Chapter 5

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DIVING EQUIPMENT

This chapter has been included to explain the operating principles and the limitations of some of the equipment currently used in free and scuba diving.

FREE DIVING EQUIPMENT

Mask

The reason we go diving is to view the spectacular underwater world. Unfortunately, our eyes are designed to see through air. In water the view is blurred and distorted – and somewhat magnified. The latter is the reason why divers exaggerate the size of the fish they see. Fishermen, who examine their catch on the surface, do not have such an excuse for their blatant lying.

The way we compensate for the water/air interface distortion, is to add an air space in front of our eyes. This can be achieved by air-filled contact lenses, swimming goggles or face masks. The last of these is used by divers.

The variety of face masks on the market suggests that the ideal mask has not yet been developed for the multitude of different face shapes.

The mask should cover the eyes and nose but not the mouth. Having the nose included allows the diver to exhale into the mask to compensate for the changes in water pressure, and so prevent **face mask squeeze** (see Chapter 12). The ability to exhale into the mask is also essential to clear a face mask flooded with water. The mask should be shaped so that the diver's fingers can reach and block his nostrils, to make ear equalising easier.

Ideally, the mask should have a small air volume so as to reduce the effort needed to equalise water pressure during breath-hold diving. The face plate should be close to the eyes, to maximise the field of vision. With a basic face mask this is limited by the nose. This problem could possibly be overcome by radical nasal surgery, but is best achieved by an indented rubber nose piece which allows the glass to be brought closer to the eyes. Clear plastic or glass side panels may also possibly help. Although this arrangement generally improves peripheral vision, the nose piece still restricts downward vision – obscuring the harness, weight belt and emergency gear.

Some face masks are fitted with a one-way exhaust or “purge” valve on the undersurface to aid elimination of water. This makes clearing the mask of surplus sea water much easier, but the valve can be an annoying source of water leakage into the mask, if it does not function correctly. Another source of leakage is a moustache or beard. These are still able to permit a seal if adequately wetted beforehand.

The body of the mask may be made of plastic, rubber, or silicone. The material needs sufficient rigidity to maintain the basic shape of the mask but a soft flanged edge (or skirt) is necessary to allow the mask to adapt to the contours of the face and provide a watertight seal. If the mask is excessively rigid it will not accommodate to water pressure changes, making face mask squeeze more likely. Masks made of silicone rubber are available for use – essential for divers with rubber or plastic allergy.

Fig. 5.1
Mask, snorkel and fins – basic free diving equipment

The viewing plate of the mask can be made of either glass or plastic. Masks, like the windscreens of cars, should be made of “tempered “ or safety glass, thereby preventing shattering and damage to the face and eyes, in the occasional event of trauma. Then it will shatter into small cubes rather than sharp splinters when broken. Good quality plastic is less likely to break, but is prone to scratching

Fig. 5.2
Silicone masks

A mask can be chosen by fitting the mask to the face and gently inhaling through the nose. A mask which seals adequately will then adhere to the face without any air leak, and not fall off. The mask should seal properly without excessive tension from the mask strap. Some mask straps are broadened at the back of the head to distribute the tension over a greater area, as narrow bands are less secure and often cause local tenderness or headaches.

CAN YOU EASILY SEE?

Fig. 5.3
Diving masks with corrective lenses incorporated into or glued onto the faceplate.

For those divers who are myopic, they may wear soft or fenestrated contact lenses, or have negative corrected lenses built into the face plate. Lenses of differing refractive index are now available which slot directly into some masks, replacing the "blank" lenses. For the “oldies”, who need spectacles to read their gauges and see the miniscule aquatic animals and plants, they may stick a positive lens onto the face plate, low down and on one side only.

Snorkel

The snorkel allows the diver to breathe while floating, with the face submerged. Otherwise he would have to disrupt his view of the underwater world to turn his head to breath – like swimmers. It can also be used during periods of surface swimming before or following a scuba dive, to conserve compressed air or return to safety without relying on the scuba cylinder, which may be near empty.

Because of the limited strength of the respiratory muscles and the effect of water pressure, it is not possible to breath through a snorkel at a depth in excess of about 50 cm. The length of the snorkel should be sufficient to allow the diver to swim face down, to look around and to swim through choppy water without the snorkel flooding. It should not be excessively long as this increases breathing resistance and respiratory "dead space". The optimum length is about 30–35 cm.

The snorkel should be of maximum diameter to reduce breathing resistance but not wide enough to create excessive dead space. The optimum internal diameter is approximately 1.5–2 cm. It should have a minimum of angles and curves, and the interior should be smooth. Corrugated tubing or sharp angles increase breathing resistance. Mouthpieces are sometimes made to swivel and rotate in order to minimise drag on the mouth and permit a comfortable hold. The latter can be assisted by individual “bite moulding” of the mouthpiece.

Fig. 5.4
A range of snorkels. Some of these have "purge" valves for eliminating water.

The breathing resistance of a poorly designed snorkel is usually not noticed during quiet breathing, but may prevent the diver from exercising to his maximum capacity when needed. With moderately heavy breathing, as with anxiety-produced hyperventilation or swimming at >1 knot, snorkels restrict the breathing capability of divers engaged in surface swimming.

Several peculiar devices have been invented to prevent water entering the snorkel during a dive. These usually employ buoyant objects such as a table-tennis ball or cork which floats into, and obstructs the end of the snorkel when it is submerged. This requires an extra U shaped bend in the snorkel which increases resistance and dead space. These devices are unreliable and unnecessary, and often catch on other objects. Divers learn to expel water from the snorkel after returning to the surface by turning their head towards the side with the snorkel and blowing hard and fast.

Some snorkels are now fitted with a small purge valve near the mouth piece and which allows most of the water to drain from the snorkel automatically. It reduces the amount of water which needs to be expelled by the diver, and therefore the effort required. It is also a potential source of leaks.

If used excessively or gripped too tightly, sometimes the jaw becomes sore after a long dive. See Chapter 32.

Fins (Flippers)

The use of fins considerably improves the diver's swimming efficiency. There are several designs available.

Fins have two basic types of foot fitting — one has a shoe integrated with the fin (enclosed heel), and the other has a half shoe fitting and a heel strap (open heels) which allows the diver to wear neoprene boots. These boots can be used for protection when walking over reefs, and offer some thermal insulation to the feet.

The blades of the fins vary in size and rigidity and some types are fitted with vents (for a venturi effect). Studies of various fin types have shown that no one type is ideal for all divers. Fins with larger, more rigid blades, allow a more powerful action but require greater strength and are more difficult to manoeuvre. Muscular cramps can result from inappropriate powerful fins. In general, fins of medium size and medium flexibility are suitable for most recreational divers.

