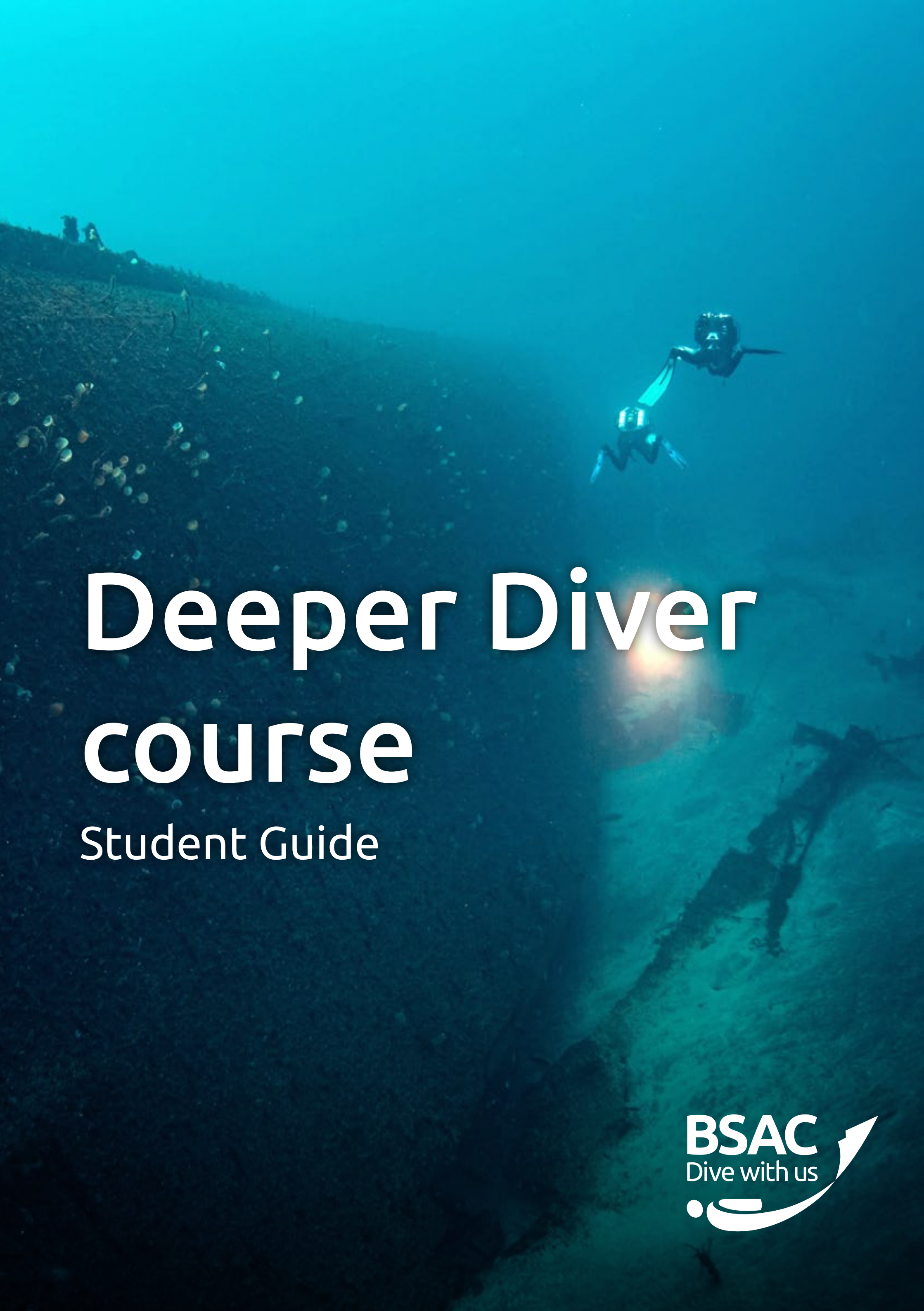

Deeper Diver course

Student Guide

BSAC
Dive with us

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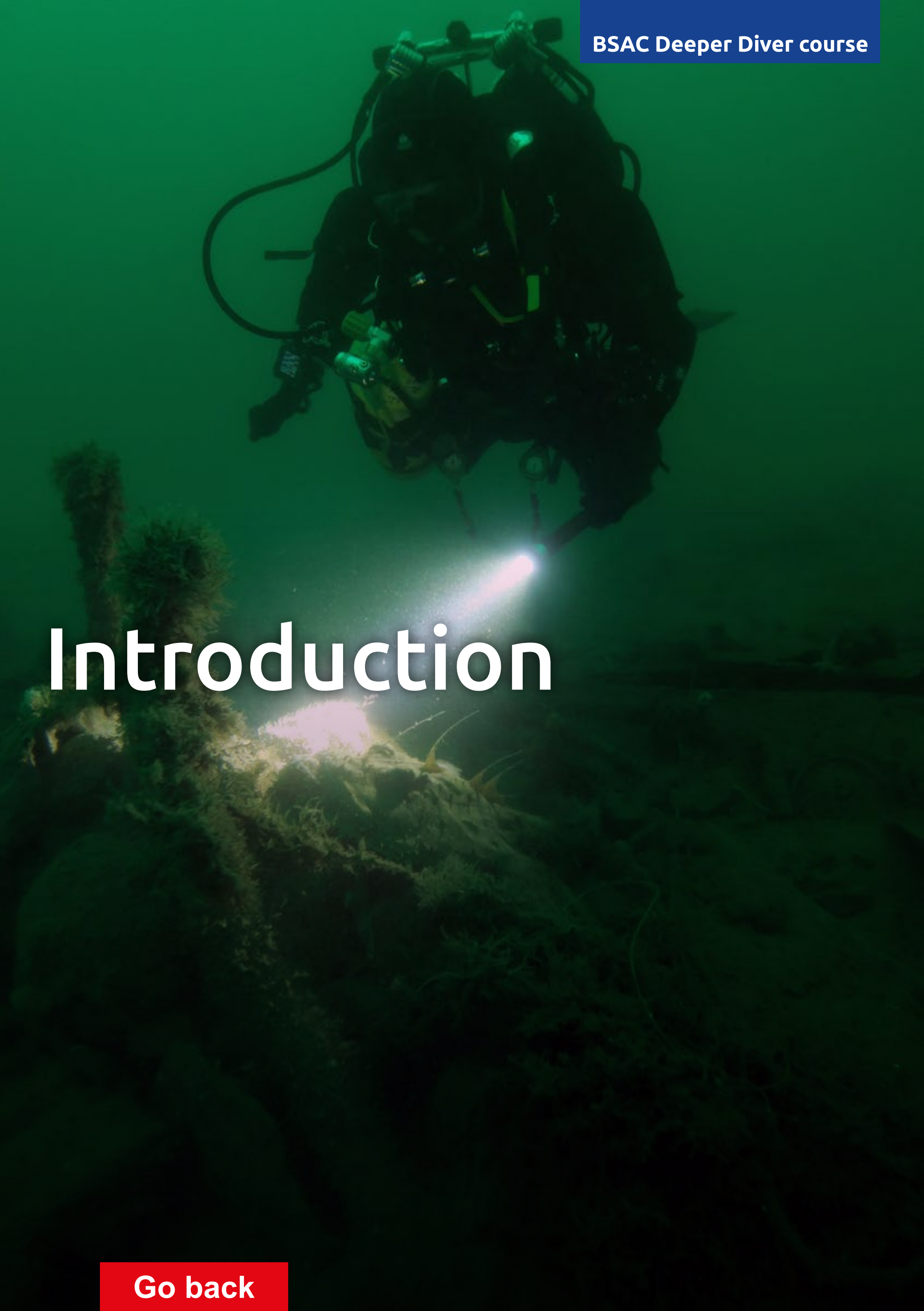

Introduction

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Introduction

Congratulations on choosing the BSAC Deeper Diver course as the next step on your diving journey.

The Deeper Diver course will take your diving knowledge beyond that gained in earlier training and allow you to dive safely to depths deeper than in previous qualifications. Once completed, you can complete optional depth progression dives to a maximum depth of 50 metres and use weak trimix as a breathing gas.

The course notes should be read in conjunction with previous training manuals, and it would be beneficial to revise the sections on diving physiology, decompression planning and gas consumption before starting.

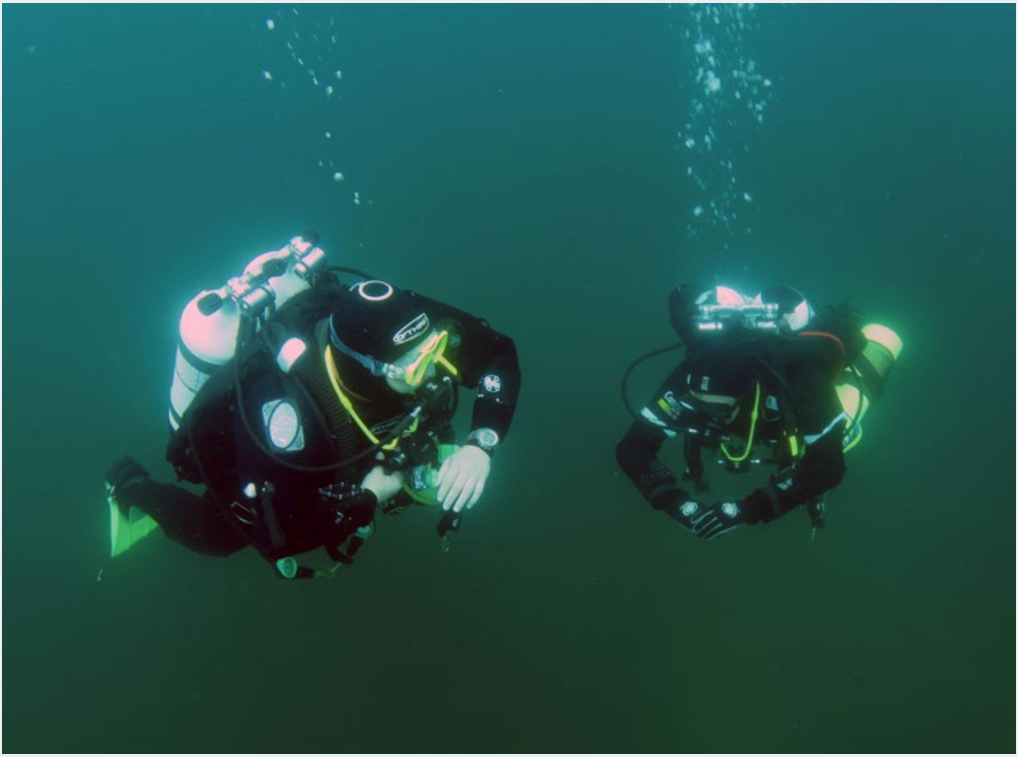
Go back

Further training

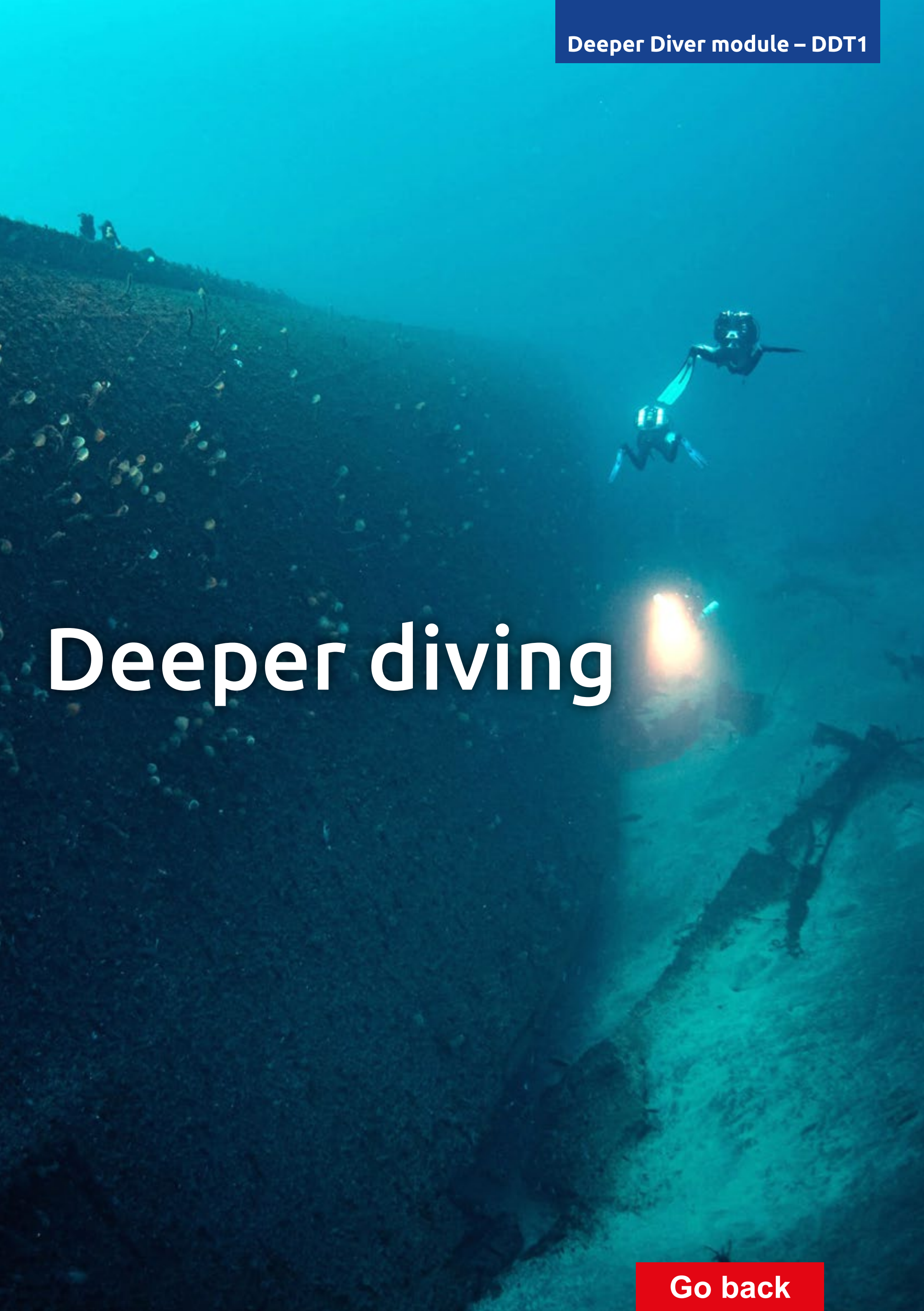
The BSAC website has an Online Learning Hub (OLH), which continually evolves with learning opportunities. The OLH has three main threads to it:

- **Programme of training webinars**
- **Programme of special interest webinars**
- **Diving skill videos which complement the Diver Training Programme (DTP)**

There is also a 'catch up' section from past webinars to allow access at a time to suit you. The content is produced by our volunteers and offers support for members and instructors within branches and centres. See **bsac.com/training/online-learning/**



Deeper diving



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Check out your eLearning video

Dive planning

Dom Robinson / Alex Warzynski will take you through this module.

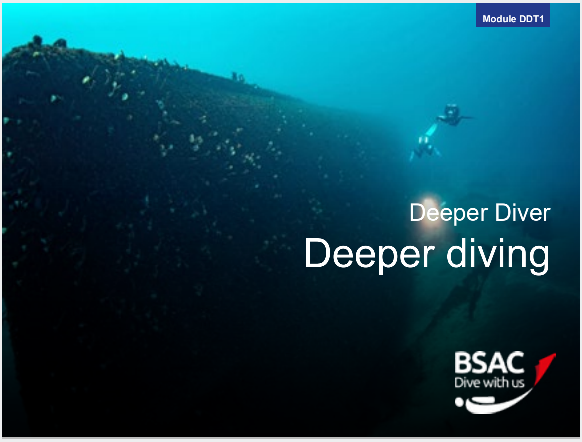
This video will cover:

- **Structure of the Deeper Diver course**
- **Qualification and how to progress**
- **Self-reliance in the buddy system**
- **Trimix analysis**
- **Cylinder configurations for deeper diving**
- **Redundancy**
- **Problem solving on deeper dives**

Remember if you need to discuss any of the theory e-mail or call your instructor at your club or centre.

Video time length | 18:35 mins.

Click the image below to start watching the video.



DDT1 Deeper diving

Module objectives

This lesson explains the structure of the Deeper Diver course, what qualification will be gained and how to progress.

It also expands previous training to cover trimix analysis and considerations for deeper diving, including cylinder configurations, redundancy and problem solving.

Module contents

The module covers the following topics:

- **The structure of the Deeper Diver course**
- **The qualification that will be gained and how to progress**
- **Self-reliance in the buddy system**
- **Trimix analysis**
- **Cylinder configurations for deeper diving**
- **Redundancy**
- **Problem solving on deeper dives**

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Course structure

The overall objective of the course is to explain how to dive safely to depths deeper than in previous qualifications.

Course components

There are two components to the course:

- **Theory knowledge**
  The theory lessons will provide the knowledge to take divers beyond the depth limits of their existing qualifications. This will enable them to make informed choices on subjects such as gas selection, equipment, and dive plans.

