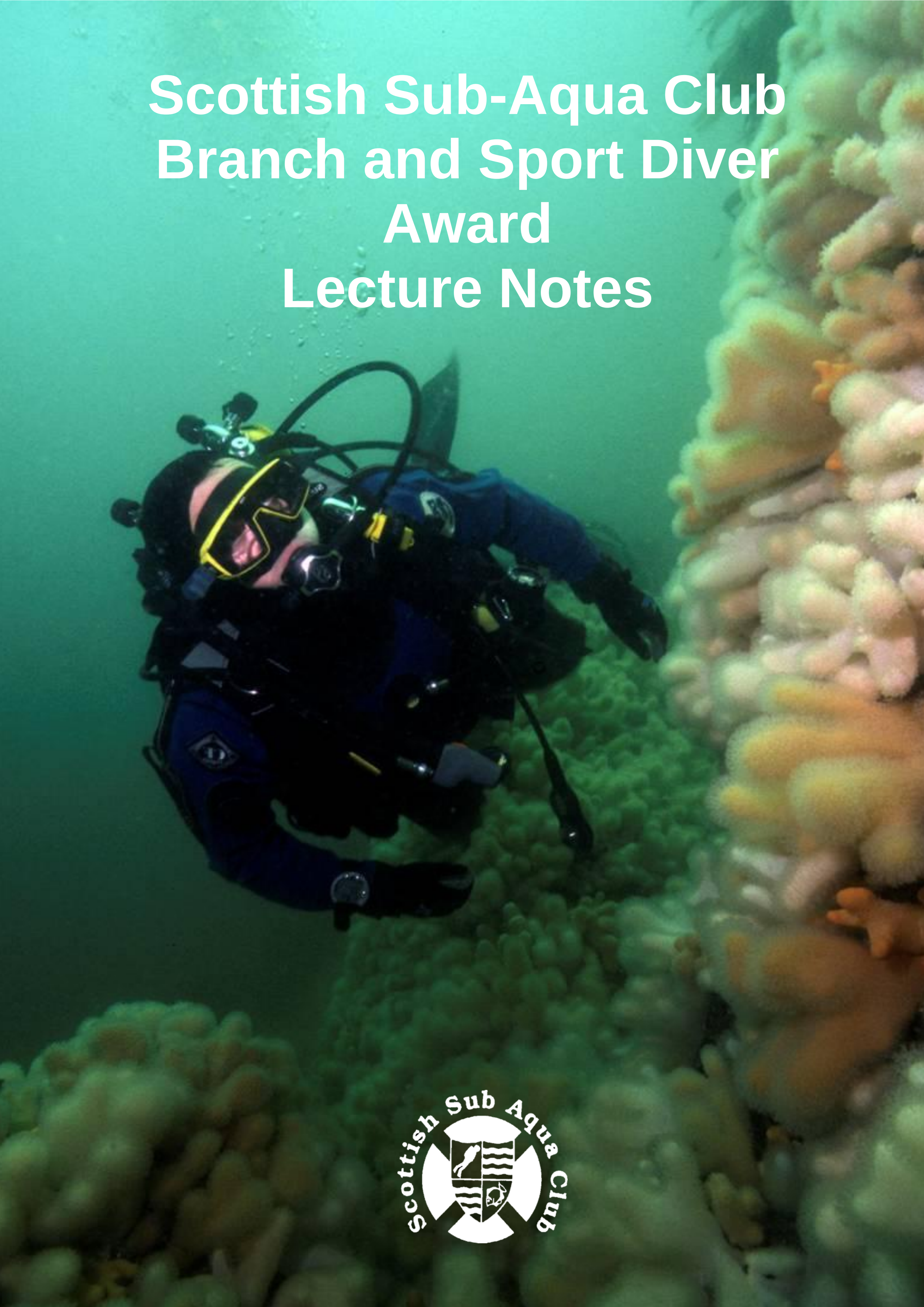
Scottish Sub-Aqua Club Branch and Sport Diver Award Lecture Notes



Branch and Sport Diver Award Lecture Notes

SCOTTISH SUB AQUA CLUB
September 2006 v.2

New Training Schedule Cross Reference added May 2014

Cover picture: Diver at St Abbs

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Disclaimer

Introduction and Important Note

These lecture notes are designed to be used in conjunction with the Scottish Sub Aqua Club lecture slides provided. They are intended to be aid to your revision prior to taking either the Branch or Sport Diver Theory assessment and as a reference for refreshing your knowledge in the future.

Please note that the work to review, reorder, renumber and rebrand these notes to match the Branch Diver and Sport Diver lectures is in progress. This is therefore an interim version and will be replaced by the finished articles once they are available. In the interim, tables cross-referencing the New Training Schedule to the 2006 Sport Diver notes sections in this document are provided below to allow you to locate the relevant training material for each theory lecture.

Thank-you for your patience,

Alastair McCulloch (Stirling)

On behalf of the ScotSAC NDC

Branch Diver

New Ref	Lecture Title	Section in these notes to read	
BDL1	ScotSAC structure	12	ScotSAC and the organisation of its training programme.
BDL2	Basic equipment and care for equipment, signals and surfacing drills. (include protective clothing)	1	Basic equipment, signals and surfacing drill
BDL3	Ears, sinuses and effects of pressure. Introduction to Buhlmann tables including safety stops (basic DCI info)	2 11	Ears, sinuses and effects of pressure Basic decompression, hazards and avoidance. (Gain a basic understanding, this is covered in more detail for Sport Diver)
BDL4	Principles of the Aqualung	8	Principles of aqualung, air endurance and air cylinders.
BDL5	Aqualung use, air endurance and buoyancy control.	3 8	Aqualung use, buoyancy control, use of buoyancy aids Principles of aqualung, air endurance and air cylinders.
BDL6	Burst lung and ascents in emergency (basic respiration, anoxia and hypoxia)	4 5	Respiration, hyperventilation, anoxia and hypoxia. Burst lung and ascent in emergency
BDL7	Open water diving procedure (including personal risk assessments ‘Am I fit/equipped to dive?’), hazards and avoidance (incl. basic navigation).	10	Open water diving and dive procedure.

Sport Diver

New Ref	Lecture Title	Section in these 2006 notes to read	
SDL1	Respiration, hyperventilation, anoxia and hypoxia.	4	Respiration, hyperventilation, anoxia and hypoxia.
SDL2	Exhaustion, protective clothing and hypothermia.	6	Exhaustion, protective clothing and hypothermia.
SDL3	Rescue and Lifesaving, CPR and recovery position.	7	Rescue, life saving and artificial respiration.
SDL4	Compass use and diving accessories; maintenance of equipment.	9	Maintenance of equipment and diving accessories.
SDL5	Decompression, hazards and avoidance.	11	Basic decompression, hazards and avoidance.
SDL6	Advanced Principles of the Aqualung (gas calculations)	8	Principles of aqualung, air endurance and air cylinders.
SDL7	Dive leadership	NEW	See separate notes “SDL7 Dive Leadership – Lecture Notes DRAFT.PDF”

Contents

1 Basic Equipment, Signals and Surfacing Procedure

1.1 Overview

1.1.1 This lecture provides information on basic equipment including mask, fins, snorkel and weightbelt. It also introduces common hand signals used in scuba diving and surfacing procedures for open water diving.

1.2 Basic Equipment: Masks

1.2.1 There are 4 parts to a mask, as shown in Figure 1.1:


Figure 1.1 Diving mask

- The Frame: This secures the lens, the body and strap together, and is generally made of a hard- wearing plastic.
- The Strap: This is either a split or single rubber or silicone strap, which holds the mask body against the wearer's face. The length of the strap can be adjusted by buckles and so tension the mask on the face, as required.
- The Lens: This must be scratch- and shatter- resistant and is usually made of tempered glass. Avoid plastic, which tends to scratch and fog easily. The lens may be kept clear by application of an anti-fog solution. Side windows are fitted in some types of mask.
- The Body or skirt: This is usually made from soft rubber or silicone to form a waterproof seal against the diver's face. It encloses the eyes and nose and allows the wearer to pinch his nose in order to clear his ears while submerged. Drain valves may be fitted to aid mask clearing, but are unnecessary and can become clogged with sand etc.

1.2.2 Silicone rubber is often used for the body of the mask. This material is non-allergic to body tissue and very long lasting. The translucent type of silicone also allows light to enter the body of the mask. Silicone rubber also maintains its flexibility over a wide range of temperatures. Since face shapes differ, a mask should be selected which will seal against the face and yet be comfortable.

1.2.3 Test a new mask for correct fit by placing it against your face without using the strap and inhaling through your nose. A correctly fitting mask should remain in place until you exhale through your nose. Also press the mask against the bridge of your nose, to ensure it doesn't hurt your nose too much. Look for masks with a good field of vision, both horizontally and vertically.

1.2.4 New masks normally have an oily film on the lens which must removed before use. Many manufacturers recommend rubbing toothpaste over the lens then washing off. Commercial cleaners are also available.

1.2.5 Before diving you must demist your mask by spitting into the inside then rinsing the mask in water.

1.2.6 Mask clearing is one of the first important skills you will learn. The flooded mask is cleared by first tilting the head back, then gently pressing one hand on the top edge of the mask whilst exhaling through the nose. This displaces water out of the mask.

1.2.7 Many different types of mask are available. Take advice from an experienced diver or instructor before purchasing your mask.

1.2.8 People who have eyesight problems can have corrective lenses fitted. Contact lens may be worn instead.

1.2.9 Generally, masks with a low internal volume are easier to clear and are less prone to mask squeeze. The mask should be stored in the box provided when not in use.

1.2.10 A mask is essential for seeing clearly underwater as the eye requires an air space to focus clearly. As light rays pass from water into the air space in the mask they are bent (refracted). This causes objects to appear larger and closer to the viewer.

1.2.11 The colour of objects is also affected underwater (Figure 1.2). White light consists of many different colours, or wavelengths of light. Each wavelength is absorbed at a different depth, with reds the first to go, and only blue and grey light reaching greater depths – this gives the underwater environment a rather muted, 'washed' appearance.

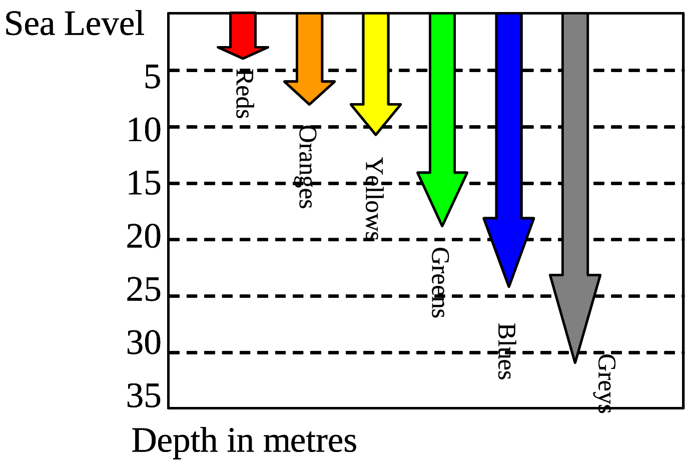


Figure 1.2 Effects of depth on colour

1.3 Basic Equipment: Fins

1.3.1 Fins are worn to propel the diver through the water by leg action alone, thereby leaving the hands free. The fin is made of two parts – the shoe and the blade. The shoe needs to be made of soft rubber to ensure maximum comfort and freedom from chafing during prolonged use. The blade should have a graduated stiffness in order to transmit the power of the finning action of the legs and feet.

1.3.2 A harder material is used for the blade section and the stiffening ridges. Various rubber, plastic or fibreglass compounds are used in the blade.

1.3.3 Many designs incorporate slots or apertures in the area in front of the toes to reduce the effort required to move the fin through the water on the recovery stroke.

1.3.4 Since the fin which satisfies all the criteria for swimming in the pool may not be the best fin for use in the open water, and vice versa, many divers keep two pairs of fins – one for the open water and one for pool use.

1.3.5 There are two types of fin: open-ended and shoe-type (Figure 1.3). The open-ended (or sea fins) generally have a larger blade and are designed to fit over boots or bootees, for use in the open water (always wear boots when trying on this type of fin). A large and/or stiff blade will give more propulsion, but will be more tiring to use.

Figure 1.3 Pool and open water fins

1.3.6 Shoe-type fins (pool and snorkelling/tropical use) are smaller, and are designed with a close fitting rubber shoe, which the foot fits into. Additional security can be obtained by using Y-shaped rubber fin retainers, which fit around the ankle and the fin-clad foot.

1.4 Basic Equipment: Snorkel

1.4.1 A snorkel allows the user to breathe while lying face down on the surface of the water. This position makes finning on the surface much easier, and also permits the wearer to continually look underwater from the surface. In its simplest form, a snorkel consists of two parts – the mouthpiece, which is gripped by the teeth and forms a seal with the lips, and a rigid or flexible tube which points upwards over the semi-submerged head. The top of the tube is open and allows the user to breathe without risk of drawing in water.

Figure 1.4 Types of Snorkel

1.4.2 The most common shapes of snorkels are either L or J shaped (Figure 1.4). A typical length will be 40-45cm. The length and width of a snorkel will affect the effort required to clear it.

1.4.3 Avoid snorkels that have complicated bends or valves at the open end. Most snorkels (purge-type) have valves at the lower end to aid clearing, which some people find useful.

1.4.4 Snorkels are usually supplied with a retaining ring or clip to attach them to the mask strap (on the left side of the mask). Here it will always be ready for use. For normal diving, many divers prefer to stow the snorkel somewhere – perhaps in their knife strap, knee pad, or in their buoyancy control device – and remove it for use when required. As with the mask, the fit of the snorkel on the wearer is the most important consideration.

1.5 Basic Equipment: Weight Belts

1.5.1 A wetsuit or drysuit will increase the diver's buoyancy, making it necessary to be weighted down so that neutral buoyancy can be attained. This is achieved by wearing lead weights around the waist on a suitable weight belt.

1.5.2 A vital part of the belt is the buckle. Buckles must be a quick release type, ensuring that positive buoyancy can quickly be attained by a *diver in an emergency situation only*, by rapid jettisoning of the weight belt. It also makes the belt easy to remove, before climbing into the boat after a dive. Many types of quick release buckle exist, so look for one which can be easily opened, even with thick gloves and cold hands, and which contrasts with the colour of the aqualung harness. It should allow the belt to come away quickly and easily without snagging. Avoid belts that are too long or too short.

Figure 1.5 Types of weightbelt

1.5.3 The most popular types of belt in use are the solid lead type and the shot belt (Figure 1.5). The former is composed of lead blocks, threaded through a webbed nylon belt. The latter consists of lead shot contained in a hollow fabric belt, which is more comfortable to use. Harness systems are also available, which are often a solution for divers who find difficulty keeping their weightbelt from slipping off their waist and keeping the weight off the back (Figure 1.6). The key issue is to never use more weight than you actually need. A common problem with many divers is that they are over-weighted. Note that the amount of weight required varies with the type of suit (and undersuit) used and whether the dive is taking place in fresh or salt water.

Figure 1.6 Incorrectly fitted weightbelt

1.5.4 Some drysuit divers find the use of ankle weights helpful in maintaining a horizontal position in the water. This helps to prevent inversion and subsequently hazardous feet-first rapid ascent to the surface.

1.5.5 One development in weighting technology is the integration of weights with the BCD jacket. Releasing the weights in this system is by pull toggle.

1.6 **Underwater Signalling**

1.6.1 The ability to communicate effectively with a dive buddy is essential to safe diving. There are a number of recognised dive signals which are commonly used.

Figure 1.7 OK Signal

1.7 **Basic Signalling: The OK signal**

1.7.1 This is the classic diving signal and is shown in Figure 1.7. It is used both to enquire that all is well with the diver's buddy and to respond to the same enquiry about oneself. It is also used in conjunction with other diving signals, to indicate that they have been received and understood. Thus, your dive leader will give you the OK signal from time to time to check that everything is well with you. Your response, if OK, would be to give the signal back immediately. If you're not OK, you give the appropriate signal from one of the other groups. If your buddy gives you any other signal you should respond with the OK signal if you agree and/or understand. Thus if your partner gives you the 'I'm out of air' signal, you give the OK signal to indicate that you acknowledge the signal and immediately go to them and administer air by an emergency method.

1.8 **Basic Signals : Normal Diving Signals**

1.8.1 The signals shown in Figure 1.8 are used together with the OK signal, will be given during the duration of a normal dive in which no untoward incidents occur. These, together with the OK signal, should form the some of signals used on a normal dive. The signal in the figure below (my contents gauge reads 50 bar or less) is the signal to terminate the dive and ascend to the surface.

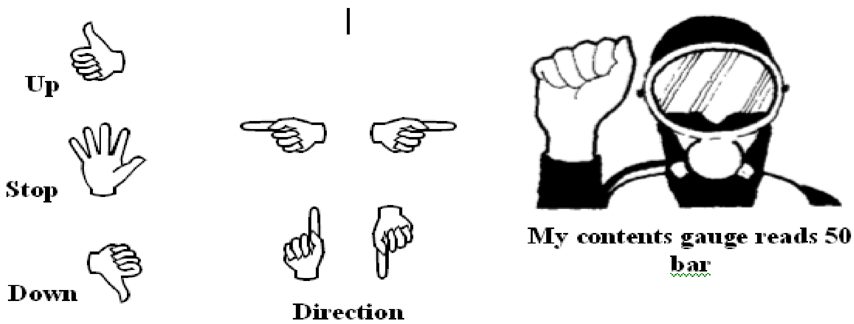


Figure 1.8 Normal Diving Signals

1.9 **Basic Signals: Adversity Signals**

1.9.1 These signals are given when something is wrong and the dive partner must respond appropriately.

1.9.2 The signal for "I have no more air" (Figure 1.9) is given when the air supply fails. The dive buddy should immediately render assistance, and both divers perform a controlled ascent to the surface.

Figure 1.9 Out of air signal

1.9.3 "I'm in distress" (Figure 1.10 & Figure 1.11) may be given for a variety of reasons, such as feeling unwell or in a state of panic or being snagged on a rock or wreckage. The signal requires the buddy to give the victim whatever assistance the situation demands.

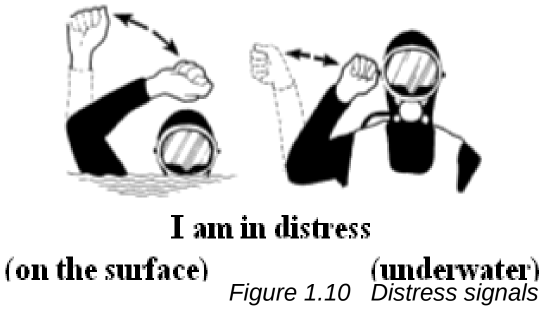


Figure 1.10 Distress signals

Figure 1.11 Distress signal (surface)

1.9.4 "Something is wrong" is a signal used as either a statement or a question to another diver (Figure 1.12). If it is a statement it is followed by an indication of the source of trouble. If it is used as a question, it will be followed by the 'you' signal to ask whether the buddy is OK.

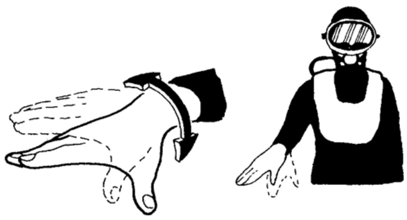


Figure 1.12 Something is wrong

1.9.5 "My air supply is giving me trouble" [not shown] is normally indicated by pointing at the demand valve and giving the 'something is wrong' signal. This signal should be given when the air supply is constricted or erratic but while air is still available. It invites the partner to examine his/her buddy's air system for some obvious cause of lack of supply, such as the pillar valve being incompletely turned on. If the problem is not immediately resolved then the dive should be terminated

1.10 Basic Signals: Information Signals

1.10.1 These signals provide information which may be very valuable but which do not necessarily lead to any action by the buddy other than giving an OK signal.

1.10.2 The "Danger" signal will be given whenever something is seen which might endanger you (Figure 1.13). For instance, sighting a hazardous marine animal or the remains of fishing net would be a suitable occasion to use it. The signal is normally accompanied by the 'pointing' signal to indicate clearly the source of the danger. The normal response would be simply to keep clear of the problem.

Figure 1.13 Danger

1.10.3 "I'm out of breath" would normally be given to your buddy to indicate you want to slow down so that you don't become exhausted (Figure 1.14). Normally he or she will give the OK signal and slow down or stop.

1.10.4 “You or me” is simply a questioning signal to establish who should do something.

Figure 1.14 You or me (left), Out of breath

1.11 **Additional Signals**

1.11.1 These are not official signals but are ones that are very effective so they have become widely used. Some examples are shown in Figure 1.15

1.11.2 “Show me your contents gauge” is the signal the dive leader should give from time to time, especially with trainees, to ensure that everyone in the group has enough air.

1.11.3 “I am Cold” (left) and “I am narcosed” or giddy (right) are signals which are used to convey to that the individual is either feeling chilled or that he/she is experiencing the effects of nitrogen narcosis (the ‘narks’). The way of dealing with the former problem is to bring the dive to an end, whilst the effects of the second can be alleviated by ascending to a point where the symptoms are found to disappear. Both signals may be used in the ‘enquiry’ mode as well.

Figure 1.15 I am narcosed (left), Show me your contents gauge (middle), I am cold (right)

1.12 **Surfacing Procedures**

1.12.1 At the end of a dive, the surface should be approached in a smooth and controlled manner, with an arm outstretched (preferably the arm which does not contain the dump valve) above the diver, the hand forming an OK signal as shown in Figure 1.16. The individual should be looking up towards the surface as the final approach is made, to ensure that there are no boats, windsurfers or other surface hazards in the vicinity. It is also a good idea to listen carefully, for the noise of boat engines, as the ascent is made. A final rotation, just prior to emerging from the water, gives safety coverage through 360^{o}.

Figure 1.16 OK on surface

2 Ears, Sinuses and the Effects of Pressure

2.1 Overview

2.1.1 This lecture provides information on a number of laws of physics which are relevant to diving. It also gives an overview of the effects of pressure on various parts of the body.

2.2 Pressure

2.2.1 Air pressure is caused by the weight of air molecules in the atmosphere exerting a 'pressing' force. It is called atmospheric pressure and is measured in bar. In space, the absence of air means there is no pressure - thus it is 0 bar. The pressure gets higher and higher on approach of the earth's surface, such that at sea level the pressure is 1 bar (sometimes called 1 atmosphere or 1 atm). This is equivalent to 1 kg of force 'pressing' down on every square centimetre of surface. This pressure does not cause any discomfort, as it is 'equalised' (or the same) in all of the air spaces in a human body.

2.2.2 Entering the sea and going progressively deeper, the pressure is the combination of both the air and the water force, so it increases progressively. At 10 metres depth, the weight of water pressing on a body is equivalent to the pressure of the atmosphere at sea level. In other words, the pressure from 10 metres of water is equivalent to the pressure exerted by the whole atmosphere. Each 10 metres of water results in another bar of pressure. Ambient pressure is the pressure surrounding the diver and is shown in Table 2-1.

Depth	Ambient Pressure
0m (Sea level)	**1 bar**
10m	**2 bar**
20m	**3 bar**
30m	**4 bar**

Table 2-1 Ambient pressure at depth

2.2.3 In air and water pressure acts in all directions, i.e. at 30m depth a body surface is subjected to 4 bar of pressure distributed uniformly.