The way fins are used is important. Traditionally, a narrow, straight-leg kicking stroke has been taught. A less graceful wide-kicking stroke using bent knees is more efficient. This comes from directing the thrust of the fin along the direction of movement of the diver. Beginners may need coaching to avoid a bicycle peddling action, which is ineffective as a swimming stroke.

Fig. 5.5

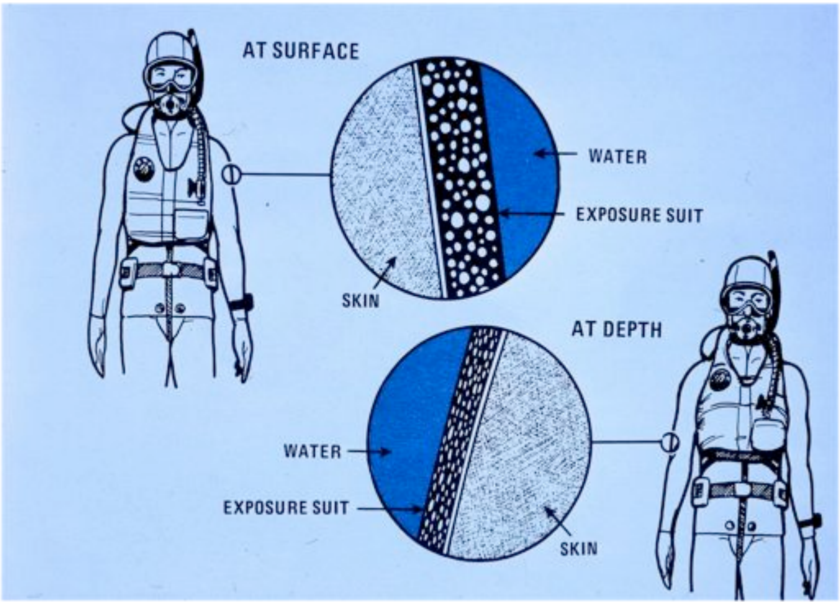
Fins with integrated shoes can often cause blistering and abrasions ("fin ulcers") on the foot or ankle, around the rim of the shoe fitting. This can be reduced by the use of socks until the diver becomes more accustomed to the particular fins. Correct fitting of the fins is necessary. If too loose, their loss will endanger the diver. An excessively tight fit may cause muscular cramps and fin ulcers.

New divers tend to rely on hand movements for propulsion. This is not effective underwater and they have to learn to employ fin propulsion

Wet Suit

The wet suit provides protection, comfort and safety. It is made from rubber or neoprene which incorporates tiny air bubbles, to provide good thermal insulation. It also provides protection from scratching, abrasions and stinging animals.

On the surface and in shallow water, these suits give great buoyancy. To overcome this effect and therefore submerge, accessory weights are usually necessary. At depth however, the air bubbles in the wet suit are compressed (remember Boyles Law?), reducing its thickness, buoyancy and insulating properties. The variations in buoyancy at different depths may need to be offset by the use of a buoyancy compensator.



A poorly fitting wet suit can cause chafing, especially around the neck and arm-pit. A wet suit with an excessively tight neck can also compress the blood vessels to the brain leading to dizziness and fainting. Tightness around the chest may cause difficulty in breathing. Zippers allow for easier access and exit, but contribute to water leakage and reduced thermal reliability.

Fig.5.6

A wet suit variant containing inflatable gas compartments can partly overcome these problems. These suits can be inflated orally or directly from a scuba tank. Careful venting on ascent is necessary in order to prevent too rapid an ascent with these suits as the gases expand. They are a modern version of the traditional "**dry suit**". The latter is used in colder waters, when a layer of gas is injected between the rubberised suit and an insulating undergarment. A gas cylinder adds air into this space during descent, and the air is exhausted during ascent, to maintain neutral buoyancy. Because of the added buoyancy problems, special training is needed to use dry suits. See Chapter 12 for suit “blow up”. Urinating in dry suits is problemmatic, and the P-Valves that permit urinating into the ocean can cause rare but serious problems with retrograde flow of sea water, air and infections into the genito-urinary tract

There are **hybrid suits** that include characteristics of both wet and dry suits, and some include fluids and malleable solids that replace the gas spaces and avoid the variable buoyancy effects with depth.

Weight Belt

A weight belt is used to offset the buoyancy of the body, wet suit and other items of equipment. Ideally the diver should use enough weight to produce neutral buoyancy at the surface (without reliance on a buoyancy vest) or at a shallow depth, about 3-5 metres – where a safety stop is often indicated. The correct amount of weight is found by trial and error and this should be done in shallow water. As the diver descends, compression of the wet suit makes the diver less buoyant. This effect can be offset by the use of a buoyancy compensating vest (B.C.).

A diver without a wet suit will usually require less than 2 kg (5 lbs) weight and many divers will require no weight at all. A diver wearing a wet suit may require about 1 kg weight for each 1 mm wet suit thickness, with an extra 1 kg for neoprene booties or hood. Inexperienced divers tend to use more weights than experienced divers, and are therefore more at risk from buoyancy problems.

Fig. 5.7

The deliberate attachment of up to 10 kg of lead weight, or more, to an otherwise neutrally buoyant air-breathing creature in the water has obvious safety consequences. It aids in descent, but may impair the

ability to surface safely. "Lead poisoning" is a common contributor to recreational scuba diver deaths

Most weights are moulded lead shapes through which the belt is threaded. For comfort these are sometimes curved, and some newer belts incorporate zippered compartments filled with lead shot for better fit to the body. Weights are usually sold in 1, 2, or 3 kg. sizes.

Fig 5.8. Being over weighted is one of the most common faults of new divers.

Fig. 5.9
Sitting on the gunwale with a weight belt on, is living dangerously.

The weight belt should be fitted with a quick release buckle, preferably one which is separate from the scuba harness release. Exceptions to this requirement are found in saturation diving and in cave diving where a sudden ascent due to inadvertent release of the weight belt could have catastrophic consequences. The buckle should be easily identified by feel and therefore different from the harness buckle. The strap should not be too long or it will hinder quick release

The weight belt should fit firmly around the waist. If it does not, compression of the wet suit at depth may result in it becoming loose and rotating around the body, with the buckle becoming inaccessible. Some new belts are made from elastic material which conforms regardless of depth.

In a significant proportion of diving accidents, the diver fails to release the weight belt at the time of the emergency. Training of divers is required to ensure that release of the weight belt is routine in an emergency. When ditching the weight belt, the diver should release the buckle with one hand and hold the weight belt well clear of the body with the other, before dropping it — otherwise entanglement with other equipment is possible. Unbuckelling the weight belt *per se* will not necessarily cause it to fall.