- **Depth progression (optional)**
  For divers who wish to extend their depth experience, this can be achieved with an appropriately qualified, experienced and current Dive Leader once all theory training has been completed.

Theory lessons

The theory lessons will cover the following:

- **Deeper diving**
- **Physiology**
- **Decompression planning**
- **Gas planning and limiting factors**

Go back

BSAC Deeper Diver

The BSAC Deeper Diver course builds on previous training and knowledge from previous courses to allow divers to progress to greater depths and use weak trimix.

Knowledge

A BSAC Deeper Diver has the knowledge that will allow them to make risk-based decisions about diving to depths greater than that previously encountered.

- **Understand the risks**
- **Safely plan deeper dives**
  Planning can be conducted using a variety of tools beyond those taught in previous courses.
- **Conduct deeper dives safely**

Diving

The knowledge gained in the course can be used to conduct more advanced diving.

- **Depth progression (max 50 m)**
  Depth can be extended in 5 m increments up to a maximum of 50 m. This needs to be done with a suitably qualified, experienced and current Dive Leader who is supervised by a Deeper Diving Instructor.
- **Dive with trimix: O_2 > 20%, He < 40%**
  A Deeper Diver can use trimix containing no less than 20% oxygen and no more than 40% helium.

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- **Maximum PO_2 of 1.4 bar**
  The maximum PO_2 that can be breathed is 1.4 bar unless additional qualifications, such as Accelerated Decompression Procedures (ADP), are gained.

Equipment

- **Open circuit only**
  Deeper Diver training is only relevant to divers using open circuit equipment. Those wishing to go deeper on a rebreather must complete the appropriate training courses for those.

The buddy system

The increase in risk from deeper dives can be mitigated using the tried and tested buddy system. This should be familiar to all divers, but there are a number of key elements.

Pre-dive

- **Planning**
  Divers should plan together, taking into account individual equipment, personal considerations and aims for the dive.

  It is critical to ensure that the plan is consistent with the one produced by the Dive Manager, which may impose limiting factors such as the available slack window, a time to be back at base or site opening hours. Once the dive plan is made with the buddy, this needs to be logged with the Dive Manager, especially if the dive will be longer than usual.

- **Dive brief**
  A good dive brief based around SEEDS is essential. While this may seem unnecessary with experienced divers, a briefing will pick up differences in equipment and diving techniques and allow special signals to be agreed. It also provides the opportunity to assign specific roles during the dive, such as who sends up a DSMB.

- **Buddy check**
  A rigorous buddy check before entering the water will identify many problems and also provides the opportunity to ensure complete familiarity with equipment. This ensures that all essential items such as inflators, dump valves and alternative supply (AS) can be quickly located and correctly operated if needed. It also allows any differences in equipment and techniques, such as primary donate, to be identified and addressed.

During dive

- **Buddy communication and discipline**
  Good buddy positioning will make a more relaxed dive for both; swimming side by side to keep an eye on each other and communicating a change of direction or stopping to look at something is much easier than with one diver following the other.

- **Torches**
  Torches, especially in dark or gloomy conditions, are an excellent way of keeping together. The signals should be briefed before the dive so both divers understand what each signal means.

  For normal use, the torch beam should be held steady and focused on a position where the other diver is able to see it unless moved away to look at an item of interest.

  An OK signal can be made by drawing 2 circles and responded to in the same way.

Go back

To get the buddy's attention, for example, to point out a feature, a slow side-to-side movement indicates this.

For an emergency, a fast waggle should elicit a rapid buddy response, making a regulator available for use if needed.

- **Problem solving**
  The impact of staying longer at depth means that there is an increased urgency to solving problems.

After dive

Buddy responsibilities do not cease once divers leave the water. Supporting each other during post-dive activities, such as moving heavy equipment, is also important. Of particular importance is to monitor each other so that the early onset of a diving disorder can be identified.

Self-reliance

Although the buddy system is critical, it is also essential that divers are self-reliant and take full responsibility for their own diving.

Pre-dive

- **Equipment preparation**
  Each diver needs to have all the equipment that may be required for the dive, such as DSMBs, distance lines, torches and slates.

- **Equipment check**
  In addition to relying on the buddy check, divers should conduct a rigorous self-check of their own equipment to ensure everything is present, correctly fitted and functioning properly.

During dive

- **Checks**
  While retaining a buddy diving ethos, divers need to be responsible for their own checks, such as gas contents, dive time and decompression obligation.

- **Decision-making**
  Divers also need to be prepared to make critical decisions underwater, such as when to turn around and/or start the ascent. These also need to be communicated to the buddy/dive leader.

- **Problem solving**
  Divers should be prepared to solve problems themselves as it may not always be possible to involve their buddy. The practice and maintenance of these problem-solving skills are an essential part of deeper diving.

Quiz 1

What is the maximum depth for the optional depth progression after this course?

What is the minimum percentage of oxygen that can be used in breathing gas after this course?

What is the maximum percentage of helium that can be used in breathing gas after this course?

Answer on page 107

Trimix analysis

Analysing trimix is a very similar process to nitrox which has been covered in previous training.

Trimix composition

- **Oxygen, helium and nitrogen**
  Trimix consists of oxygen, helium and nitrogen. It is normally created by blending helium, oxygen and air to gain the mix desired.

- **Annotated as 20/30 (oxygen/helium)**
  Once analysed, the mix is expressed using the oxygen and helium percentage separated with a slash. The remaining percentage is nitrogen.

Trimix analyser

A trimix analyser is more complex than a nitrox analyser and consists of two analysers in one.

- **Oxygen analysis**
  The oxygen fraction is measured in exactly the same way as a nitrox analyser, using a galvanic cell that outputs an increasing voltage as the fraction of oxygen increases.

- **Helium analysis**
  Helium cannot be directly measured, so a helium sensor uses either the speed of sound or thermal conductivity and measures it in comparison to a reference gas.

Use

- **Calibration**
  Before taking a reading, the displays should be calibrated with a known gas. Usually, this is air (20.9% oxygen) or neat oxygen (100%) with air used to calibrate the helium cell to 0%.

  The readings can be affected by temperature and humidity, so readings taken in hot or humid areas will need a compensating factor applied to get an accurate reading. Most analysers are supplied with a lookup table.

- **Pass gas through analyser**
  The gas flow should be kept steady and low. Most trimix analysers come with a flow control valve that is screwed into the cylinder valve, and the flow rate adjusted with a thumb screw.

- **Note composition**
  When the readings on the analyser stabilise, then the result should be noted.

Mark cylinder

Once the analysis is complete, the result should be marked on the cylinder and not removed until the mix has changed.

A common format to follow is:

Analysis		**Date**
	MOD	
Pressure		**Initials**

- **Maximum Operating Depth (MOD)**
  In the same way as nitrox, the Maximum Operating Depth (MOD) is calculated using the oxygen percentage at the maximum PO_2 that will be used.

- **Date**
  The date of analysis.

- **Composition**
  Details of the gas mixture, e.g., 20/30.

- **Pressure**
  The cylinder pressure at the time of analysis.

- **Initials**
  The initials of the person who analysed the gas.

Cylinder configurations

Gas planning is covered in more depth later in the course, but deeper diving normally requires more gas, both for the dive and as a reserve, which is often achieved by using different cylinder configurations.

Different cylinders

- **Larger capacity cylinders**
  15 L cylinders are a common size for larger cylinders. There are also 18 L and even 20 L cylinders, but these, especially when full, are heavy and can be difficult to move around on land.

- **Twin-sets**
  Two cylinders carried by the diver. These can be completely independent or joined together with a manifold. Independent cylinders can also be side-mounted using a dedicated system.

  Each of these systems poses its own challenges, and it is strongly recommended that divers receive appropriate training, such as through the BSAC Twin-Set Diver course.

- **Emergency cylinders**
  These are smaller capacity cylinders which have a supply of emergency gas that can be used by the diver or their buddy.

  A calculation needs to be made to understand how long the cylinder will last at depth, which should be used to influence the size chosen. The commonly used 3 L pony may not contain enough gas to enable a diver to surface safely, which is why 5 and 7 L cylinders are often considered to be a better choice.

Go back

It is also important that regulators are prominently identified, as there have been several incidents where divers have mistakenly breathed from their emergency cylinder rather than the main and run out of gas.

Buoyancy

With any diving, being correctly weighted is the first step to minimise the amount of gas volumes needed to maintain neutral buoyancy at any point in the dive.

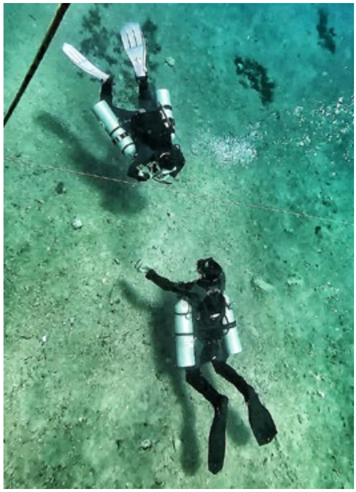
Adding or changing cylinders can have a very significant impact on the weight required by a diver.

- **Adequate lift at the surface**
  With larger capacity cylinders and twin-sets, the weight of the gas in full cylinders needs to be considered. A traditional jacket-style BC may not have enough lift, and the lift may not be in the correct place to keep the diver flat in the water when finning on the dive. A wing system is designed to support the cylinders in the water and may be a better choice.

- **Confirm weighting with shallow check dive**
  If diving in a different configuration, a shallow check dive should take place to ensure that weighting and trim are correct.

- **Weighting with low gas**
  There can be a big change in the buoyancy characteristics of cylinders between full and empty. With virtually empty cylinders, the diver should be able to maintain neutral buoyancy just below the surface, and this needs to form part of the shallow check dive.

Redundancy



Redundancy provides a wider range of options to improve problem solving, although care should also be taken not to increase complexity and the task loading on divers.

The diver should consider what is critical equipment and ensure they have redundancy for these. Items that are not considered critical do not need to be backed up.

It should be remembered that a well-practised buddy pair is the safest form of redundancy.

Buoyancy

- **Lift**
  Having a form of redundant buoyancy is important. For correctly weighted divers, a drysuit should provide enough lift to enable the diver to surface. Where a wetsuit is used, a redundant twin-bladder system may be needed.

- **Inflation if out of gas**
  Consideration should be given to how buoyancy devices can be inflated in an out-of-gas situation or should the inflator fail. Options include spare inflator hoses from an independent gas source, multiple inflators and/or hoses that can be swapped between inflators.

- **Weight**
  Splitting the weighting system into some ditchable and some fixed will enable the diver to still dump weight in an emergency to become positively buoyant, but can arrange the weights to enable flat, comfortable in-water trim.

Gas

One of the most common incidents is for divers to run out of breathing gas, either through poor planning or equipment failure.

- **Dual outlet valves**
  In European countries, a single cylinder fitted with a valve with two outlets is common. Two regulators can be fitted, providing regulator redundancy. This does not provide a backup in the case of the failure of the valve or a problem with the fill itself (pressure or quality of gas).

- **Independent gas source**
  Although the buddy's alternative supply (AS) provides a form of redundancy, some of the options discussed on the previous slide, such as twin-sets and emergency cylinders, are far superior.

Other equipment

- **Mask**
  Carrying a backup mask is a sensible precaution, as if the diver cannot see, a controlled, safe ascent will be difficult.

- **Instrumentation**
  When planning decompression diving, backup instrumentation is essential. The use of a backup dive timer and planning slate, or two dive computers, is sensible.

- **Cutting tools, reels, torches and DSMBs**
  Cutting tools should be placed on the diver's equipment so they can be reached with either hand. The traditional large diver's knife strapped to the leg should be avoided as it creates a snag hazard and is difficult to reach.

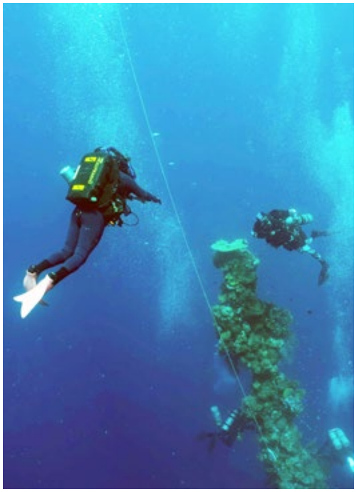
Go back

At greater depths, a torch often becomes essential so carrying both a primary and spare is recommended.

A small backup DSMB and spool can be carried to be used if the diver's main DSMB becomes unavailable.

Problem solving

Out of dive gas



- **Avoid!**
  Avoiding an out-of-gas situation by carrying enough gas to enable both divers to make a safe ascent, even in the event of equipment failure, is the most preferable solution.

- **Planned what to do**
  The buddy pair should have agreed what they will do in an out-of-gas situation. The diver can switch to their own redundant supply or use their buddy's emergency regulator. When deeper diving, these skills become even more essential, so should be practised. If the buddy pair are doing the drill regularly, then a potential emergency situation will be handled in a much calmer manner.

- **Decompression**
  In the worst case, divers may not have sufficient gas to complete all decompression stops. In this situation, they should complete as much decompression as possible, surface and then be given oxygen while the emergency services are contacted.

Go back

Controlled buoyant lift

A controlled buoyant lift from depth is very similar to shallower diving but has specific issues that must be considered.

- **More challenging ascent**
  The additional equipment carried may make the ascent more complex as the diver may have gas in the BC to compensate for the additional weight. Regular practice will help in the event of a real emergency.
- **Decompression stops?**
  If an incapacitated diver needs to be lifted to the surface but has decompression stops to complete, the rescuer needs to judge whether the potential effects of a direct ascent are more of a risk than completing the decompression stops. Not all divers who need a CBL are unresponsive - they may just need a CBL as they are panicked. An unresponsive diver who is not breathing should be lifted to the surface as the chances of drowning are high, but decompression illness can be treated. There may be consequences for the rescuer if they omit decompression stops.

Exceeding run time

It may be that a buddy pair accidentally exceed their dive time which is likely to have significant implications for decompression and diving gas.

- **Backup plans**
  Good planning will enable the pair to switch to their backup plans, and knowing their minimum gas will enable them to make a clear judgement as to how close to the limit of their reserve they are getting.
- **Surface gas**
  Additional cylinders of gas can be deployed by the surface support using a pre-arranged signal, usually a single yellow DSMB. This needs to be pre-arranged, and the equipment provided by the diver

Quiz 2

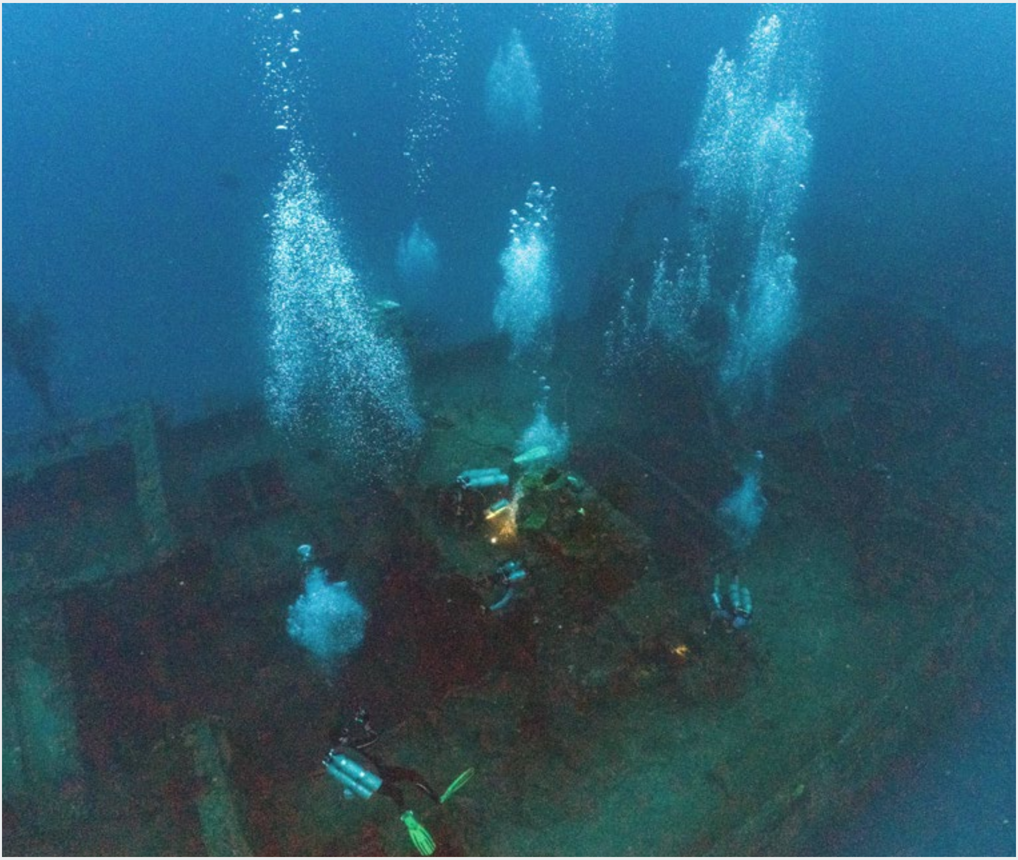
1. **What individual gases make up trimix?**
2. **Different cylinders may have an impact on buoyancy. What should a diver do before taking them on a deep dive?**

Answer on page 107

Summary

You should now understand;

- ✔ **The structure of the Deeper Diver course**
- ✔ **The qualification that will be gained and how to progress**
- ✔ **Self-reliance in the buddy system**
- ✔ **Trimix analysis**
- ✔ **Cylinder configurations for deeper diving**
- ✔ **Redundancy**
- ✔ **Problem solving on deeper dives**



Go back

Test yourself

1. When can the optional depth progression dives be done?
2. Are Closed Circuit Divers allowed to use Deeper Diver training to go deeper than their current CCR qualification permits?
3. What are some of the benefits of a rigorous buddy check before entering the water?
4. Deeper diver are responsible for their own checks during a dive. What do these include as a minimum?
5. What is the convention for annotating helium mixes?
6. What is a potential issue with a 3 L pony cylinder on a deeper dive?
7. Equipment redundancy is important for deeper divers. What are the two important areas that should be considered for redundancy?