2.3 Measuring Pressure

2.3.1 When measuring pressure, instruments are normally related to atmospheric pressure i.e. a simple gauge reads zero when the pressure is 1 bar, due to atmospheric pressure. Thus the pressure gauge on a diving cylinder might read

2.3.2 200 bar, when it is actually 200 bar above atmospheric pressure. This is called **gauge pressure**. The real pressure is 201 bar. This is called the **absolute pressure**. In the table above, absolute pressure is used.

2.3.3 **NB: Absolute Pressure = Gauge pressure + Atmospheric pressure.**

2.4 Gas Laws

2.4.1 There are a number of gas laws relevant to diving. These govern how we use equipment and how we plan and conduct dives.

2.5 **Dalton's Law - Partial Pressure**

2.5.1 Air is a mixture of gases, containing approximately 80% nitrogen, 20% oxygen (for the purposes of easy calculation). In reality, there are also small amounts of other gases including carbon dioxide etc. Dalton's law of partial pressure states that in a mixture of gases, the pressure exerted by one of the gases Is the same as it would exert if it alone occupied the same volume.

Dalton's Law of Partial Pressures

The sum of the partial pressures in a mixture of gases is equal to the total pressure of that gas. (Assumes constant temperature and volume)

2.5.2 For example, since air has 80% nitrogen and 20% oxygen, 80% of the pressure is caused by the nitrogen and 20% by the oxygen.

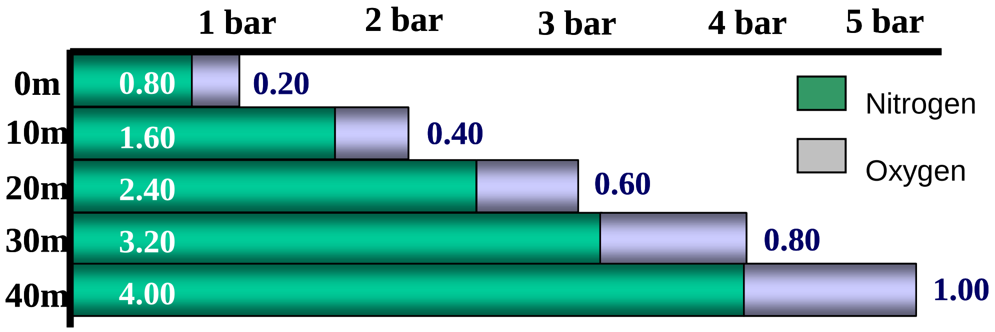


Figure 2.1 Partial Pressure of Air

Air at 1 bar pressure:
Partial pressure of nitrogen = 80% of 1 bar = 0.8 bar
Partial pressure of oxygen = 20% of 1 bar = 0.2 bar.

Air at 4 bar pressure
Partial pressure of nitrogen = 80% of 4 bar =3.2 bar
Partial pressure of oxygen = 20% of 4 bar = 0.8 bar

2.6 **Boyles Law - Pressure and Volume**

2.6.1 Consider a balloon full of air, which has been blown up at sea level. If this balloon was taken on a dive, it will be become smaller with depth, as the pressure acting on the balloon forces the air in the balloon into a smaller volume. This is shown in Figure 2.2. Conversely, if the balloon were taken up through the atmosphere, the pressure acting on it would decrease and the balloon would increase in size as the air within it expanded.

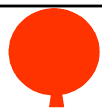
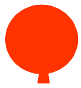
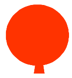
Depth (m)	Pressure (bar)	Volume	
0	1	One	
10	2	Half	
20	3	Third	
30	4	Quarter	

Figure 2.2 Effect of pressure on volume

Boyles Law
Pressure varies inversely with volume, i.e. the greater the pressure, the smaller the volume will be.

2.6.2 This relationship between pressure and volume is fundamental to diving. It governs the principles of buoyancy and has important safety implication which will be discussed in later lectures.

Mathematically:
$P_1V_1=P_2V_2$
P_1= initial pressure V_1= Initial volume
P_2= final pressure V_2= final volume
(for a fixed temperature)

2.7 **Henry's Law – Absorption of gas in liquid**

2.7.1 Henry's Law is very important when understanding the causes of decompression sickness. It governs the way in which our body absorbs and releases nitrogen. This will be discussed fully in later lectures.

Henry's Law
The amount of gas that dissolves in a liquid with which it is in contact is proportional to the partial pressure of that gas.

2.8 **Gay-Lussac Law - Pressure and Temperature**

2.8.1 This gas law is particularly significant when charging a cylinder. The process of charging a cylinder will heat up the outside of the tank. When the cylinder cools down, there will be a resulting drop in pressure. The faster a cylinder is filled, the hotter it will become and the more the pressure will drop when it cools.

Charles' law (Gay-Lussac)
For any gas at constant volume, the pressure of the gas will vary directly with the absolute temperature

2.9 Air Spaces in the Human Body

2.9.1 Air is held in the human body in a variety of places. The main locations are: ears; sinuses; respiratory airways; lungs; stomach and gut. The rest of the human body can be assumed to be either liquid or solid and is not affected by pressure to the same degree.

2.9.2 Any compressible airspace in the diver's body will be affected by pressure and will vary in volume, according to Boyle's Law. As a diver descends, the increasing pressure will compress the air spaces in the body into a smaller volume (known as 'squeeze'). Similarly, on ascent, the reverse occurs and the air spaces will expand as the pressure decreases.

2.10 Ears

2.10.1 The effects of pressure is felt particularly in the ears. The ears are very sensitive to pressure and will be affected within about 2 metres of leaving the surface e.g. the effect is noticed diving to the deep end of a swimming pool. Figure 2.3 illustrates the internal ear spaces. On descent, increasing external water pressure will force the air in the middle ear to compress, pushing the eardrum inwards and causing feelings of discomfort. It is essential that the diver takes immediate action to equalise the pressure in the ears, as damage to the eardrum can occur very easily (Aural Barotrauma). This is normally achieved by the following method:

2.10.2 Holding the nose and blowing gently down through it. This is termed the Valsalva manoeuvre, or simply 'ear clearing', and can be accomplished by using the nose pocket in the front of the mask. Air is forced into the middle ear through the Eustachian tube, such that the pressure on both sides of the eardrum is the same and the discomfort alleviated. Some individuals can achieve the same effect by swallowing hard, waggling their jaws or lifting the base of the tongue. It is important to remember not to use excessive force when attempting to clear, as it

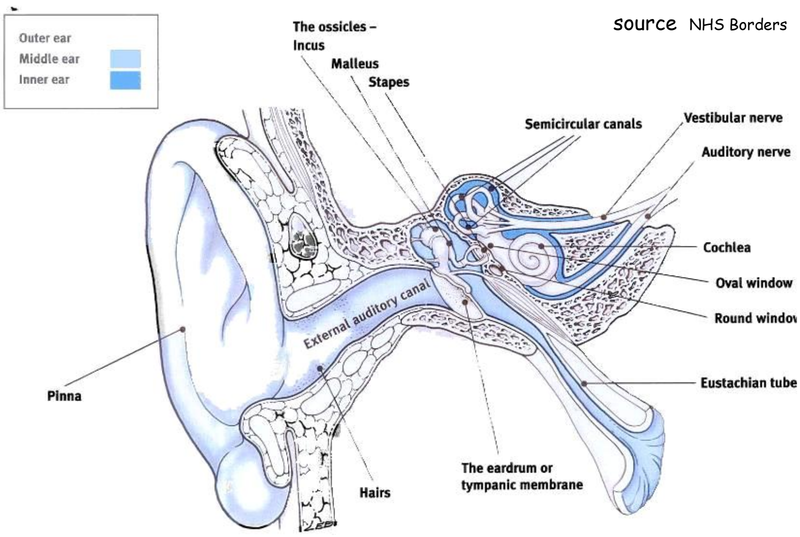


Figure 2.3 Internal ear spaces

is possible to damage the eardrum by using this technique. In the event that the ears will not clear, the diver must first stop descending, ascend a few metres and try again until successful. It is best to descend in a head-up position to facilitate clearing.

2.10.3 During the dive, it may be necessary to equalise the ears regularly. On ascent at the end of the dive, the reverse happens: the air in the middle ear expands, pushing the eardrum outwards. Air should automatically be released through the Eustachian tubes back into the throat to equalise the pressure. Problems can sometimes occur with dive hoods that are very tight-fitting. Ear equalisation difficulties during ascent are, however, uncommon.

2.10.4 Failure to dry ear spaces following a dive may lead to a feeling of imbalance. This is known as Vertigo.

2.10.5 Ear-plugs should never be worn whilst diving, as they effectively cause a pressure drop in the outer ear canal during descent, causing there to be pressure exerted on the drum from the middle ear.

2.10.6 Never dive with a cold or other respiratory infection. This makes the process of equalisation difficult, at best, or altogether impossible. Even if pressure damage does not occur, there is a possibility of forcing infection down the Eustachian tubes and into the middle ear, with the risk of permanent hearing damage.

2.11 **Sinuses**

2.11.1 The sinuses are air filled spaces inside the bone of the skull and are connected to the upper nasal passages (Figure2.4). They exist to effectively reduce the weight of the skull and to protect against infection. They tend to equalise pressure automatically as long as they are healthy. In the event of a cold or any kind of nasal infection, hay fever or heavy catarrh, the passages connecting the sinuses (and ear) to the throat will be inflamed and may be clogged up or closed by mucus. IF THIS IS THE CASE, DO NOT DIVE. It is unlikely that the diver will be able to equalise the sinuses on the way down or on the way back up and this will result in painful pressure damage (sinus barotrauma). Using decongestant medicines may help an individual make a descent, but the implications of such tablets wearing off prior to the conclusion of the dive should be fully considered. Additionally, increased pressure may alter the medication’s effects with potentially serious consequences.

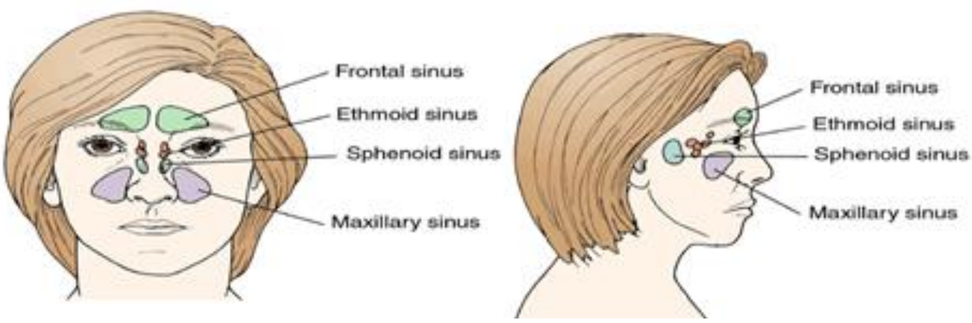


Figure2.4 Sinuses

2.12 Lungs

2.12.1 The air in the lungs will compress on the dive, and so will the total lung volume, on a ‘breath-holding’ (i.e. snorkel) dive. When breathing compressed air at ambient pressure, the lung volume remains constant, thus each breath taken will contain the same total amount of air as a breath at the surface.

2.12.2 On ascent, the air in the lungs will expand. If the diver has a cold, so will any pockets of air, which may be trapped in the lungs by mucus. Furthermore, if breath is held on ascent, there is a likelihood of pressure damage to the lungs, with potentially fatal consequences. This is Pulmonary Barotrauma. It is easy to avoid:

- NEVER HOLD YOUR BREATH FOR ANY REASON
- NEVER DIVE WITH A COLD
- BREATHE NORMALLY AT ALL TIMES

2.13 Other Air Spaces

2.13.1 It is possible to experience pain caused by air cavities in dental fillings (especially old fillings) This is Dental Barotrauma. It is rectified by a visit to the dentist and replacement of the filling(s). Mask squeeze is another potential problem. The air in the mask is a compressible space, and will be reduced in volume on descent. This can lead to discomfort if not equalised by exhaling some air through the nose into the mask, on descent or at any time during the dive when the mask feels uncomfortable.

3 Aqualung Use and Buoyancy Control

3.1 Overview

3.1.1 This lecture covers the basic components which make up the aqualung and describes their use. The principles of aqualung use and buoyancy control are discussed.

3.2 The Cylinder

3.2.1 The diver's air supply is contained in one or more high pressure cylinders. Cylinders come in a variety of sizes and working pressures. Common cylinder sizes include 3, 7, 10, 12, 15 and 18 litres as shown in Figure 3.1. Common working pressures are 232 and 300 bar. The size and working pressure of a cylinder will determine the amount of air you carry as a diver.

Figure 3.1 Types of cylinders

3.2.2 Cylinders can be fitted with either an A-clamp or Din fitting pillar valve (Figure 3.2).

3.2.3 An A-Clamp is suitable for pressures up to 232 bar. Before fitting a regulator to an A-clamp it is important to check the O ring is properly seated.

3.2.4 Din fitting pillar valves can be used to pressures up to 300 bar. As the O-ring is enclosed within the pillar valve it is less liable to sealing problems.

Figure 3.2 Cylinder pillar valves and first stages

3.2.5 Converters are available to convert Din fitting pillar valves to A-clamp – a small threaded insert is placed into the pillar valve. However, 300 bar Din fittings cannot be converted for safety reasons. It is also possible to convert a valve from Din to A-clamp by use of a converter which screws onto the end of the 1st stage thread.

3.3 Regulators

3.3.1 Regulators consist of a first and second stage. The first stage regulates air from the cylinder at high pressure, to an intermediate pressure of 8-12 bar. The second stage regulates air from intermediate to ambient pressure, allowing the diver to breathe air on demand.

3.3.2 The first stage will contain a variety of HIGH PRESSURE (HP) and LOW PRESSURE (LP) ports. A contents gauge can be connected to a HP port, and will give a reading of the remaining pressure in a cylinder (usually in bar). The second stage, together with any suit / BCD inflators, are connected to LP ports. The full configuration is shown in Figure3.3.

Figure3.3 Regulator configuration

3.4 Different types of Buoyancy Compensator

3.4.1 Adjustable Buoyancy Life Jacket (ABLJ)

Figure 3.4 ABLJ

3.4.1.1 The adjustable buoyancy life jacket (ABLJ) was, on introduction, a major contribution to more relaxed and safer diving. The in-built emergency inflation system of the ABLJ is a small air cylinder of about 0.4l volume. When this cylinder is filled from a normal diving air supply it has about 80 litres of air available for inflation of the lifejacket. To ensure that this supply is always available, the diver refills the small cylinder from the main diving cylinder at the start of every dive. This guarantees that there is a full emergency inflation system present. Air is fed into the jacket by opening the twist-grip valve on the small cylinder.

3.4.1.2 The ABLJ is usually fitted with an oral inflation tube with a valve-operated mouthpiece. The tube is held above the head and the mouthpiece valve operated to allow the air in the jacket to escape. For normal buoyancy control air is supplied to the jacket by a direct-feed from the aqualung (this is controlled by an inflation button, situated next to the mouthpiece).

3.4.1.3 Most ABLJ's are fitted with cord-operated vent valves (dump valves). These make the procedure of dumping air even easier – pulling the cord causes the air to escape. This valve may incorporate the excess pressure valve (needed to prevent over-inflation). Since the small cylinder contains an appreciable quantity of breathable air, in the unfortunate circumstance of running out of air it is possible to breathe from the contents. This technique requires considerable practice to avoid becoming over buoyant or breathing in water. Some ABLJ's are fitted with an automatic mouthpiece (a sort of basic demand valve) which makes emergency breathing much easier.

3.4.2 Stability (STAB) jacket

3.4.2.1 This is shaped like a waistcoat, and is usually attached to the diving cylinder. It can eliminate the need for a harness, and is very comfortable to wear. Many jackets have inflatable areas at the diver's back, front and sides. While swimming horizontally, air for buoyancy adjustment will be located in the small of the back. When fully inflated, the air will be in the front of the jacket causing the diver to float face upwards. Stab jackets may use small air cylinders for emergency inflation and have direct feeds for routine buoyancy adjustment.

Figure 3.5 STAB Jackets

3.4.3 Wings

3.4.3.1 The wings style stab jacket is designed for more specialist divers ('technical' divers) who often require more than one cylinder. The buoyancy is all provided behind the diver, holding them in a horizontal position whilst diving. A lot more buoyancy is provided with wings to compensate for the weight of the extra tanks. However, wings have a tendency to position an unconscious diver face down on the surface.

Figure 3.6 Wings

3.5 Aqualung Assembly

3.5.1 Fit the tank to the BCD/Wing as tightly as it will go. Make sure the hole in the pillar valve faces forwards. If pillar valve is of A-clamp type, ensure that the O-ring is in place and in serviceable condition.

3.5.2 Fit the regulator (demand valve) to the pillar valve of the tank, making sure the regulator is seated correctly on the O-ring (A-clamp) or screwed to hand tight (Din).

3.5.3 Hold the contents gauge with the glass facing away from you or anyone else as a precaution against breakage during pressurisation. Holding it against the ground or the side of the tank is a good idea. GENTLY turn on the pillar valve (anti-clockwise). Never look at the contents gauge while turning the air on. Wait until the hissing of air has stopped. If there are any obvious leaks turn off the air, purge regulator and reseat.

Figure 3.7 Aqualung assembly

3.5.4 Check the regulator will supply breathing air from the mouthpiece. 'Taste' the air, as contaminants due to a faulty compressor may be noticeable. Ensure the volume of available air is sufficient to meet your dive plan and discuss with your dive leader or instructor.

3.5.5 Turn off the air and examine the contents gauge. The indicating needle should remain in its original (pressurised) position. If it falls towards zero, it is an indication of a leak in the system and should be investigated further. If all is well, breathe from the regulator. After two to five breaths the valve should resist giving air and the contents gauge should read zero. If the regulator continues to give air, there is a major leak in it and it is unsafe to dive with.

3.6 **Fitting of the Aqualung**

- Ensure that the BCD/Wing is fitted as tightly as possible, and that both of the shoulder straps are connected.
- Lift the aqualung onto your back. It is quite heavy: you may want to get someone to help you.
- Pull the shoulder straps as tight as possible.
- Connect the waist strap, and pull it as tight as is comfortable.
- Connect any other straps (e.g. chest or crotch straps).
- Connect direct feed to suit

3.7 **Buddy checks**

3.7.1 The buddy check is carried out by each diver once the diver and his or her buddy are fully kitted and ready to enter the water. The basic routine is:

- Check that all straps are fastened correctly and ensure that the weight belt and aqualung waist straps are distinct and separate.
- Ensure that the air is turned on. A couple of breaths should be taken from the regulator, whilst checking the contents gauge for any fluctuations. Any change of indication means that the air supply is not functioning properly.
- Ensure that all their direct feeds are working properly. Establish where the relevant dump valves are.
- Ensure that the drysuit (if worn) zip is properly closed
- Check the presence and location of all other essential items of diving equipment.
- Demonstrate any unusual or different signals e.g. diabetics signal

3.7.2 Further details on buddy checks is given in Lecture 10.

3.8 **Buoyancy – Archimedes' Principle**

3.8.1 ARCHIMEDES PRINCIPLE (Figure 3.8) states that if an object e.g. diver is immersed in water then it will receive an upward thrust equal to the weight it displaces or the volume it occupies.

Figure 3.8 Archimedes' Principle

3.9 **Buoyancy Control**

3.9.1 Buoyancy control is probably the most important diving skill and is employed on every single dive. Successful mastery of this skill will make diving more enjoyable, comfortable and considerably safer. When diving, it is normally desirable to keep buoyancy neutral. A diver is neutrally buoyant if he or she slowly begins to sink when breathing out and gently ascends when breathing in. Thus, neutral buoyancy underwater is essentially a state of weightlessness and is akin to flying. Objects which float in water are said to be positively buoyant and objects which sink are termed negatively buoyant.

Figure 3.9 Diver demonstrating neutral buoyancy

3.9.2 A diver's static buoyancy is affected to a considerable degree by the equipment worn for diving and by the build and weight of the individual.

3.9.3 Control of dynamic buoyancy is achieved in two ways: coarse buoyancy control is achieved by the inflation or deflation of the BCD, wing or dry suit; fine buoyancy control is achieved by the diver controlling the amount of air contained in the lungs. A degree of positive buoyancy can also be achieved by finning action: this is the principle of treading water.

3.10 **Wetsuit or Semi-Drysuit diving**

3.10.1 On the surface, wetsuits are very buoyant due to gas bubbles trapped in the expanded neoprene rubber they are made of. As the diver descends the bubbles of gas compress and therefore the suit loses buoyancy. Thus a correctly weighted diver (i.e. neutrally buoyant) at the surface (with an empty buoyancy aid) will be negatively buoyant at depth (the diver will sink deeper). To combat this the buoyancy aid is partially inflated to regain neutral buoyancy. During the dive, neutral buoyancy is maintained by partially inflating and deflating the buoyancy aid as necessary.

3.10.2 **Drysuit diving - Membrane Drysuits**

3.10.2.1 The only factor that affects the buoyancy of a membrane drysuit is the air inside it. Any air in the suit on the surface will compress as the diver descends, causing negative buoyancy and discomfort due to the suit pressing against the diver's body. Therefore, instead of using the buoyancy aid to compensate for loss of buoyancy, more air is introduced into the suit to compensate instead. Neutral buoyancy is maintained by this introduction of air, with any excess being dumped through a valve fitted to the suit.

3.10.3 **Drysuit diving - Neoprene Drysuits**

3.10.3.1 The situation with neoprene drysuits is the same as with membrane drysuits, except there is the added complication that the suit's buoyancy changes with depth, as with wetsuits.

3.10.4 Other factors that affect buoyancy and should be taken into consideration are:

- Aqualung : Aluminium alloy tanks are lighter than steel ones, therefore more weight will be required for a dive with an aluminium alloy tank than with a steel tank. Also, a tank's buoyancy increases as the volume of air inside the tank decreases, so there will be a variation in buoyancy depending on the capacity of the cylinder.
- Breath Control: If the lungs are kept full during the dive, 1 or 2kg more buoyancy will be achieved as compared to the case when the lungs are empty. Note that it is dangerous to keep the lungs full, especially on ascent as there is the danger of pulmonary barotrauma, if the air contained is not expired by breathing normally. However, fine buoyancy control can be achieved by varying the amount of air in the lungs.
- Use of fins: Somewhere between 1.5 and 3kg of thrust from the fins is achievable over a sustained period.
- Weightbelt: judge the weight to be put onto the belt, by taking into account the increase in buoyancy as the air is used up from the aqualung, as well as the size and material of the cylinder. Essentially, a diver is correctly weighted if he or she can remain just neutrally buoyant at a depth of 3m, wearing full equipment and with virtually all air removed from the dry suit or buoyancy aid (and an air volume of less than 500 litres in the air cylinder). This is so that if a diver should be in a low air situation but still have sufficient air for a safety or decompression stop he / she will still be able to hold neutral buoyancy at 3 to 4 metres for the duration of that stop.
- Use of extraneous objects: Accessories will add to the diver's total negative/positive buoyancy according to their characteristics. The use of devices such as a Surface Marker Buoy (SMB) or Delayed Surface Marker Buoy (DSMB) can result in increased positive buoyancy.
- Fresh or Sea water: The salt in sea water makes it slightly more dense than fresh water. As a result divers moving from salt to fresh water may need to decrease the amount of weight on their weightbelts accordingly.

4 Respiration, Hypoxia, Anoxia, Drowning and Hyperventilation

4.1 Overview

4.1.1 This lecture describes the process of respiration and discusses the cause, signs and symptoms of hypoxia, anoxia, drowning and hyperventilation.

