	11	G
	40			4	4	27	3	18	G
	50			8	6	41	4	27	H
	60		3	10	8	61	6	33	K
	70		6	13	9	92	7	49	L
	80		9	16	13	113	9	62	L
	90		12	21	14	143	10	73	L
	100	2	14	25	14	181	10	89	L
36	20				1	9	1	7	E
	25			1	2	14	2	9	F
	30			3	3	18	2	13	G
	40			7	4	34	3	22	G
	50			10	6	48	4	32	H
	60			13	9	83	7	43	H
	70	2	10	16	12	110	9	60	L
	80	4	12	21	14	142	11	72	L
	90	7	15	25	15	184	11	89	L
	100	9	17	29	19	229	13	106	L

Depth	Mins	Air Stops 18	Air Stops 15	Air Stops 12	Air Stops 9	Air Stops 6	Air Stops 4.5	50/50 6	50/50 4.5	RG
39	15					1	6	1	4	F
	20				1	2	11	1	9	F
	25				3	2	17	2	12	G
	30			1	4	4	23	3	15	G
	40			4	7	6	41	5	25	H
	50		1	7	11	8	66	6	34	H
	60		4	9	16	10	102	7	55	K
	70		7	11	20	15	133	11	69	K
	80	1	9	15	25	15	178	11	87	L
42	15					2	7	1	6	E
	20				2	2	12	2	9	F
	25			1	4	3	18	2	14	G
	30			3	6	4	26	3	18	G
	40		2	6	9	6	46	5	30	G
	50		5	8	13	9	85	7	44	H
	60	1	7	11	17	14	116	10	64	K
	70	3	9	15	24	14	163	10	82	L
45	10						4		4	E
	15				1	2	8	2	6	E
	20			1	3	2	15	2	10	F
	25			3	4	4	22	3	15	G
	30		1	4	7	4	33	3	21	H
	40		4	7	10	7	55	6	33	H
	50	2	6	10	15	11	101	8	54	K
	60	5	8	13	22	14	142	10	72	K

When using EAN50 or greater for decompression all stops up to 6m must be completed as well as the 6m & 4.5m stops on EAN50. All stops from 21m and up may be completed on EAN50 for additional safety.