Answers on page 107

Go back

Deeper diving physiology

Go back

Check out your eLearning video

Deeper Diving Physiology

Dom Robinson / Alex Warzynski will take you through this module.

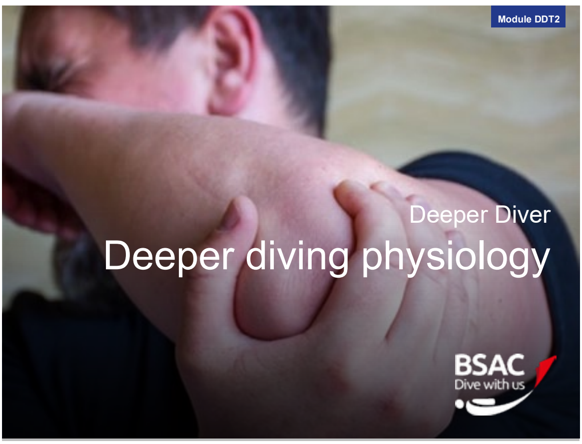
This video will cover:

- **Nitrogen narcosis**
- **Helium**
- **Gas density**
- **Oxygen toxicity**
- **Decompression theory**
- **Immersion pulmonary oedema**

Remember if you need to discuss any of the theory e-mail or call your instructor at your club or centre.

Video time length | 30:44 mins.

Click the image below to start watching the video.



Go back

DDT2 Deeper diving physiology

Module objectives

At the end of this module, you should have a good understanding of the physiology involved in deeper diving.

Module contents

This module builds on previous learning to ensure that you understand the physiology of deeper diving and the impact it will have.

Much of the information has been covered in previous training, but it is important that you are refreshed and up to date with current knowledge.

- **Nitrogen narcosis**
- **Helium**
- **Gas density**
- **Oxygen toxicity**
- **Decompression theory**
- **Immersion pulmonary oedema**

Nitrogen narcosis

Narcosis has been covered in previous training, but the key points are below.

Cause

- **High partial pressure of nitrogen**
  The cause of nitrogen narcosis is not fully understood, but it is generally believed that when nitrogen is dissolved in fatty nerve cells, it impairs the transmission of nerve impulses.

- **Not generally noticed until approx. 30 m**
  Although commencing earlier, narcosis is not generally noticed until around 30 m.

- **Increases with depth**
  It is important to remember that onset of symptoms, their severity and the exact depth varies greatly between individuals, but they always increase with depth.

Symptoms

The impact of narcosis is often compared to increasing levels of anaesthetics or alcohol.

Although some divers will claim they have never been ‘narked’, it is important to realise that all divers suffer from narcosis to some degree when diving, particularly below 30 m. Because a diver is suffering from narcosis, it is difficult for them to realise that they are, in fact, ‘narked’, as the ability to monitor their own performance is one of the first things to be affected.

Go back

- **<30 m Mild impairment**
  At shallower depths, brain functions such as memory, concentration, reasoning and judgment are the first to be affected by narcosis. If a diver is feeling happy in their surroundings, a sense of overconfidence may be felt, but if the conditions are dark or challenging, then anxiety may be experienced.

- **30-50 m Reasoning and judgement impaired**
  As the diver goes deeper, reasoning and judgment become more impaired, coordination can become poorer and simple tasks may be difficult to perform. This can include delays in responding to buddy signals, reading errors, task fixation, confusion about the dive plan and/or overconfidence. Some divers even report dizziness and hallucinations.

- **>50 m Level of impairment becomes dangerous**
  BSAC recommends 50 m as the absolute limit for air diving because beyond this depth, the level of impairment can become dangerous in many individuals.

Resolution-ascend!

If you have narcosis, then it is very likely that your buddy is experiencing the effects as well. Monitoring between the buddy pair is even more important at depth by regularly checking breathing gas and maximum depth. If they are slow to respond, then it is likely that they have narcosis.

The safest action to take if narcosis is identified is to ascend to a shallower depth. Fortunately, narcosis resolves itself very quickly in shallower, and therefore safer, water.

Go back

Narcosis contributors

Certain factors will increase the effects of nitrogen narcosis.

Personal factors

- **Anxiety, apprehension, inexperience**
  Narcosis has an impact on mental performance, so it will be exacerbated if other factors are already present.

- **Alcohol or medication**
  Recent drinking or some medications such as sedatives or some antihistamines - if taking any medication, a diver should check they are okay to dive. If in doubt, contact BSAC HQ or a medical referee.

Dive profile

- **Rate of descent**
  Rapid compression rapidly increases partial pressure of nitrogen (PN_2) and can temporarily raise carbon dioxide levels. This exacerbates the narcotic effect.

- **Increased physical effort and fatigue**
  Increased physical effort, getting tired or fatigued will increase breathing rate and the possible build-up of carbon dioxide, which predispose divers to nitrogen narcosis. If a diver is both mentally and physically fit, then this will improve their ability to recognise and cope with narcosis.

Underwater conditions

Underwater conditions will have a physical and psychological impact on the diver, which can increase the impact of narcosis.

- **Cold water**
- **Poor visibility**

Helium

Helium is a key component of trimix and the best way of reducing nitrogen narcosis.

Characteristics

- **Odourless, colourless, non-toxic and inert**
  Helium is a non-toxic, colourless, odourless, tasteless, inert, and lightweight gas.

- **Expensive**
  Helium is also relatively expensive due to its rarity. Although most of the Earth's helium can be found in the atmosphere, the economic cost of extracting it is extremely high due to its low concentration in the air. Instead, it is obtained from some natural gas fields during extraction of methane. The cost of helium has risen dramatically and will continue to do so for the foreseeable future as sources are depleted.

Effect on divers

- **Reduced narcosis**
  The low narcotic effect is the principal reason for using helium.

- **Easier to breathe**
  The low density of helium makes it easier to breathe than nitrogen at the same depth.

- **Different decompression profile**
  Helium has low solubility and high diffusivity, which means that it theoretically enters and leaves tissues much quicker than nitrogen. Although there is a debate about the decompression profiles for helium-based gas mixtures, most current models give more decompression for trimix dives than the same dive on air.

- **Chilling**
  Helium conducts heat approximately 6 times more effectively than nitrogen. This can increase the rate at which divers lose body heat when they breathe and also makes it a poor choice as a gas for filling drysuits.

- **Vocal distortion**
  Helium distorts speech due to the speed of sound in helium being faster than that of air. This has minimal impact on open circuit divers but is noticeable in rebreather divers who sometimes like to talk through their mouthpieces.

Managing narcosis

Management of narcosis is a key aspect of diving deeper and there are different techniques for doing this.

Equivalent narcotic depth (END)

Equivalent narcotic depth (END) is a means of calculating the narcotic effect of a breathing gas at a particular depth.

Go back

- **Narcotic effect of breathing air**
  END is assessed to be the equivalent depth which would produce about the same narcotic effect as breathing air.

  To illustrate, if a breathing mixture had an END of 25 m, then the narcotic effect is believed to be the same as breathing air at 25 m.

- **END of 30 m often chosen**
  Many deeper divers aim to select a gas that has a maximum END of 30 m, which is assessed to reduce narcosis to a level at which it no longer has an impact.

Preparation

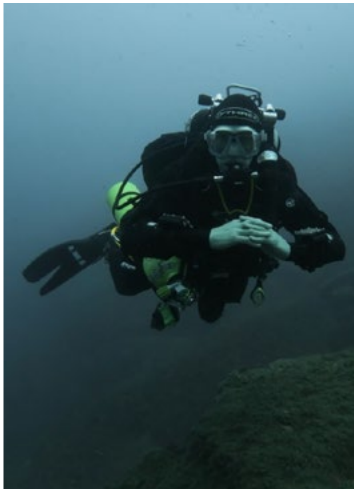
- **Choose breathing gas to minimise**
  The best means of reducing narcosis is to use a suitable breathing gas. For deeper dives, this normally requires a gas that includes helium.

- **Fitness and training**
  Divers who are mentally and physically fit will be better equipped to operate with the reduced capacity caused by narcosis. A high level of training is another factor that will improve the diver's performance when hindered by narcosis.

- **Acclimatisation through build-up dives**
  Acclimatisation to depth can be done by progressively building depth experience. Although this will not prevent narcosis, it will mean that the diver has increased awareness and will be used to diving with reduced capacity.

Gas density

Gas density has recently been identified as a factor that can have a significant impact on divers at greater depth. Although it is a more significant issue for rebreather divers, it also needs to be considered by those using open circuit equipment.



Issue

- **Gas is denser at depth**
  Increased pressure at depth makes gas more dense.
- **Dense gas is harder to breathe**
  Increased gas density at depth means that it requires more energy to breathe at depth. This, together with other effects of depth, means that it becomes increasingly difficult for the body to remove carbon dioxide.

Recommendations

- **Use appropriate equipment**
  A poorly performing or badly maintained regulator may be difficult to breathe from, especially at depth with a higher gas density. This has a dual effect of poor lung ventilation and increased breathing effort.

  Divers should use regulators that are recommended for deeper diving and have them maintained regularly.
- **Breathe gases within recommended limits**
  BSAC publishes recommendations for gas density limits in Safe Diving which should be followed.

  It is recommended the density of the breathing gas should not be greater than 6.3 $g.L^{-1}$; the ideal density is less than 5.2 $g.L^{-1}$.

Go back

- **Risk-based approach to recommendations**
  Like many diving recommendations, the gas density limits should be treated as points along a spectrum of risk. Adopting them does not guarantee safety, and many dives have been successfully completed breathing gas that exceeds the current recommended limits.

Gas selection

Choosing a gas that complies with BSAC gas density recommendations can be done through various means.

Calculating gas density

- **Complex calculations**
  Calculating gas density is relatively complex but is possible using Dalton's law of partial pressures to add together the density for each gas at the chosen depth.

  The density for each gas can be found by multiplying the fraction of each gas in the mixture(F_{gas}) by the density of each gas at that temperature and the ambient pressure (P_{abs}).

  The two examples below are for air and 23/35 trimix at 50 m (6 bar absolute).

Air

Component Gas	Fraction	Density ($g.L^{-1}$)	Absolute Pressure	Gas Density ($g.L^{-1}$)
Oxygen	0.21	1.41	6	1.78
Nitrogen	0.79	1.23	6	5.83
			Total	7.61

23/35 Trimix

Component Gas	Fraction	Density ($g.L^{-1}$)	Absolute Pressure	Gas Density ($g.L^{-1}$)
Oxygen	0.23	1.41	6	1.95
Helium	0.35	0.18	6	0.38
Nitrogen	0.42	1.23	6	3.10
			Total	5.43

- **Further information in manual/online**
  The course manual and BSAC website contains significant additional information on gas density and this should be studied by those who wish to learn more.

Computer generated

- **Software, app, dive computer**
  The ability to calculate gas density is often included in dive planning software, diving apps and even diving computers.

Gas Density tables

- **Use online tables**
  The recommended method to select a gas is to use the **BSAC gas density tables** for the appropriate partial pressure of oxygen. For open circuit diving, there are two; **one for 1.4 bar PO_2** and the other for 1.6 bar PO_2. Only the 1.4 bar table should be used unless further training has been received such as Accelerated Decompression Procedures, mixed gas and CCR courses.

- **Select depth and choose gas**
  Using the tables is relatively straightforward; simply select the maximum depth of the dive to see the recommended mixes.

Go back

Gas Density Table (1.4 bar PO_2)

Depth (m)	Mix	Density ($g.L^{-1}$)	END (m)
35	31%	5.80	29
35	31/12	5.23	22
40	28%	6.42	36
40	28/23	5.20	21
45	25/15	6.16	32
45	25/31	5.23	20
50	23/23	6.19	31
50	23/39	5.17	19

Standard gases (1.4 bar PO_2)

Depth (m)	Mix	Density ($g.L^{-1}$)	END (m)
40	28/20	5.26	23
50	23/35	5.43	22

At each depth, there is a gas that approximates to the upper limit of 6.3 $g.L^{-1}$ and another that is close to 5.2 $g.L^{-1}$. In some cases, the recommended gases exceed both levels by small amounts, but this isn't something that should cause concern as the increase in risk is very small.

As the tables only provide depths in 5 m increments, dives that sit in between these should use the deeper increment to select the gas, e.g., if the dive is planned for 43 m, then 45 m should be used to select the gas.

Go back

- **Equivalent narcotic depth (END)**
  It can be seen that any gas which meets the gas density requirements also has an END of 30 m, or less.

- **Standard gases**
  There are also a smaller set of tables that provide standard gases which are not necessarily optimum but provide easily recognised helium percentages.

Additional information on gas density and the gas density tables can be found at **https://vimeo.com/433880335/e82b9dbbc7.**

Quiz 1

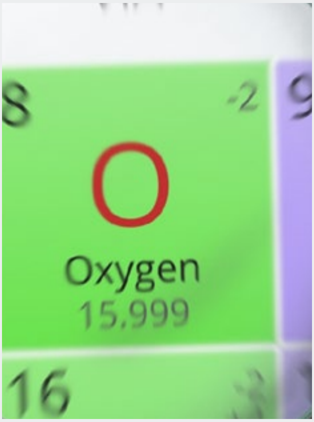
1. **At what depth is the level of impairment caused by narcosis considered to be dangerous?**
2. **What are the effects on divers of breathing mixtures containing helium?**
3. **What are the BSAC recommendations for avoiding issues created by gas density?**
4. **Using the standard gas table, what is the recommended gas for a dive to 50 m?**

Answer on page 109

Go back

Review of oxygen exposure

This is a review of information that has been presented in previous training.



Hyperoxia

- **Oxygen is toxic at high partial pressures**
  For single mix nitrox diving, it is unlikely that divers will be exposed to excessively high partial pressures as long as the diver knows the gas they are breathing and does not exceed that gas's MOD.

- **Toxicity is related to partial pressure and duration of exposure**
  Oxygen toxicity does not necessarily impact a diver the moment they are exposed to elevated partial pressures. The onset of symptoms comes after a time of exposure, and these times and partial pressures can vary between dives, and the susceptibility can vary between divers or even the same diver on different days.

  In recreational diving, unless a series of quite extreme, long duration dives are carried out, it is unlikely that the diver will be exposed to the risk of oxygen toxicity.

Types of oxygen toxicity

There are two distinct types of oxygen toxicity; both are the result of exposure to an elevated PO_2 for a period of time.

- **Central nervous system (CNS) toxicity**
  This is the most likely of the two types of oxygen toxicity, and research shows that below 1.4 bar, there is an acceptable risk for

the sort of exposures experienced by recreational divers. Above 1.6 bar, the chance of a CNS attack rises steeply.

- **Whole body toxicity**
  This is a long-term effect of oxygen toxicity, and is also known as pulmonary oxygen toxicity. The extent of the exposure required for whole body toxicity to appear is longer than would be normally experienced during sport diving.

  Whole body oxygen toxicity is monitored using Units of Pulmonary Toxicity Dose (UPTD), also known as Oxygen Toxicity Units (OTUs). BSAC recommends a maximum limit of 300 in any 24 hour period.

Symptoms of CNS toxicity

CNS toxicity is the most likely form of oxygen toxicity to be experienced by recreational divers.

Symptoms

The symptoms of CNS oxygen toxicity can be remembered using the mnemonic CONVENTID, although they can appear in any order or combination.

- **CON - Convulsions**
- **V - Vision**
- **E - Ears, hearing disturbances**
- **N - Nausea**
- **T - Twitching**
- **I - Irritability**
- **D - Dizziness**

Go back

Most of the minor symptoms are quite weak and can be confused with other ailments. Some divers report that even after a CNS event, minor symptoms did not occur although it is possible that they were not recognised or remembered.

Convulsions (cycles)

The onset of convulsions can be so rapid as to appear instantaneous. They are also the most serious and damaging symptoms. They normally appear in cycles that have the following pattern and increase in severity:

- **Tonic phase**
  Rigid extension of the neck, body and limbs, probable rapid loss of consciousness.
- **Clonic phase**
  This follows around 30 seconds after the tonic phase. The muscle spasms can be extremely violent before subsiding gradually.
- **Post convulsive depressive**
  The diver will relax and go limp, most likely unconscious.