4.2 Respiration

4.2.1 What is Respiration?

4.2.1.1 Respiration is the process by which OXYGEN (O_2) is transported from the air that is breathed to the body tissues, and by which CARBON DIOXIDE (CO_2) produced in these tissues is vented to the air. This process becomes clear when the composition of inhaled (breathing in) and exhaled air (breathing out) is examined:

% Composition	Inhaled Air	Exhaled Air
Nitrogen (N_2)	78	78
Oxygen (O_2)	21	16
Carbon Dioxide (CO_2)	Trace	5
Other gases	1	1

Figure 4.1 Composition of inhaled and exhaled air

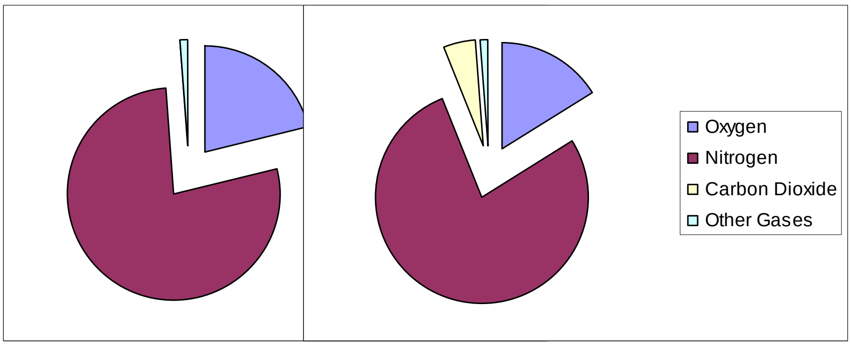


Figure 4.2 Composition of inhaled (left) and exhaled air

4.2.1.2 It is apparent that whilst the air has been in the lungs, some of the oxygen has been used and a small amount of carbon dioxide added. Note that nitrogen is not involved in this process (i.e. it is non-metabolic), so that its contribution remains unaltered. It is important for other reasons (e.g. it is responsible for nitrogen narcosis and decompression sickness).

4.2.2 Why is Respiration necessary?

4.2.2.1 In the same way that a fire needs oxygen to burn (i.e. to release the chemical energy in the fuel e.g. coal), a human body needs oxygen to release energy from food. Carbon dioxide is a waste product of this process and needs to be removed from the body. The process is known as metabolism.

- **Food + O_2 = Energy + CO_2 +WASTE PRODUCTS**

4.2.3 **How is breathing accomplished?**

4.2.3.1 Air is drawn into the lungs by the action of intercostal muscles and the diaphragm. To breathe in, the rib cage is pulled up and the diaphragm down. This increases the volume of the lungs, causing the internal pressure to fall and air to move in to fill the space. Breathing out is the reverse of this action. The lungs are 'squeezed' by letting the rib cage fall and pulling the diaphragm up, which results in the air being pushed out.

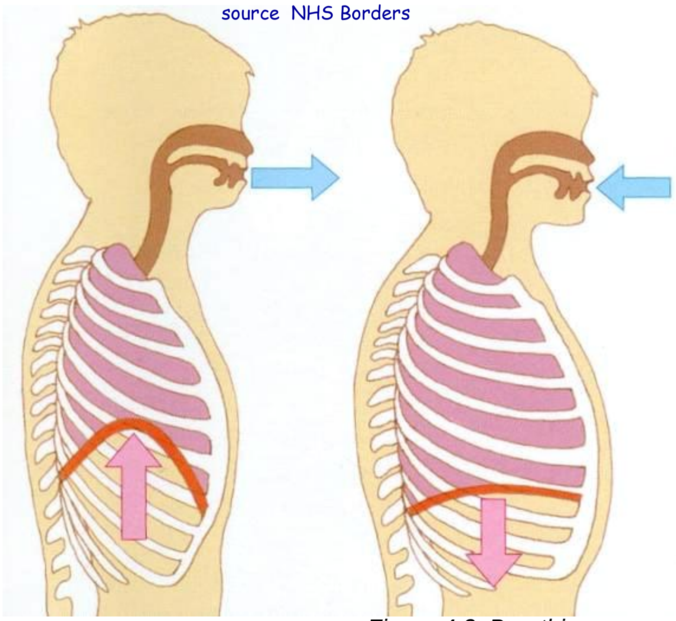


Figure 4.3 Breathing process

4.3 **Airways**

4.3.1 The path by which air enters the lungs is as follows:

- Mouth & Nose => Larynx => Trachea => Bronchi => Lungs (Alveoli).
- It leaves in the reverse direction.

4.4 **The Lungs**

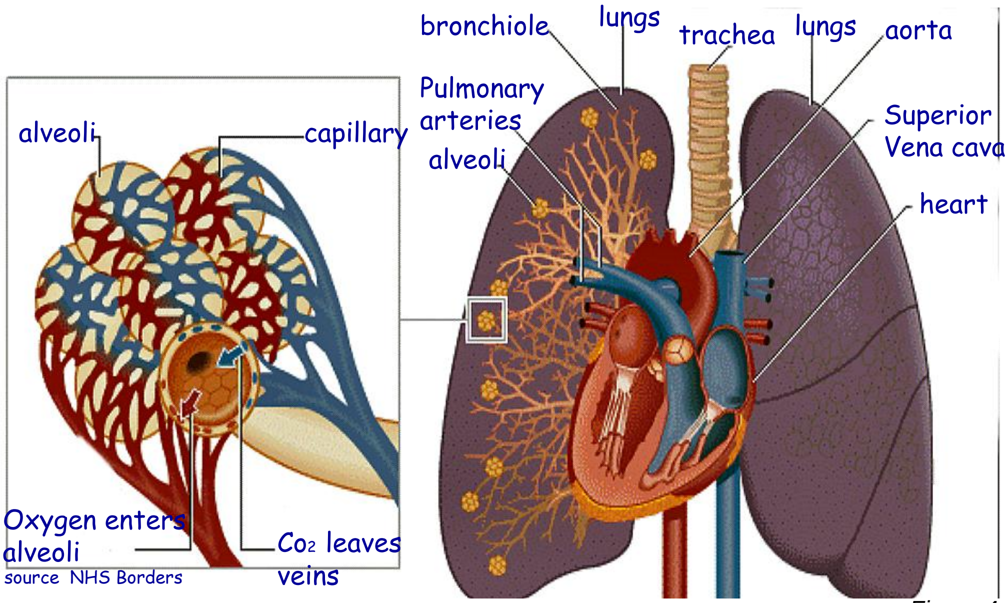


Figure 4.4

4.4.1.1 The lungs are the organs where the exchange of gases between the atmosphere and the blood takes place. They occupy, along with heart, almost all of the chest cavity. The lungs are rather dense organs, similar in structure to a sponge. The holes in this 'sponge' are represented by air spaces, within which air is continually moving in and out and the structure of the sponge is the small blood vessels, called CAPILLARIES, which contain de-oxygenated blood. These air spaces are actually microscopic sacs, called ALVEOLI. Their function is to allow the transfer of O2 and CO2 between the air in the sac and the de-oxygenated blood surrounding it, with O2 moving from the air to the blood and CO2 from the blood to the air. The lungs are completely filled with alveoli, providing a surface area equal to the size of a tennis pitch over which gaseous exchange can occur.

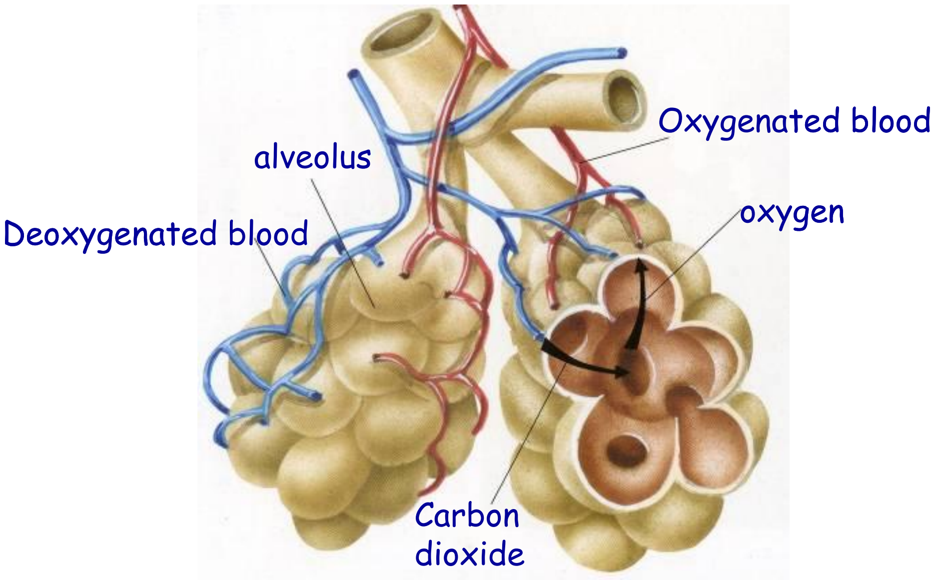


Figure 4.5

4.4.2 **Lung Capacity**

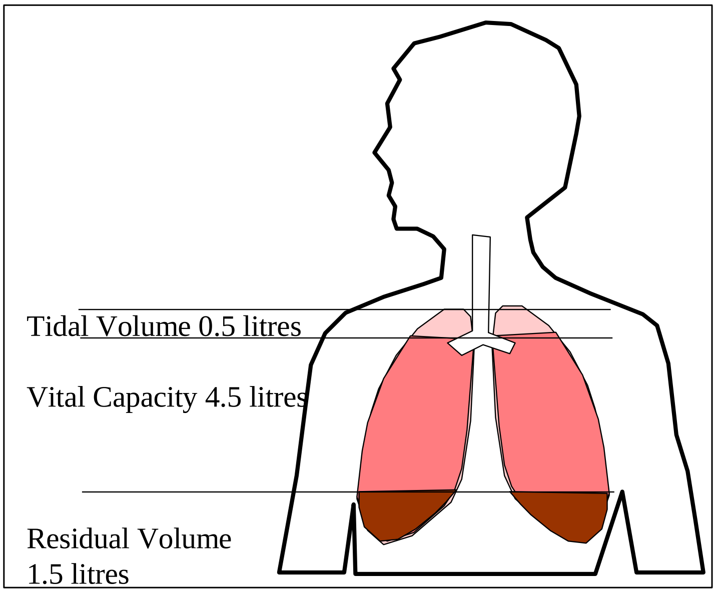


Figure 4.6 Lung volume

4.4.2.1 The total volume of air that the lungs can hold varies with the size of the person – the average person can hold about 6 litres. At rest only 0.5 litre is breathed in and out with each breath - this is known as the tidal volume. Vital Capacity is the maximum amount of air we can breathe in one breath – normally around 4.5 litres. The difference between total and residual lung capacity is known as the residual volume – normally c. 1.5 litres. Residual volume is of importance to snorkel divers. A diver with full lungs on surface (6 litres at 1 bar) will have only 1.5 litres at 30m. After this point the volume of air in the lungs becomes less than the residual volume and the increased pressure compresses the chest and may lead to lung damage.

4.4.3 The Blood Stream

4.4.3.1 Oxygen is transported round the body via the blood. It is principally carried via RED BLOOD CELLS. These are shaped like discs, to maximise their surface area and so make gaseous exchange easier. The cells are full of a compound called HAEMOGLOBIN, which has a strong affinity to oxygen. When oxygen comes into contact with a molecule of haemoglobin, it seizes it and forms a molecule of OXYHAEMOGLOBIN. This moves around the body to where it is needed, whereupon the oxygen is released and the molecule reverts to being haemoglobin. Oxygen also dissolves in the blood plasma and is transported in that way. Carbon dioxide is also transported via the blood, mostly in solution.

4.4.4 The Circulatory System

4.4.4.1 Blood is transported around the body by means of a highly efficient pump: the heart. It circulates blood within a closed circuit system known as the CIRCULATORY SYSTEM. This circulation takes oxygenated blood (oxygen rich, little carbon dioxide) from the lungs to those tissues which require it and de-oxygenated blood (oxygen depleted, carbon dioxide rich) back to the lungs, where the CO_2 is vented and more O_2 is captured. This process is illustrated in Figure 4.7.

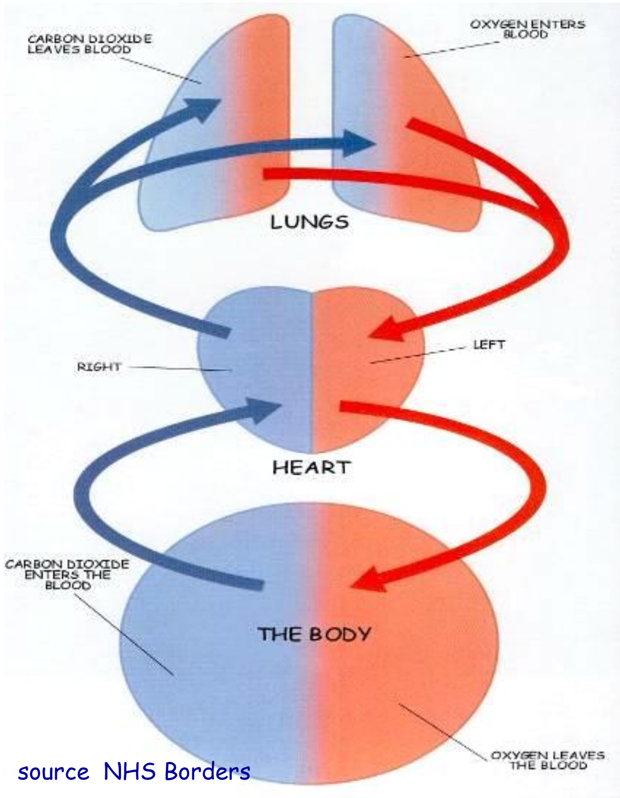


Figure 4.7 Circulatory system

4.4.5 **Where does the desire to breathe originate?**

4.4.5.1 The breathing rate (i.e. the number of breaths taken per minute) varies depending on the work rate. Thus the harder the work rate, the more air is taken. This occurs because energy is being burned faster and so there is a need to consume more oxygen. The trigger for the breathing action is not, however, the amount of oxygen in the blood, but rather its pH. Carbon dioxide dissolves in the blood to form a weak acid called CARBONIC ACID ($CO2+$ water). The more carbonic acid in the blood, the lower the pH, and the greater the desire to breathe.

4.5 **Hypoxia and Anoxia**

4.5.1 **What Are Hypoxia & Anoxia?**

4.5.1.1 It has already been established that a body's demand for oxygen varies proportionally with the workload. Hypoxia describes a situation where an insufficient amount of oxygen is received. This term can apply to the entire body or to specific organs e.g. the brain. It is defined as a partial lack of oxygen. If steps are not taken to increase the supply of oxygen, Anoxia can result, which is the complete absence of oxygen. Body cells cannot survive without oxygen. Brain cells are particularly sensitive and can die within as little as 4 minutes.

4.5.2 **How It Can Occur?**

4.5.2.1 Hypoxia can occur for a number of reasons:

- There is an obstruction of the airway
- There is too little oxygen in the breathing gas (partial pressure < 0.14 bar);

- The lung(s) is/are damaged or diseased e.g. a burst lung;
- Carbon monoxide poisoning has occurred (CARBOXYHAEMOGLOBIN);
- The heart is unable to pump with sufficient force to supply all the body tissues
- An extraordinary incident such as hyperventilation or drowning

4.5.3 **Symptoms - Subjective/Objective**

4.5.3.1 There are many symptoms of hypoxia, depending on its severity:

- drowsiness
- lack of co-ordination
- headache
- increased respiration and pulse rate
- lips/nails/ear lobes turning blue (cyanosis)
- unconsciousness and death

4.5.4 **Treatment**

4.5.5 Restore a supply of oxygen (at least 0.16 Bar absolute) as soon as possible, using pure oxygen if available. If the victim is not breathing, Rescue Breathing and perhaps CPR will be necessary.

4.6 **Drowning**

4.6.1 Drowning prevents oxygen from reaching the body tissues i.e. it causes hypoxia. The term, strictly speaking, should only be applied if death occurs. Individuals who inhale water but are resuscitated have experienced a 'near drowning' situation. Drowning is the ultimate cause of death in most diving fatalities.

4.6.2 **Types of Drowning**

4.6.2.1 **White or Wet Drowning**

4.6.2.1.1 This is a much more severe, and more likely to be fatal, form of drowning, in which water enters the lungs. There are two types:

- Seawater Drowning: Water is removed from the blood by osmosis, leading to HAEMOCONCENTRATION. This can put a great strain on the heart.
- Freshwater Drowning: This is the more severe situation. Water rapidly enters the bloodstream, again by osmosis, causing HAEMODILUTION. This causes the red blood cells to burst and subsequent heart fibrillation, leading to rapid death from hypoxia or heart attack.

4.6.2.2 **Blue or Dry Drowning**

4.6.2.2.1 No water enters the lungs as a result of an EPIGLOTTAL SPASM, which seals off the trachea. However, water may enter the stomach. Hypoxia will occur and, unless breathing is restored, anoxia will result followed by death.

4.6.2.3 **Secondary Drowning**

4.6.2.3.1 A small amount of water in the lungs causes irritation. Fluid produced in the lungs as a result can accumulate to cause drowning up to 72 hours after the original near drowning incident

4.6.2.3.2 Casualties who have suffered near drowning must always be seen by a doctor as soon as possible, even if they appear to have recovered.

4.6.3 Treatment

4.6.3.1 Clear the airway, and apply Rescue Breathing / CPR as necessary. Always seek professional medical help: secondary drowning ,due to the lungs filling up with fluid because of damage to the alveolar membrane, can occur up to twelve hours after the original incident.

4.7 Hyperventilation

4.7.1 How Does It Occur?

4.7.1.1 The object of hyperventilation, before a breath-holding dive, is to increase the length of time the diver can remain underwater. It may be accomplished by taking a series of very deep breaths prior to breath-holding and commencing the dive. This, in effect, significantly reduces the level of CO_2 in the body and only marginally increases the O_2 level. Thus the CO_2 breathing trigger is at an artificially low level at the start of the dive. During the dive, especially with the diver finning hard, O_2 is being used up rapidly. However, the desire to breathe is suppressed due to the low level of CO_2 The outcome of this is that the secondary receptors in the heart and brain detect the lack of O_2 , before the CO_2 trigger is reached. The diver then lapses into unconsciousness.

4.7.2 Why Does It Happen?

4.7.2.1 After the first two or three breaths the haemoglobin in the blood is saturated with oxygen. Subsequent breaths add no more oxygen, but remove more and more CO_2 from the bloodstream, increasing the pH of the blood. When the dive begins, the body starts to use up the available oxygen, generating CO_2 in the process. However, because the amount of CO_2 in the blood was reduced to a low level by hyperventilating, it does not build up to the level at which a breathing reflex is triggered until well after the diver has used up all the available oxygen in the blood (Figure 4.8). As a result the individual become seriously hypoxic and finally anoxic. The problem is exacerbated with depth and is common in persons engaged in commercial spear-fishing.

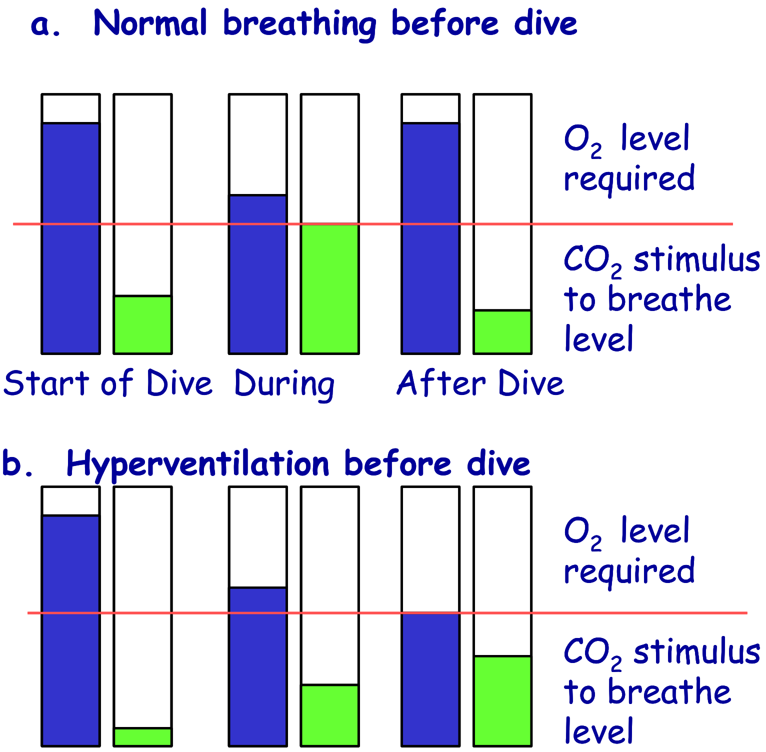


Figure 4.8 Oxygen and Carbon Dioxide levels

4.7.3 **What is the Safe Way to Swim Underwater?**

4.7.3.1 Take only 2 medium deep breaths, at most, before setting off on a breath-holding dive. Never overwork or linger at depth. Snorkel divers, like their aqualung counterparts, should always operate in pairs. One should remain on the surface whilst his/her buddy is diving. The divers should arrange to be buoyant from 10m upwards, as problems normally occur on ascent or at the surface

5 Burst Lung and Emergency Ascent

5.1 Overview

5.1.1 This lectures reviews knowledge of Boyle's law before describing the cause, signs and symptoms of a burst lung. The procedure for emergency ascent is also discussed.

5.2 Pulmonary Pressure Damage

5.2.1 Boyle's Law states that pressure varies inversely with volume. For a fixed mass of gas, the pressure increases as the volume decreases, and vice versa. A diver who fails to exhale while ascending runs the risk of over-expansion of the lungs. Air can be forced into the blood stream or can cause lung tissue to rupture, trapping air in pockets in the chest cavity. This condition is not preceded by any warning signals, as with the ears, as the 'full to bursting' sensation (Hering-Breur reflex) is very weak in human beings. The results of this are dramatic and often fatal. Injuries of this sort are collectively referred to as 'burst lung'.

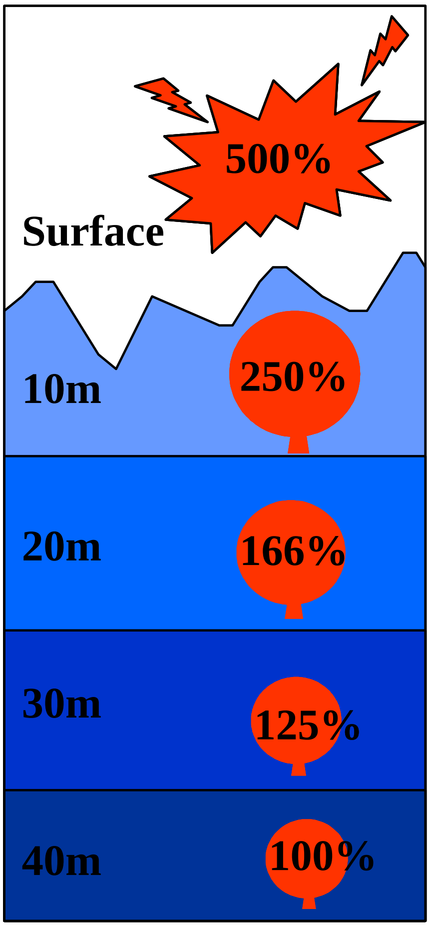


Figure 5.1 Effects of pressure on volume

5.2.2 Pulmonary Tissue Damage

5.2.2.1 This is the rupture of a few alveoli. It always precedes other types of burst lung. Symptoms include breathing difficulties, coughing and bloody sputum.