The attachment of weights to the diver using rope or an ordinary belt buckle which cannot be rapidly released, has sometimes proved more permanent than the diver would have wished.

The **weight belt should always be the last item of equipment put on before entering the water, and the first removed before leaving the water.** If this advice is followed, then an inadequately equipped diver who does fall back into the water, is more likely to float and not sink or drown.

Diving Knife

Fig. 5.10

Contrary to the popular Hollywood image, the diver's knife has limited usefulness in fighting marauding sharks. It is, however, an essential item of safety equipment which can be used to cut the diver free from entanglements such as rope, kelp, fishing lines and nets. Scissors may be more effective for this.

Although stainless steel blades resist rust, inferior quality steels do not hold a cutting edge well. The knife should be of robust construction and of a reasonable size. It should be strapped to the diver at a location where it will not cause snagging (e.g. the inner surface of the calf or arm), and easily accessible. It should not be attached to any item of equipment, such as the weight belt or scuba harness, which may be ditched in an emergency.

Spear Guns

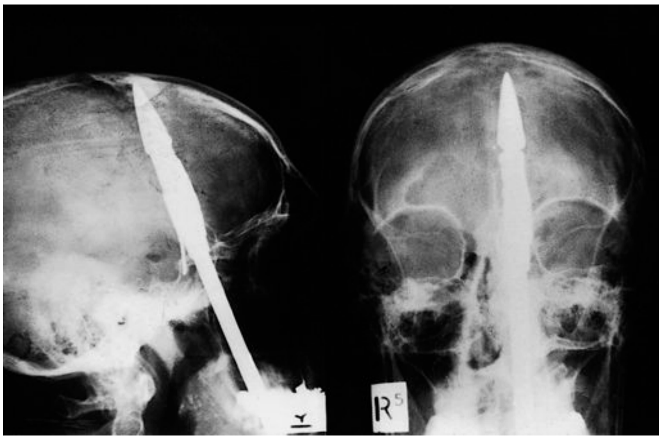


Fig 5.11

Although there is usually some value to specific bits of diving equipment, with inevitable problems accompanying them, the only piece of common diving equipment which can be universally condemned, is the spear gun. The senior author is so scared of divers carrying this equipment, that he departs the water as soon as one is observed. Sometimes the injury is to other divers, sometimes to the spear fisherman himself. The latter was the case in the fig 5.11. He managed to spear himself with the spear (seen as the white rod in the X-ray) penetrating his soft palate, the optic chiasm (nerves to the eye), the sinus and a lot of the frontal part of his brain (which he probably was not using, as he possessed this implement).

COMPRESSED GAS DIVING EQUIPMENT

The use of this equipment has given divers a high degree of freedom underwater and the capacity to go deep and stay there for long periods of time.

Strictly speaking, the term "**scuba**" refers to all **self contained underwater breathing apparatus** but these days it is generally restricted to open-circuit transportable air equipment only (initially called the "Aqualung"). With this equipment the diver breathes compressed air from a cylinder carried on his back, and then exhales into the water.

Other equipment used by divers includes **surface supply compressed air breathing apparatus** (Hookah or SSBA) and **rebreathing apparatus** (semi-closed or closed circuit). **Closed circuit** and **semi-closed circuit rebreathing apparatus** allows a diver to rebreathe some of his exhaled gas. It includes a chemical "scrubber" or absorber to remove exhaled CO_2. By re-using exhaled gas it makes economical use of the gas supply, as well as minimising bubble release into the water. They have obvious advantages for military, technical and commercial operations. See Chapter 43.

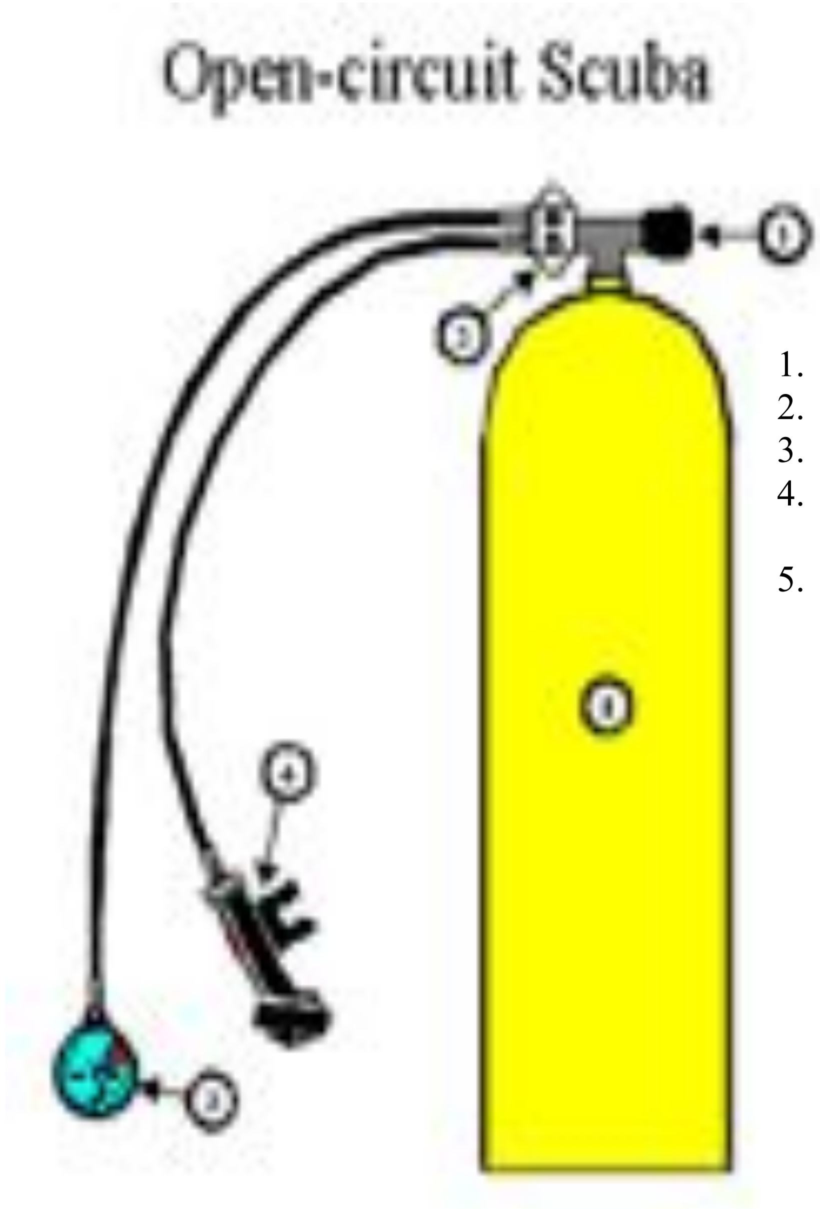
SCUBA

There are two basic forms of this system — the **twin-hose system** and the **single-hose** type. The twin-hose system is rarely used now.