Managing CNS oxygen toxicity

Like most diving disorders, there are simple steps that can be taken to minimise the risk of oxygen toxicity and treatment is relatively straightforward.

Avoid

- **Analyse gas and check MOD**
  The prime cause of oxygen toxicity is through breathing an inappropriate gas for the depth so the planned Maximum Operating

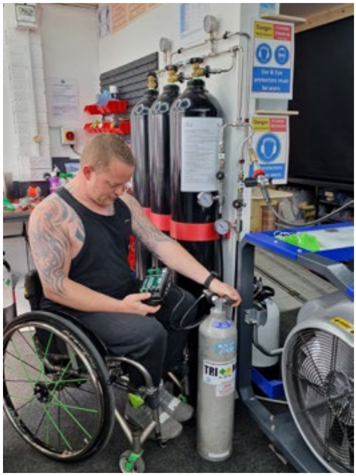
Depth (MOD) for the diving gas should not be exceeded.

It is also one of the reasons why gas analysis, correct marking of cylinders and identifying the correct regulator for the appropriate MOD cylinder is so important.

- **Breathe normally and avoid hard exercise**
  The risk of oxygen toxicity is increased by high levels of carbon dioxide, which can be created by failure to breathe normally and/or high levels of physical activity.

- **Monitor oxygen toxicity level**
  There are various tools for monitoring oxygen toxicity, including the ones used in previous training. Other options include computer programmes, such as those mentioned in later lectures or integrated into dive computers.

  The BSAC recommendation is to ensure CNS remains below 80%.



Treatment

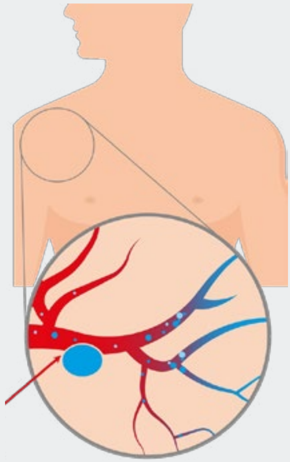
- **Remove from high PO_2 environment and water asap**
  A diver experiencing CNS toxicity should be removed from the high PO_2 environment, even though this may require decompression stops to be missed.

  Once on the surface, they should be removed from the water as soon as possible and the emergency services contacted.

- **Do not ascend if convulsing or rigid**
  If the diver cannot vent gas from their lungs, then lifting them is likely to result in a burst lung. Wait until they have relaxed.

- **On surface, administer oxygen**
  At normal atmospheric pressure of approximately 1 bar, oxygen will be beneficial to the casualty.

Decompression illness (DCI)



Previous diver training will have introduced many of the concepts associated with decompression theory, including bubble formation, burst lungs and symptoms.

Causes/mechanism

The umbrella term decompression illness (DCI) is used to cover two different conditions which present in a similar manner.

- **Bubble formation**
  During a dive, tissues in the body absorb inert gas from the breathing gas in proportion to the surrounding pressure. As long as the diver remains at pressure, the gas presents no problem. If the pressure is reduced too quickly (Henry's law), the gas comes out of solution and forms bubbles in the tissues and bloodstream. This commonly occurs as a result of violating or approaching too closely the diving table limits, but it can also occur even when accepted guidelines have been followed.

- **Lung injuries due to gas expansion**
  The second mechanism occurs when gas expands in the lungs (Boyle's law) but cannot be released quickly enough. This can occur in relatively shallow water and even after short dives.

  The best way to avoid lung expansion injuries is to breathe normally during an ascent, or breathe out if a rapid ascent is being made.

Go back

All dives require decompression

Regardless of the dive profile, there will be some form of decompression.

- **Surface decompression (always)**
  This is the period on the surface after the dive until the inert gases in tissues have returned to ambient pressure.

- **In-water decompression (sometimes)**
  Deeper and longer dives will require carefully managed ascents with multiple stops of ever-increasing durations. Methods of planning decompression have been covered in previous training but will be extended in the next lesson.

DCI symptoms

Any abnormality

Any abnormality after a dive should be treated as DCI, but the ones listed below are some of the more common ones.

- **Denial**
  It is common for divers to attribute the problems they are experiencing to other factors, and they can take some convincing.

- **Itches, rashes on skin**
  The rash is typically marbled red and blue. Sometimes itchy, but not always.

Go back

- **Numbness, tingling, joint pain**
  Pains in limbs and/or joints. Often described as deep and within the bone.

- **Vision disturbances**
  This may include tunnel vision and inability to focus.

- **Dizziness, nausea, headaches, confusion**
- **Weakness, paralysis of limbs, loss of bladder/bowel control**
  Paralysis of limbs, from small defined patches to whole limb. If the diver has not urinated during the dive, not being able to urinate after a dive is unusual.

- **Shortness of breath, chest discomfort/pain**
  Any difficulty in breathing which starts after arriving on the surface.

- **Shock, memory loss, unconsciousness**
  Loss of short, medium or long-term memory, established by questioning or response to those around the diver.

May appear seconds to hours after diving

Occasionally signs and symptoms may start during the ascent to the surface and for up to 48 hours afterwards.

Go back

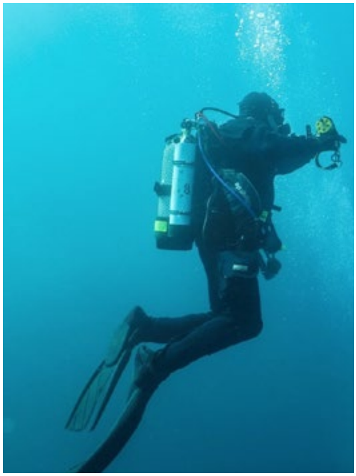
Managing the risk of DCI

There are many techniques to minimise the risk of decompression illness.

Dive profile

- **Plan the dive, dive the plan**
  Divers diving deeper must carefully plan their dive in advance and then follow the profile during the dive.

- **Appropriate ascent rate**
  It is important to ascend at an appropriate rate which is normally 8-10 m/min for most dive computers. An ascent that is too slow will increase the amount of nitrogen that is absorbed into some tissues and decrease the rate of off gassing in other tissues. This will increase the duration of decompression stops that are required. If the ascent is too rapid, this does not allow adequate time for nitrogen to be removed and, in extreme cases, may also lead to a burst lung.



Behaviour

- **Keep hydrated, but not overhydrated**
  It is extremely important to be well-hydrated, and this is a slow and gradual process that should start at least 12 hours before the dive. Divers should check their urine to ensure that it is 'clear and copious', which is a good indication of appropriate levels of hydration.

Go back

- **Keep warm and light exercise**
  Divers should be warm, particularly on decompression stops. Gentle finning while on decompression stops will help with this but also keep blood circulating and assist with gas transfer.

- **Avoid post-dive exercise and pressure changes**
  Divers should aim to minimise exercise for as long as possible after a decompression dive.

  It is also important to avoid pressure changes such as travelling over hills or flying in planes, particularly unpressurised ones.

Personal factors

- **Age, fitness, previous history**
  Some people are more predisposed to DCI due to a variety of factors, including age, levels of fitness and previous DCI history.

- **Patent Foramen Ovale (PFO)**
  Around 1 in 4 people have a Patent Foramen Ovale (PFO), which is a flap covering a hole in the heart between the left and right atria. All of us have one before we are born, and it provides a 'short circuit' that avoids the lungs allowing us to gain oxygenated blood from our mother. In the majority of people, this hole naturally closes during birth so that blood now passes through the lungs.

  In some people, the hole does not fully close, which allows blood to pass directly through the heart without being filtered by the lungs. While there is no impact on normal life, there is evidence that it can increase the risk of DCI.

Treatment of DCI

The treatment for DCI is very straightforward and forms a key part of the Oxygen Administration Skill Development Course (SDC), which is recommended for all divers.

When to treat

- **Any symptoms**
  Any abnormality after a dive should be treated as DCI and first aid delivered.

- **Missed decompression/rapid ascent**
  Something may cause a diver to miss decompression stops or have a rapid ascent. They may show no signs or symptoms and appear well, but it is better to err on the side of caution and treat them before symptoms develop.

First aid

- **Lie down**
  If the casualty is conscious, then they should be laid on their back. An unconscious casualty or one that is likely to vomit should be placed in the recovery position.

- **Keep calm**
  The situation is likely to be extremely stressful for the casualty, so they should receive regular reassurance.

- **Administer 100% oxygen**
  The casualty should be administered the highest percentage of oxygen possible, which will accelerate the removal of nitrogen and provide more oxygen to tissues that need them.

Go back

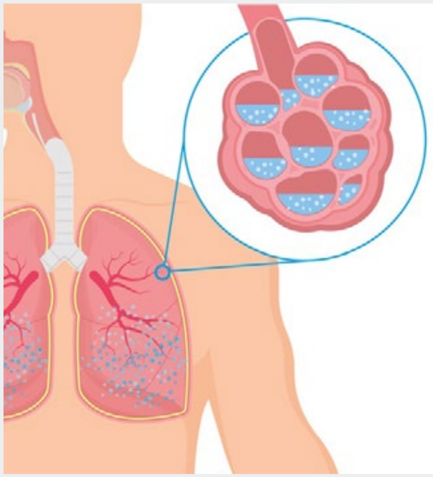
- **Give fluids by mouth**
  Small sips of fluids will benefit the casualty.

- **Evacuate**
  The casualty should be evacuated to a recompression chamber as soon as possible.

Immersion pulmonary oedema

Previously considered rare, immersion pulmonary oedema (IPO) has been identified as a factor in a number of diving incidents.

What is it



IPO is a response to the body being immersed in water and can occur even in very fit people.

- **Body fluids in the lungs**
  IPO is caused by fluid from the body pooling in the lungs. This can cause breathing difficulties and, if not corrected, become fatal.

- **Caused by immersion in water**
  Immersion causes a redistribution of the fluids in our body and the circulation in particular. The result is we have more blood in the blood vessels than we need. The excess water is moved out of the vessels, normally through the kidneys and to the bladder.

- **Similar to drowning**
  IPO can be confused with drowning as both result in a build-up of fluids in the lungs.

Go back

Risk factors

The risk of IPO is increased by the factors below.

- **Cold water**
  Cold water is a recognised risk factor for getting IPO because constriction of blood vessels is greatest in the cold. Again, the constricted blood vessels will need less blood in them, and excess fluid is moved out of the circulation.

- **High blood pressure**
  People with pre-existing heart disease and high blood pressure (hypertension) are also believed to be more susceptible to IPO. In both the previous scenarios, the excess of blood causes an initial rise in pressure.

- **Strenuous exercise**
  Exertion and stressful events during immersion increase blood pressure in the alveolar capillaries, and their additive effects can be enough to cause IPO.

- **Overhydration**
  It has an additive effect on the increase in alveolar capillary pressure resulting from immersion. It is important to be adequately hydrated before a dive but not overhydrated. Post-dive rehydration is protective of DCI and not linked to IPO.

- **Negative inhalation pressure**
  Excessive negative pressure in the alveoli is encountered when a demand valve is poorly serviced or where the hydrostatic lung loading on a rebreather requires greater inhalation effort.

Go back

IPO symptoms (underwater)

A diver with IPO will find the symptoms extremely distressing and is unlikely to identify IPO as the issue. They may try increasingly extreme options to overcome their difficulties which will be increasingly apparent to their buddy.

Breathing disruption

As the diver has fluid in their lungs, they will experience disruption to their breathing.

- **Difficult and/or abnormal breathing**
  The diver will find it difficult to breathe without any apparent cause. They may also experience rapid, uneven, heavy and/or distressed breathing.
- **Persistent coughing**
  Persistent coughing as the lungs try to expel the water is another very common symptom.

Thinking equipment is faulty

Most divers will initially believe that their breathing problems are created by faulty equipment, which they will then try to address.

- **Believe regulator is not functioning correctly**
  The diver is likely to believe that their current regulator isn't functioning properly.

- **Signalling out-of-gas/switching to AS**
  As they have been taught to do, the diver will either switch to their own alternative supply (AS) (even if their contents gauge is showing full) or signal out-of-gas so that they can breathe from their buddy's AS.
- **Rejecting other regulators**
  The diver will find that the next regulator does not solve the problem either, and this should be the final confirmation that the diver is suffering from IPO.

Panic

Having exhausted all options to resolve their breathing issues, the diver with IPO is then likely to panic and may well rush to the surface.

First aid for IPO

Get casualty out of the water

As IPO is created by immersion, removing the casualty from the water should resolve the issue.

- **Surface safely as soon as possible**
  The casualty will be want to get to the surface as quickly as possible.
- **Escort to the surface**
  Wherever possible, someone should accompany the casualty to the surface.

Go back

- **Get out of water without delay**
  This will take the load off their body systems and allow the vascular compartment to return to normal.

Surface treatment

The treatment for IPO is similar to many other diving illnesses, especially drowning, but it is key that the diver is not given fluids as this will exacerbate the condition.

- **Sit upright (if conscious)**
  Sit the casualty upright as this will enable them to breathe more easily.
- **Give 100% oxygen**
  Administering 100% oxygen by an appropriate means will help overcome the poor lung performance created by the fluid that they contain. It is also likely that the diver will have made a more rapid ascent than normal and potentially missed decompression stops, so this will assist with that.
- **Keep warm**
  The diver is likely to be suffering from shock, so keeping them warm is an important means of overcoming that. It will also help with circulation.
- **Do not give fluids!**
  Fluid overload is the problem, so giving them more will not help.

Seek medical attention urgently

As with any diving injury, it is important to evacuate the casualty to medical care as quickly as possible.

Quiz 2

1. How can CNS oxygen toxicity be avoided?

2. What are the two most obvious symptoms of immersion pulmonary oedema (IPO)?

Answer on page 110

Summary

You should now understand:

- ✔ **Nitrogen narcosis**
- ✔ **Helium**
- ✔ **Gas density**
- ✔ **Oxygen toxicity**
- ✔ **Decompression theory**
- ✔ **Immersion pulmonary oedema**

Test yourself

1. In diving what does the mnemonic END stand for?
2. Why is END important?
3. Is it unsafe to breath gas outside the BSAC recommendations for gas density?
4. What is the BSAC recommended method of selecting a gas that meets BSAC gas density recommendations?
5. What are standard gases?
6. What mnemonic is used to remember the symptoms of oxygen toxicity
7. What form of decompression is required even by no stop dives?
8. Why is ascending too slowly an issue?
9. What surface treatment should be given to a diver suffering from IPO?

Answers on page 110

Go back

Decompression planning

Go back

Check out your eLearning video

Decompression Planning

Dom Robinson / Alex Warzynski will take you through this module.

This video will cover:

- **Planning with BSAC 88 and nitrox tables**
- **Decompression models and conservatism**
- **Alternative planning tools**
- **Run time slates**

Remember if you need to discuss any of the theory e-mail or call your instructor at your club or centre.

Video time length | 16:01 mins.

Click the image below to start watching the video.

DDT3 Decompression planning

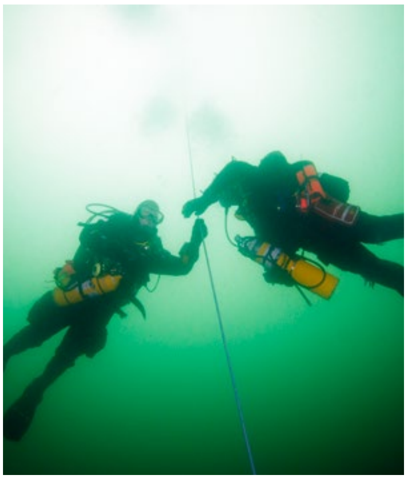
Module objectives

This module builds on previous dive planning training to give you the knowledge of other decompression planning tools and how to prepare run time slates.

Module contents

This lesson covers the following:

- **Planning with BSAC 88 and nitrox tables**
- **Decompression models and conservatism (gradient factors)**
- **Alternative planning tools**
- **Run time slates**



BSAC Table 88 revision

Divers should be familiar with the BSAC 88 and nitrox tables from previous training.

Using Level 1 tables, work through the example below.

Example : Table A

- **Depth 27 m**
- **Duration 34 mins**

Plan

- **Stop required is 1 minute at 6 m**
- **Surfacing Code is G**

LEVEL 1 (greater than 984 millibar)
TABLE A

DEPTH (metres)	ASCENT (mins)	DIVE TIME (mins) No-Stop Dives						Decompression Stop Dives							
3	(1)	–	166	∞											
6	(1)	–	36	166	593	∞									
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	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	
42	3			–	9	10	12	21	23	26	28	29	31	32	
45	3			–	8	9	10	19	22	24	26	27	28	30	
48	3				–	8	9	18	21	23	24	25	26	28	
51	3					–	8	17	19	21	22	24	25	26	
DECOMPRESSION STOPS (mins) at 9 metres									1	1	1	2	2	3	
at 6 metres								2	3	6	9	12	15	18	
SURFACING CODE			*B*	*C*	D	E	F	G	G	G	G	G	G	G	

Go back

BSAC Nitrox Table revision

Using the Nitrox Decompression Tables, work through the example below. Ensure that you are able to correctly calculate the Surfacing Codes and decompression stops.