5.2.3 Air Embolism

5.2.3.1 An embolism is a blockage of circulation. The alveolar membrane can stretch, allowing tiny bubbles of air to enter the capillaries and thus the bloodstream. The circulation will carry these bubbles - which unite into larger bubbles - to the brain, heart and other vital organs where they could lodge, blocking further blood flow and thus oxygen supply. This is, in effect, a stroke and death can occur within seconds. Symptoms usually appear rapidly after surfacing: giddiness; numbness; paralysis; visual disturbances; respiratory difficulties; heart failure and death are all associated with this type of injury. N.B. This can occur from as little as 3m depth.

5.2.4 Spontaneous Pneumothorax

5.2.4.1 In some cases the alveolar tissue may suffer a major tear, allowing considerable quantities of air to escape outwards and become trapped between the lung sac and chest wall (Figure 5.2). As the ascent continues, the pressure of the trapped air will be greater than that of the air in the lungs, and this will cause the lung sacs to collapse. The lungs will then be starved of oxygen. Symptoms (in addition to the above) include severe pain on breathing, shortness of breath, coughing of blood and swollen appearance of chest cage.

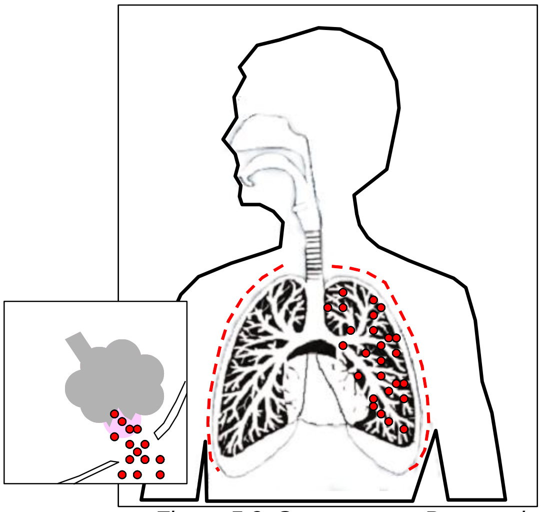


Figure 5.2 Spontaneous Pneumothorax

5.2.5 **Interstitial Emphysema**

5.2.5.1 Larger bubbles of air that escape from torn lung tissue can travel inwards between the lung sacs, into the vicinity of the heart and the major blood vessels (Figure 5.3). This trapped air will also have a serious effect on normal respiration. Symptoms include shortness of breath, swollen appearance of skin at base of neck and also those of air embolism.

5.2.5.2 It should be mentioned that air embolism may also be present in cases of pneumothorax and emphysema. Burst lung conditions can also include effects and symptoms of hypoxia, since normal respiration is upset, i.e. blueness of lips, ear lobes, finger nail beds, and unconsciousness.

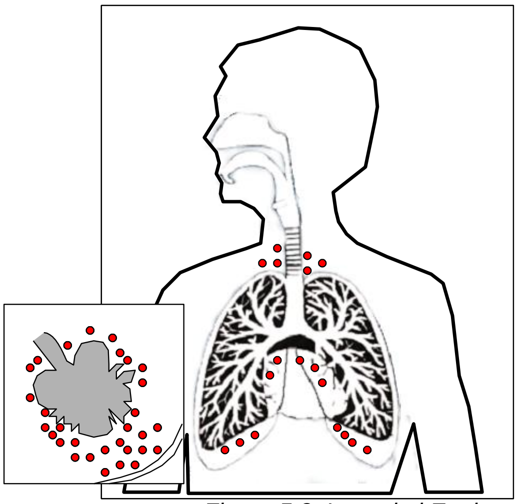


Figure 5.3 Interstital Enphysema

5.3 **Treatment for Burst Lung**

5.3.1 In all cases, oxygen should be administered immediately to the victim. The only successful treatment for air embolism is immediate recompression in a chamber. Pneumothorax and emphysema may require minor surgical treatment. Consequently, professional medical assistance should be sought immediately. The victim should be placed with the head lower than the feet, to encourage air away from the heart and brain. If breathing difficulties are experienced, they can be alleviated by administering rescue breathing.

5.4 **Prevention**

5.4.1 Every diver should successfully undertake a proper medical examination. Diseased lungs are weakened and are therefore more susceptible to damage. During colds, mucous clogs lungs and increases the risk of lung damage if diving is conducted. Most importantly:

5.4.2 ALWAYS BREATHE NORMALLY: NEVER HOLD YOUR BREATH

5.5 **Ascent Procedures**

5.5.1 **Normal Ascents**

5.5.1.1 This is the standard situation at the end of a dive.

- The diver exchanges ‘go up’ signal with buddy. ‘OK’ signals are also exchanged.
- Both divers fin gently upwards whilst monitoring depth gauge/computer, buddy and small bubble ascent rate.
- A rate of 10m/min should not be exceeded. Normal breathing must be maintained at all times. The divers should look up for surface obstacles or other hazards above (e.g. jellyfish, boats, other divers etc.).
- In a poor visibility situation, the diver should hold his/her hand above the head and hold on to buddy.
- As the divers pass the 10 m point, the ascent rate should be carefully controlled.
- The divers must stop at a depth of 3 metres to do the final safety stop of at least one minute. This will greatly reduce the chance of contracting decompression sickness etc.
- On surfacing, the divers should check all around (360^0 circle) for approaching vessels.
- The divers should exchange ‘OK’ signals with each other and the boat or shore cover. BCDs may be inflated.

5.5.2 **Emergency Ascents**

5.5.2.1 These occur most often through poor dive practice and not due to equipment failure. Running out of air is the most common reason.

5.5.2.2 **Assisted Ascent**

5.5.2.2.1 This procedure assumes that the buddy is in close proximity and his/her attention can be attracted quickly.

- The distressed diver gives the “I am out of air” signal.
- The assisting diver (AD) approaches from the right (due to position of regulator) as quickly as possible. The AD takes hold of buddy’s aqualung pillar valve or harness with left hand (diver being assisted takes buddy’s harness with right hand).
- AD takes gives buddy octopus
- Assisted diver breathes normally from octopus.
- When regular rhythm is established, donor gives “up” signal and checks rates of ascent.

5.5.2.2.2 NB At time of going to print, the National Diving Council of 2006 has suspended shared ascent exercises. This page should be updated if situation changes.

5.5.2.3 **Free Ascent (should never be practised)**

5.5.2.3.1 Used when contact with buddy cannot be made. This method is dependant on calm, controlled technique for its success.

- The diver immediately begins to fin steadily upwards.
- If this is found to be difficult, the weightbelt can be jettisoned.
- The diver should remove mouthpiece and exhale gently and continuously through pursed lips.
- As the diver approaches 10m, it is essential to start breathing out more forcefully to avoid serious pressure damage.

5.5.2.3.2 The feeling of air starvation may well diminish slightly if the breath is held BRIEFLY until the residual air in the lungs expands with the fall in the surrounding water pressure. Another breath may be obtained from the regulator for the same reason.

5.5.2.3.3 There will be enough oxygen in the bloodstream to supply muscles, carbon dioxide will be removed, therefore there should be no undue desire to breath. After this (or any) type of emergency ascent, the diver should be observed for any signs of pressure damage or decompression sickness.

5.5.2.4 **Buoyant Ascent (should never be practised)**

5.5.2.4.1 Most ABLJs and STAB jackets are fitted with direct feed and (occasionally) an emergency air cylinder, which can be used to bring a diver to the surface in an emergency.

- The weight belt must not be removed as it maintains correct body position.
- The ABLJ/STAB emergency cylinder tap is opened, or the direct feed button is depressed, just sufficiently to begin the ascent.
- As the ascent commences, the tap/direct feed should be turned off.
- The diver should lean back, breathe out and look towards the surface.
- The ascent rate may be controlled by venting the ABLJ/STAB/drysuit. Care must be taken not to vent excessively such that the diver becomes negatively buoyant and starts descending again.

5.5.2.4.2 NB Full inflation of an BCD induces an ascent rate of 120m/min, which could cause explosive decompression and air embolism.

6 Hypothermia and Protective Clothing

6.1 Overview

6.1.1 This lecture covers the cause, signs, symptoms and treatment of exhaustion, hypothermia and the use of protective clothing. Diving is a physically intensive sport where exposure to temperature extremes, above and below the water, is experienced. The nature of the sport presents health risks associated with exhaustion and hypothermia. It is thus important that divers are able to recognise the signs and symptoms of both conditions, as well as knowing how to deal with them.

6.2 Exhaustion

6.2.1 Exhaustion is a condition that is more easily recognised than defined, but may be described as a point where the individual is unable to respond adequately, either physically or mentally, to further demands. Within the context of diving, exhaustion may (most commonly) be due to physical exertion. It may also be attributed to mental/physical fatigue or the effects of depth and hypothermia. It is characterised by deep, laboured breathing. Exhaustion is a condition which must be avoided by divers because they are submerged in an alien environment which will not support life. Hence an inability to cope can lead to death by drowning.

6.2.2 Avoidance and Treatment

6.2.2.1 **Physical Exertion**: Hardworking muscles (lifting/finning) may become overloaded, causing lactic acid to be released. Lactic acid creates a dull ache in the muscles and increases the blood's acidity. This stimulates the breathing reflex in the same way as CO_2. The result is laboured breathing which will continue after the exertion has ceased, which allows the body to reclaim the oxygen debt built up by the exertion. It follows logically that it is in the interests of the individual to maintain a reasonable level of fitness for diving.

6.2.2.2 Avoid exhaustion by finning at a comfortable pace. If a diver should become breathless, a signal should be made to his/her buddy ('out of breath') and finning should cease. If there is a swell, tide or a strong current, it is better to find a secure object to hold on rather than expending energy against the elements. If submerged, it is essential to keep track of the depth and time. If there is nowhere secure, it is preferable to drift while carefully monitoring the depth/time/buoyancy. The diver should concentrate on controlling the breathing to a deep, slow rhythm. Once the diver feels comfortable again and has regained normal breathing, an 'OK' signal can be given to the buddy and the dive continued. It is important that the sequence of activities which contributed to the initial exhaustion is not repeated. Thus, it may be necessary to conclude the dive at this point.

6.2.2.3 If normal breathing cannot be regained, then the dive must be terminated. Appropriate signals should be exchanged and the divers should make a controlled ascent to the surface. In a severe situation, diver rescue may be necessary. When the surface is reached, the condition of the exhausted diver should be monitored. ABLJ/STAB jackets should be fully inflated. If conditions permit, the mask and demand valve should be removed. Appropriate signals, depending on the severity of the situation, should be given to the shore/boat cover. After regaining the shore/boat, rest and perhaps hot drinks should be administered and the individual's condition monitored. Shock can occasionally follow exhaustion.

6.2.2.4 **Hypothermia**: loss of body heat results not only in physical discomfort but also in slow mental reactions and loss of muscle power. It is an important, and often unrecognised, underlying cause of exhaustion and a contributing factor in many accidents. To continue with a dive whilst feeling chilled is not only foolhardy but also dangerous.

6.2.2.5 **Mental Fatigue or Stress** can also lead to exhaustion. Late nights, early starts, responsibility/organisation and equipment assembly are all factors in the exhaustion equation. Particularly problematic are dives late in the day and/or at the end of a diving weekend.

6.2.2.6 **Deep diving and Decompression diving** will make a diver more susceptible to exhaustion. As depth increases, so does air density and consequently breathing resistance. At 30m, the diver's maximum ventilation rate is halved and the ability to eliminate CO2 diminished. Thus, at depth, it becomes increasingly important to avoid heavy exertion in any form. Such behaviour is not only wasteful of air, but leads to exhaustion underwater. It can also lead to an increased likelihood of N_2 narcosis and decompression sickness.

6.2.3 Exhaustion avoidance:

- Minimise exertion whilst diving. The effects of tide, current and surface wind/swell should be taken into account. This will not only avoid the diver becoming exhausted, but is essentially good diving technique.
- Maintain a reasonable level of physical fitness.
- Do not dive if feeling tired, cold or unwell.
- Signal to dive buddy as soon as the effects of exertion are noticed.
- Take extra care at depth.

6.3 Hypothermia

6.3.1 Hypothermia is the depression of temperature in the body core. The temperature of UK seawater can vary from 4 -16^{0}C and the temperature in freshwater lakes and water-filled quarries can be as low as 0^{0}C. Water conducts heat 25 times better than air, so it is apparent that divers are particularly vulnerable to the condition of loss of body heat or hypothermia. The normal human body core temperature is 37^{0}C. The body is extremely sensitive to changes in deep core temperature and a drop of as little as 1^{0}C will cause shivering and discomfort. The rate of heat loss is related to the surface area of the body and the rate of heat production is related to body volume. Therefore, smaller individuals such as children are more susceptible to hypothermia because their surface area to body volume ratio is small. The extremities (hands, feet etc.) are less dependent on temperature and hence have a less extensive blood supply and can withstand mild coldness. This results in less heat being lost from these extremities, due to the reduced blood flow. This, in turn, increases the level of blood in the body core (CBV: Central Blood Volume) which increases the blood pressure and, consequently, the load on the heart. The body senses this and attempts to reduce the blood level by passing more water through the kidneys i.e. urine production is increased.

6.3.2 **Signs & Symptoms**

6.3.2.1 Core temperature is crucial and a fall of only 1-2 degrees C brings a flood of homeostatic mechanisms into place in an attempt to counteract further temperature reduction:

- Shivering - muscular respiration releases heat.
- Metabolic rate increases - to release heat.
- Goose pimples - body hairs trap air for thermal insulation.
- Vasoconstriction - blood vessels contract and minimise outflow from the body's core.

6.3.3 It should be stressed that there are considerable individual differences in the experience of and variability in reactions of different people to cold. Factors such as weight, fitness levels and overall health will effect the susceptibility to hypothermia.

Core temp (^{o}C)	**Symptoms**
35-36	Sensation of cold, numbness, 'goose pimples', controllable and then uncontrollable shivering occurs. Metabolic and respiratory rate increases.
34-35	Heat, metabolic, and respiratory rates begin to decrease, causing confusion, lethargy and behavioural changes.
33	Amnesia begins, Shivering stops and muscles become rigid. Mental confusion and communication difficulties. Semi-consciousness occurs.
30	Unconsciousness, pupil dilation, irregular respiration.
28	Respiration ceases, ventricular fibrillation.
25	Death

Figure 6.1 Symptoms of hypothermia

6.3.4 Treatment

6.3.4.1 Prevention of further heat loss is crucial. Remove from cold and protect from wind chill. For mild cases: if a dry location is available (i.e. not the case in an open boat), the casualty should change into warm clothing. They should be gently re-warmed by hot drinks and/or the use of an exposure blanket or even by others warming the victim with their own body heat. For serious cases: serious hypothermia is a life-threatening situation and requires urgent admission to hospital. Professional medical assistance should be sought immediately. It may be necessary to give CPR if the victim has no pulse and has ceased breathing. Handling of the casualty should be kept to a minimum. They should lie still with the feet raised to contain the blood within the body's core and so prevent shock, caused by a fall in blood pressure. An exposure blanket/other body warming method should be used, concentrated on raising the casualty's core temperature. The victim should be reassured and closely monitored until help arrives.

6.3.4.2 DO NOTS:

- Do not give alcohol. It causes blood vessels to dilate and permits cold peripheral blood to return to the body's core.

- Do not apply local heat or rub extremities. Cold blood may rush into the torso and cause a further drop in the core temperature. This is a major factor in ‘re-warming’ deaths and results in the heart being stopped either by the surge of cold blood or a reduction in blood pressure, due to peripheral vessel dilation. It is known as afterdrop.

6.3.5 **Preventing Hypothermia**

- Be aware of the signs & symptoms of hypothermia.
- Wear adequate protective clothing during the dive i.e. a wetsuit, or drysuit.
- Wear windproof and waterproof clothing, especially on the head, to prevent coldness before and after a dive.
- Be aware of the effects of wind chill.
- Take hot, high-energy drinks to help maintain body heat level.
- Terminate the dive if the feeling of cold persists.

6.4 **Protective Clothing**

6.4.1 Protective Clothing protects the diver against the effects of cold, abrasion, pollution and hazardous creatures.

6.4.2 **Wetsuits, Semi-Drysuits & Drysuits**

6.4.2.1 A Wetsuit or Semi-Drysuit traps a thin layer of water between the suit and wearer’s body, which warms and so provides thermal protection. If the suit does not fit snugly then the warmed water will be constantly flushed away and replaced with cold water, resulting in reduced thermal performance. No special training is required prior to use in the open water.

Figure6.2 Divers wearing wetsuit (left), and semi-drysuit

6.4.2.2 Drysuits are waterproof suits which have seals at the neck and wrists, thus (theoretically) excluding water entirely. Insulation is provided by wearing some sort of thermal underclothing, depending on the drysuit type. Drysuits are much warmer than wetsuits as air is a better insulator than water. They are also normally more expensive to buy. Since drysuits are used for buoyancy control, special training is required prior to use in the open water.

Figure 6.3 Types of drysuit – neoprene (left), membrane (right)

6.4.2.3 There are two main types of drysuit available: compressed neoprene and membrane. Compressed neoprene suits (left) are generally warmer. Insulation is given from the suit material itself, so thinner thermal underclothing is needed. Membrane suits (right) are thinner and more flexible, but require more insulation.

6.4.3 Thermal Underclothing

6.4.3.1 There are a number of different types of underclothing available for use under a drysuit (Figure6.4). Normal, or specialist diving thermals may be worn (usually in conjunction with a neoprene suit). For added protection, a Thinsulate™ may be worn (usually under a membrane drysuit). The type of thermal protection worn will affect buoyancy, so care should be taken when changing types of undersuit.

Figure6.4 Thermal underclothing – thermals (left), specialist thermals, Thinsulate™ undersuit

6.5 After the dive

6.5.1 After a dive you may be cold and wet. To help keep body heat up a hat is a must: you lose 75% of body heat through your head. Wind chill if on a boat trip back may be a factor in hypothermia, so use of a windproof anorak or sailing jacket will help reduce this risk. Hot drinks will also help warm you up.

6.6 Hyperthermia

6.6.1 Hyperthermia (also known as heat or sun stroke) usually occurs due to:

- Prolonged exposure to heat e.g. out in the mid day sun without a hat on, or at sea with no cover
- Excessively working hard (exhaustion)
- Dehydration

6.6.2 When the body temperature exceeds 41ºC brain tissue will begin to die. At 50ºC immediate death occurs.

6.6.3 Symptoms include:

- Increased heart rate
- Headache
- Dizziness
- Weakness
- Nausea
- Feeling faint or fainting
- Becoming pale
- Clammy, cool skin
- Quickened breathing
- Dramatic increase in pulse
- Ignoring heat exhaustion leads to heat stroke.

6.6.4 Treatment / Avoidance

6.6.4.1 Diving in strong sun light or water temperatures above 12^{o}C will increase the risk of hyperthermia. Avoid heat stroke by keeping body temperature down – stay in the shade, cover up and use a hat, Avoid excessive exercise – move kit slowly, work in the shade, top up body fluids frequently with water or isotonic drinks . Do not kit up before you need to – sitting around fully kitted is hot and exhausting.

6.6.4.2 Hyperthermia is not usually a problem when diving in Scotland, but should be considered when diving in hot climates.

7 Rescue, Lifesaving and Artificial Respiration

7.1 **Overview**

7.1.1 This lecture will introduce possible scenarios which may require a diver to be rescued, and cover rescue procedures in and out of water.

7.2 **Situations requiring assistance**

7.2.1 There are a number of situations which may occur in which a diver cannot continue a dive without assistance. These situations may include:

- Basic equipment failure – loss of mask, weight belt loose / dropped
- Vital equipment failure – air failure, stab / suit inflation failure
- Diver feeling unwell – cramp, blackout or other medical condition
- Entanglement

7.2.2 In the majority of cases, with some assistance from a buddy, the diver will be able to surface safely under their own control. In a small number of situations, a buddy will be required to take control of the situation and bring diver to surface. These may include:

- Loss of consciousness
- Panic
- Lack of response

7.3 **Early signs of problems**

7.3.1 There are many early signs of problems developing:

- Lack of response to signals
- Repetitive checking of gauges
- Increased arm movement
- Increased breathing
- Wide eyes
- Panic
- Out of air/ distress signal

7.3.2 Vigilance of your buddy's behaviour is essential – you should always be on the lookout for behaviour which is 'out of the ordinary' for your buddy. However, often there may be no outward indication of a problem before it starts.

7.4 **Minimising risk**

7.4.1 Incident reporting shows many diving incidents could have been avoided through better equipment maintenance, improved dive planning and execution or diver fitness. A risk assessment should form part of the dive plan. Factors to consider include:

- type of dive (e.g. boat, shore, drift, training)
- dive site (any dangers above or underwater)
- Diving experience and qualifications
- Entry and exit (jump in or long swim in)

- Weather

7.4.2 All divers should develop training and experience progressively.

7.4.3 Remember: Plan your dive and dive your plan.

7.4.4 However, there are a small number of situations, where no amount of planning and preparation could have prevented an incident.

7.5 Recognising a rescue situation

7.5.1 Anyone giving the 'distress' signal should be treated as in need of help until further communication is received. In some situations, divers may not be able to give distress signal – lack of movement or response to signals should initially be treated as a rescue situation. This is equally important when undertaking shore cover. Look at Figure 7.1 and consider if this diver is looking at the sky, or unconscious and in need of assistance?

Figure 7.1 Unresponsive diver

7.5.2 It is important to establish that a diver does need assistance – a stationary diver may be simply looking at wildlife, and will not appreciate being lifted to the surface! Always give an OK signal and await a response.

7.6 Initial Risk Assessment

7.6.1 Never place yourself in additional danger in responding to an incident!

7.6.2 Look before you approach – why is the diver in distress?

- Entanglement
- Panic
- Equipment failure
- No visible problems

Figure 7.2 Risk of entanglement

7.6.3 Are there physical dangers? Is the distressed diver a danger?

7.6.4 It is important to make an informed decision as to whether it is safe to approach the casualty.

7.7 Initial approach and preparing for lift

7.7.1 In preparation for lifting the diver, consider the following:

- On approaching the diver, give a clear OK signal close to the face.

- Make physical contact – tap on head, shake shoulder – is there a response?
- Is the casualty conscious and breathing?
- Check mask and demand valve are in place
- You should have a firm grip of the casualty, and clear access to inflator / deflator BCD, with access to the dump valves of the casualty's drysuit.

7.8 **The lift**

7.8.1 There are different methods of lifting a diver – your instructor will outline your Branch's preferred method.

- A rescue lift is always carried out using the casualty's buoyancy - this ensures the casualty will reach the surface if separation occurs.
- Neck should be extended for the duration of the lift – minimising the risk of a burst lung.
- BCD or suit should be slowly inflated until positive buoyancy is gained.
- The lift should progress in a controlled manner, dumping air on ascent.
- If the casualty is wearing a dry suit attention must be paid to the position of the dump valve.

7.8.2 The decision as to whether to carry out any safety/decompression stops will depend on the severity of the situation and an assessment of the possible implications of missing required stops.

7.9 **Recovering the casualty: the tow**

7.9.1 On surfacing ensure both you and your casualty are buoyant. The distress signal should be clearly given to shore/boat cover. 10 initial rescue breaths should be administered via 'mouth to nose' (if it is suspected that casualty is not breathing). Casualty should be towed to safety with 2 additional rescue breaths every 15 seconds during the tow. Pistol grip should be maintained during tow if possible. In rough weather rescuer should place themselves between casualty and oncoming waves to shield casualty.