The single-hose unit uses compressed air contained within a steel or aluminium cylinder ("**scuba tank**"). It is usually filled to a pressure of 150–200 Bar (2250–3000 psi). Some systems developed in Europe improve endurance by utilising cylinder pressures of approximately 300 Bar (4500 psi). New cylinders manufactured from alloy-mix materials permit greater pressures, and are smaller and lighter. In most countries, laws require that all cylinders are visually and hydrostatically tested every 1–2 years.

A **cylinder valve** fitted with a mechanical tap and connecting fitting is threaded into the neck of the cylinder. Standards require the fitting of a "**burst-disc**" to this valve so that this will burst before the cylinder in the event of overpressure.

A **"first-stage" pressure reducing regulator** attaches to the cylinder**,** usually by a universal screw-on or clamp fitting. This regulator reduces the pressure of the gas in the cylinder of 150–200 Bar to an intermediate pressure of 7-10 Bar (100-150 psi) above the local pressure and supplies air at this pressure to an **air hose** which passes over the diver's shoulder. The first stage regulator is thus designed to adjust the pressure in the air hose to the water pressure at the depth the diver is swimming (the environmental or "ambient" pressure). It automatically maintains this pressure differential as the diver changes depth.



1. Air supply, cylinder, tank
2. On/Off cylinder valve
3. First stage regulator
4. Second stage regulator, demand valve
5. Pressure gauge, replaceable by Console with multiple gauges

Fig. 5.12
A basic scuba set, without harness, console, octopus reg. or buoyancy compensator

The **air hose** is a small diameter flexible tube made of pressure resistant material which carries air from the first stage regulator to a **second stage regulator** (or **demand valve**) which in turn supplies air to the diver through the mouthpiece. With inhalation, a diaphragm moves to open a valve in the demand regulator, and air passes from the air hose to the diver, at the environmental pressure.

The diver exhales directly into the water through one or more one-way valves which should prevent water from entering the demand valve during inhalation.

It is important that the pressure of the air supply to a diver does not vary as the scuba cylinder empties, otherwise it will become progressively more difficult to breath as the tank pressure falls. Modern first stage regulators are much improved on the earlier models and have incorporated devices such as "balanced" valves to reduce this problem to some degree.

With most equipment, it is necessary for the diver to create a slight negative pressure in the mouthpiece during each inhalation in order to activate the demand valve mechanism. This negative pressure should be minimal or breathing becomes tiring. A regulator which is easy to breathe from at the surface, may not necessarily be able to deliver the large gas flows required during exertion at depth. When choosing a regulator, divers should refer to independent (e.g. U.S.Navy) testing.

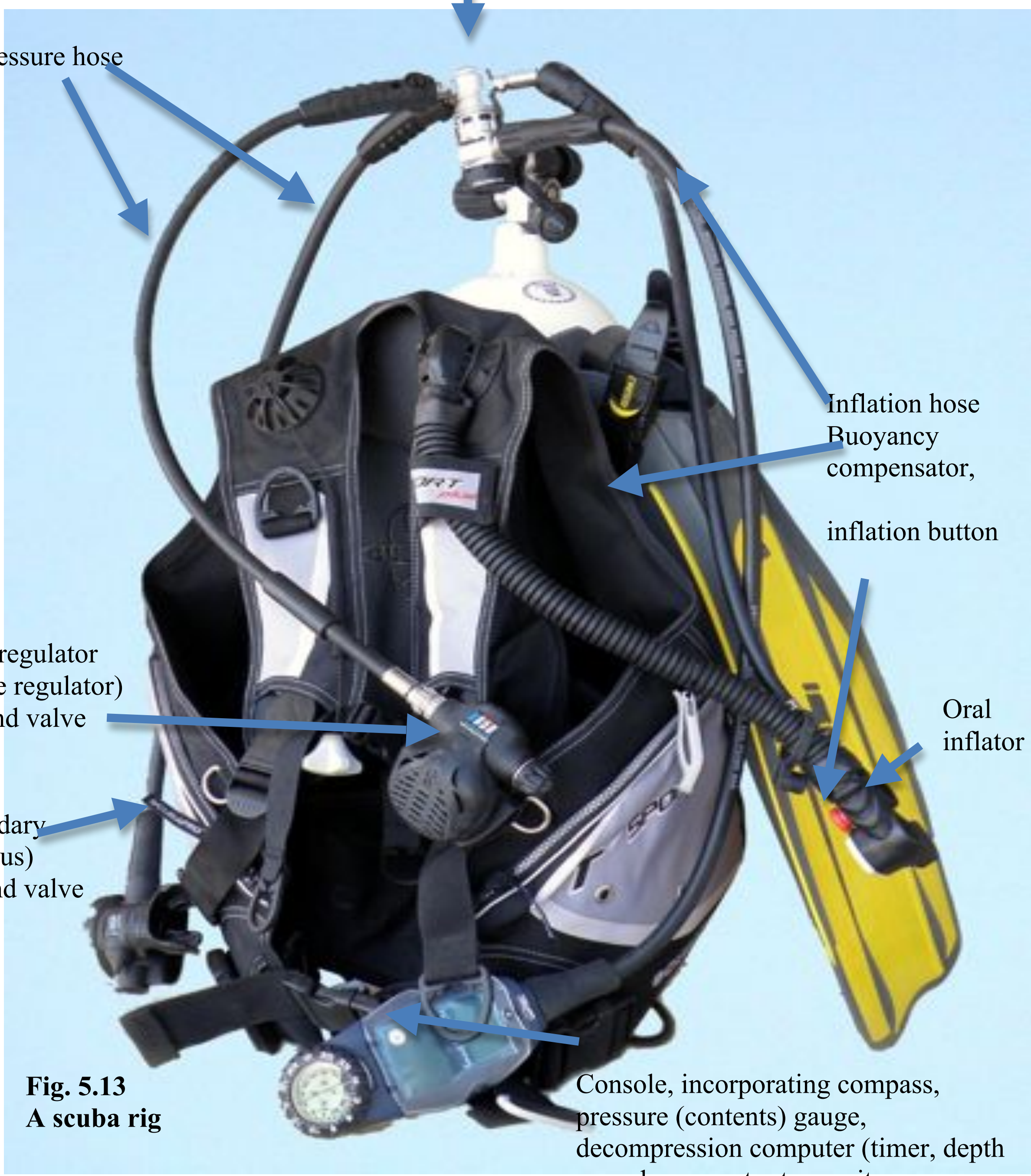


Fig. 5.13
A scuba rig

Difficulties are still encountered in obtaining adequate air supply with reasonable respiratory efforts under the following conditions :

- low cylinder pressures (observable on contents gauges), < 50 Bar
- cylinder valve not fully opened
- resistance in the first or second stage regulators (poor design or inadequate maintenance)
- increased respiration (exertion, hyperventilation, negative buoyancy etc.)
- at greater depths where the air breathed is more compressed (dense), > 30 metres
- with other demands on the air supply (inflating buoyancy compensator, octopus reg. etc.)