First dive

- **26 m for 33 minutes using nitrox 32**
- **Surfacing Code is F**

Surface interval

Use the Surface Interval Table to calculate the Current Tissue Codes for the second dive.

- **3 hours**
- **Current Tissue Code is C**

Second dive

Use the correct table to calculate the stops required for the second dive

- **20m for 25 minutes using nitrox 32**
- **Stop required is 1 minute at 6 m**
- **Surfacing Code is G**

If you are finding this challenging, then remember there is further guidance and examples in the front of the tables.

Go back

32% OXYGEN LEVEL 1 (greater than 984 millibar)
TABLE A

DEPTH (metres)	ASCENT (mins)	DIVE TIME (mins) No-Stop Dives						Decompression Stop Dives							
3	(1)	–	*480*												
6	(1)	–	86	*480*											
9	1	–	31	133	384	*480*									
12	1	–	16	63	157	190	227	[illegible]	330	353	371	388	405	423	441
15	1	–	10	38	89	107	125	[illegible]	184	197	206	215	223	231	239
18	1	–	6	26	58	69	80	[illegible]	123	134	141	147	153	159	165
21	1		–	19	41	48	56	[illegible]	90	99	105	110	115	120	125
[illegible]	2		–	15	32	37	[illegible]	[illegible]	71	78	83	88	92	96	100
27	2			12	26	[illegible]	34	[illegible]	57	64	68	72	76	79	83
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

DEPTH (metres)	ASCENT (mins)	No-Stop Dives						Decompression Stop Dives						
30	2		–	10	21	24	[illegible]	[illegible]	48	53	57	61	64	67
33	2		–	8	17	20	[illegible]	[illegible]	41	46	49	52	55	58
36	2		–	7	15	17	[illegible]	29	36	40	43	46	49	51
DECOMPRESSION STOPS (mins) at 9 metres											1	1	1	1
at 6 metres								1	3	6	9	12	15	18
SURFACING CODE			*B*	C	D	E	F	G	G	G	G	G	G	G

SURFACE INTERVAL TABLE 21%, 27%, 32% & 36% OXYGEN MIXES

Minutes: 15, 30, 60, 90 — Hours: 2, 3, 4, 10, 12, 14, 15, 16

Last Dive SURFACING CODE							
G	G	F	E	D	C	B	A
F	F	E	D	C	B	A	
E	E	D	C	B	A		
D	D	C	B	A			
C	C	B	A				
B	B	A					
A	A						

32% OXYGEN - LEVEL 1 (greater than 984 millibar)
TABLE C

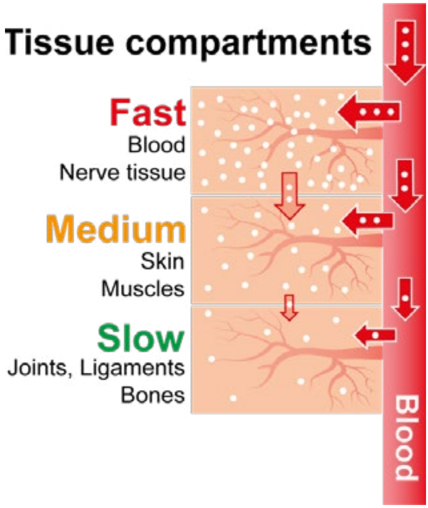
DEPTH (metres)	ASCENT (mins)	DIVE TIME (mins) No-Stop Dives					Decompression Stop Dives							
3	(1)	*480*	304	–										
6	(1)		–	*480*										
9	1		–	185	339	*480*								
12	1		–	44	71	104	176	206	229	247	264	281	299	317
15	1		–	21	32	45	78	95	103	117	125	133	141	149
[illegible]	1		–	12	19	26	[illegible]	58	66	72	78	84	89	95
21	1			8	12	[illegible]	32	[illegible]	47	51	56	60	64	68
[illegible]	2			–	9	13	[illegible]	32	37	41	44	47	50	54
27	2			–	7	10	[illegible]	26	30	33	36	38	41	45
30	2				–	8	[illegible]	22	26	28	30	32	34	
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

Go back

Decompression models

All decompression planning uses mathematical models that are based on an imperfect understanding of how the body behaves while diving.

Perfusion models (Bühlmann)



Perfusion is the passage of blood through tissue, and other natural channels. Explanations for decompression based on gas transfer by perfusion were initially developed by John Scott Haldane in the early 20th century, and then refined by his successors. The most commonly used algorithms based on this model were created by Professor Albert Bühlmann.

- **Multiple tissue compartments**
  Perfusion models have compartments, each of which is used to represent different categories of body tissue, such as muscle, fat, the brain, etc. Initial models had 5 or 8 compartments, but modern ones normally have 12 or 16.

- **Different rates of gas absorption**
  Each compartment absorbs and releases gas at different rates.

  The time to reach 50% saturation is known as the half time, which can range from a few minutes (fast tissues) to multiple days (slow tissues).

- **Saturation of compartment linked to DCI**
  DCI is assumed to occur when the gas saturation of a specific tissue exceeds a certain level which is known as the M value.

Go back

Tables and dive computers based on perfusion models aim to keep individual compartments below the M value using decompression stops at different depths.

Bubble models

Other theories that are used to explain and manage DCI can be grouped together and described as bubble models. Bubble theories form the basis of two well-known algorithms; the Variable Permeability Bubble Model (VPM) and Reduced Gradient Bubble Model (RGBM).

- **Large bubbles are linked to DCI**
  In general, these are based on the observation that there seems to be a link between bubble size and DCI.

- **'Squeeze' bubbles to reduce size**
  It is observed that bubbles grow when ambient pressure is reduced but 'squeezing' them with external pressure causes gas to diffuse from inside the bubble to the solution in which they exist. This reduces their size and the likelihood of DCI.

Conservatism

Algorithm modifications allow different risk profiles to be applied to dives which allows divers to have their own approach to the risk of decompression illness. This approach may vary based on a diver's particular circumstances, which may include physiological factors, such as age and fitness, the nature of the dive or even the availability of post-dive medical treatment.

Some dive computers, generally the more basic or older models, offer levels of conservatism, set pre-dive by the diver.

Go back

Gradient factors (GF)

Gradient factors are one of the most common means of applying conservatism.

- **Pair of numbers Low and High**
  Gradient factors (GF) are a pair of numbers which control the first decompression stop (GF Low) and when the diver can surface (GF High).

  Between the first decompression stop and surfacing, the GF increases between the two values.

- **Together they control ascent profile**
  The effect of the GFs is to produce a modified M-value for each depth and so the ascent profile.

Two useful resources for understanding gradient factors are the following webinars:

- **Introduction to Gradient Factors - https://vimeo.com/424689773/171b0ff712**
- **Understanding Gradient Factors - https://vimeo.com/418828856/e810931839**

BSAC recommendations

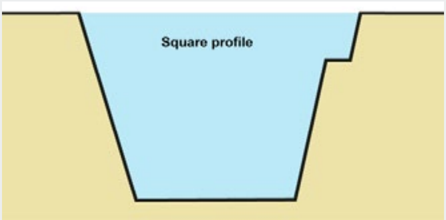
BSAC Safe Diving contains recommendations for both the algorithm and gradient factors that should be used.

- **Bühlmann ZHL-16C algorithm**
- **85/95 for air/nitrox**
- **60/80 for trimix**

The rationale for the differing GFs between trimix and air/nitrox is due to the types of diving undertaken using the respective gases. The rationale is that air/nitrox dives are generally shallower and shorter than those using trimix.

Dive profiles

Square



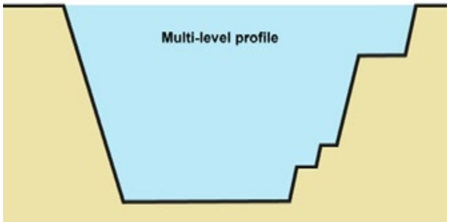
Previous courses have used tables for dive planning. These assume that dives follow a 'square' profile.

- **Single depth**
  Square profile dives assume that the diver descends to the maximum depth of the dive and then remains there until they start the ascent. The diver then ascends at the maximum ascent rate until they reach any decompression or safety stops.

- **Simple to plan**
  Square profile dives are relatively straightforward to plan, which is why they work well with tables and for air consumption.

  As divers rarely spend the entire time at the maximum depth, planning for square profile dives naturally builds in an element of conservatism for decompression planning and gas consumption.

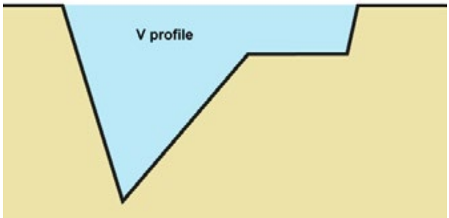
Multi-level



The alternative to square profiles are multi-level dives.

- **Steps at different depths**
  A multi-level dive is one where the diver descends to the maximum depth and spends some time there. They then ascend to a slightly shallower depth for a period and this continues as many times as deemed necessary.

- **V (bounce)**
  An extreme form of multi-level dive is one that follows a V profile where the diver briefly reaches the maximum depth and then ascends nearly continuously.



- **More complex to plan**
  Planning multi-level dives is more challenging, so normally requires the use of technology.

Run time slates

Run time slates are used to record the dive plan and are then consulted during the dive to ensure it is progressing as planned.

Plans

Previous training emphasised the importance of having multiple plans to cover eventualities, such as exceeding the maximum planned depth. This is still important regardless of which planning tool is used.

Go back

It is normal to produce the plans listed below, as a minimum. Other plans such as deeper and/or longer can also be produced if required.

- **Dive plan**
  This is the plan for the dive.

- **Deeper and longer**
  A single slate can be used to cover the three potential situations of a diver exceeding depth, exceeding time or exceeding both depth and time. The exact parameters on which the deeper and longer plan is based are chosen based on individual preferences and assessment of the risk. Two common options are 3 metres deeper/3 minutes longer or 2 metres deeper/2 minutes longer.

Columns

The run time slate needs to be in a clear an unambiguous format.

- **Depth**
  The depth for each stage of the dive.

- **Stop time**
  The duration spent at each depth.

- **Run time**
  This is the time the diver needs to leave that particular depth.

- **Gas used**
  The slate should identify the breathing gas to be used. This becomes more important if/when dives with multiple gases are used.

Quiz 1

1. What is the BSAC recommended algorithm and gradient factors for dive computers?

2. What does the run time column on a run time slate show?

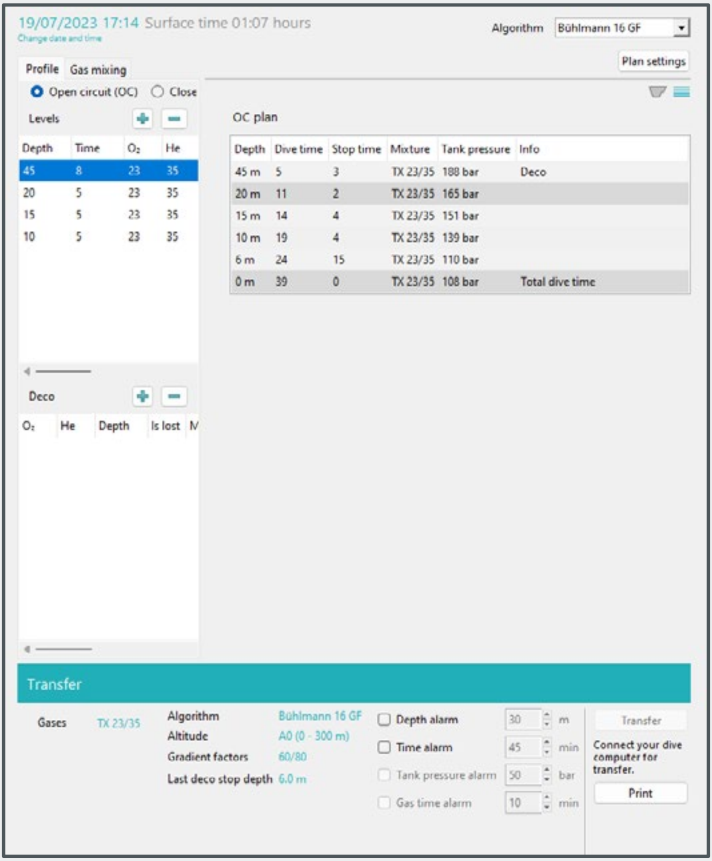
Answers on page 111

Decompression planning

During previous training, dive planning has been carried out using tables, but there are many other options available. When selecting a tool to support dive planning, it is important that the underlying assumptions and settings are fully understood to ensure that it is compatible with the planned dive profile and any dive computer(s) being used..

Multiple planning tools

- **Tables**
  Previous training used the BSAC 88 and nitrox tables to plan dives and this was reviewed at the beginning of this lesson.   Other agencies and organisations also produce diving tables, although relatively few provide the same level of detail.



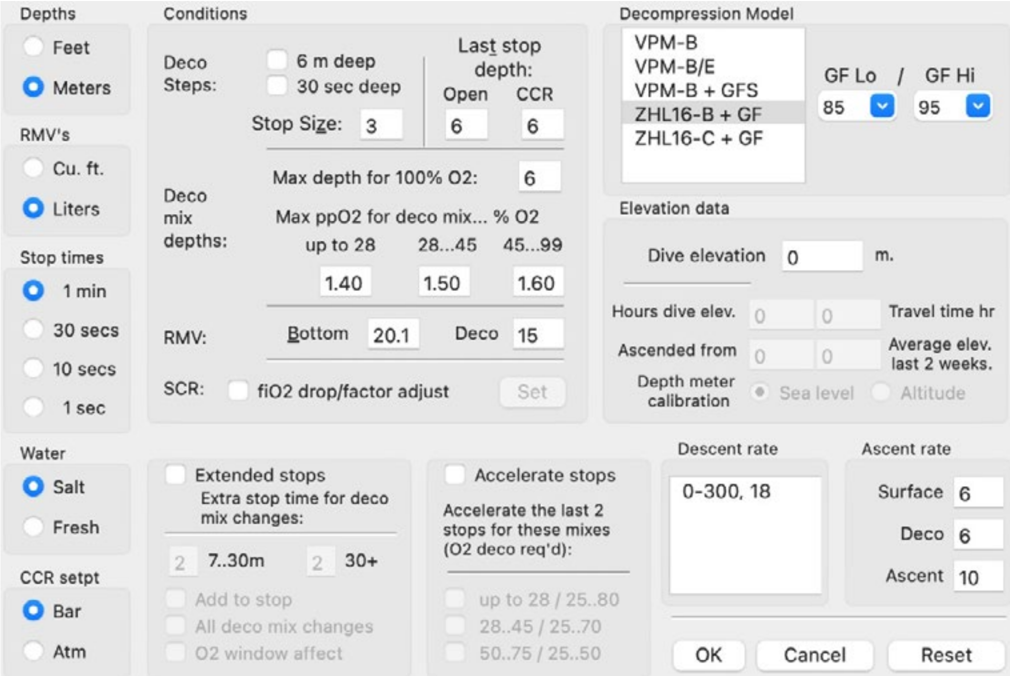
- **Dive computers**
  Most dive computers offer a planning function, although the exact capabilities can vary considerably and are discussed more later in this lesson.

- **Software**
  There are many different programmes available across various platforms, including computers, tablets and mobile phones. The latter means that dive planning can easily be done on the dive site.

Go back

Settings and assumptions

All planning tools will have settings that are relevant to the dive. Sometimes these can be adjusted, but often they are fixed.



Not surprisingly, it is important to understand the underlying settings, as failure to follow these during the dive may create an unexpected and unpleasant surprise.

- **Algorithm**

  Regardless of which planning tool is being used, it is important to understand the algorithm that is being used to plan the decompression requirements.

  Aim to use well established software algorithms, such as Bühlmann ZHL-16C, rather than the latest one with unknown potential safety risks.

Go back

- **Ascent/descent rates**
  Ascent rates can vary from 8-18 metres per minute.

- **Stop depths**
  The last decompression stops are often at 6 m, but this can be much shallower at 3 m.

Compatibility

Not all planning tools are compatible with each other or individual dive computers, so it is important to understand them before they are used. An excellent example is that BSAC dive tables assume an ascent rate of 15 metres per minute (to the first stop), whereas most modern dive computers use 10 metres per minute.

Planning with dive computers

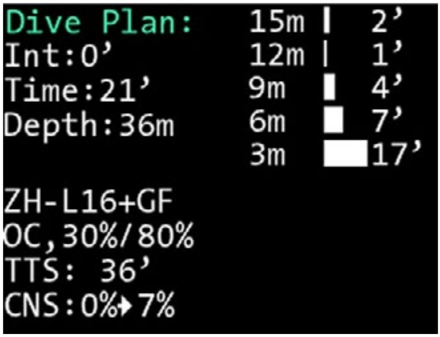
Most dive computers have some form of built-in planning tool.

Decompression plan

- **No stop plan**
  Some recreational dive computers, particularly those aimed at the recreational market, will only provide dive plans that do not involve decompression stops. They will provide the maximum amount of time a diver can spend at a given depth before they enter decompression.

Go back

- **Decompression plan**
  More sophisticated dive computers can generate decompression dive plans. The diver sets the gases available, the depth and dive time, and the dive computer generates a dive plan showing the decompression stops required for that dive.