7.10 **Recovering the casualty: Landing**

7.10.1 On reaching boat/shore ensure coastguard has been informed of situation (999, channel 16).

7.10.2 **Recovering to boat**

- Boat cover should have firm grip of casualty
- 10 rescue breaths should be given prior to dekitting and landing of casualty
- Once casualty is dekitted, remove your own kit
- Remove casualty from water and begin administering CPR/first aid.

7.10.3 **Recovering to shore**

- On reaching shallow water walk diver to shore line – shore cover should be ready to assist
- Administer 10 rescue breaths
- Remove kit and lift clear of the water (remembering the tide may come in!)

- Begin administering CPR/first aid.

7.11 **Dealing with a distressed diver on the surface**

7.11.1 Shore cover should always be on the look out for divers in distress on the surface. Not all divers will be able to signal for help. Key indicators of problems include:

- diver on their own on the surface
- no communication with shore cover
- panicked divers with excessive arm movements

7.11.2 Panicking divers should be approached with care. If possible throw a line or float before approaching. The rescuer must always put their own safety first – a panicking diver may submerge their rescuer in an attempt to get clear of the water. Vocal reassurance may be enough to control the situation until party reaches shore.

7.12 **Informing the Coastguard**

7.12.1 On a boat with VHF Radio:

- Select channel 16 and radio a MAYDAY message
- Give vessel name and location
- State nature of emergency
- Await response and further instruction
- Repeat if no response received
- Coastguard will take charge of procedures

7.12.2 On land:

- Dial 999 and ask for Coastguard
- Give your name and contact number
- Give location (being as accurate as possible)
- State nature of emergency
- Coastguard will co-ordinate evacuation and relay medical advice

7.13 **Assessing the victim**

7.13.1 After landing the victim, you should carefully assess the situation before taking further action. Taking incorrect action could be as damaging as taking no action. There are a number of useful cards and handbooks which can aid in emergency situations – these should be kept with your dive kit.

7.14 **ABC of Resuscitation**

7.14.1 The following information is no substitute for proper first aid training. ScotSAC strongly recommends all members attend a first aid / heartstart and oxygen administration course. Please note that guidance on resuscitation changes frequently and you should make yourself aware of recent changes.

7.14.2 **Rescue Breathing**

7.14.2.1 Rescue Breathing allows a casualty's lungs to be ventilated with air from the rescuer's lungs. This is possible because the air that is expired still contains 16%

Oxygen, enough to maintain life. The casualty will automatically expel this air, in turn, due to the natural elastic recoil of the rib cage.

7.14.2.2 Rescue breathing is an easy technique to apply and can be done with little training. It can be performed either mouth to mouth, or mouth to nose. The important issue in both cases is to form a good seal so that expired-air may be efficiently transferred.

7.14.2.3 Assessing the need for rescue breathing

- The subject is not breathing
- The victim's skin has a blue-grey appearance (cyanosis), particularly at the lips, ear lobes and nail beds
- The pulse is erratic and slow

7.14.3 **Rescue Breathing Procedure**

7.14.3.1 Supporting the head, turn the casualty onto their back

- Listen carefully for signs of breathing and look for signs of chest rising
- If no signs of breathing, open casualty's mouth and remove any debris.
- Check also that the tongue has not been swallowed and therefore might impede rescue breathing
- Extend the neck to open the air route to the lungs
- Two full breaths of rescue breathing should be given, by either mouth-to-mouth (on land), or mouth-to-nose (in water)
- Examine the chest after each breath to ensure it is rising.
- Check carefully for signs of circulation
- Continue giving rescue breathing at two breaths every 10 seconds until the casualty starts breathing on their own, or until expert help arrives

7.14.3.2 The casualty may be sick during the above process. If this happens they must be moved onto their side, supporting and extending their head, until vomiting ceases. Their mouth must be cleared before continuing with rescue breathing.

7.14.3.3 If the chest fails to rise, there may be an obstruction or other blockage. An attempt may be made to clear this by turning the casualty on their side and administering three sharp blows between the shoulder blades or, if this fails, by manual abdominal thrusts (casualty on back). Both of these methods may induce vomiting.

7.14.4 **Cardio-pulmonary resuscitation (CPR)**

7.14.4.1 Administering rescue breaths by itself is futile if the heart is not pumping the oxygen around the body. If the heart has stopped it must be restarted by using a compression technique to activate the muscle and re-induce blood circulation in the subject

7.14.4.2 **Signs of cardiac arrest:**

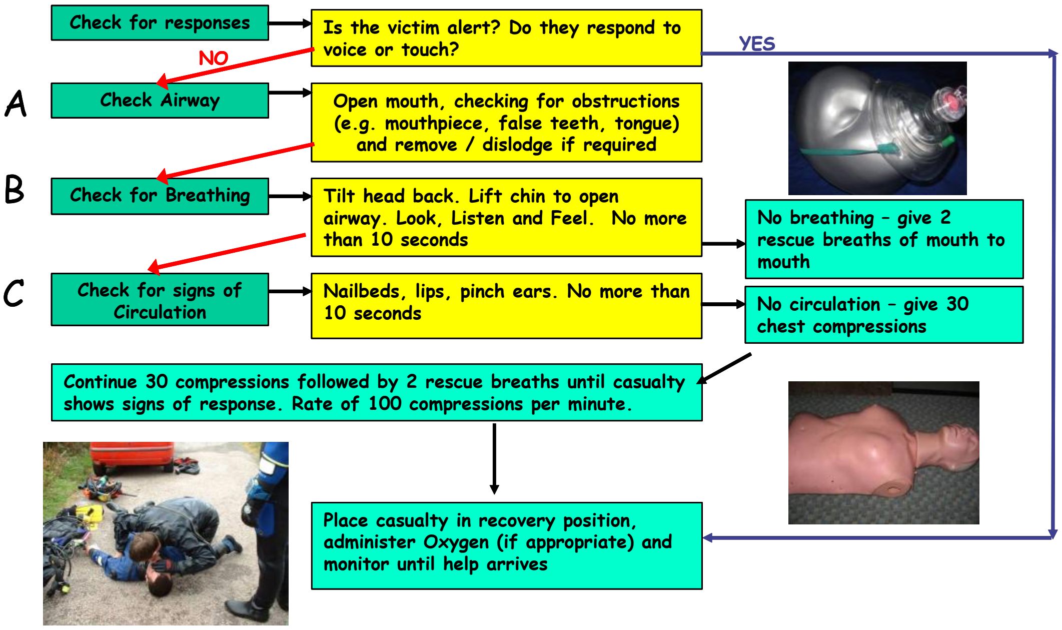
- The casualty has no detectable signs of circulation. Check for signs of circulation (pinch ear, check lips etc.)
- The casualty's eyes are widely dilated and do not respond to light
- The casualty is not breathing
- The casualty has an ashen pallor

7.14.5 Administering CPR

- Lay the casualty on their back on a firm surface
- Check for signs of circulation for no longer than 10 seconds
- Locate the centre of the chest, interlock fingers and prepare for cardiac compressions
- Pressure should be applied through a forward rocking motion keeping the arms straight. The sternum should be depressed a distance of about 4-5cm for the average adult. Rocking back will release pressure on the chest and allow blood to fill the heart again

7.14.6 CPR should be combined with rescue breaths (and performed at a rate of about 30 compressions every 10 seconds, interspersed with two rescue breaths as before

7.14.7 Always continually check to ascertain if a pulse has been re-established. If a pulse is detected CPR should cease immediately.



Recommended CPR ratios are updated regularly. Check up to date medical advice

Figure7.3 First Aid flowchart

7.15 First Aid

7.15.1 It is advised to have diver first aid equipment readily available on dive sites. Items should include:

- Oxygen kit
- Thermal blanket
- First aid kit (for general injuries)
- Isotonic drinks

7.15.2 If any items are removed, ensure they are replaced/replenished before next dive trip.

7.16 Evacuation

7.16.1 Due to remoteness of many dive sites, evacuation is often by air. It is important to carefully follow instructions from Coastguard/Emergency services to facilitate this.

7.16.2 Dive site names such as ‘Anchor Point, Loch Fyne’ are little use in emergency situations – in order for emergency services to locate you quickly an accurate location is required: it is useful to have a grid reference for any dive site you use.

Figure 7.4 Helicopter evacuation

7.16.3 If a diver is evacuated it is important to send as much information about the dive as possible with them, whether in the form of a note detailing dive time, profile, activity and depth, or the dive computer.

7.17 Avoidable complications

7.17.1 Difficult entry / exit points may complicate an already tricky rescue situation – they should be avoided if at all possible. Bad weather can hamper recovery – never be afraid to call off a dive at the last minute if the weather turns bad. Heavy seas can also cause motion sickness, which may contribute to complications on the dive.

Figure7.5 Difficult entry point

7.17.2 Last minute equipment problems (e.g. fin strap broken) should always be properly repaired before entering water: small equipment problems can trigger a rescue situation.

7.18 Separation

7.18.1 On every dive there is a possibility that divers will become separated. Once separated, the individual diver is in a more vulnerable position with no access to immediate help. Separation need not lead to a rescue or emergency situation if handled correctly - a separation procedure should be agreed during dive briefing and followed by all.

7.18.2 ScotSAC does not advocate Solo Diving.

Figure7.6 Separated diver

8 Principles of the Aqualung and Air Endurance

8.1 Overview

8.1.1 In this lecture you will cover the principles of the equipment comprising the aqualung, including how they function. You will also learn about dive planning and the associated calculations.

8.2 Principles of the Aqualung

8.2.1 The ‘aqualung’ or SCUBA (Self Contained Underwater Breathing Apparatus), is the main equipment with which safe underwater breathing may be carried out. Its invention is credited to the late diving pioneer, Jacques Cousteau, who developed the first apparatus for self-contained underwater breathing in the late 1940’s. The set comprises a cylinder of breathing air under high pressure, which is subsequently reduced to ambient pressure through the regulator. Other parts of the aqualung are the O-ring, backpack, protective mesh, handle and the cylinder boot.

8.3 Cylinder

8.3.1 Cylinders store compressed air at extremely high pressure. They are conventionally made from steel or aluminium alloy and come in various colours, sizes and working pressures. Due to the high pressures present within a tank, great care must be taken in handling and storage.

8.3.2 Steel cylinders have a thin wall of 4-5 mm thickness. Aluminium alloy tanks have thicker walls, of around 11 mm. However, for the same cylinder capacity, the steel tank will probably be lighter due to this thickness variation, even although aluminium alloy is actually a lighter material. As a further result, the aluminium tank will also be bulkier. Steel tanks normally change from substantially negatively to slightly negatively buoyant between full and empty (note that air weighs 1.2 grams per litre). Aluminium tanks will change from slightly negatively to positively buoyant over the same range. This is an important factor when considering the amount of weight to be carried on the weightbelt.

Figure 8.1 Steel cylinder

8.3.3 A steel cylinder has a rounded bottom due to the process of manufacture. This means that it must be fitted with a rubber ‘boot’, in order that it may stand upright. An aluminium cylinder has a flat bottom and may or may not be fitted with a boot. Either type, if left standing unattended, should be placed on its side as a safety measure.

8.3.4 Aluminium is a softer material than steel and, consequently, is more prone to superficial damage. First-stage cylinder, or pillar, valves are normally made of brass which can corrode into the aluminium, due to electrolytic action. This can cause seizure of the valve in the cylinder threads unless it is periodically removed and cleaned.

8.3.5 The capacity, working pressure and material used in manufacture classify a cylinder. Working Pressure (WP) is the operational pressure of the cylinder, measured in BAR. Tanks usually have working pressures in the range 150-232 BARS, although some newer types can take up to 300 Bar. Cylinder capacities (termed their 'water capacity', in litres) range from 0.7L (emergency BCD cylinder) to 18L (extra large main diving cylinder).

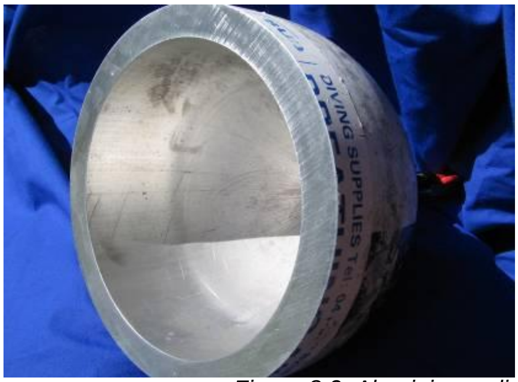


Figure 8.2 Aluminium cylinder

8.3.6 Cylinders are normally fitted with a plastic mesh, to protect their outer surface from damage. To aid transportation, cylinders may have a handle fitted e.g. underneath the pillar valve.

8.3.7 Cylinders when filled will heat up. Therefore it is important to fill them as slowly as practicable to maximise the available air, due the variation of pressure with temperature. Fully charged cylinders should not be stored in an environment that can be exposed to high temperatures e.g. a car boot or standing in direct sunlight for any length of time.

8.3.8 Steel tanks are more prone to test failure due to corrosion as they suffer from a progressive 'rusting' process (Figure 8.3). Aluminium tanks are affected by oxidation, which results in the formation of a coating which arrests the corrosive action, so preventing further deterioration. Both types can be painted to offset these corrosion effects and to act as a visible indicator underwater. Yellow and white are popular colours.

Figure 8.3 Corrosion inside a steel cylinder

8.4 Cylinder Regulations

8.4.1 Cylinders made in the UK have to meet the requirement of British Standard number En 1968: 2002 (steel) or En 1802 : 2002 (aluminium). All cylinders must carry markings on their 'shoulders'. Typical markings are:

- Manufacturer's Mark and Serial Number
- Specification (i.e. En 1968 or 1802, or BS 5045 Part I or Part 3 for older cylinders)
- Date of Manufacture and other test dates

- Water Capacity (WC) – the physical internal volume.
- Cylinder Weight – physical weight of empty cylinder.
- Working Pressure (WP) – normal filling pressure.
- Test Pressure (TP) – normally 1.5 times the working pressure.

8.4.2 Cylinders must be visually inspected every two and a half years from new and hydrostatically tested every five years, by suitably-qualified persons, at a registered test station. This is a requirement for all diving cylinders, including small emergency cylinders (which are often neglected). It is illegal and extremely dangerous to fill a cylinder which is out of test.

8.4.3 A visual inspection involves an internal and external inspection for damage, scores, pitting, corrosion and thread damage, all of which can cause failure. Light corrosion may be removed by special cleaning processes.

8.4.4 The hydrostatic test consists of measuring the cylinder diameter when empty, filling it with water and then hydraulically pumping it up to its Test Pressure. The expansion of the cylinder is measured. When the pressure is released the expansion should return to normal. If the permanent expansion is more than 5 %, the cylinder will fail the test.

8.4.5 Satisfactory performance in all aspects of the test means that the cylinder is fit for further use and it will be issued with a test certificate and the shoulder of the cylinder will be stamped with the date of test and the test house stamp. The BS 5430 regulation requires that the test house destroy any cylinder which fails the test.

8.5 **Cylinder Valve**

8.5.1 The cylinder valve (cross flow or pillar valve) is screwed into the cylinder neck with either a parallel thread, sealed with an O-ring, or on older tanks with a taper thread sealed with PTFE tape. It is normally opened and closed like a water tap i.e. anti-clockwise opens the valve and clockwise closes it.

Figure 8.4 Cylinder pillar valves: parallel (left), tapered

8.5.2 All valves have an anti-debris tube, which extends deep into the cylinder and so prevents dust and rust from reaching the valve mechanism when the cylinder is inverted. This tube is called a “Stag Tube”.

8.5.3 An O-ring is used to form a seal so that the diving regulator can be connected to it using an A-Clamp, or for higher pressure (up to 300Bar), a screw DIN clamp. The O-Ring should always be inspected for damage prior to connecting the A-clamp.

8.5.4 In operation the valve should be opened fully anticlockwise and turned back a quarter turn. When closing the valve, excessive force should not be used as this can damage the valve seat. If there is any stiffness in the operation of the valve or it fails to turn off or on properly, then the equipment officer or other experienced person should be informed.

8.5.5 Note: The screw DIN fitting is the standard connection in some countries, so when travelling abroad it is important to establish ask what type of tank fittings are employed if it is intended to use a UK-pattern regulator. The DIN fitting is becoming popular in many countries being considered by many divers to be a much safer design than the older A-clamp device. A DIN fitting is essential for cylinders with a working pressure over 232 bar.

8.5.6 All cylinders will have an indication of their last test date stamped on the neck of the cylinder. All cylinders must display a sticker indicating the gas contained within it (e.g. breathing air, or nitrox).

Figure 8.5 Cylindre pillar valves and connections

Figure8.6 Cylinder testing label (left) and cylinder contents label

8.6 **Regulator**

8.6.1 The regulator supplies air to the diver on demand. All modern regulators reduce air from cylinder pressure to ambient pressure in two stages and are therefore called two stage regulators. They may be balanced or unbalanced by design.

8.6.2 The first stage is attached to the cylinder and is normally constructed from plated brass. The second stage is the part which contains the breathing mechanism and is made of a lightweight durable material (e.g. plastic). Both valves operate in relation to the ambient pressure and the pressure downstream of the valve.

8.7 **First Stage Valves**

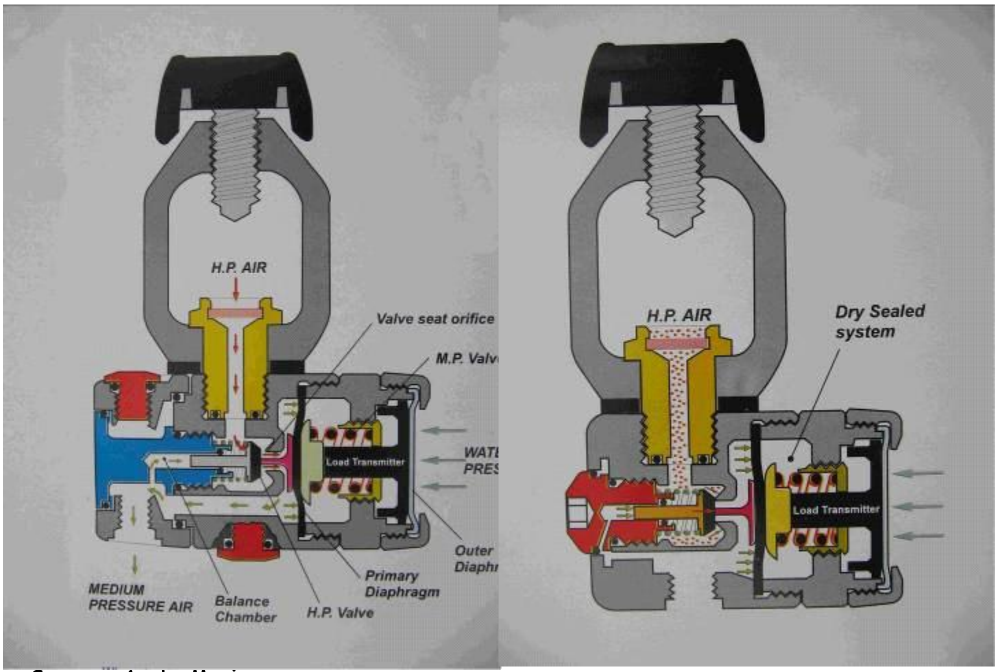
8.7.1 When the diver inhales, the pressure in the intermediate hose drops allowing the first stage valve to open and air then flows from the cylinder into the intermediate hose until the pressure reaches a pre-set level of around 8 – 12 bar.

8.7.2 The diaphragm type first stage operates simply by allowing the drop in intermediate pressure (IP) to lift the valve, allowing air to flow from the high pressure (HP) side to the IP outlet.

Figure 8.7 Regulator first stages

However, as the IP rises, the valve is returned to its seat and the airflow ceases. This is an 'upstream' type valve.

8.7.3 In the more modern balanced configuration, both ends of the valve stem are exposed to IP air. This results in less force being exerted on the valve stem as it is returned to the seat. Water, at ambient pressure, pushes the valve away from its seat as the diver inhales, so allowing air to pass through. This configuration is fail-safe by design and consequently modern regulators of this type are highly reliable. In the event of a component failure, the system would revert to free-flow operation (i.e. continuous air).



Source; Apeks Marine

Figure8.8 Internal mechanism of regulator first stage

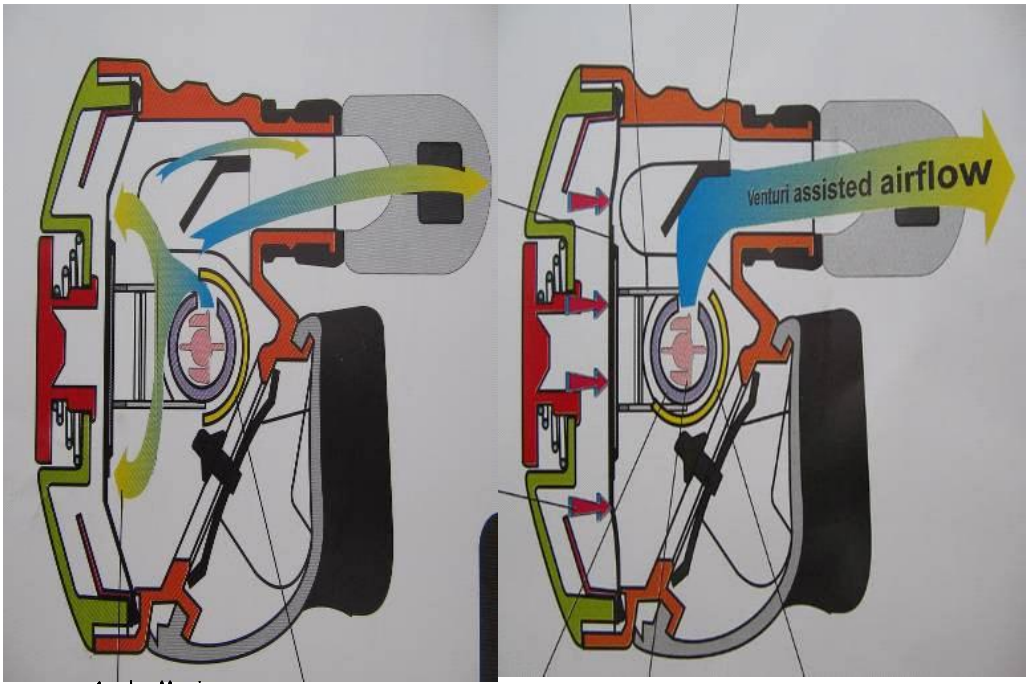
8.7.4 The first stage on a regulator will have high pressure (HP) and intermediate or low pressure (IP)/(LP) outlets. The cylinder contents gauge is connected to a HP outlet. The IP outlets are for connecting the second stage, an octopus rig (a spare second stage) and direct feed hoses for drysuits.

8.8 Second Stage Valves

8.8.1 When the diver is not inhaling, the pressure inside the mouthpiece is the same as the pressure outside and the second stage valve is closed. When the diver inhales, the pressure inside the mouthpiece drops slightly and the second stage valve opens allowing air to flow to the diver. When the diver exhales, the pressure increases inside the mouthpiece and the exhaust valve opens allowing the expired air out.