Some demand valves are bulky and quite heavy, requiring continual tension on the bite and the jaw to retain the mouthpiece. This can lead to painful spasm of the jaw muscles and a dysfunction of the jaw (temporo-mandibular) joint (see Chapter 32). Malleable plastic mouthpieces are available which attempt to spread the load evenly over the teeth. A soft silastic mouthpiece may be more valuable. Lugs attached to the mouthpiece are designed to keep the mouth open slightly, in a comfortable position and to locate and retain the demand valve correctly in the mouth. It should not be necessary to grip the lugs tightly.

Cylinder Valve

The gas outlet from the cylinder to the regulator is controlled by a high pressure valve or tap. High pressure "burst discs" are fitted by law to all scuba cylinder valves to minimise the risk of explosion if the tank is over-pressurised.

A common problem with divers is when they open the valve to check tank pressure, then close it to prevent accidental air loss *en route* to the dive site. The high pressure remains in the hoses and so the pressure gauge reads “full”. There is enough gas in the hose to permit a breath or two as the diver descends. Very soon he finds the supply of gas suddenly depleted, the pressure gauge then reads “zero”, or nearly so, and a rapid and embarrassing ascent is required.

Twin Hose Scuba

The twin or dual hose unit has both a first and second stage reducing valve combined in a single module attached to the cylinder yoke. Air is delivered by an intake hose to the diver's mouth at a pressure equal to the surrounding water. An outlet hose exhausts the exhaled air to the regulator for release to the water.

Since the diver's exhaust gas bubbles are released behind the head from the regulator, they tend not to interfere with vision. The twin hose apparatus has the disadvantage of requiring two bulky corrugated air hoses of around 2.5–3 cm diameter, and it is more difficult to purge the system of water. These units are rarely used today, except by photographers and in sites where regulators may freeze. The twin hoses were very prone to perishing and leakages.

HOOKAH and SSBA

Air can be supplied to the diver by a hose from the surface, either from a compressor (**hookah unit**) or from a cylinder or bank of cylinders (**surface supply breathing apparatus - SSBA**).

The air from SSBA is supplied directly to the demand valve at a pressure which is manually preset according to the depth at which the diver is operating. The first stage reducing valve (regulator) is located on the cylinder at the surface, and can be adjusted according to the diver's depth. This system can allow almost unlimited diving duration, which poses a risk of decompression sickness if the depth and time of the dive is not monitored.

Fig. 5.14
A hookah compressor and motor with capacity for two divers.

Fig 5.15
Surface supply

If the gas pressure in the hose from the surface fails due to a hose rupture, compressor failure or an empty cylinder, a pressure gradient can rapidly develop between the diver's respiratory tract and the failure site. Unless a non-return valve is incorporated in the gas supply line, near the diver, this pressure gradient can result in parts of the diver returning to the surface through his air hose. See Chapter 12.

Surface hookah units usually include a small pressurised reservoir as an emergency supply for breathing in case of compressor failure. Many divers carry small compressed air cylinders with them underwater ("pony bottles" or "bail-out bottles") which are able to be operated manually in the event of a main supply failure.

STANDARD DRESS or HARD HAT

This traditional piece of equipment uses compressed air delivered by a flexible hose to a rigid brass or copper helmet, usually connected to a heavy duty dry suit. The depth of the dive determines the pressure of the delivered air. A continuous air flow is supplied to the helmet at a rate sufficient to supply the diver's oxygen needs and to flush out exhaled gas. Originally hand powered compressors were used, later superseded by motorised compressors. A bank of compressed air cylinders can also be used, as with SSBA.

This system is bulky and requires heavy lead weights (usually boots and chest corsets) to offset the buoyancy of the helmet and the suit. Failure of the gas supply to keep up with the diver's rate of descent, or loss of the air supply (in the absence of a non-return valve), can lead to the diver being compressed into the helmet — causing head or body barotrauma. See Chapter 12.

Fig. 5.16
A "hard hat" or
standard dress rig.

A modern variant of this system is used today in deep diving. It utilises a smaller, light-weight fibreglass or aluminium helmet or mask in conjunction with a dry or warmed wet suit, enabling the diver to swim and move more freely. The tethering line may go to the surface or a diving bell. The diver usually breathes gas mixtures which include helium, to prevent the development of nitrogen narcosis.

Fig. 5.17

A modern professional diving mask in rear with Standard Dress helmet in the foreground.

Closed and Semi-closed Circuit
REBREATHING APPARATUS

With this equipment some or all of the diver's exhaled gas is passed through a carbon dioxide absorber ("scrubber") and then rebreathed from a breathing bag ("counterlung"). This minimises gas usage, produces fewer bubbles and allows smaller cylinders to be used for an equivalent dive duration.