- **Look forward**
  Some have a look forward function to allow future dives to be planned with the correct tissue loading for that moment.

Nitrox and trimix

Most modern computers have nitrox capability, but if trimix is being used, then it is important that this is also provided.

Other information

Dive computers can also be used to produce other information that may be useful.

- **Oxygen toxicity levels**
  Some dive computers can monitor CNS and/or UPTDs (aka OTUs) as well as forecast what they will be after a dive.

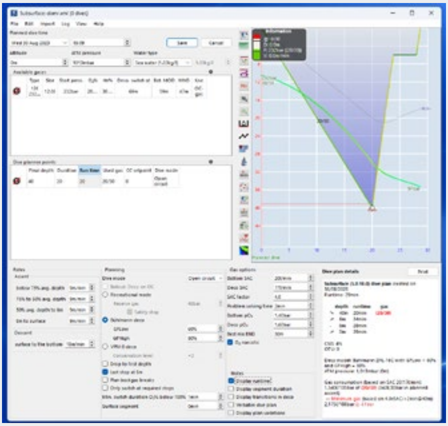
- **Gas consumption**
  Some dive computers can estimate how much gas will be used during the dive.

Planning demo - dive computer

Your instructor should demonstrate how to plan a dive using the planning function on one or more dive computers. They should emphasise that importance of understanding the settings and assumptions that the computer(s) use.

After the plans have been produced they should be transferred to a run time slate.

Planning with software



Software tools suitable for dive planning are available for all types of devices, including phone, tablet and computer. Some of these are produced by dive computer manufacturers, so are guaranteed to be compatible with them.

Features

- **More capable than dive computers**
  Almost all software planning tools provide additional functionality to that found in dive computers, which makes them far more capable. Those on handheld devices

Go back

mean that they are easy to transport and normally available on the dive site (subject to weather considerations!).

- **Straightforward contingency planning**
  Most dive planning software offers the ability to adjust many different settings to produce a plan that perfectly suits the diver. They can also be easily used to see what happens in particular situations.

- **Multi-level planning**
  Very few tables or dive computers support multi-level planning, so software tools are normally the best way to do this.

Considerations

- **Complexity**
  Many software planning tools have an extensive array of configuration options. Although this provides a high level of flexibility, it can also make them relatively complex to use.

- **Cost and support**
  Like any piece of software, there may be cost(s) associated with acquiring and receiving support/updates.

An online tutorial on the use of one piece of planning software (Multi-deco) can be accessed at **https://vimeo.com/417120627/5f1b0506f8**

Planning demo - software

Your instructor should demonstrate how to plan a dive using the planning function on one or more pieces of software. This should include one or more multi-level dives.

The instructor should emphasise that importance of understanding the settings and assumptions that the software uses.

After the plans have been produced they should be transferred to a run time slate.

Additional considerations

Dive computer compatibility

Almost all divers will be using dive computers, and failure to check they are compatible with the plan can create lots of confusion underwater.

A good way to check dive computer compatibility is to use the dive planning facility on them to see if it produces similar plans to whatever other tool is used.

- **With plan**
  Examples of areas where compatibility should be checked include the breathing gas being used, ascent rates, decompression algorithm, depth of decompression stops and conservatism settings.

- **Within the buddy team**
  It is also important that there is compatibility between the dive computers used by all members of the dive team.

Ascent rates

- **Too slow is not good**
  Whatever tool has been used to plan the dive, there will have

Go back

been an assumption made about the ascent rate. If the ascent is too slow, then the diver will not be able to follow the run time slate as had been planned, and there will be additional nitrogen/helium absorption that will not have been considered during dive planning. Taken together, this increases the risk of DCI.

- **Needs to be just right!**
  Ascending too rapidly is outside the parameters of the dive plan and creates other risks, such as an uncontrolled ascent and burst lung, so should also be avoided.

Quiz 2

1. **What are three settings/ assumptions that should be checked when using a dive planning tool?**

2. **What sort of dive plans do most dive computers allow to be produced?**

3. **What ascent rate do most dive computers assume?**

Answer on page 112

Go back

Summary

You should now understand:

- ✔ **Planning with BSAC 88 and nitrox tables**
- ✔ **Decompression models and conservatism**
- ✔ **Alternative planning tools**
- ✔ **Run time slates**

Go back

Test yourself

1. What decompression stops are required on a Level 1 table A for a 30 minute dive time at 39 metres?
2. What decompression stops are required whilst breathing 32% nitrox on a nitrox table A for a 40 minute dive time at 36 metres?
3. Using a perfusion model (Bühlmann), when is DCI assumed to occur?
4. Why might a diver wish to have a more conservative dive profile?
5. What is a multi-level dive?
6. What are the minimum columns that should be on a run time slate?
7. What are the three categories of tools that can be used to plan decompression diving?
8. Why is it important to ensure that decompression planning tools and computers are compatible with each other?
9. Which category of planning tools typically offer the most features?

Answers on page 112

Gas planning and limiting factors

Go back

Check out your eLearning video

Gas planning and limiting factors

Dom Robinson / Alex Warzynski will take you through this module.

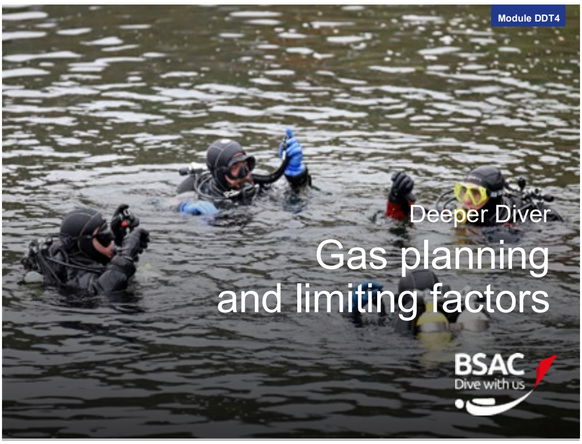
This video will cover:

- **Review of gas consumption**
- **Calculating individual gas consumption**
- **Calculating the gas reserve for a dive**
- **Overcoming limiting factors for deeper diving**

Remember if you need to discuss any of the theory e-mail or call your instructor at your club or centre.

Video time length | 27:12 mins.

Click the image below to start watching the video.



DDT4 Gas planning and limiting factors

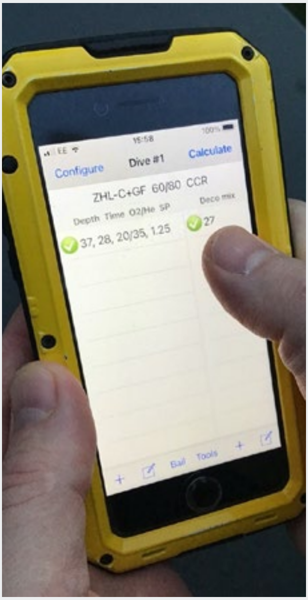
Module objectives

This module reviews the gas planning taught in previous courses and introduces methods to calculate individual gas consumption. It also shows how gas reserves can be calculated for deeper dives.

Module contents

This module covers the following:

- **Review of gas consumption**
- **Methods of calculating individual gas consumption**
- **Methods of calculating the gas reserve for a dive**
- **Limiting factors for deeper diving and methods to overcome them**



Review of gas consumption

As covered in previous training, breathing rates are not fixed and will vary, determined by many factors. Understanding how they will change for others and how to respond is important knowledge.

What increases consumption?

The factors below explain how consumption is increased. The converse is also true so changes in the opposite direction can be used to reduce gas consumption.

Factors such as cold, stress and exertion are particularly relevant for inexperienced divers who often have poorly fitting suits, may be nervous and/or haven't grasped techniques that make things such as finning easy!

- **Depth**
  Gas consumption rates haves a mathematical link to absolute pressure. An increase in depth will change gas consumption in proportion to the change of absolute pressure. As an example, going from the surface (1 bar) to 10 m (2 bar) will double the rate of gas consumption. The same thing happens going from 10 m (2 bar) to 30 m (4 bar), which means that the consumption at 30 m will be four times that on the surface.

Go back

- **Exertion**
  The body demands more oxygen during periods of physical exertion and the only way to achieve this is to increase the breathing rate so it is faster and deeper.

- **Cold**
  The body reacts in many ways to cold and one thing that happens is for breathing rates to increase.

- **Stress**
  During periods of stress or anxiety, the body prepares to respond quickly, which means that the breathing rate will naturally increase.

- **Emergency situations**
  As well as the stress created by an emergency situation, it is also possible that two divers may be breathing from a single gas supply.

Max breathing rates

- **May double, triple or more**
  Research and analysis of incidents have indicated that the breathing rates of divers can double, triple and more during periods of high work rate and stress.

So what?

Gas consumption should be considered before the dive and then monitored throughout.

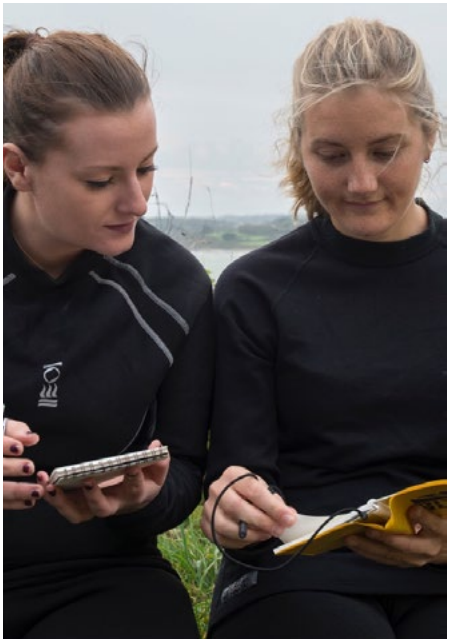
- **Prepare for worst case scenarios**
  When selecting the gas supply for a particular dive, consideration should be given to the worst possible case scenario. This will provide flexibility in the event of something going wrong.

Go back

- **Terminate dive?**
  If, at any time, there is a concern that gas supplies may be inadequate for the dive, then it is important that the dive is terminated or changes made that reduce gas consumption.

Individual gas consumption

Gas consumption rates will vary significantly between individuals, so a cylinder appropriate for one diver on a given dive may not be adequate for another. That is why understanding how to calculate gas consumption rates is useful and can be used to assist in more accurate dive planning.



Surface air consumption

Another term for Surface Air Consumption (SAC) rate is Respiratory Minute Volume (RMV) rate.

- **Individual value – calculate and record**
  The SAC rate is an individual value, so needs to be calculated for each diver.

  It is useful to maintain a record of gas consumption rates. It is especially useful for inexperienced divers, those returning to diving after a break and people who frequently dive in different equipment configurations/environments.

Go back

- **Will help with planning**
  Divers who know their gas consumption rates can use this to refine gas consumption planning, which is particularly important for deeper dives.

- **Indicative only**
  The gas consumption rate for each person will vary between dives which is due to some of the factors that have already been discussed. They only provide an indication of likely gas consumption, so should not replace regular gas monitoring throughout the dive.

Calculation methods

There are multiple different methods to calculate individual gas consumption rates. The first two will be considered in more detail later in this module.

- **Maximum depth**
  This method assumes the diver is at the maximum depth for the duration of the dive.

- **Constant depth**
  This method requires the diver to monitor their gas consumption over a specific time period while maintaining a constant depth.

- **Gas integrated computer**
  Some dive computers with integrated gas contents monitoring will calculate gas consumption rates.

Calculating gas consumption rates

All methods of calculating gas consumption require the same information and use the same formula.

Information required

- **Gas used (litres)**
  The gas used is found by multiplying the cylinder size (litres) by the cylinder contents used (bar).
- **Absolute pressure (bar)**
  Absolute pressure is a function of depth.
- **Duration(mins)**
  The duration is the time over which the gas was used.

Formula

Gas consumption rate can be calculated using the formula below:

$$\textit{Surface gas consumption rate} = \frac{\textit{Gas used}}{\textit{Absolute pressure x Duration}}$$

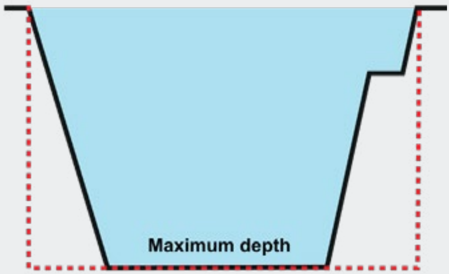
Go back

Method 1 – maximum depth

This is the traditional method to calculate gas consumption. It assumes that the diver spends the entire dive at the maximum depth that was achieved.

Although inherently inaccurate, it is simple to calculate and be retrospectively applied to past dives.

Requires



- **Details from entire dive**
  This method requires information from an entire dive and uses the maximum depth to provide the absolute pressure.

Disadvantages

- **Pressure changes create inaccuracy**
  Divers will change depth during a dive due to ascents, descents and variable depth of the seabed. This means that the absolute pressure, calculated from maximum depth, is not accurate and so the actual surface gas consumption rate is likely to be lower than calculated.

  Some dive computers provide the average depth for a dive. This can be used instead of maximum depth to improve the accuracy of this method.

Advantages

- **Builds in additional reserve**
  The inaccuracy of this method, which is almost certain to produce higher calculated gas consumption rates than reality, means that it also builds in an additional safety reserve.

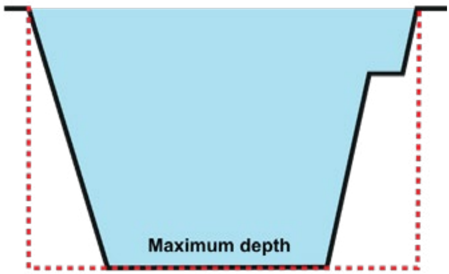
Go back

- **Historical dives can be used**
  Provided that the diver has recorded the information required in their log book, then this method can be applied to historical dives. These rates can be used in various ways, such as long-term trend monitoring, combined to assess average gas consumption or as a reference for particular equipment/environments.

  Data from multiple dives will provide different results that can be used to provide a spectrum of likely gas consumption rates. For extra conservatism, the highest rate should be used for planning.

Method 1 – example

This example assumes that a diver completed a dive to a maximum depth of 20 m with a surface-to-surface time of 30 mins. During this time, they breathed 150 bar from a 12 L cylinder.



Applying these figures to the formula results in a breathing rate of 20 litres per minute (L/min).

$$= \frac{Gas\ used}{Absolute\ pressure\ x\ Duration}$$

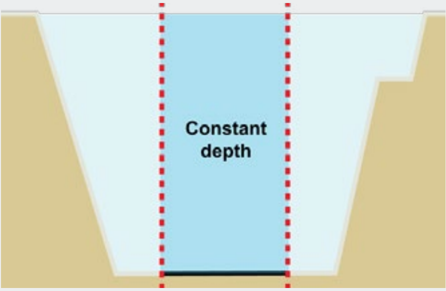
$$= \frac{150\ bar\ x\ 12\ litres}{3\ bar\ x\ 30\ mins}$$

$$= 20\ litres\ per\ minute$$

Go back

Method 2 – constant depth

This method is far more accurate but requires a dedicated period of the dive to acquire the relevant data.



Monitor

This method assumes that the diver uses a dedicated period of the dive to monitor their instruments.

- **Gas use at constant depth and fixed duration**
  The diver remains at constant depth while recording the contents gauge at the beginning and end of the monitoring period.

Disadvantages

- **Gauge inaccuracy**
  It can be difficult to read small changes of pressure contents gauges so readings tend to be the nearest 5 or 10 bar. The impact of these inaccuracies will be more significant when relatively small amounts of gas are used. This means that this method is most accurate if it can be applied over a longer period.

- **Cannot be applied to past dives**
  Unless the diver has completed a similar exercise during previous dives, calculations cannot be performed retrospectively.

Advantages

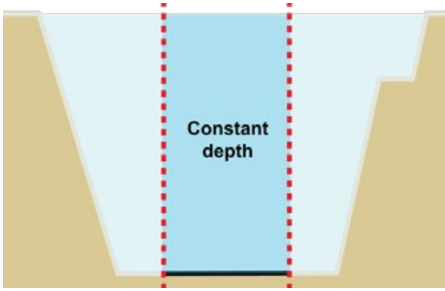
- **Most accurate**
  If the impact of contents gauge inaccuracies can be minimised, such as using digital devices, then this method produces the most accurate results.

Go back

Method 2 – example

This example assumes that a diver remained at 30 m for 6 minutes, during which they breathed 40 bar from a 12 L cylinder.

Applying these figures to the formula results in a breathing rate of 20 litres per minute (L/min).



$$= \frac{Gas\ used}{Absolute\ pressure\ x\ Duration}$$

$$= \frac{40\ bar\ x\ 12\ litres}{4\ bar\ x\ 6\ mins}$$

$$= 20\ litres\ per\ minute$$

Method 3 - Computer log

Download the dive log

- **Refer to user instructions**

The method used varies between dive computer models. Some connect using a cable, others via Bluetooth. The user instructions for the specific model of dive computer should be used as a reference.

Go back

Input cylinder pressures and size

- **Start pressure**
- **End pressure**
- **Cylinder size**

Software calculates SAC

The software then calculates the air consumption based on the inputted figures, and the actual dive profile recorded by the dive computer.