8.8.2 Valves operate by virtue of a large thin diaphragm, which senses the difference between the ambient water pressure and the diver's inhalation or exhalation pressure. The modern configuration is the piston type. It operates when a lever attached to the diaphragm is moved by the inhalation action. This pulls the valve against the spring and allows air to pass through to the mouthpiece. Exhalation causes the diaphragm to move outwards and allows the lever and spring to close the valve

8.8.3 All second stage regulators have a purge button that may be depressed to manually open the air inlet valve. This can be used to test the device prior to diving, to expel water and debris from inside the second stage and to relieve the inter-stage pressure prior to disassembly of the aqualung. The exhaust valve location varies with different regulator types, but is conventionally at the bottom of the mouthpiece and angled away from the diver's field of vision.



source: Apeks Marine

Figure 8.9 Internal mechanism of regulator second stage

8.9 **Dive Planning**

8.9.1 It is important to plan all dives ensuring you have sufficient air required to complete the dive. Divers should also have sufficient air in reserve to cope with adverse events. Running low or out of air should not arise under normal diving conditions.

8.10 **Cylinder Capacity**

8.10.1 The amount of air in a cylinder is dependent on the volume of the cylinder and the pressure of the air inside. This can be calculated using the simple formula:

- Volume of air = size of cylinder (litres) x contents (bar)

8.10.2 The following diagram shows a variety of cylinder sizes and combinations with contents pressures in bar. The total available air is shown in below.

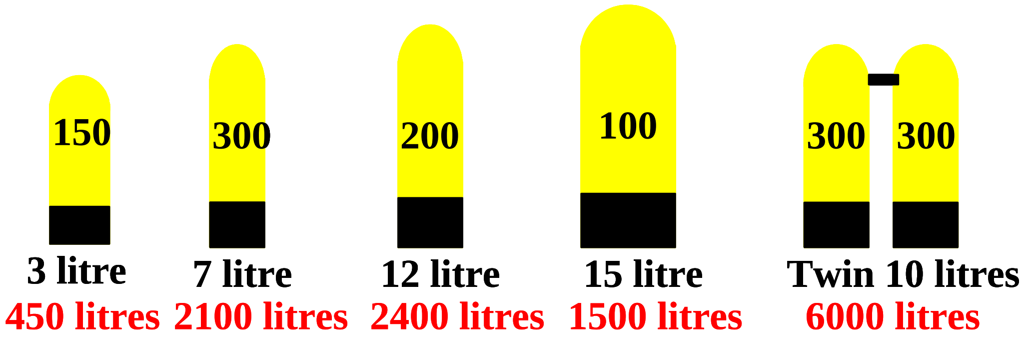


Figure 8.10 Cylinder sizes and volumes

8.11 **Air Endurance**

8.11.1 The amount of air that a diver breathes in a minute is affected by:

- Personal breathing rate
- Fitness
- Temperature
- Mental state
- Lung capacity
- Diving experience

8.11.2 Normal air consumption, for an average person at rest on the surface, is approximately 10 litres per minute. For an average person swimming on the surface, the rate may be considered to be around 25 litres per minute. It should be noted that all air endurance calculations should be regarded as a rough guide only.

8.11.3 Since pressure increases by 1 bar for every 10 metres of water, air consumption also increases with depth. For example, a diver with a surface breathing rate of 25 ltr/min will require 50 ltr/min at 10m, 75 ltr/min at 20m and 100 ltr/min at 30m.

8.11.4 In order to calculate the amount of required air for a dive, the following calculation may be used:

- **Required Air = Surface Rate (ltr/min) x Ambient Pressure (bar) x Duration (min)**

8.11.5 These calculations can now be used to assess the amount of air that is required for a particular dive.

8.11.6 Example 1 - A diver with a 10 litre cylinder filled to 230 bar plans to carry out a 20 minute dive to 20 metres. Will the diver have sufficient air?

- Cylinder Capacity = Size of cylinder x contents = 230 x 10 = 2300 litres
- Required Air = Surface rate x Ambient Pressure x Duration = 25 x 3 x 20= 1500 litres
- Reserve of 1/3 = 1500 ÷ 2 = 750 litres
- Total air required = 1500 + 750 = 2250 litres
- **Yes, the diver will have sufficient air**

8.11.7 Example 2 – A diver with a 15 litre cylinder filled to 210 bar plans to carry out a 20 min dive to 20 metres. Will the diver have sufficient air?

- Cylinder Capacity = 210 x 15 = 3150 litres
- Required Air = 25 x 3 x 20 = 1500 litres
- Reserve of 1/3 = 1500 □ 2 = 750 litres

- Total air required = 1500 + 750 = 2250 litres
- **Yes, the diver will have sufficient air**

8.11.8 Example 3 - A diver with a 12 litre cylinder filled to 150 bar plans to carry out a 15 min dive to 30 metres. Will the diver have sufficient air?

- Cylinder Capacity = 150 x 12 = 1800 litres
- Required Air = 25 x 4 x 15 = 1500 litres
- Reserve of 1/3 = 1500 ÷ 2 = 750 litres
- Total air required = 1800 + 750 = 2250 litres
- No, the diver will not have sufficient air.

8.11.9 On dives where decompression stops are planned, further calculations are required. Decompression is covered in lecture 9.

8.12 Cylinder Capacity

8.12.1 To determine the amount of air in a cylinder, multiply the cylinder size by the pressure in the cylinder:

- Contents (litres) = Size of cylinder (litres) x contents (bar)

8.13 Calculation of Air required for a dive

8.13.1 There are several methods of calculating air consumption. The most conservative method assumes max depth for entire dive duration.

8.13.2 In addition to required air, a suitable reserve supply should be available in case of unplanned adverse events: for non-decompression dives, an appropriate reserve of 1/2 to 1/3 of the overall cylinder content.

8.14 Air Monitoring

8.14.1 Each diver is responsible for monitoring their air supply during a dive – it is their lifeline! The Dive Leader should also monitor the air for all divers.

8.14.2 Air consumption may increase as a result of physical effort or apprehension - any increases in air consumption may affect the dive plan. Terminate the dive early if required.

8.14.3 Running out of air should not come as a surprise!

8.15 Alternate Air Sources (AAS)

8.15.1 An alternate air source (AAS) can be used to provide air to a diver or buddy in the event of air loss or equipment failure. This backup should allow for a controlled ascent by both buddies without the need to share a single regulator. There is a variety of AAS available, appropriate to different levels of diving and equipment factors. ScotSAC recommends that all divers carry at least one AAS.

8.15.2 Types of AAS

- Octopus - Additional second stage on primary cylinder - Resist the temptation to use a cheaper 2nd stage as an octopus as it may affect the performance of your valve
- BCD Demand Valve - Regulator incorporated within BCD inflator

Figure 8.11 Pony cylinder

- Pony Cylinder (Figure 8.11) - Additional independent cylinder (usually 3ltr) with dedicated first and second stage
- Independent twin cylinders (Figure 8.13) - Two equal sized cylinders, each with dedicated first and second stages
- Manifolded Twin Cylinders (Figure 8.13) – as above, joined via twin manifold bar. Some cylinders also allow for isolation in the event of equipment failure.

Figure 8.12 BCD demand valve

8.15.3 Each AAS is appropriate to different levels of diving.

Figure 8.13 Manifolded twin cylinders (left), independent twin cylinders

9 Maintenance of Equipment and Diving Accessories

9.1 General Equipment Maintenance

9.1.1 Diving equipment is regularly submerged in salt water, so unless it is properly cleaned, maintained and stored, it will start to decay or rust and become unsafe. Chlorinated water, as in the swimming pool, or dirty freshwater will have a similar effect. Equipment maintenance is therefore necessary to keep the equipment in safe working order and prolong its operational lifetime.

9.1.2 In general, you should avoid exposure to hydrocarbons such as oil, petrol, grease, suntan lotion etc and avoid contact with underwater obstacles (e.g. abrasive rocks, wrecks etc.) and sand/grit.

- Look after your equipment and it will look after you!

9.1.3 Equipment maintenance means maintaining all diving equipment in a safe working condition. This involves:

- Cleaning
- Repair and Maintenance
- Storage

9.2 Before the dive

9.2.1 In advance of any dive, it is wise to check your equipment for faults. Examples of faults which may cause problems include:

- Perished suit seals
- Damaged hoses
- Broken fin straps
- Insufficient air contents

9.2.2 Early detection of faults allows time to repair and avoids disappointment at the dive site, or danger to the diver or buddy.

9.3 After every dive

9.3.1 As soon as possible after every dive, washing of the equipment will ensure the salt water does not cause unnecessary damage. Always wash equipment in plenty of fresh water. This prevents salt building up, removes any sand, grit or other debris. Equipment should also be given time to air dry before storage. Equipment should be stored away from direct sunlight and a cool dry place.

9.3.2 After every few dives perform regular visual inspection and check:

- Generally for signs of wear and damage.
- Rubber straps and hoses for sign of perishing (‘cracking’ effect)
- Webbing and suit seals for signs of fraying.
- Buckles for correct operation.

9.3.3 NEVER attempt professional repairs yourself.

9.4 **Cylinder Maintenance**

9.4.1 Exposed metal of a cylinder will rust and corrode. Fitting a cylinder mesh and boot will help to protect the paintwork from scratches on rocks or other equipment.

9.4.2 Check the condition of the O-ring regularly as they can become misshapen or cracked and lead to failure. Keeping a supply of spare O-rings in your dive bag will help avoid disappointment at the dive site.

9.4.3 Over-tightening of the pillar valve when opening and closing can cause internal damage to the valve.

9.4.4 Cylinders are designed to operate at their working pressure, so overfilling, or exposing the cylinder to sunlight, will stretch the cylinder walls and reduce working life.

9.4.5 Avoid emptying a cylinder as this may allow dampness or debris to enter and lead to corrosion. A pressure level of 50 Bar is adequate, but note that cylinders should not be stored at full pressure for long periods as this will reduce their life, due to expansion of the metal.

9.4.6 Cylinders should be stored in an upright position, as this will allow any moisture to gather at the bottom.

9.4.7 Whilst transporting cylinders, care should be taken not to damage the outer surface in any way, through improper handling or movement during carriage. Transportation by air requires that cylinders must be empty of air, which is an undesirable state. It is rarely necessary, however, as dive centres abroad normally have an adequate supply of cylinders for hire.

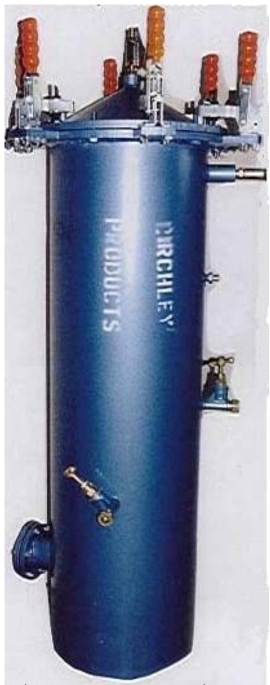
9.5 **Cylinder Testing**

9.5.1 All cylinders require a visual inspection by a registered testing premises every 2.5 years and a hydraulic test every 5 years.

9.5.2 The visual inspection covers both the internal and external surfaces of the cylinder. The test looks for damage, scores, deep scratches, pitting corrosion and thread damage, all of which can cause the cylinder to fail.

9.5.3 The hydraulic (hydrostatic) test consists of filling the cylinder with water before hydraulically pumping the cylinder to its test pressure. The expansion (‘stretch’) of the cylinder is measured in a specialist chamber (Figure 9.1). When the pressure is released, that expansion should return to normal. If the permanent expansion (permanent ‘Set’) is more than 5%, the cylinder will fail.

9.5.4 Emergency air cylinders (EAC) such as BCD and SMB inflators are pressure vessels and should be treated in the same way as a main cylinder for testing.



Hydrostatic Testing Chamber

Figure 9.1

Figure 9.2 Visual inspection, internal and external

9.5.5 Figure 9.2 shows an internal and external cylinder inspection taking place using special lighting.

Figure 9.3 Cylinder inspection using thread gauge

9.5.6 During both visual and hydrostatic inspections, a thread gauge is used to verify the size of the cylinder threads. If the threads have stretched or are damaged, the pillar valve may not be secured and the cylinder will fail. This is shown in Figure 9.3.

9.6 Regulators

9.6.1 A regulator is an essential piece of equipment, and probably one of the most expensive pieces you will buy; most importantly IT'S YOUR LIFELINE. It should be maintained with particular care. Manufacturers recommend yearly service by an authorised dealer.

9.6.2 HP and IP/LP outlet hoses should be inspected periodically and replaced if they show any signs of damage, bulging or perishing. Hose protectors are useful in protecting the metal unions at the hose ends and to reduce the amount of bending at these points

9.6.3 Whilst in use:

- Don't let it trail in sand or dirt
- Don't let it kick about the boat or car park
- Don't allow hoses to kink and twist
- Keep it clear of being knocked from other equipment on a boat
- Use common sense and take care of your whole kit

9.6.4 At the end of each dive:

- Carefully use HP air from the cylinder to blow away water and debris from the first stage inlet
- Replace the dust cap on the first stage before washing/ storage
- Rinse carefully after every dive
- Check carefully for damage to hoses, mouthpieces and direct feed connection

9.6.5 Depending on usage, servicing is recommended annually or after 50 dives (whichever is soonest) and should only be performed by qualified technicians.

9.7 Buoyancy Compensators

9.7.1 Your buoyancy compensator plays an important role of holding together your equipment, and providing you with buoyancy on the surface and below the water. The following checklist will help keep your BC in good condition:

- After use, rinse the inside as well as outside with clean fresh water.
- Periodically rinse the inside with a weak disinfectant solution to kill any bacteria.
- Check for leaks before and after every dive.
- Treat the Emergency Air Cylinder (EAC) the same as a main cylinder.
- Re-grease the purge button on EAC after every 15 or so dives.
- Inspect webbing regularly for damage e.g. caused by the weightbelt rubbing.

9.8 Drysuits

9.8.1 Drysuits may vary widely in terms of material and design, but overall maintenance remains the same for all types of drysuit.

- Close zip and wash outside of suit after every dive. If suit has flooded, rinsing the inside is also recommended before hanging upside-down.
- Check all seams and seals regularly for deterioration.
- Dust neck and wrist seals with talc, gel or French chalk after rinsing and drying.
- Keep the zip clean (inside and out) and lubricated, using beeswax or special zip cleaner/lubricant.
- Check inflation/dump valves for correct operation.
- Avoid contact with hydrocarbons, which cause perishing of seals.
- Avoid folding, especially zip, during storage. Hang to store.

9.8.2 Neck and wrist seals are easily damaged. Latex seals will perish if into contact with oil and petrol. The seams of neoprene seals may fray over time causing suit leak. Maintenance is essential to prevent suit failure.

Figure9.4 Diver with incorrectly fitting drysuit

9.8.3 A poorly fitting suit may lead to problems during a dive. Air can move around a loose suit, collecting in legs and feet. This may lead to buoyancy problems and, in extreme cases, this will cause buoyant ascent with expanding air in the lower body. Fins may also dislodge as air moves to the feet. Drysuit training in pool and open water is essential. New or unfamiliar drysuits should be tried in pool/confined water prior to a dive.

9.9 Wetsuits

9.9.1 Wetsuits require sufficient rinsing inside and out, with plenty of fresh water. The suit should be allowed to dry, preferably out of direct sunlight. Zips should be kept free of dirt and debris and lubricated if required. Tears or damage can be repaired using patches or stitching.

9.10 Torches

9.10.1 Maintenance of a dive torch varies depending on the design. Some torches are sealed and not designed for regular opening. Rinsing in plenty of fresh water after use and checking for external damage should be sufficient. Other designs of torch require silicone grease to be applied to the O-ring on a regular basis. The screw threads must be kept clean to avoid leakage.

9.10.2 If using rechargeable batteries, follow the recommended maintenance schedule in the manufacturer's instructions.

9.10.3 In general, do not use dive torches for extended periods of time out of water, as the resulting heat may damage the torch.

9.10.4 Most torches have a safety lock – this should be engaged before transport and storage.

9.11 Watches and Dive Computers

9.11.1 Anything battery operated can fail, and the most likely time for a dive computer to fail is whilst it is in the water on a dive. Having a backup method of recording time and depth will avoid unnecessary complications. Dive computers should be washed in fresh water after every dive and allowed to dry. Failure to dry the contacts of many computers will cause the computer to remain on, reducing battery time.

9.11.2 Dive computer batteries can last for several years. Refer to manufacturer's recommendations when changing battery.

9.11.3 Rubber straps used on dive computers can perish after contact with salt water. Checking regularly and replacing when required may avoid the loss of your computer in water.

Figure 9.5 Dive timers and computers

9.12 **Dive Knives**

9.12.1.1 All knives rust to some extent due to the metal used in manufacture. Knives must be washed in fresh water and dried after EVERY dive. Rust can be removed with wire wool. Periodically check for bluntness and sharpen as necessary.

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Figure 9.6 Divers knives

10 Open water diving and dive procedures

10.1 **Overview**

10.1.1 This lecture covers the safety considerations of open water diving, and common procedures which should be followed on every dive.

10.2 **Preparing for your first dive**

10.2.1 Your first open water dive is a milestone in your diving career - a good dive and you're hooked for life. If you have a bad dive, you may not be able to dive again or be able to go back in the water for many months. Your first dive must be easy, safe, enjoyable and send you away on a high. It should be fun: no assessments.

10.3 **Key Personnel**

10.3.1 There are a number of key personnel which play an important role in the planning and undertaking of open water dives.

- Expedition Organiser – Takes general charge of planning the day's diving and is heavily involved in pre-dive preparations and appointing of other key officers.
- Dive Marshall - In charge of diving area that day. All divers should report to dive marshal before entering water.
- Safety Officer – Keeps a close watch on the days diving, in charge of safety divers
- First Aid Officer - Self-explanatory & properly equipped
- Equipment Officer - Equipment is serviceable & 'A' flag is displayed
- Dive Leaders - Responsible for the briefing of their divers and safety in water. Should ensure safe entry and exit from water Lead dive safely ensuring group fins at speed of slowest diver.

10.3.2 It is not always necessary to appoint each of the roles above to different individuals, but rather to ensure sufficient members of your group take on the necessary roles.

10.4 **Good Conduct**

10.4.1 Many dive sites are open to the public: that includes children - so your dress code and language could bring you or your Branch of the Scottish Sub-Aqua Club into disrepute.

10.4.2 Treat others as you would like to be treated. Always leave dive sites clean and tidy. Whenever possible try to help others with problems (e.g. spare hoses, fin clips - you don't know when you may need a helping hand yourself).

10.4.3 Share your local knowledge with others.

10.5 **Pre-dive Planning**

10.5.1 Choice of site will be determined by many issues including:

- Access to site
- Experience of divers
- Weather and Tides

- Equipment

10.5.2 Dive groupings should be decided and key personnel appointed.

10.5.3 Details of the site should be discussed:

- Depth
- Bottom terrain
- Tidal influences
- Dive time
- Anticipated visibility
- Exit and entry points
- Other hazards etc.

10.5.4 The current weather conditions are taken into consideration: this may cause a major change to the intended diving and necessitate the usage of an alternative dive plan.

10.6 Risk Assessment

10.6.1 A risk assessment should be performed before every dive. Points to consider include:

- Safety of entry / exit points
- Changeable tides / weather
- Experience of divers
- Air consumption

10.6.2 Refer to ScotSAC Health and Safety Manual for further information.

10.6.3 Full details of location, nearest telephone, hospital and recompression chamber should be recorded

Figure 10.1 Dive site entry

10.7 Personal Equipment

10.7.1 Do you have all the equipment you require to undertake a dive? Do not rely on others to bring it for you!

10.7.2 Protective equipment

- Drysuit/wetsuit
- Boots
- Gloves, hood, swim trunks or swimsuit
- Undersuit

10.7.3 Basic Equipment

- Mask
- Snorkel
- Fins

10.7.4 Safety Equipment

- BCD
- Knife
- Weightbelt

- Depth gauge
- Watch, computer

10.7.5 Breathing Equipment:

- Cylinder(s)
- Demand Valve(s)
- Contents gauge(s)

10.7.6 Ancillary Equipment:

- Delayed Surface Marker Buoy (DSMB)
- Compass, torch etc. (as required)
- Spares

10.7.7 All equipment should be in good working order.

10.8 **On site equipment**

10.8.1 One member of the dive group should take responsibility for bringing the following safety equipment for the dive site:

- Oxygen Kit
- First Aid Kit
- A Flag

Figure 10.2 Items of safety equipment

- Phone or other form of communication

10.9 **On site briefing**

10.9.1 Once on site, a quick briefing will remind everyone of their roles and responsibilities for the dive ahead. The following should be covered:

10.9.2 Site description:

- Entry / exit points and risks
- Description of seabed
- Currents / tides
- Likely visibility
- Danger of obstructions

10.9.3 Dive planning:

- Dive pairings

- Depth
- Time
- Assessments?

10.10 **Kitting up**

10.10.1 Assembling equipment should be done carefully and correctly, checking for last minute signs of damage.

10.10.2 Kitting up should be done in co-ordination with your buddy – avoid the temptation to get ready early. Standing around fully kitted can lead to tiredness and exhaustion.

10.10.3 The method of kitting up will depend on the dive site – should you carry individual pieces of kit to the beach, or kit up at the car?

10.10.4 Dive pairs should work in conjunction with one another, helping with heavy or tricky items.

Figure 10.3 Diver donning fins with help

10.11 **Buddy Checks**

10.11.1 Buddy checks must be carried out before every dive. They give you the opportunity to check that you have assembled your equipment correctly, and to make yourself familiar with your buddy's equipment. The following SEEDS checks should be carried out:

- SAFETY: separation and emergency procedures
- EXERCISE: dive purpose
- EQUIPMENT: air contents check/ABLJ/STAB operation/drysuit (if worn) operation and valve type/ instruments/ weightbelt release.
- DISCIPLINE: relative position of dive leader and buddy/specific duties.
- SIGNALS: signals to be used during dive/at surface/ in low visibility

10.12 **Separation procedure**

10.12.1 An agreed separation procedure should be followed in the event that you lose site of your buddy. This will have been agreed during the buddy check. The actual procedure may be site dependant, but should follow these guidelines:

- Turn around slowly looking in all directions for buddy
- Visual and audible signals – torch, tank tap etc
- If no contact ascend to surface at a normal ascent rate
- Signal to shore / boat cover
- Look for buddy on surface – signs of bubbles / flat spot
- DO NOT descend – even if you see their bubbles: mark spot and communicate to standby diver

10.13 **Entry and Exit Points**

10.13.1 Shore diving – Are there slip hazards? Is your entry/exit point clearly recognisable (fig 10.4 &10.5)? This is especially important for night diving.

Figure 10.5 Preparing to enter water

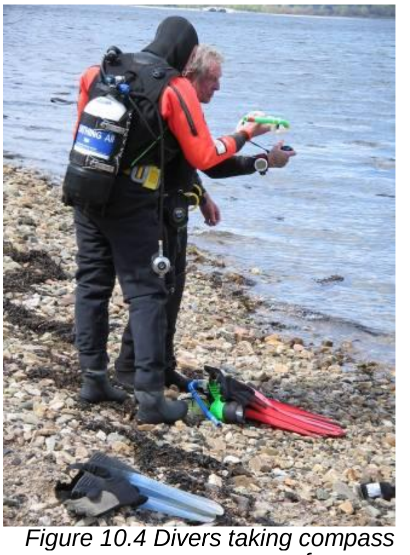

Figure 10.4 Divers taking compass references

10.13.2 Entry from height – Is there a safe exit point? Are there underwater obstructions? Before stepping out, make sure all equipment is secured, hold mask and DV and check the water is clear below. On surfacing, give OK signal (fig 10.6).