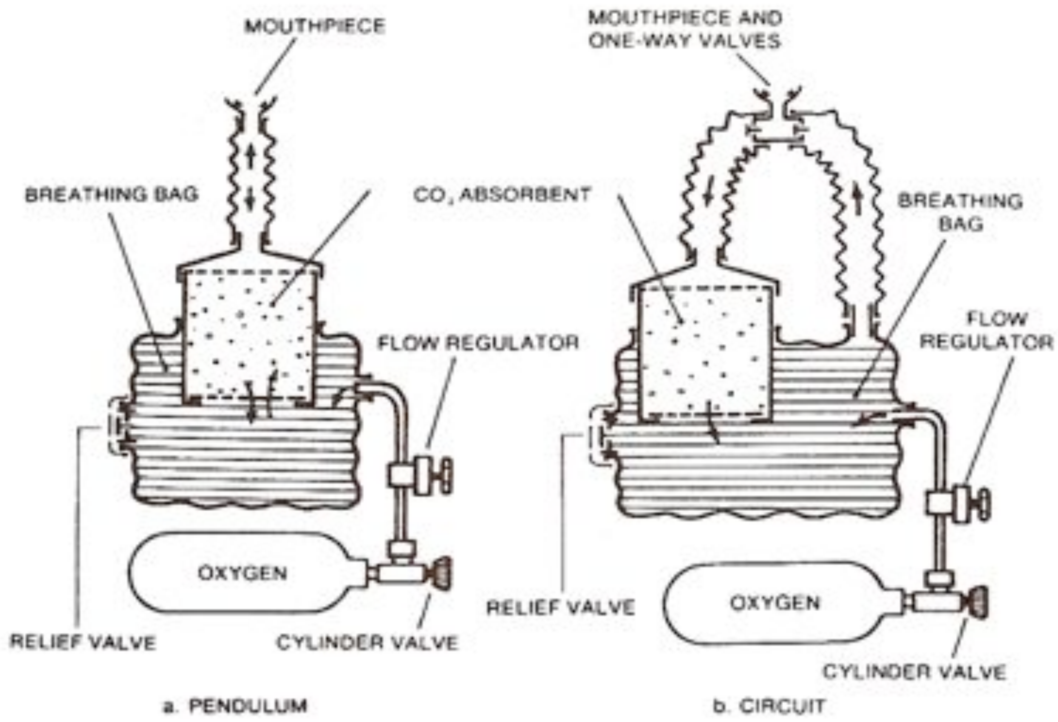


Fig. 5.18
Diagram of two types of closed circuit oxygen rebreathing sets.

A military system, using 100% oxygen in a closed circuit, is employed for clandestine operations (blowing up ships, examining potential landing sites, etc.). Because the diver rebreathes 100% oxygen, there is a risk of oxygen toxicity, so these sets have a practical depth limit of 9 metres.

Some of these sets have a demand-type system, where gas is supplied automatically when the volume in the counterlung is reduced. Others have a continual gas supply, with excess being exhausted.

Closed circuit mixed-gas rebreathing systems are used in technical and deep diving operations. These are further described in Chapter 43, but are not recommended for use by other than very experienced and meticulously trained divers.

Fig. 5.19 **Military diver wearing oxygen rebreathing sets.**

ANCILLARY DIVING EQUIPMENT

Buoyancy Compensator, Buoyancy Vest, B.C.

This device was originally devised as a modified life jacket to provide emergency flotation for the diver at the surface. Its value in compensating for changes of buoyancy due to wet suit compression with depth, was realised and it was modified to allow the gas content to be varied during the dive, depending on the buoyancy needs. It was also variously called a B.C.D. or B.C.V. (buoyancy compensating device or vest) or A.B.L.J. (adjustable buoyancy life-jacket)

Desirable features. When inflated the B.C. positive buoyancy should be sufficient to offset the negative buoyancy of the submerged weight of the diver and his equipment. It should support an unconscious diver so that his face is clear of the water. Ten kilograms (22 lbs) of buoyancy is more than adequate to achieve this. Most B.C.'s have excess capacity.

The B.C. should have a means of oral inflation, as well as a means of manually inflating with gas from a compressed air cylinder. With modern B.C.s the latter usually takes the form of an auxiliary "direct low pressure feed" line from the first stage or reducing valve. This direct-scuba-feed allows the B.C. to be inflated using air from the scuba tank. This may provide insufficient or slow inflation with a low tank pressure at depth, especially if air is also needed for breathing.

Ideally there should be a separate emergency supply of inflating gas — this may be either a CO_2 cartridge or a small compressed air bottle. If a CO_2 cartridge is used it should have the ability to fully inflate the vest at depth, which usually requires at least a 20 gram capacity. The CO_2 cartridge triggering device is especially prone to corrosion and needs to be regularly maintained and inspected before each dive. The toggles which operate these cartridges can snag on passing obstructions, accidentally inflating the vest. This can have disastrous consequences in cave diving, saturation and decompression dives and other situations.

Some B.C.s are fitted with a small compressed air bottle for emergency inflation. This is activated by a rotating valve which will not open accidentally. The bottle can also serve as an emergency source for a few breaths of air if a modified demand valve is fitted to the vest. These bottles are usually charged from the main gas cylinder at the surface just prior to fitting the B.C.

The B.C. should have a pressure relief valve to prevent rupture from over-inflation on ascent. There also needs to be an easily accessible air-dumping valve to allow quick release of gas. The direct scuba feed line should also have an easily operated "quick-release" fitting at the B.C. end in case of a jammed inflator valve causing greater inflation than can be released by a dump valve.

The B.C. should be designed so that it will not ride up onto the throat when inflated. This was traditionally accomplished by fitting a crotch strap or attachment to the scuba harness. B.C.s are becoming increasingly more complex and expensive, and may contribute to diver errors and therefore injuries. Operating a B.C. requires repeated training.

Jacket B.C.s incorporating a scuba-tank backpack have become popular in recent years. These are comfortable and convenient to use, do not compress the chest and eliminate many of the straps associated with a traditional scuba-tank harness. With most of these units, however, it is difficult in an emergency to ditch an empty scuba tank on the surface without losing the B.C.

Fig. 5.20 This is the type of B.C. you do not want. One that tips the unconscious diver face down in the water

BUOYANCY OVERVIEW

General. Problems with buoyancy dominate diving accidents and deaths. To understand this vital aspect of diving, there is no better way than to take a specific buoyancy course with one of the diving instructor organizations - after a basic diving qualification has been obtained and before any further open water experiences.

In over half the diving deaths there were buoyancy problems contributing to the death. Most new divers need to understand the following facts (see above and Chapter 34 for more detailed explanations).

1. Most divers' bodies are almost neutrally buoyant when immersed in sea water. They tend to sink in fresh water.
2. The equipment used (wet suit and buoyancy compensator,) have air within them. Weights are needed to overcome this buoyancy effect and help the diver to descend. Novice divers tend to use many more weights than experienced divers. One large buoyancy producing area is the diver's lungs (around 5 litres). Because of greater anxiety, novices hyperventilate more and breath at higher lung capacities. As they relax, both during an individual dive and with more diving experience, they breath less and then need less weights. Even some experienced divers, who may be anxious, use more weights than they need, and compensate for this by greater reliance on their buoyancy compensators (B.C.s).
3. If a diver is over-weighted, he assumes a more head-up position when swimming horizontally. If underweighted, he adopts a head-down orientation. Both mean more energy and greater air consumtion.
4. In comparing deaths with survivors from diving accidents, the survivors ditched their weights and inflated their B.C.s twice as often. Key factors in reducing fatalities were; neutral buoyancy during the dive, and positive buoyancy once a problem developed.
5. In a fatality survey on buddied divers who experienced a low-on-air or out-of-air (LOA/OOA) situation, it was of interest that irrespective of who became OOA first, the over-weighted diver was the one who died – at a 6:1 ratio.
6. Based on the formula below, 40% of divers who perished were found to be grossly over-weighted at the surface. Despite that, 90% died with their weight belt on and 50% did not inflate their B.C. This factor would have been greater at depth. When weighted according to this formula, a diver should be neutrally buoyant at or near the surface. In this state, descent or ascent are equally easy.
7. Many cases of decompression sickness are related to loss of buoyancy control.