- **Some dive computers can be set to do this live**

Some models can have this information programmed into them and are able to calculate this during the dive.

Very accurate

As the actual dive profile is used, this method is the most accurate as it does not require any assumptions on the profile.

Quiz 1

What factors increase the consumption of breathing gas?

What does SAC stand for?

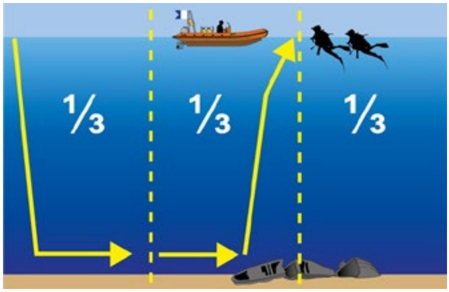
What is the formula to calculate SAC?

Answer on page 113

Reserve gas planning - rule of thirds

Gas planning using the rule of thirds was taught during previous training. The limit of decompression diving for Sports Divers (maximum of 10 minutes of stops on any dive and 20 minutes in any day) is well within the safe gas reserves the rule of thirds calculates.

Technique



- **One third out**
- **One third back**
- **One third reserve**

Calculation

- **Calculate gas for dive**

  This is done using the absolute pressure at the planned depth, multiplied by the bottom time.

- **Add 50% for the reserve**

  The 1/3 reserve is calculated by adding 50% to the gas required for the dive. Adding 50% is the same as multiplying by 1.5.

- **Consider cylinder size**

  Once the total gas for the dive and reserve has been calculated, then it is used to find what size of cylinder is required.

  The gas in a cylinder can be found by multiplying the volume in litres by the pressure. As an example, if a 12 litre cylinder is filled to 200 bar, then the total quantity of gas is 12 x 200 = 2400 litres.

Rule of thirds - example

Dive

- **Dive to 40 m for 15 mins**
  The absolute pressure at 40 m is 5.0 bar.

- **SAC of 20 L/min**
- **5 (bar) x 15 x 20 = 1,500 litres**
  This formula is based on the one for Surface Air Consumption but with the figures rearranged so that gas used is calculated.

  Absolute pressure x Duration x Surface Air Consumption (SAC) rate = Gas Used

Reserve

- **Add reserve (x 1.5) = 2,250 litres**
  The 50% reserve required by the rule of thirds can be found by multiplying the planned consumption by 1.5.

Cylinder size

Having calculated the amount of gas required for the dive, this should be used to identify what size of cylinder is required.

- **10 L at 220 bar = 2,200 litres**
  A 10 litre cylinder filled to 220 bar contains 10 x 220 = 2,200 litres of gas.

- **12 L at 220 bar = 2,640 litres**
  A 12 litre cylinder filled to 220 bar contains 12 x 220 = 2,640 litres of gas.

Go back

Rule of thirds – practice

You should practise calculating the gas required under the rule of thirds method. Two examples are shown below, but others can be used.

Remember the formula for gas used.

Example 1

- **Dive to 45 m for 12 mins**
  The absolute pressure at 45 m is 5.5 bar.
- **SAC of 20 L/min**
- **Total required is 1,980 L**
  The table shows how this is calculated:

Phase of dive	Duration (mins)	SAC (L/min)	Absolute pressure	Gas Used (litres)
Dive	12	20	5.5	1,320
Reserve (+50%)	N/A			660
			Total	1,980

Example 2

- **Dive to 30 m for 15 mins**
  The absolute pressure at 30 m is 4.0 bar.
- **SAC of 25 L/min**
- **Total required is 2,250 L**
  The table shows how this is calculated:

Phase of dive	Duration (mins)	SAC (L/min)	Absolute pressure	Gas Used (litres)
Dive	15	25	4	1,500
Reserve (+50%)	N/A			750
			Total	2,250

Reserve - minimum gas

For dives with extended decompression it is beneficial to have higher quantities of reserve gas than calculated using the rule of thirds method. The minimum gas method is one means of achieving this.

The decision on which method of calculating reserve to use should be based on factors such as amount of decompression, approach to risk, dive profile, availability of other gas and experience of divers.

Factors

- **More complex than rule of thirds**
  As will be shown in the worked example, the minimum gas method for calculating a reserve is more complex than the rule of thirds.
- **Uses different breathing rates**
  Post-incident analysis has shown that under stressed conditions, breathing rates increase dramatically, and this is exacerbated for less experienced divers. These are typically 2-3 times greater than normal but under extreme stress can be higher.

  Typically the breathing rate will be much higher during the initial part of the incident but then reduce over time, and as the diver reaches shallower depths.
- **Much larger reserve**
  The minimum gas calculation results in a much larger gas reserve than the rule of thirds.

Stages

During a real incident, SAC values are likely to start off high and then reduce over time.

The minimum gas method attempts to estimate what is required by breaking the ascent into three stages. At each stage an approximation of SAC is used to calculate the gas required and these are then added together to give a total.

It is important to appreciate that, like all gas calculations, the minimum gas method is simply an approximation and real gas usage is very likely to be different.

- **Settling time**

  This is the part of the dive where the gas usage will be the highest. The out-of-gas diver needs to access the buddy's alternate source and decisions made about the next step. This may include things such as deploying a DSMB and/or returning to a datum before commencing the ascent.

  Typically this takes at least 2-3 minutes, during which time the SAC for both divers should be planned to at least double.

- **Ascent**

  Both divers will have an elevated breathing rate, and the ascent is likely to be faster than usual. The out-of-gas diver will not have access to any gas for buoyancy control, so the ascent rate may vary.

  The gas used during the ascent can be calculated using the absolute pressure at the depth of the mid-point of the ascent. For a no decompression dive, this is half the maximum depth but is a bit more tricky to calculate for a decompression dive. The easiest way to find it is to add the maximum dive depth to the depth of the first decompression stop and then divide by two. For example, if the maximum depth is 45 m and the first decompression stop is at 9 m, then the mid-point of the ascent is (45 + 9) x 0.5 = 27 m which has an absolute pressure of 3.7 bar.

Gas consumption during the ascent should be calculated based on an SAC of at least double the normal rate.

- **Stops**
  If there are no mandatory decompression stops, the buddy pair need to make a decision whether a safety stop is required or whether the need to surface safely is more urgent, omitting the safety stop.

  If there are mandatory decompression stops and the divers are not carrying separate decompression cylinders, then both divers will have to complete their decompression stops using the same gas source. As they are shallow, the breathing rate is likely to reduce down to a more normal level than that experienced so far. They also need to add the post-decompression final ascent to the surface.

  During this phase, the normal SAC can be used for the calculation.

Minimum gas – example

This example shows the reserve calculated using the minimum gas method for a dive.

Dive

- **Dive to 40 m with a 3 min stop at 6m**
- **ISO stressed rate of 50 L/min**
- **Drops to 25 L/min at first deco stop**

Go back

Calculation of reserve

- **Total SAC is 75 L/min (50 + 25)**
  The two divers are breathing 50 L/min and 25 L/min respectively, giving a total breathing rate of 75 L/min..

- **10 m/min for ascent (4 mins)**
  This is a no decompression dive, and it is assumed that no safety stop is carried out as there is an urgency to get to the surface that outweighs the potential risk of DCI.

  It will take 4 minutes for a diver to ascend at 10 m/min from 40 m to the surface.

- **Mid-point of ascent is 20 m (3 bar)**
  The gas used during the ascent can be calculated using the pressure of the mid-point. In this case this is 40 x 0.5 = 20 m. This depth has an absolute pressure of 3 bar.

- **Deco stop at 6m for 3 mins**
  At this point it is likely the divers will have calmed and a normal breathing rate can be used.

Phase of dive	Duration (mins)	SAC (L/min)	Absolute pressure	Gas Used (litres)
Settling time	3	75	5	1,125
Ascent	4	75	3	900
Stop	3	50	1.6	240
			Total	2,265

Cylinder pressure required

The pressure required for the reserve can be calculated by dividing the total gas by the cylinder size.

- **15 L = 2265 ÷ 15 = 151 bar**

Go back

- **12 L twin-set = 2265 ÷24 = 94 bar**

  A cylinder smaller than 12 L is unlikely to have an adequate reserve capacity.

Complex calculation

Calculating minimum gas is relatively complex and can easily lead to calculation errors. A way to reduce these errors is to use a lookup table.

Depth	Gas reqd	15m stop 1	5	12m stop 1	5	10	9m stop 1	5	10	6m stop 1	5	10
20	975	125	625	110	550	1100	95	475	950	80	400	800
25	1209											
30	1463											
35	1734											
40	2025											
45	2334											
50	2663											
	Min gas (litres) = Direct + deco stops											

Use BSAC Minimum Gas Lookup Table

- **Based on ISO breathing rates**

50 L/min for the settling and ascent

Normal for the decompression stops

- **Recalculate the table if breathing rates are known**

Minimum gas - example

This example shows the reserve calculated using the lookup table.

Dive

- **Dive to 45 m**
- **Decompression stops of 1 min at 9m and 6 min at 6m.**

Lookup values in the table

Select the value from the yellow depth column. If in between, use the next deeper value.

Select the values from the blue row for the gas used on the decompression stops.

Depth	Gas	15m stop		12m stop			9m stop			6m stop		
	reqd	1	5	1	5	10	1	5	10	1	5	10
20	975	125	625	110	550	1100	95	475	950	80	400	800
25	1209											
30	1463											
35	1734											
40	2025											
45	2334											
50	2663											
	Min gas (litres) = Direct + deco stops											

- **Minimum gas calculation**

  Is the sum of all of the selected values, in this case 2334 + 95 + 80 + 400 = 2909 L

- **Calculate the value in bars in the cylinder used**

  Divide the reserve value by the cylinder capacity, in this case

  12 L twin-set = 2909 ÷ 24 = 121 bar

Use minimum gas to calculate dive limits

Dive planning using the rule of thirds is normally an iterative process as the diver tries to identify the dive time that will provide a reserve which is achievable with their cylinder capacity.

This iterative process is not required if reserve gas is calculated using the minimum gas method as we can take the minimum gas away from the total gas available to give us the amount of gas available for the dive, using our normal breathing rate.

Dive

- **Known breathing rate of 15 L/min**

This should be measured using one of the previous methods

Gas available for the dive

- **From the previous calculation, the reserve is 121 bar.**
- **Gas for the dive is 220 - 121 = 99 bar.**

Dive limits

Using the formula below, the maximum bottom time can be calculated.

$$\text{Bottom time} = \frac{\text{Cylinder pressure x capacity}}{\text{SAC x absolute pressure}}$$

For this example this gives:

$$\frac{99 \text{ bar x } 24 \text{ L}}{15 \text{ L/min x } 5.5 \text{ bar}}$$

= 28.8 minutes (round down to 28)

Dive limits

The diver can use a decompression planning tool to plan a dive that has the maximum parameters above. As long as they plan a dive shorter than this, they will have enough reserve gas.

- **No more than 28 mins bottom time**
- **Max 1 min at 9m and 6 min at 6m deco**

Go back

Dive limits – student practice

Students should practise calculating dive limits building on the two previous examples.

Example 1

- **Dive to 30 m**
- **Max 5 mins of deco at 6 m**
- **15 L cylinder at 220 bar**
- **SAC of 12 L/min**
- **1,863 L reserve (124 bar)**
- **Available gas for the dive = 220 - 124 = 96 bar**
- **Max bottom time = (96 x 15) ÷ (4 x 12) = 30 mins**

Example 2

- **Dive to 40 m**
- **Max 10 mins of deco at 6 m**
- **Max 5 mins deco at 9 m**
- **12L twin-set (24L) at 220 bar**
- **SAC of 15 L/min**
- **3,330 L reserve (137 bar)**
- **Available gas for the dive = 220 - 137 = 83 bar**
- **Max bottom time = (83 x 24) ÷ (5 x 15) = 26 mins**

Go back

Overcoming limiting factors

It should be clear that there are significant limitations to deeper diving which will restrict duration and depth.

There are well-established solutions to these limitations, but these require additional training outside the scope of this course.

Gas

- **Twin-set**
  Diving with a twin-set will provide significantly more gas and enhance safety through redundancy.

- **Rebreather**
  Rebreathers use gas in a very different way to open circuit equipment, which means that they can support extended dive durations.

  To learn more about rebreathers watch the video at **https://vimeo.com/410600503/db2d4471d4**

Decompression

- **Nitrox**
  Nitrox can be used as a dive gas to reduce the amount of decompression for a given dive profile, and this should be familiar to all students on this course.

- **Accelerated decompression**
  Very high percentages of nitrox, such as 50 or 80%, can be used to reduce decompression requirements significantly. Normally these are carried in a separate cylinder (stage), and then the diver switches to it a depth shallower than the Maximum Operating Depth (MOD).

- **Rebreather**
  Rebreathers continually mix gas to provide the optimum breathing gas regardless of depth.

Depth

The use of trimix to reduce narcosis has already been highlighted, but this can also be used to go deeper than the limitations of this course.

- **Open circuit mixed gas**
- **Rebreather mixed gas**

What next?

Use your knowledge. Encourage the students to use the knowledge that they have gained.

- **Trimix analysis**
  Analyse and breathe trimix within the limits of the training, i.e. no less than 20% oxygen, no more than 40 % helium, maximum PO2 of 1.4 bar and within gas density limits.

- **Decompression planning**
  Plan decompression dives using the different tools that they have been shown.

- **Gas planning**
  Consider the different methods for calculating reserve breathing gas and use the most appropriate one for the dive that is being done.

Depth progression (optional)

Students will probably be keen to depth progress but this needs to take place within an appropriate context.

- **Under supervision of Deeper Diving Instructor**
  All depth progression needs to be supervised by a BSAC Deeper

Diving Instructor.

- **5 metre increments**
  The maximum depth progression in a single dive is 5 m beyond the previous maximum depth to which the student has dived.

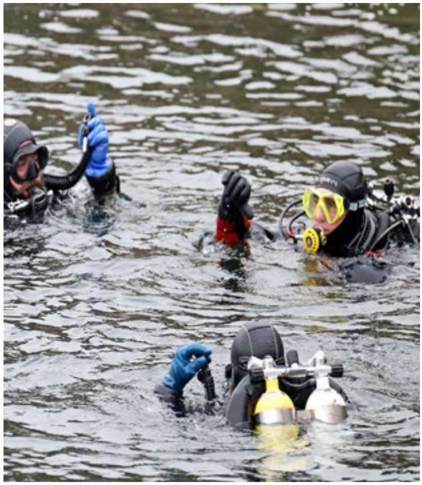
Quiz 2

What are two methods to calculate the gas reserve?

What are the three stages considered during the minimum gas method of calculating reserve gas?

Answers on page 114

Summary



You should now understand:

- ✔ **Review of gas consumption**
- ✔ **Methods of calculating individual gas consumption**
- ✔ **Methods of calculating the gas reserve for a dive**
- ✔ **Limiting factors for deeper diving and methods to overcome them**

Test yourself

1. What is another term for Surface Air Consumption (SAC)?
2. In an emergency what level can breathing rates reach?
3. Is maximum depth or constant depth the most accurate means of calculating SAC?
4. How is the breathing gas reserve calculated using the rule of thirds method?
5. The minimum gas method of calculating a gas reserve has three stages. What are they?
6. Which method calculating a gas reserve will normally result in the largest reserve?
7. Decompression is normally a limiting factor for deeper divers. What are three methods of reducing the amount of decompression required?

Answers on page 114

Go back

End of module quiz answers

Go back

DDT1

Quiz 1 answers

1. 50 m
2. A minimum of 20% oxygen
3. A maximum of 40% helium

Quiz 2 answers

1. Oxygen, Helium, Nitrogen
2. The different cylinders that are often used for deeper diving may have an impact on buoyancy. What should a diver do before taking them on a deep dive?
   - Check there is adequate lift to support the diver at the surface
   - Confirm weight and trim with a shallow check dive
   - Check neutral buoyancy can be maintained with low gas

Test yourself answers

1. The optional depth progression dives can only be done once all theory training has been completed.
2. No, Closed Circuit Divers cannot use Deeper Diver training to go deeper than allowed by their current CCR qualification?

Go back

3. A rigorous buddy check before entering the water will identify many problems and also provides the opportunity to ensure complete familiarity with equipment.
4. Deeper divers need to be responsible for their own checks, such as gas contents, dive time and decompression obligation.
5. Helium mixtures are expressed with the oxygen and helium percentages separated by a slash, i.e 20/30 contains 20 percent oxygen and 30 percent helium with the remainder (50%) being nitrogen.
6. A 3 L cylinder may not contain enough gas to enable a diver to surface safely.
7. It is very beneficial to have a redundant gas supply and buoyancy. Other important items include masks, instrumentation, cutting tools, reels, torches and DSMBs.