Figure 10.6 Diver performing giant stride entry

10.13.3 RHIB – Space will be limited on board so co-ordination in kitting up is essential. When instructed to do so, you should position yourself on the edge of the side tube, and secure all equipment. Entry to the water is by a backward roll off the side of the tube (fig 10.7). Exiting the water, back onto the boat is achieved by passing equipment into the boat, then finning up onto the tube. Once onboard you should stow your equipment away neatly to avoid accidental damage or loss.

Figure 10.7 Divers entering from RHIB

10.13.4 Hardboat – Whilst there may be more space on a hard boat, it is important to keep your kit together in a neat and tidy order. Small pieces of equipment are easily lost overboard in a surge. When instructed to do so, begin kitting up with your buddy. Entry to the water will vary depending on the type of hardboat, but is usually either a backwards roll or step off the side of the boat.

Exiting the water is via a ladder, fully kitted. Depending on the type, you may have to remove your fins.

10.14 Surfacing Drill

10.14.1 The "go up" signal must be exchanged and acknowledge by all the divers. During the ascent face your buddy and check rate of ascent. Remember to breathe normally at all times. Control of buoyancy is essential.

10.14.2 Required decompression/safety stops should never be routinely missed.

10.14.3 As you approach surface hold hand above head, turning 360^o and watching for obstacles such as boats. Repeat 360^o turn on surfacing, being ready to take evasive action. Exchange the "OK" signal with your buddy and keep close

10.14.4 Inflate your BC jacket and signal to your shore/boat cover.

10.15 Abandoning a dive

10.15.1 Ending a dive is not wrong, or poor dive planning. It is often necessary. Abandoning a dive may save a life. So at what point do you or the dive leader stop the dive?

- Bad weather
- Poor sea conditions
- Poor visibility
- Low on air
- Equipment problems
- Diver problems

10.15.2 How would you cope with the following scenarios?

- Your tank falls out of your B.C.
- You lose a fin
- You lose your weight belt
- Regulator begins to leak / freeflow
- Mask continually flooding

10.16 Debriefing

10.16.1 After the dive it is important to carry out a debrief. The following should be discussed:

- Did the dive go to plan? If not, why not?
- How did you feel? Were you comfortable in the water?
- Assessments – did they go to plan? Were they successful?
- Equipment – were you comfortable with it? Were there any problems?

10.16.2 Be aware of any signs or symptoms of diving illnesses. If you feel at all unwell, alert your buddy.

10.16.3 Log books – it is essential that these are filled out correctly and properly signed by dive buddies. This is a record of your training and dive experience. Do not leave it until later, as important information may be forgotten.

Figure10.8 Logbook completion post dive

10.17 What will you see?

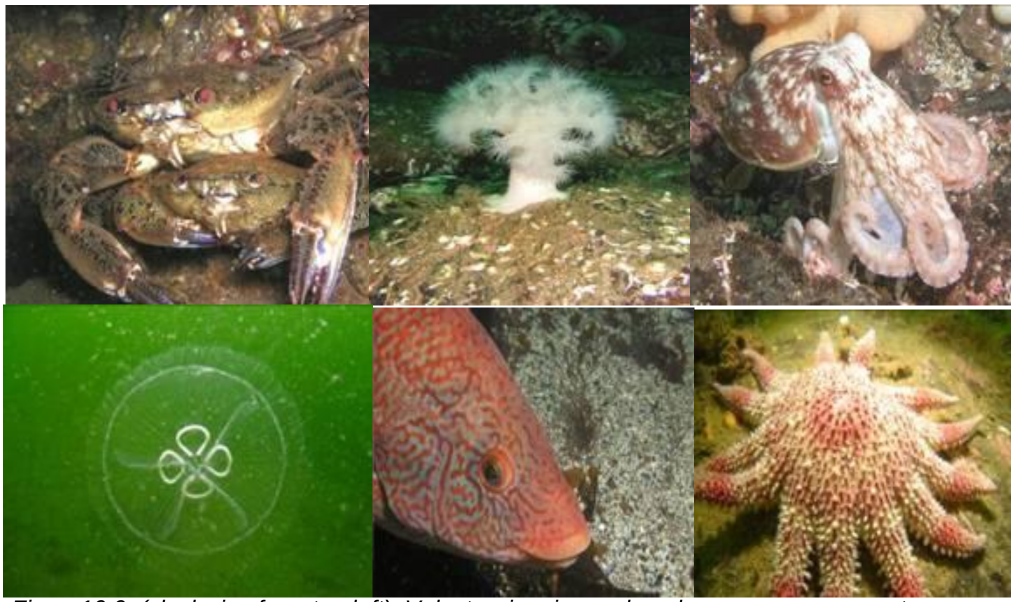

Figure10.9 (clockwise from top left): Velvet swimming crabs, plumose anemone, octopus, sun star, wrasse, common jellyfish

11 Decompression, hazards, avoidance and treatment

11.1 Overview

11.1.1 This lecture covers the principles of decompression sickness, treatment and avoidance, and introduces the concept and use of dive tables in dive planning. Nitrogen Narcosis is also covered.

11.2 DCS –The Risk

11.2.1 Every time you dive, you are putting yourself at risk from decompression sickness. All dives are potentially dangerous. The use of decompression tables makes diving safer, but does not guarantee 100% safety. As such, it is important to know the cause of decompression sickness, recognise the signs and symptoms, and know how to treat it.

11.3 Cause of DCS : nitrogen absorption

11.3.1 Our body absorbs more nitrogen (N_2) during diving due to the increased partial pressure of N_2 at depth. The longer and deeper the depth, the more N_2 our body absorbs.

11.3.2 Some body tissues will absorb and release N_2 more rapidly than others, depending on the fat content of the tissue and the blood supply to it. 'Fast' tissues include the brain, heart and muscles. 'Slow' tissues include cartilage and tendons.

11.3.3 On ascent, the pressure decreases and our body begins to release N_2. If a diver ascends too quickly, the N_2 in their bloodstream will come out of solution, forming small bubbles in the blood (a similar thing happens when you open a fizzy juice bottle too quickly!).

11.3.4 The bubbles which form can travel around the body, lodging themselves in certain areas, blocking blood flow, causing pains in the joints and other more serious effects.

11.4 Controlled Ascents and Stops

11.4.1 In order to minimise the chance of bubble formation, a maximum ascent rate of 10m per minute is recommended. In addition, a minimum 1 min safety stop at 3m must be carried out on ALL dives. This allows more time for the body to release N_2, giving a larger safety margin. Even with a safety stop, excess N_2 will still be present in your body for some time after surfacing. It can take several hours, or even days for your body to return to normal levels. On longer or deeper dives, the body absorbs more N_2 than it can release safely on a normal ascent. Decompression stops at set depths and times are required to ascend safely.

11.5 Predisposing Factors

11.5.1 There are a number of physiological factors that can make a diver more susceptible to DCS. These can be divided into broad, long term factors, and day to day factors.

11.5.2 Broad, long term physiological factors include:

- Age and weight – the older you are, the higher your body mass index, the greater the risk of DCS. This is due to a decrease in your body's ability to off-gas N2.
- Fitness – the fitter you are the less likely you are to experience DCS whilst diving a safe profile.
- Patent Foramen Ovale (PFO) -A small hole in the heart, thought to be present in 25% of the population. This allows bubbles in the blood to move from right to left ventricle, causing more serious DCS effects.

11.5.3 Day to day factors include dehydration, fatigue and low temperatures. All can lead to a reduction in the body's ability to off-gas N_2, making the diver more susceptible to DCS.

11.6 **Signs and Symptoms**

11.6.1 Signs of DCS normally occurs within an hour of surfacing, though symptoms can occur up to 48hrs after the dive.

11.6.2 Common symptoms of DCS include:

- Extreme fatigue
- Pain in joints / muscles – discomfort / numbness in or around joint/ muscle
- The chokes – shortness of breath, coughing, tightness or pain in the chest
- Skin – rash on the upper body and thighs
- Spinal – tingling sensation, loss of feeling or movement in a limb, paralysis. May be preceded by back pain, abdominal pain or cramp
- Cerebral –personality changes, severe headaches, confusion, dizziness, visual/speech disturbance, staggering, unconsciousness, convulsions, paralysis

11.6.3 Often apparently minor symptoms can later develop into life-threatening complications. Divers often deny DCS symptoms, increasing the risk of the condition and delaying treatment.

11.7 **Frequency and Onset**

11.7.1 Symptoms of DCS by frequency (source USN)

- Local joint pain 89 %
- Arm 70 %
- Leg 30 %
- Dizziness 5.3 %
- Paralysis 2.3 %
- Shortness of breath 1.6 %
- Extreme fatigue & pain 1.3%
- Collapse / Unconsciousness 0.5%

11.7.2 Time of onset of symptoms (source USN)

- 50% within 30 minutes
- 85% within 1 hour
- 95% within 3 hours
- 1% delayed more than 6 hours

11.8 **Treatment**

11.8.1 Any diver showing signs of DCS should be immediately placed on Oxygen or other air enriched gases whilst awaiting medical attention. The Coastguard should be contacted on 999 immediately.

11.8.2 The only effective treatment for DCS is through controlled recompression in a recompression chamber. The Coastguard will co-ordinate the evacuation from dive site to nearest available chamber. The diver's buddy should be prepared to go with them. A note of dive profile, incident time, any first aid treatment given and dive computer (if used) should accompany the diver.

11.9 **Recompression**

11.9.1 On arrival at recompression facility the diver will be assessed by a medical team and placed in recompression. Recompression therapy involves immediate recompression, followed by gradual decompression. This prevents new bubbles forming and shrinks the bubbles which have already formed.

11.9.2 There are three basic approaches to therapeutic recompression:

- Recompression to a pressure (depth) dependant on the depth and duration of dive
- Recompression to a fixed depth using standard tables of recompression and known gas mixtures (usually air or O_2)
- Recompression to a depth with produces a clinically acceptable result

11.9.3 NEVER attempt in water recompression

11.9.4 NEVER deny symptoms of DCS: better to be safe than sorry.

Figure11.1 Recompression facilities

11.9.5 Figure 11.2 & Figure11.3 illustrates the DDRC diving accident management flowchart and worksheet.

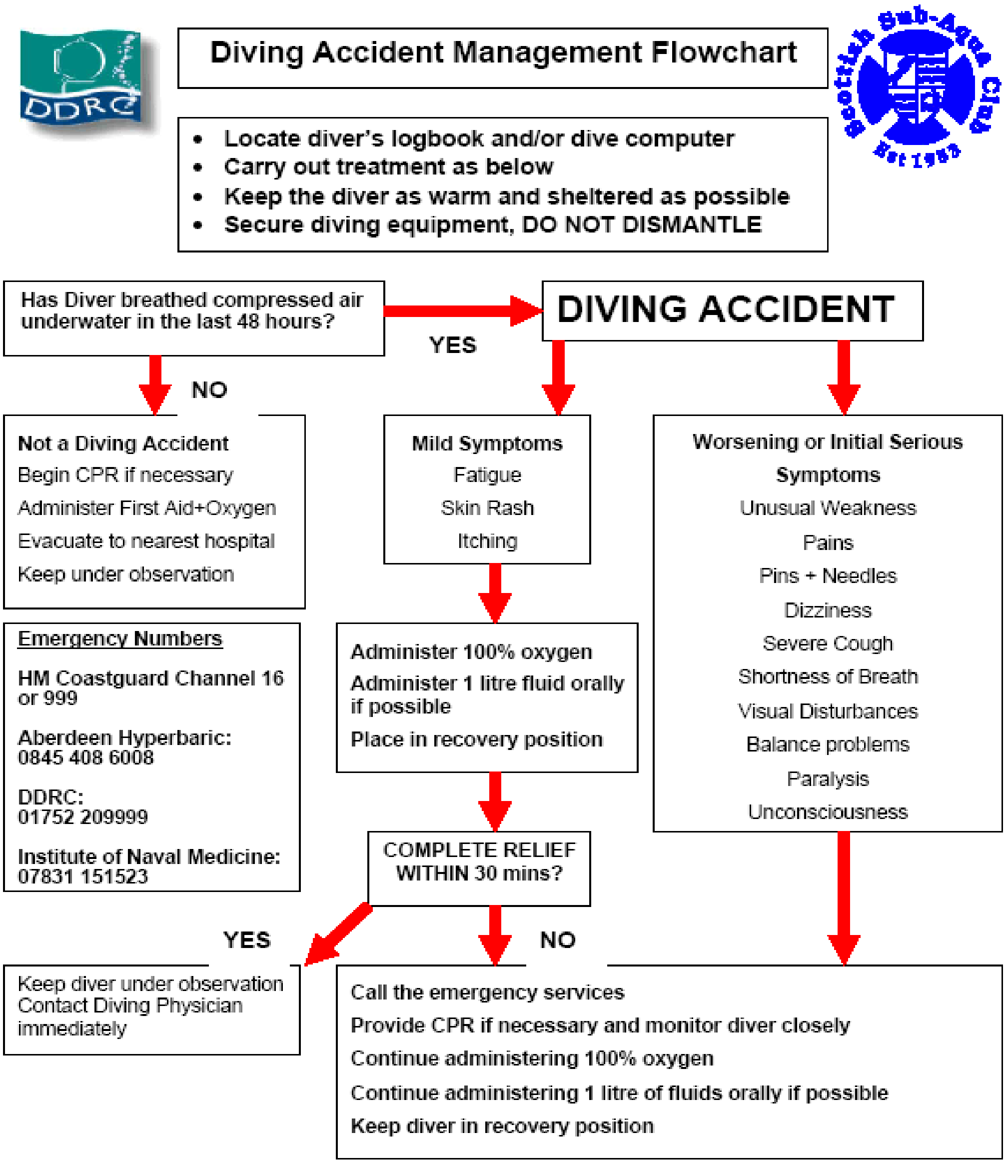

Figure 11.2 DDRC Accident Management Flowchart

DIVING DISEASES RESEARCH CENTRE
ACCIDENT MANAGEMENT WORKSHEET

Attention: Emergency Personnel and Physicians

The individual identified on this sheet has been involved in SCUBA-diving activities and may have suffered a pressure-related injury. This may involve Decompression Illness and/or lung over-expansion. If you want further advice please contact:

DDRC ABERDEEN 08454086008

Diver's Name	**Age**
Address	
Contact (Relative/Friend)	**Telephone**
Incident Details	

Signs/Symptoms	**Time**	**Signs/Symptoms**	**Time**

Dive Profile

Last Dive		**Previous Dive**		**Previous Dive**	
Date		Date		Date	
Time In		Time In		Time In	
Time Out		Time Out		Time Out	
Depth		Depth		Depth	
Deco.		Deco.		Deco.	

Comments (History, allergies, medication)

Figure11.3 DDRC Accident Management Worksheet

11.10 **Decompression Hazards**

11.10.1 Poor dive planning and execution can increase the chance of developing DCS: Rapid ascents are a major contributor to micro bubble formation, which greatly increases the chance of developing DCS. Multiple dives will also increase risk, due to the increase in nitrogen loading.

11.10.2 Similarly, saw tooth and reversed profile dives will also increase risk, and should be avoided. These are shown in Figure 11.4.

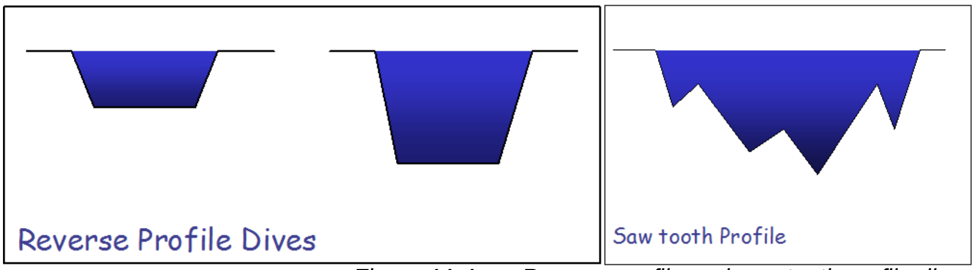

Figure 11.4 Reverse profile and saw tooth profile dives

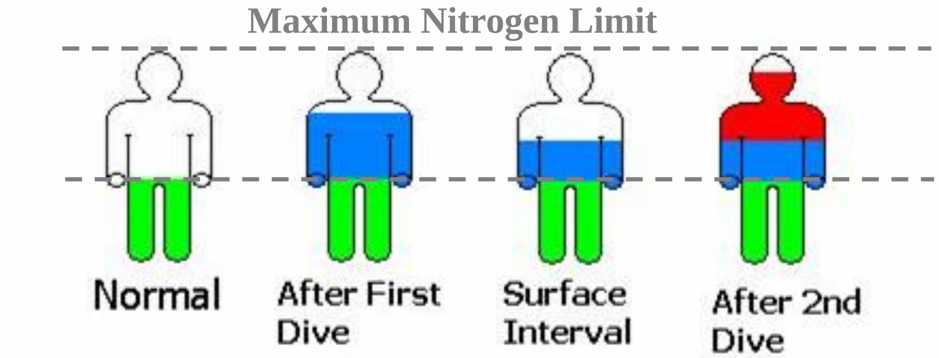

Figure11.5 Nitrogen limits in a diver

11.11 Decompression Avoidance

11.11.1 Always ascend in a controlled manner. Never exceed 10m per minute.

11.11.2 Never miss a safety or decompression stop. Both are necessary to release N_2 from your body and prevent the formation of bubbles.

11.11.3 Physiological factors which can decrease your chance of developing DCS include:

- Improving your overall fitness
- Drink plenty of water in the run up to a dive
- Don't dive if you feel off colour

11.11.4 Modifying diving practices may also reduce the risk. Limiting the depth and bottom time of a dive, avoid poor profiles and deep repetitive deep dives can all help. Divers should not ascend mountains or fly immediately after diving as the reduced partial pressure of N_2 at altitude may lead to symptoms of DCS. They should also avoid over exertion after a dive as this may induce DCS.

11.12 Safety Stops

11.12.1 Safety stops should be carried out on ALL dives. ScotSAC recommends a minimum 1 minute at 3m for every dive. Carrying out a safety stop has been shown to decrease bubble formation in the bloodstream, reducing the risk of developing DCS.

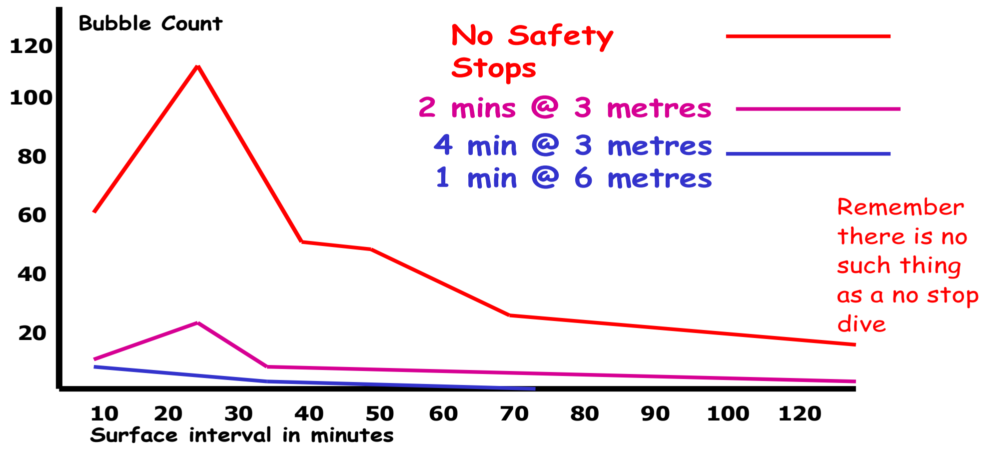

Figure11.6 Effect of safety stop on bubble count

11.13 **Decompression Tables – History**

11.13.1 The need for deeper diving in the Navy prompted the establishment of the first Admiralty Deep Diving Committee in 1905. The unit started at Surrey and later moved to HMS RECLAIM in Loch Fyne and also established itself at HMS Vernon, Portsmouth. Tests were run on both goats and men, helping to shape the diving tables we use today.

11.13.2 Decompression tables are based on theoretical models of N_2 diffusibility in tissues. There are many types of tables available. ScotSAC have opted to use a Buhlmann based system. For altitude dives, other tables are required.

11.13.3 Buhlmann tables assume a 'square profile' dive giving an index of decompression stops required for a given depth and duration of dive.

11.13.4 A repetitive group letter (RGL) is also given indicating the amount of excess N2 remaining in a divers body after a dive. A penalty system is used to account for excess N_2 when planning a second dive.

11.14 **Working with Buhlmann Tables**

11.14.1 Some definitions:

- Bottom Time: The time between leaving the surface at the start of the dive and commencing the ascent to the surface (normal profile) OR The time from leaving the surface to reaching the 9m mark at the end of the dive (irregular profile).
- Depth: The maximum depth during the dive.
- Residual Group: An alphabetical code used within the ScotSAC Buhlmann Tables to (RG) represent tissue loading. It has no other significance.
- Residual Nitrogen Time. (RNT): Expressed in minutes and calculated from ScotSAC Buhlmann Table 3, representing the residual nitrogen loading from previous dives.
- Surface Interval The period between surfacing from a dive and entering the (SI) water for the next dive.

- Safety Stop: In the ScotSAC Buhlmann Tables this is a one-minute stop at 3m during the ascent, to help reduce the amount of silent bubbles.
- Decompression In the ScotSAC Buhlmann Air Tables stops are included during the ascent at 9m, 6m and 3m to allow some of the accumulated excess nitrogen to released.
- Desaturation Total time in hours to return to normal (or close to normal) nitrogen saturation at sea level.
- Time to fly: The time in hours between the end of last dive and flying. NB For safety reasons it is recommended that wherever possible you extend this time to 24 Hrs.
- Dive time: The total duration of the dive i.e. the time from leaving the surface to regaining the surface at the end of the dive.
- No Stop Time: The maximum time that a diver can spend at a given depth, without incurring any decompression stop time.

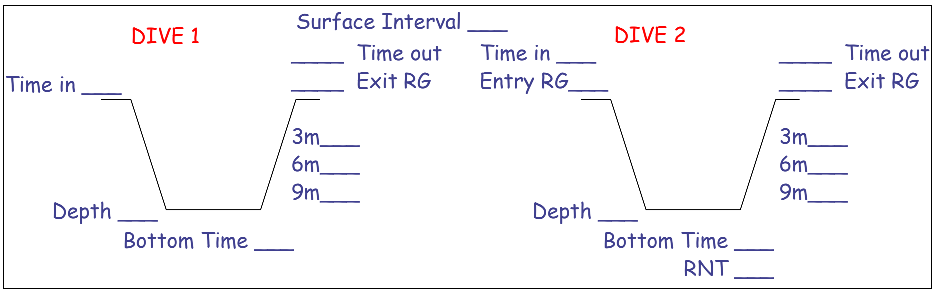

Figure11.7 Sample dive planning worksheet

11.14.2 All decompression tables work on a square profile basis. A square profile dive assumes that the diver descends directly to the deepest part of the dive and remains there until the ascent begins.