Wet suit effects. How much weight is needed to overcome the gas bubbles in a wet suit on the surface? Check it out yourself. Get rid of all extra air spaces and add weights to the wet suit until it starts to sink. That is your answer, and it indicates how much extra weight you need to add to your weight belt.

Weights. You will need approximately 1 kg for each 1 mm wet suit thickness, 1 kg for "long john" extensions, bootees and a hood, 1 kg for a filled aluminium tank, ± 1–2 kg for individual body variations in buoyancy (fat divers are more buoyant, thin are less). Thus with a wet suit of 3 mm thickness, you may need around 4 kg weights.

On descent, the weights needed will decrease according to Boyles Law. Thus at 10 m. in the above example, you will need half that weight, and you will be too heavy, and sinking, until you add 2 kg of air to your B.C. Also, gas spaces elsewhere (gastro-intestinal tract, B.C., under suit, etc) are reduced and so more air may be needed in the B.C.

The scuba tank may be negatively buoyant ant the start of a dive, and positively buoyant near the end – after the compressed air has been lost.

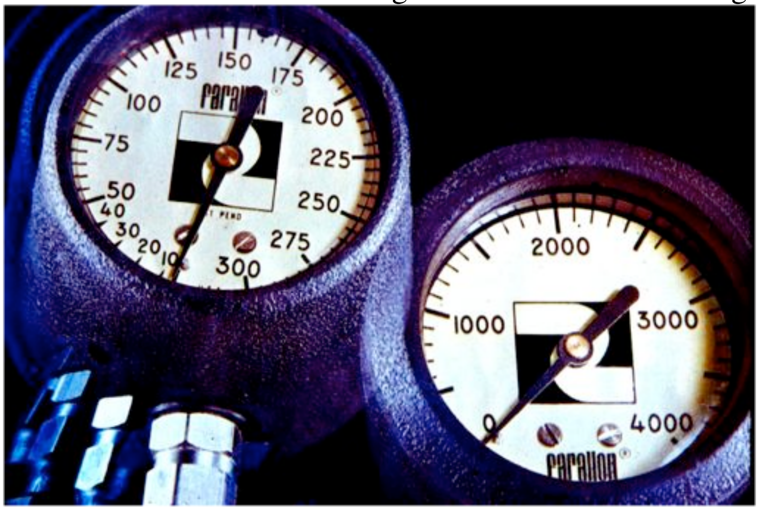
Buoyancy compensator. All divers will be impressed with the way they can rapidly inflate their B.C. on the surface, and the noise it makes. Unfortunately, in an emergency underwater, it is much slower as the air supply also reduces because of the Boyles Law effect. A diver in difficulties may not realize that the B.C. air-supply button has to be depressed for longer to get the same effect. It takes much longer to inflate 4 litres of air in the B.C. than it does to drop a 4 kg. weight belt. Also, the 4 litres of air will expand as you ascend and produce the emergency rapid ascent – the "polaris effect", with all its complications and with the requirement to off-load gas. In an emergency, this may not be easy. Release of a weight belt produces a more consistent rate of ascent throughout.

Rescue implications. As a general rule, in assisting in a diving incident, it is preferable to ditch the victims weights more than the rescuers, and inflate the victims B.C. more than the rescuers. As separation often occurs, the possibly unconscious diver will still reach the surface if these actions are performed.

Contents Gauge

It is essential to monitor the air content of the scuba tank during a dive, to allow a sufficient air reserve for return to safety, emergency use and for decompression.

The pressure observed in the contents gauge overestimates the air available, because a substantial pressure is required just to drive air through the regulator. Thus something like 40 Bar should be deducted from the reading to calculate the remaining air available for the dive.



"Reserve" valves are not adequate substitutes for contents gauges since they may be inadvertently opened before or during the dive, and have been observed to leak or fail under operational conditions.

To gain maximum advantage from the contents gauge the diver should refer to it frequently, and should be aware of the values in respect to his own diving air consumption at that depth.

Fig. 5.21.
Depth and contents gauges (calibrated in feet of sea water and psig, respectively).

Alternate Air Source

The **octopus regulator** is a second-stage demand valve which can be used by the diver in the event of failure of the main demand valve, or which may be used by another diver who has an equipment failure or air exhaustion. The hose for the octopus or second reg. is longer than the primary reg so that it can be used easily by the OOA/LOA (out-of-air, low-on-air) diver. This facility eliminates the need for buddy breathing from a single demand valve, which can be difficult and dangerous to perform in high stress situations or between inexperienced divers.

Obviously, two divers using the same scuba system will halve the endurance of the tank. An alternative is to carry a complete separate emergency "**spare air**" unit with an adequate supply of air to reach the surface. At depth, and with a low tank pressure, insufficient air may be available for simultaneous use of the demand valve and the octopus regulator. Other alternative air sources include twin scuba cylinders (and independent regulators) and air breathing from a B.C. supply.

Fig. 5.22
A Spare Air unit

Diving Watch

A reliable, accurate, waterproof watch or dive timer is an essential piece of scuba diving equipment, in order that decompression requirements can be calculated.

The device should include some means of measuring elapsed time. A rotating bezel on the face of the watch is a simple and popular way of achieving this. It is not essential, but it is traditional, for divers to wear black-faced watches. Digital watches with elapsed time counters are also used.

Electronic dive timers, which are automatically triggered after a shallow descent, may not only record the dive duration but also the time between dives (surface interval).

Depth Gauge

It is necessary for the scuba diver to have an accurate knowledge of his depth exposure so that decompression requirements can be calculated. A depth gauge should be easily read under all visibility conditions. There are several types of depth gauge currently available. The simplest type uses an air-filled **capillary tube**. As the air in the tube is compressed during descent, water enters the capillary tube and the position of the water interface on a calibrated scale indicates the depth. This type of gauge is very accurate at depths down to about 10 metres but it is inappropriate in excess of 20 metres, due to the small scale deviations available on the gauge at these depths.

A **Bourdon tube gauge** incorporates a thin curved copper tube which straightens slightly as increased water pressure compresses the air within the tube. The movement of the tube is magnified by a gearing system which moves a needle across a scale. This type of gauge may become inaccurate due to salt obstructing the water-entry port, repetitive mechanical damage and altitude exposure.