DDT2

Quiz 1 answers

1. 50 m
2. The effects on divers of breathing mixtures containing helium are:
   - Reduced narcosis
   - Easier to breathe
   - Different decompression profile
   - Chilling
   - Vocal distortion

Go back

3. The BSAC recommendations for avoiding issues created by gas density are
   - Use appropriate equipment
   - Breathe gases that comply with gas density limits
4. 23/35 trimix with a gas density of 5.43 $g.L^{-1}$ and an END of 22 m

Quiz 2 answers

1. How can CNS oxygen toxicity be avoided?
   - Analyse gas and check MOD
   - Breathe normally and avoid hard physical exercise
   - Monitor oxygen toxicity level
2. What are the two most obvious symptoms of immersion pulmonary oedema (IPO)?
   - Breathing disruption
   - Thinking equipment is faulty

Test yourself answers

1. The term END stands for Equivalent Narcotic Depth.
2. END is important because it provides a means of calculating the narcotic effect of breathing gas at a particular depth.
3. Use appropriate equipment and breathe gases that comply with gas density limits

Go back

4. 23/35 trimix with gas density of 5.43 g.L-1 and an END of 22 m

Quiz 2 answers

1. Analyse gas and check MOD, breathe normally and avoid hard physical exercise
2. Breathing disruption and thinking equipment is faulty

Test yourself answers

1. The term END stands for Equivalent Narcotic Depth.
2. END is important because it provides a means of calculating the narcotic effect of breathing gas at a particular depth.
3. The gas density recommendations are points along a spectrum of risk. Adopting them does not guarantee safety, and many dives have been successfully completed breathing gas that significantly exceeds the current recommended limits.
4. The recommended method to select a gas that meets BSAC gas density recommendations is to use the BSAC gas density tables for the appropriate partial pressure of oxygen.
5. There are a smaller set of gas density tables which provide standard gases that are not necessarily optimum but provide easily recognised helium percentages.
6. The mnemonic CONVENTID is used to remember the symptoms of oxygen toxicity

7. **Even no stop dives require surface decompression. This is the period on the surface until the inert gases in tissues have returned to ambient pressure.**
8. **An ascent that is too slow will increase the amount of nitrogen that is absorbed into some tissues and decrease the rate of off gassing in other tissues. This will increase the duration of decompression stops that are required.**
9. **A casualty on the surface suspected of suffering from IPO should be given the following treatment:**
   - **Sit upright (if conscious)**
   - **Give 100% oxygen**
   - **Keep warm**
   - **Do not give fluids!**

DDT3

Quiz 1 answers

1. **Bühlmann ZHL-16C algorithm, 85/95 for air/nitrox, 60/80 for trimix**
2. **This is the time at which the diver needs to leave that depth**

Quiz 2 answers

1. **Algorithm, Ascent rates, Stop depths**

Go back

2. No decompression plans
3. 10 m/min

Test yourself answers

1. A 30 minute dive time at 39 metres on a BSAC 88 Level 1 table A requires decompression stops of 1 minute at 9 metres and 9 minutes at 6 metres.
2. A 40 minute dive time at 36 metres on Nitrox table A whilst breathing 32% nitrox requires decompression stops of 6 minutes at 6 metres.
3. Perfusion models (Bühlmann) assume that DCI occurs when the gas saturation of a specific tissue exceeds a certain level which is known as the M value.
4. A more conservative dive profile allows a divers may to reduce their level of risk. This may vary based on a diver's particular circumstances, which may include physiological factors, such as age and fitness, the nature of the dive or even the availability of post-dive medical treatment.
5. A multi-level dive is one where the diver descends to the maximum depth and spends some time there. They then ascend to a slightly shallower depth for a period and this continues as many times as deemed necessary.
6. The minimum columns that should be on a run time slate are:
   - Depth
   - Stop time
   - Run time
   - Gas used

Go back

7. **The three broad categories of tools that can be used to plan decompression diving are:**
   - **Tables**
   - **Dive computers**
   - **Software**
8. **Not all planning tools are compatible with each other or individual dive computers, so it is important to understand them before they are used. An excellent example is that BSAC dive tables assume an ascent rate of 15 metres per minute (to the first stop), whereas most modern dive computers use 10 metres per minute.**
9. **Software planning tools typically offer the most features.**

DDT4

Quiz 1 answers

1. **Depth, Exertion, Cold, Stress, Emergency situations**
2. **Surface Air Consumption**
3. $$SAC=\frac{Gas\ used}{Absolute\ pressure\ x\ Duration}$$

Quiz 2 answers

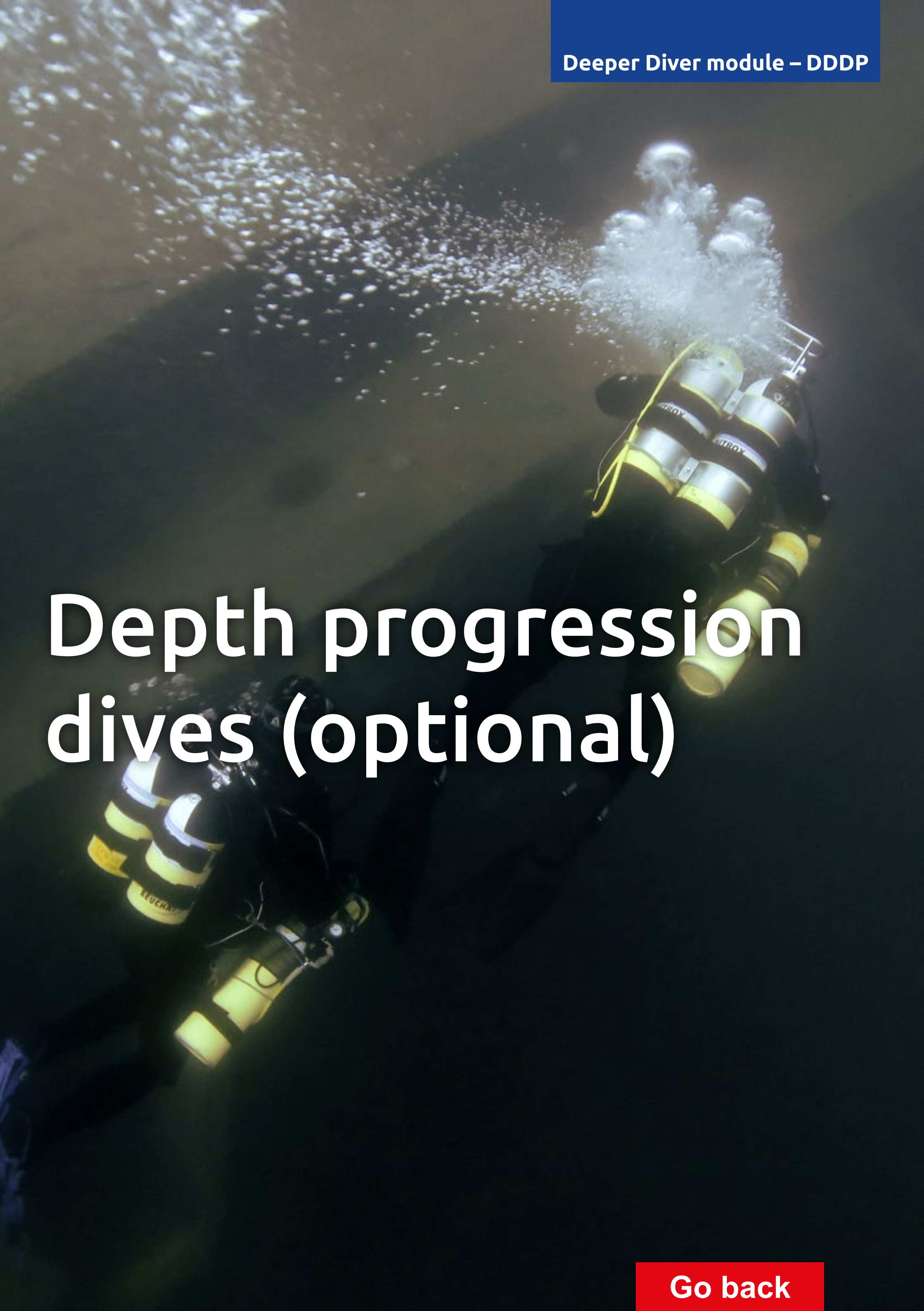
1. **Rule of thirds and minimum gas**
2. **Settling, Ascent, Decompression**

Go back

Test yourself answers

1. Another term for Surface Air Consumption (SAC) is Residual Minute Volume (RMV).
2. Research and analysis of incidents have indicated that the breathing rates of divers can double, triple and more during periods of high work rate and stress. This means they can reach 50-75 L/min, or more.
3. Constant depth is the most accurate means of calculating SAC
4. The reserve required for the rule of thirds method is calculated by adding 50% to the gas required for the dive. Adding 50% is the same as multiplying by 1.5.
5. The three stages used by the minimum gas method of calculating a gas reserve are:
   - Settling time
   - Ascent
   - Stops
6. The minimum gas method of calculating a gas reserve will normally result in the largest reserve.
7. Three methods of reducing the decompression required for deeper dives are
   - Nitrox as a dive gas
   - Accelerated decompression
   - Rebreathers

Go back



Depth progression dives (optional)

Go back

DDDP - Depth progression dives (optional)

The optional depth progression dives can only take place once all the theory lessons have been recorded as complete, and you have been awarded the Deeper Diver qualification.

Diving gases

The optional depth progression dives may be conducted with air, nitrox or trimix that have a maximum PO_2 of 1.4 bar.

If trimix is used, then it must contain no less than 20% oxygen and no more than 40% helium.

Factors

Before the dives, the instructor will need to consider whether you are capable of completing depth progression. Specific factors that may need to be considered include:

- **Previous dive experience**
  What previous dive experience do you have? Have you done many deep dives in

similar conditions to those likely to be encountered, and have any of them involved mandatory decompression?

- **Previous depth experience**
  What is the maximum depth that you have previously experienced? When was it achieved, and what were the conditions when it occurred?

- **Equipment**
  Is your equipment suitable for the dive and have you checked their weight?

- **Dive computers**
  Particular attention should be paid to the dive computers that are being used to ensure they are compatible with each other and the dive being planned.

- **Other agency divers**
  If you are another agency diver with qualifications equivalent to Sports Diver, then you may not have received training on how to conduct decompression dives, or completed dives involving mandatory decompression.

Based on the answers to these questions, the instructor may wish to complete additional training before the depth progression dives. This may include:

- **Theory**
  The instructor may wish to recap or teach some of the theory lessons from the Diver Training Programme (DTP).

- **Shallow check dive**
  This can be useful to check weighting and buoyancy control, particularly on decompression stops, and is especially useful if you have new equipment and/or are not used to the conditions.

Go back

- **Build-up dives**
  A series of dives that build up the maximum previous depth can be useful to build confidence and prepare for the depth progression. Normally these are done in 5-10 m increments.

- **Ascents**
  Ascending at the correct rate is very important when using run time slates. If you are used to making slow, gradual ascents, then additional training may be required to get used to ascending at the rates specified by the planning tool.

- **Dives with mandatory decompression**
  Mandatory decompression will almost certainly be needed for the depth progression dives. If you do not have an adequate previous experience of dives with mandatory decompression at different levels, then you need this experience before the depth progression dives.

Dive planning

The instructor should take you through the steps below for planning a deeper dive.

- **Limiting factors**
  Look at the factor(s) that will limit the dive, and ensure they are considered.

- **Gas selection**
  Choose an appropriate gas for the dive, considering Maximum Operating Depth, gas density, and narcosis.

- **Dive profile**

Select a profile based on equipment and experience. A multi-level dive with very limited time at the maximum depth is one likely option.

- **Dive planning**
  Using an appropriate planning tool, plan a suitable depth and time with a contingency plan (deeper and longer), or plans.

  If you require additional support during the dive planning, then this will be provided by your instructor. This may be relevant if you completed the theory some time ago and/or feel that it is necessary.

- **Gas planning**
  It is unlikely that a diver will have a wide range of equipment from which to choose. Using their available equipment, the plan may need a couple of iterations between available gas and decompression plan to ensure the plan leaves the divers with the minimum gas reserve and within the limiting factors identified earlier.

- **Produce a run time slate**
  Produce run time slates for each of the dive plans and ensure that all divers are carrying one.

Gas analysis and cylinder marking

Before the dive, the gas should be re-analysed and confirmed it is still within the planned parameters. If different from the previous analysis, check that the dive plan is still valid.

Diving cylinders should be marked with the appropriate information, including MOD.

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Depth progression

The depth progression dives will take place in increments of no more than 5 m depths beyond your previous maximum and will not exceed 50 m. So, if you have previously not dived beyond 38 m you should complete depth progression dives to maximum depths of 43, 48 and then 50 m.

Go back

Deeper diver qualification record book

Go back

Deeper Diver qualification record book

These pages can be printed off and used to record completion of lessons and depth progression dives.

Deeper Diver theory modules

Code	Description of Training	Date	Instructor's signature and number
DDT1	Theory Lesson **Deeper diving**		 No:
DDT2	Theory Lesson **Deeper diving physiology**		 No:
DDT3	Theory Lesson **Decompression planning**		 No:
DDT4	Theory Lesson **Gas planning and limiting factors**		 No:

DDDP - Depth progression dives (Optional)

Code	Description of Training	Date	Instructor's signature and number
SPQ25	Practical **Depth progression to 25 m**		 No:
SPQ30	Practical **Depth progression to 30 m**		 No:
SPQ35	Practical **Depth progression to 35 m**		 No:
SPQ40	Practical **Depth progression to 40 m**		 No:
DDDP45	Practical **Depth progression to 45 m**		 No:
DDDP50	Practical **Depth progression to 50 m**		 No:

Go back

Qualification card

BSAC photo-ID qualification cards are a universally accepted and convenient proof of qualification.

Obtaining your QCard (qualification card)

Once you have successfully completed all the training your instructor will be able to apply for your qualification and digital card online.

Please be aware that you must supply the following information to them:

- Your full name
- Your BSAC membership number
- You should ensure your MyBSAC profile has a photo uploaded for your digital qcard.

Not able to download your digital qcard?

It can take time to process all qualifications so please allow 2 weeks from submission from instructor to viewing you qualification in your MyBSAC Profile.

Please contact qcards@bsac.com with the following if you cannot see your qualification on MyBSAC with:

- Your full name
- Your BSAC membership number
- The qcard you are expecting, i.e Dive Leader
- The name of the instructor who submitted the application
- The completion date of the training

After your course...

Go and use your newly acquired skills

Go diving... with the support of your club, you will be able to encounter a fascinating variety of wildlife and shipwrecks in seas, rivers, quarries, lochs and lakes. Plus, you will be able to dive anywhere in the world with your internationally-recognised qualification.

Progress your diver training...you can quickly move onto your next grade in BSAC's Diver Training Programme.

We recommend for your next course

Accelerated Decompression Procedures

To start the course, discuss your options with your Training Officer/ Diving Officer of your branch, your Regional Coach or local BSAC Partnership Centre...

Learn new specific skills...you could also develop specific skills such as safety and rescue, wreck diving or driving a dive boat.

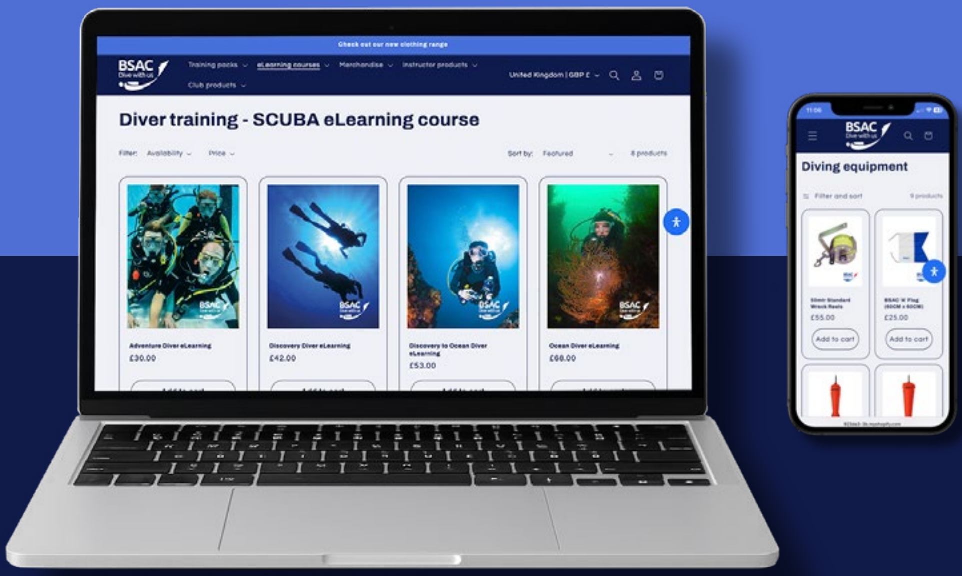
Other courses you may like

MOD 1 CCR
Boat Handling
Accelerated Decompression Procedures
Twin-set Diver

To book and pay for your Skill Development Course simply click on the link to get going...

bsac.com/events

Shop online at **bsac.com/shop**



Login to MyBSAC (BSAC.com/mybsac) to obtain:

- Secure online ordering
- Up to 35% discount for all BSAC members
- Training packs, merchandise, decompression tables, BSAC manuals and lots more
- Buying online from the BSAC shop supports our work in underwater heritage, marine conservation and protecting our seas

Let's grow the love of British diving together

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Notes

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