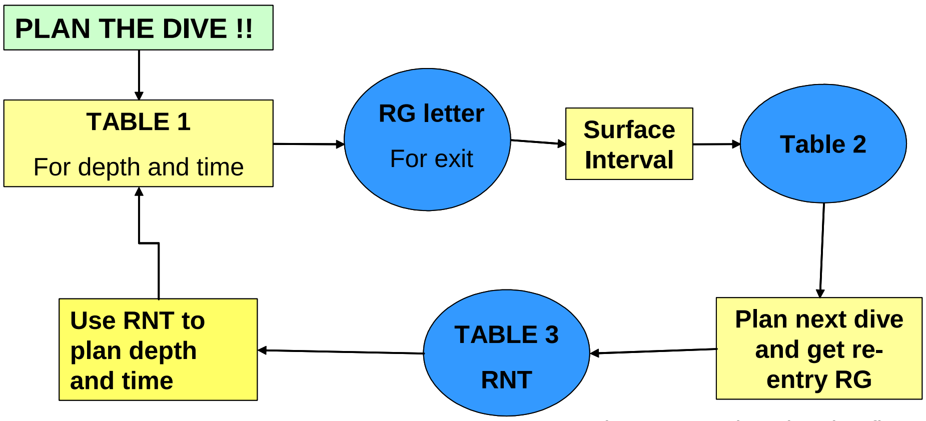

Figure 11.8 Dive planning flowchart

11.14.3 Bulhmann tables consist of three sets of tables. The first contains an index of bottom time and depth, which indicates decompression stops required, and gives an exit RGL for the dive. Table 2 works out the entry RGL for the second dive, based on surface interval between dives. Table 3 calculates the Nitrogen ‘penalty time’ for the second dive, which is based on the entry RGL and depth of second dive. The penalty time is then added to the planned bottom time for second dive, and decompression requirements for second dive calculated from table 1. The exit RGL for the second dive can then be taken to table 2 to work out desaturation and no fly time.

11.15 Worked Example

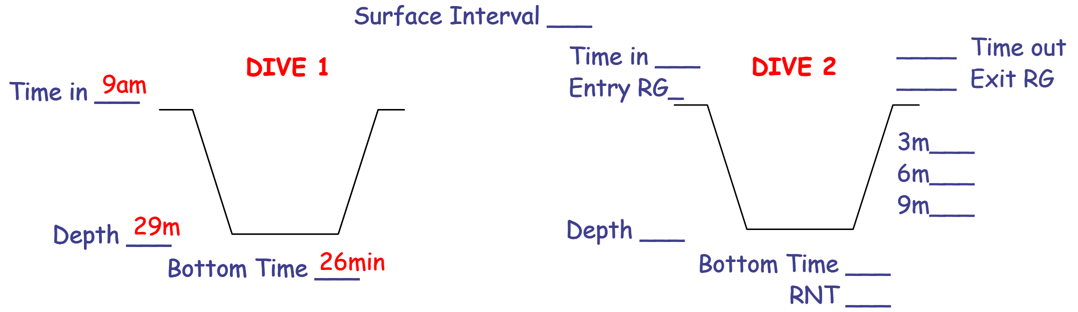

Figure 11.9 Worked example

11.15.1 A diver plans to dive to 29m, bottom time 26 mins, starting at 9am in the morning. This information can be used to fill out the Buhlmann profile below:

11.15.2 Table 1 – look down the left hand column for depth - if the depth of your dive is not present go to next deepest. Now read across to the nearest bottom time (if bottom time is not present take the next greatest time). By reading across the column, decompression information and Residual Gas Letter can be found. This information can then be put into the Buhlmann profile, and exit time worked out.

Depth (m)	BT (min)	Stops 9m	Stops 6m	Stops 3m	RG
30	9			1	A
	11			1	B
	16			1	C
	17			1	D
	25			5	E
	30		2	7	F
	35		5	14	G

Figure 11.10 Extract from Bhulmann tables

11.15.3 NB the Duration of the dive is the sum of bottom time, decompression stops and ascent time. So, for the above dive: Duration = 26min (bottom time) +9min (total deco time) +3min (ascent time) = 38 min.

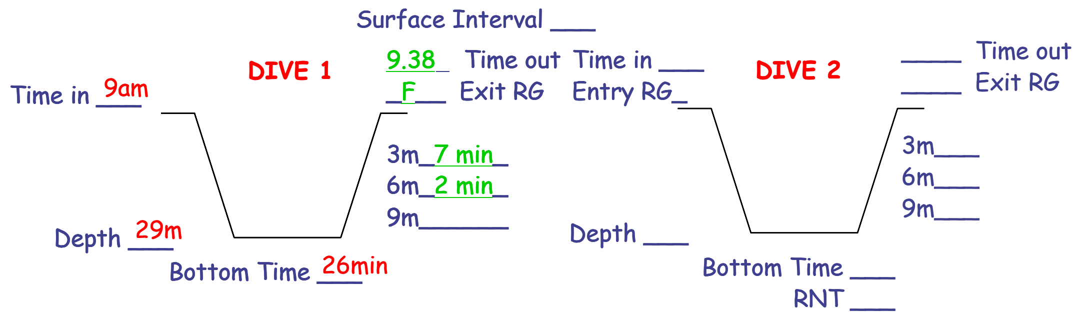

Figure 11.11

11.15.4 With reference to Table 2, 'no fly' and desaturation time can be found, by reading along the row for 'F' – in this case, the diver should not fly for at least 4 hours, and will not be clear of excess nitrogen for 8 hours. If the diver plans a second dive before 8 hours has lapsed, they must use Table 2 to look up their entry RG for the second dive.

11.15.5 A second dive of 22m for 25mins was planned after a surface interval of 65 mins - Take the exit RG from 1st Dive (F) and read across table 2 to the nearest surface interval time. If the exact surface interval is not shown, choose the lesser time, which gives a bigger penalty.

Table 2

						A	2	2
					B	20	2	2
				C	10	25	3	3
			D	10	15	30	3	3
		E	10	15	25	45	4	3
	F	20	30	45	75	90	8	4
G	25	45	60	75	100	130	12	5
	F	E	D	C	B	A	0	Time to Fly
(minutes)							(hours)	

Figure 11.12

11.15.6 In this case, the diver would choose 45mins and read down to give an entry RG of C.

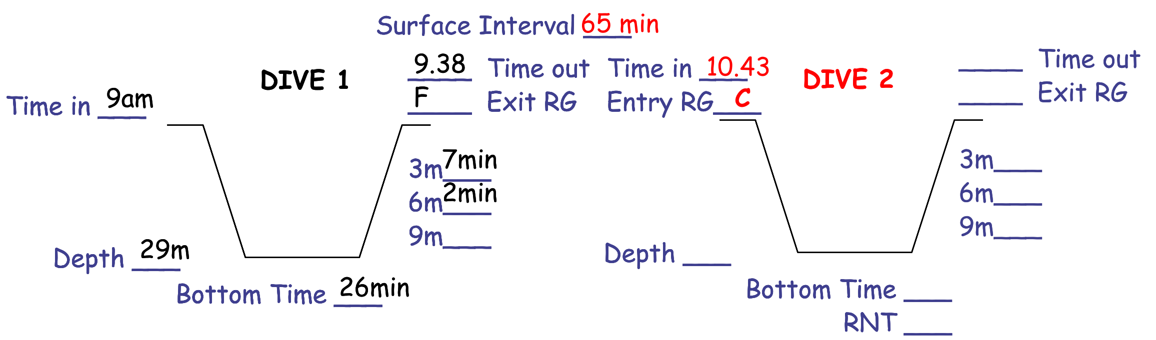

Figure 11.13

11.15.7 Using the entry RG, and depth of next dive, Table 3 will give the penalty time for the next dive. (If depth of dive is not listed, take the next shallowest dive – giving the bigger penalty).

11.15.8 This time is added to the actual bottom time of the

RG	RNT for repetitive dives Next Dive Depth (m)						
	9	12	15	18	21	24	27
A	25	19	16	14	12	11	10
B	37	25	20	17	15	13	12
C	55	37	29	25	22	20	18
D	81	57	41	33	28	24	21
E	105	82	59	44	37	30	26
F	130	111	88	68	53	42	35

Figure 11.14

planned dive and entered into table 1 to determine decompression stops.

11.15.9 For the above dive, bottom time entered into table 1 would be:

- 22min (penalty)+25 min (bottom time) = 47 mins
- Accordingly, decompression requirements for the dive would be 17 mins at 3 metres, giving an exit RG of G. The Buhlmann profile for the second dive can now be completed.

Depth (m)	BT (min	Stops			RG
		9m	6m	3m	
24	11			1	A
	13			1	B
	20			1	C
	25			1	E
	35			4	F
	40			8	F
	50			17	G

Figure 11.15

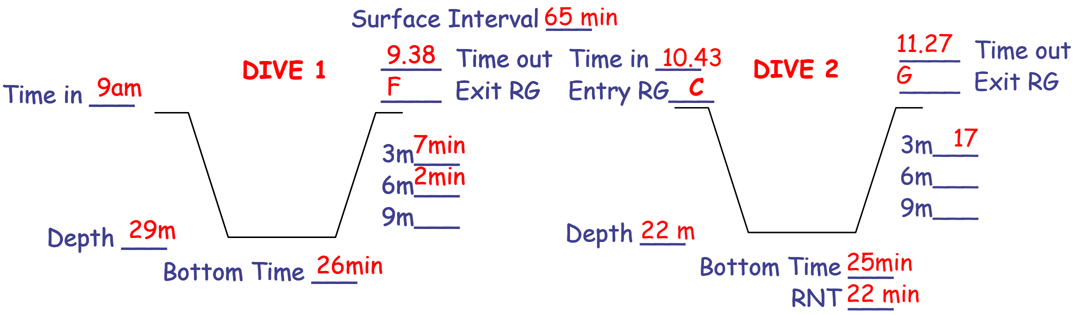

Figure 11.16

11.15.10 Reference to Table 2 indicates the diver will be clear of excess nitrogen after 12 hours, and should not fly for 5 hours.

Table 2								
						A	2	2
					B	20	2	2
				C	10	25	3	3
			D	10	15	30	3	3
		E	10	15	25	45	4	3
	F	20	30	45	75	90	8	4
G	25	45	60	75	100	130	12	5
	F	E	D	C	B	A	0	Time to Fly
	(minutes)						(hours)	

Figure 11.17

11.16 Other Tables

11.16.1 ScotSAC in the past have taught and used a variety of tables including the Royal Navy's (RNLP) table, before moving to BUHLMANN. Other Agencies use diving tables specific to their needs. Figure 11.18 shows tables from other diving organisations.

11.16.2 When a diver is using mixed gases they may generate tables specific to the dive to be completed.

11.17 Computers

11.17.1 Dive computers consist of an internal clock and depth gauge which provides input to a microprocessor. This in turn uses a stored program/algorithm to continually recalculate the decompression requirements throughout the dive.

Figure 11.18 BSAC Decompression tables

11.17.2 Information displayed on screen may include elapsed dive time, current and maximum depth, ascent time to surface and decompression requirements. A dive planner and log book may also be included. Mixed gas and air integrated versions are available.

11.17.3 Whilst computers are versatile and convenient, they are no substitute for knowledge of decompression tables. They are battery operated and are most likely to fail whilst in use. Always have a back up.

11.17.4 As computers more accurately reflect your true profile they tend to give 'more' time on the bottom than a dive table would. However, they suffer from the same problems as dive tables in that they are based on theoretical formulas that model tissue saturation (again usually in fit divers). They cannot take account of predisposing factors to DCS and do not guarantee 100% safety.

11.17.5 Different manufactures use different algorithms to work out decompression requirements, so your buddy's computer may often show different decompression requirements to yours. You should always go by the most conservative computer, doing additional stops if necessary.

11.17.6 Computers are no substitute for proper dive planning. You should never dive to the limit of decompression – if your computer tells you that you have 1 minute bottom time remaining before you go into decompression, chances are you are at or beyond that limit. 'Chasing' decompression by ascending slightly to increase your remaining bottom time is very dangerous and should be avoided at all times. As with tables, you should always plan the dive and dive the plan.

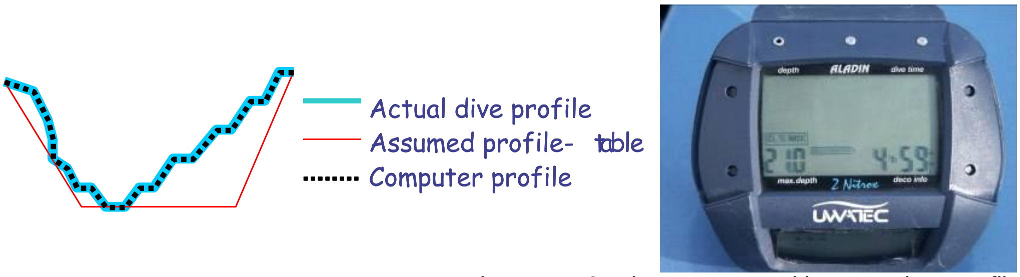

Figure 11.19 Dive computer with comparison profile

11.18 **Nitrogen Narcosis**

11.18.1 Nitrogen Narcosis affects ALL divers. It is generally thought to occur as a result of the raised partial pressure of N_2 effecting nerve cells and the transmission of impulses. It can occur at any depth, though generally it occurs at depths greater than 30m.

11.18.2 The effects of Nitrogen Narcosis increase with depth. Many are similar to those associated with the use of anaesthetics or alcohol. Symptoms vary depending on the individual and are also exacerbated by alcohol, fatigue, over exertion, poor visibility and cold water.

11.18.3 The effects are immediately relieved by ascending to a shallower depth (after giving the appropriate signals to your buddy).

11.18.4 A tolerance to nitrogen narcosis can be built up by repeated exposure to depth.

11.18.5 The only relationship between Nitrogen Narcosis and DCS is the involvement of N_2. Nitrogen narcosis is not a symptom of DCS, but its effects may indirectly lead to the onset of DCS. It is important to recognise and acknowledge symptoms of nitrogen narcosis as impaired reasoning and other associated effects will increase the risk of accidents during diving. No diving fatality has ever been attributed to nitrogen narcosis - unlike alcohol, it leaves no trace in the body. However, it is likely that a number of fatalities and diving accidents were a direct result of actions taken whilst under the influence of nitrogen narcosis.

11.18.6 Table 11-1 illustrates the effect of nitrogen narcosis on a diver.

Effects of Nitrogen Narcosis				
Depth (m)	Mood	Intellectual Function	Response to Stimuli	Balance / Co-ordination
10	Mild euphoria	Mildly impaired reasoning	Delayed Response to Visual and Auditory Stimuli and instruction	Little impairment
20				
30	Over confidence and laughter	Calculation errors and fixation		
40				
50	Hysterical laughter and fear	Confusion, drowsiness, impaired judgement	Severe delay in response time	Dizziness and impaired dexterity
60				
70	Hallucinations	Stupor	Unconsciousness	Severe impairment of dexterity
80				
90+	Death			

Table 11-1 Effects of nitrogen narcosis (SSAC Sport Diving Manual)

12 ScotSAC Organisation and its Training Programme

12.1 Overview

12.1.1 The Scottish Sub Aqua Club (ScotSAC) was founded in 1953, and is one the oldest amateur diving organisations in the world. It currently has around 1900 members in Scotland, Northern England & Ireland, with more than 60 active branches.

12.1.2 ScotSAC is the governing body for scuba diving in Scotland.

12.1.3 It is an amateur organisation, which is funded through membership subscription and a grant from SportScotland.

12.2 History of Diving

12.2.1 Traces of diving can be found back to the 19th century, when Chales and John Deane used diving bells and helmets. In 1865 a French low pressure tank of 40 bar was designed. Later, a Frence pioneer underwater photographer Louis Boutan produced an air cylinder to 200bar. French Navy officers, Yves Le Prieur and Jacques Cousteau, designed the first regulator in the early 20th century. At the same time Hans Hass and an American Guy Gilpatric were using old flying goggles as diving masks. In March 1953 Graham Holborn, Jim Campbell and Tom Lochrey start the first Dive club in Scotland (Govan Sub-Aqua Club). This later became what is now the Scottish Sub-Aqua Club.

12.3 National Structure

12.3.1 Today, ScotSAC exists with a national structure consisting primarily of the General Committee (GC) and National Diving Council (NDC). The NDC are responsible for all diving, training and safety aspects, whilst the GC are responsible for the executive management, development and operation of the organisation. Members are elected to hold a variety of positions on both bodies.

12.4 Branch Involvement

12.4.1 Core to the activity of ScotSAC are Branches. There are around 60 Branches, being supported by the GC, NDC, and ScotSAC Headquarters. A number of other members support activity including:

- National Coach: responsible for Regional Coaches
- Examiners: highest instructor level in ScotSAC
- Regional Coaches: provide supervision and support to individual Branches

12.5 National Diving Council

12.5.1 The NDC are responsible for ALL training and instruction, awards and endorsements conducted throughout ScotSAC. There are up to 6 members of the NDC, elected each year through nomination / postal ballot. The NDC is chaired by the National Diving Officer (NDO). The NDC appoint a National Coach and a number of Regional Coaches annually to provide support to branches. In addition to the elected members, the NDC also includes the National Coach, Regional Coaches and Examiners as ex-officio members.

12.6 **Branches**

12.6.1 Branches and the members within them are key to the operation of ScotSAC. Branches are responsible for their own finances and operation, but are required to follow the rules and regulations of ScotSAC. Many areas of the ScotSAC training programme are delivered directly by Branches, whilst other courses such as instructor and speciality courses are delivered at regional or national level. All branches must have a branch committee, headed by a Branch Diving Officer (BDO). The BDO is responsible for the supervision of all diving activities in the branch and the correct implementation of the ScotSAC training schedule. Many branches offer a range of other social benefits in addition to diving tuition and participation. Other members of a branch committee include Treasurer, Chairman, Secretary and Equipment Officer.

12.7 **Training Programme**

12.7.1 The ScotSAC training programme is focused on safety and quality, and has been developed over many years. It is designed to be progressive, obtainable and paced to suit the individual diver and flexibility of branches. Training is advanced in a safe manner suitable for diving in Scottish waters. Building up experience is as much part of your training as progressing through practical assessments. The current training programme incorporates five diver grades and three instructor/Examiner grades.

12.8 **ScotSAC Diving Rules**

12.8.1 ScotSAC diving rules can be found in front of ScotSAC Training schedule or Qualification and Record Book. These include:

- Training & diving in branches shall be carried out as laid down by the Club
- No member shall use aqualung in open water unless they can demonstrate good knowledge of lectures and have completed confined open water assessments.
- Members of club shall not dive for personal gain.
- A qualified instructor must witness all training dives.
- No member shall dive deeper than 20m until they have gained their Sport Diver award.

12.9 **Training Environments**

12.9.1 ScotSAC training is delivered in a range of training environments. This allows for learning of all aspects of the sport in a safe and progressive manner.

- Lectures: Sport Diver training includes a series of 12 lectures introducing the areas of theory required for the level. Most other ScotSAC diving grades and instructor grades also include elements of theory.
- Pool (confined water) Training: Many branches are able to offer pool training. Training in the pool gives members the opportunity to learn and develop new skills in a controlled environment prior to further development in the open water.
- Open Water Training: Most divers are learning the skills in order to apply them in an open water environment. However, in order to ensure safety

and enjoyment in an open water situation, divers must first demonstrate knowledge of lectures, and performance in skills learned in lectures and confined water training.

12.10 **ScotSAC Diving Grade Structure**

12.10.1 ScotSAC diver training has been designed over many years to equip divers with the skills and knowledge to dive in Scottish conditions. Core to all training are the following five diver grades.

- Junior Snorkeler
- Branch Diver
- Sport Diver
- Master Diver
- First Class Diver

12.10.2 In addition to the range of diving grades, there are three Instructor Grades

- Branch Instructor – A branch instructor is a member who has gained sufficient experience beyond Sport Diver level (minimum 75 dives) and has developed the skills and knowledge to deliver diver training within his/her own branch.
- Regional Instructor – A Regional Instructor is member who has developed their instructional experience within the branch environment to be able to deliver a wider range of training at Regional level. A Regional Instructor is the minimum qualification required to act as a Regional Coach.
- Club Examiner – An Examiner is a member who has been involved in a wide range of assessments and instructional activities at all levels.

12.11 **Diving Endorsements**

12.11.1 In addition to the core diver training, ScotSAC offers a range of additional optional endorsements available to members who have particular interests. Full details of these endorsements are available at www.scotsac.com or from your Branch Diving Officer or Regional Coach.

- Drysuit
- Diver 1st Aid
- Heartstart
- O2 Administration
- Nitrox
- Deep Rescue
- Deep Diving
- Underwater Archeology

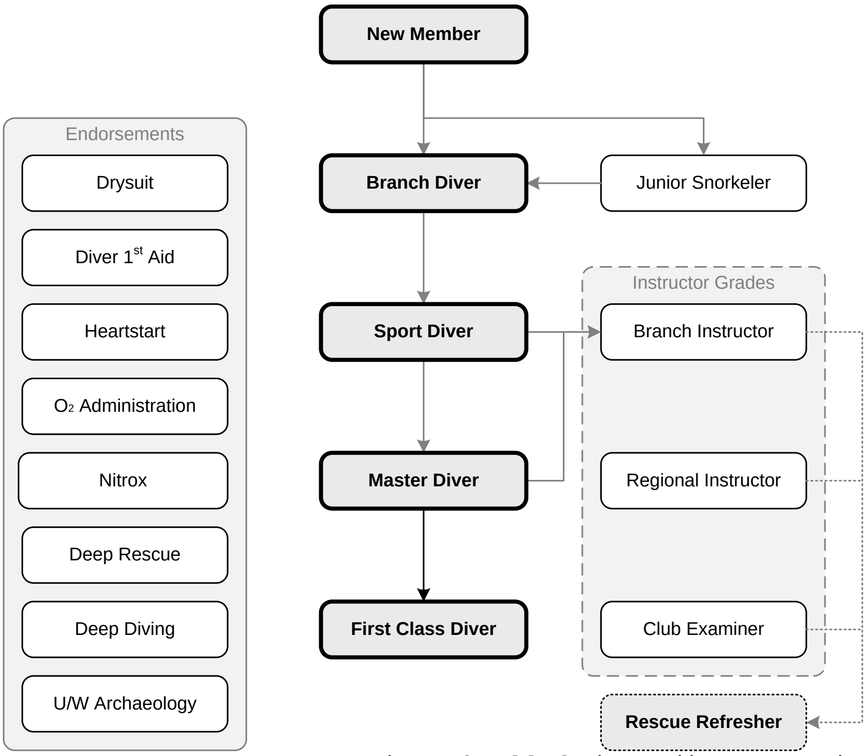

Figure 12.1 SSAC Diver and instructor grades

12.12 ScotSAC Resources

12.12.1 ScotSAC members have a number of core resources available to them for learning and development, and for continued enjoyment of the sport. A selection are shown below.

- Scottish Diver - A bi-monthly ScotSAC publication, written by ScotSAC members, and other contributors and edited by the ScotSAC General Committee Editor. Contributions are welcome from all members.

Figure 12.2 Scottish Diver magazine

- **www.scotsac.com** - The ScotSAC website contains a wide range of information to members of all levels. Everything from training materials, members photo galleries, membership forms and the latest news and course dates.

- Try Dive Pool – Used as a major external marketing tool, the Try Dive pool is a semi portable, freestanding 1.5m deep heated pool suitable for try dives at outdoor exhibitions, fun days, and other public events.

Figure 12.3 SSAC Try Dive Pool

- Members – Arguably the biggest and most valuable resource in ScotSAC is its members. The wealth of knowledge available to all members by interacting with fellow members is fundamental to the club system.

12.13 **Summary**

12.13.1 ScotSAC is an amateur diving organisation run by its members, for members. Core to ScotSAC is the club structure where local responsibility is given to deliver diver training.

12.13.2 ScotSAC can go from strength to strength with your help – why not introduce a friend?

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