Another type of gauge has a flexible **diaphragm** incorporated into the casing of the gauge. The diaphragm moves a needle through a magnifying gear system. This type of gauge has the advantage of relative simplicity and reliability.

Modern micro-processor technology has produced digital depth gauges which measure depth using a **pressure transducer**. This type of gauge is dependant on an adequately charged battery with water-tight integrity for reliable operation.

A device which records the **maximum depth** attained (maximum depth indicator or M.D.I.) is recommended as the diver may fail to note the greatest depth attained during a dive. This knowledge is necessary in calculating decompression requirements.

A depth gauge should be regularly recalibrated to ensure its accuracy. Some depth gauges incorporate a capillary depth gauge which will provide a cross check of calibration at shallow depth. Often depth gauges are contained in "consoles" which also contain cylinder contents gauges, timers and compasses.

Compass

Possibly one of the least appreciated pieces of equipment, until one needs it to navigate both underwater and on the surface.

Decompression Meters and Dive Computers (D.C.) (see Chapter 14)

A decompression meter or dive computer uses a mechanical or electronic model of the inert gas uptake and elimination by the diver. The dive computers (D.C. or D.C.M.) are based on decompression theories or algorithms (the principles on which the tables were developed) but often omit some of the safety factors incorporated in the formal tables. It is impossible for them to exactly duplicate the very complex gas uptake and elimination from a living diver and to allow for individual variation. They do however, accommodate the divers need to undertake both repetitive diving and multi-level diving in a much more manageable manner than the formal decompression tables.

Most current D.C.s also incorporate accurate devices for recording times, depths, ascent rates, cylinder contents and even water temperatures. Some provide "print-out" capabilities or connections to a computer. These enable accurate graphical representations of a diver's dive profile, and are useful to diving physicians treating cases of decompression sickness and to demonstrate where the diver went wrong. Unfortunately, sometimes it is the dive computer that goes wrong, not the diver.

Communication Systems

The safety of the buddy system of diving depends on the two divers being in constant communication. Divers who are not in constant communication are in reality only diving in the same ocean and may or may not be available to assist their buddy in an emergency. Even when they do, third party rescue is often needed. Buddy lines and buddy diving are discussed in Chapter 34.

Surface detection aids

The purposes of this class of personal equipment are to:

- allow the support boat to monitor and find divers on the surface during or after a dive
- prevent the diver being struck by boat traffic
- mark the diver's position when drift diving or while at the decompression stop
- help rescue services in lifeboats and helicopters to locate the diver

• Fig. 5.23
An inflatable safety sausage or "divers condom".

Surface detection aids include:

- Surface marker buoy, Decompression buoy, Delayed SMB, safety sausage or blob
- Red or yellow collapsible flag - high visibility, robust, bungeed to cylinder
- Glow stick - for night diving
- Whistle - cheap, will only be heard by people far from engine noise
- Torch/flashlight - if at sea after night fall
- Strobe light - needs long-lasting batteries
- High pressure whistle - expensive but effective
- Orange water dye - increases diver's visibility from search helicopters
- Mirror, such as a used compact disc, to reflect sunlight or searchlights
- Red or Orange Pyrotechnic flares -for helicopters and lifeboats
- Emergency Position-Indicating Rescue Beacon (EPIRB)

A **whistle** may be of value on the surface, in attracting support from the boat crew or other divers. Another system of drawing attention and demonstrating the divers position on the surface, where most accidents either commence or end up, is a depth-resistant **distress signal** (smoke for daytime, flare for night).

A 2 metre orange plastic tube, able to be inflated by scuba or mouth, is of value and is marketed as the **Safety Sausage**. If erect, it is easily seen from aboard boats. Aircraft can identify it more easily when it is laid flat on the water surface. It is also known as the "Diver's Condom".

Underwater a diver can be contacted by a variety of transmitting and homing devices. **Lights** are of real value at night, if the visibility is good.

It is a sad fact that most divers' bodies are retrieved only after a search — and usually death occurs without the buddy-diver's knowledge. Many deaths could possibly be prevented by the proper use of such simple and cheap systems of communication.

Most divers rely on diving close to each other, with visual communication only. Variations, such as one diver leading the other or diving with a group, results in an antithesis of the buddy system – as there is no clear and complete responsibility of each diver for the other.

A **buddy–line** keeps a pair of divers in close contact. It consists of a short length of cord (2–4 metres in length and preferably of floating line) which is attached to each diver's arm by a detachable strap. Any emergency affecting one diver will soon become apparent to the buddy even if he is not watching. Possibly the only instance where the buddy line should be discarded is when snagging is likely, or if a large shark takes a serious interest in one's buddy

STAND-BY DIVER

In all commercial diving, all surface-supplied diving, and in most well organised diving operations, there is preparation made for the possible adverse incident, which could lead to injury or death. This may eventuate from environmental problems (currents, marine animal injury etc.), equipment failures (out-of -air, regulator failure etc.) and medical illnesses (dive-induced or natural). Then there needs to be a previously planned and rapid rescue of the incapacitated diver, followed by competent resuscitation (see Chapters 39-42).

Rescue will require a means of rapid detection and usually a surfacing of the diver, by a stand-by diver and a surface attendant, a means of rapid transport (usually a rescue craft) and manhandling of an unconscious body onto a resuscitation platform. This all requires pre-incident planning. A stand-by diver should be skilled at recovering an unresponsive diver from depth, and assisting a trapped diver to get free, and may be required to provide an alternative breathing gas.

The stand-by diver will be prepared in the same way as the working diver, but will not enter the water until needed. He will usually be prepared to enter the water, and then will remove his mask or head-piece, and will then sit in as comfortable a place as possible. In case of an emergency he is prepared for immediate action. It is frequently necessary to cool the standby diver to avoid overheating, and dehydration must be prevented.

In an emergency, the stand-by diver will be instructed by the dive supervisor to reach the incapacitated diver, address any emergency (out-of-air situation, entanglement etc.) and return the diver to safety. For this reason a stand by diver should a very competent diver, but does not have to be expert at the specific work skills needed by the other divers.

When the standby diver is sent in he will normally follow the umbilical of the incapacitated diver. If he has hands-free communications, the stand-by diver is expected to give a running commentary of progress so that the supervisor and surface crew know as much as possible what is happening and can plan accordingly.

There is some rescue equipment that can make the standby diver more effective. A rescue tether is a short length of rope or webbing with a clip at one or both ends, which the stand-by diver uses to clip onto the unresponsive diver's harness, freeing both his hands for a recovery. This ensures that the injured diver will not be separated, as the stand-by diver signals and is then pulled to the surface (if a line - not an air hose - is attached to the rescuer).