done on assembly to make sure line pressures are correct.

Failure to check equipment as mentioned above is a frequent problem. Before you leave your house to go diving, give all of your equipment, including your first and second stages, a good visual inspection, checking things like mouthpiece clamps, 'O' rings, exhaust ports and hose fittings. Once at the dive site, check your own equipment before you put it on, and then check your buddy's before you get in the water.

It is easy to become complacent with things as they become more routine. Complacency is insidious, and leads to poor dive management. If you ask a room full of people to assess their driving practice, most of them will think they are above average car drivers and yet most will have picked up many bad habits over the years. It is the same with diving or any other thing we do regularly; that is why in chamber operation and occupational diving we have pre-dive checklists and why pilots have pre-flight checks.

Inexperience is a common feature. We all have to start somewhere, but with apologies to the recreational dive training agencies, recreational divers receive very limited training. If you know a member of your dive group is inexperienced, spend some extra time helping with their pre-dive checks and keep an extra eye out for them in the water.

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Depth gauges, contents gauges and miscellaneous equipment problems reported in the Diving Incident Monitoring Study

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Key words
Diving equipment, scuba, incidents, injuries, morbidity, deaths, survey

Abstract
Problems with depth and contents gauges reported to the Diving Incident Monitoring Survey are reviewed. The development of these gauges and their safe and unsafe use are discussed. A method of diving safely without a contents gauge, used by the Royal Navy for decades in the past, is explained. Attention is drawn to the fact that running out of air was the most common cause of death in divers in the 1990s. This is usually due to diver error (not checking the contents gauge frequently) but can be due to faulty contents gauges. Another common diver error leading to death is failure to drop the weight belt. Depth and contents gauges are known to go out of calibration and dive computers to be faulty, so regular testing of both sorts of gauges should be carried out. Some personal experiences are used to illustrate the message that diving safety involves preparation and attention to detail.

It is now accepted that depth and contents gauges are essential parts of a diver's equipment. This was not always so. Reports in early diving magazines make it clear that scuba divers often did not have contents or depth gauges in the early years of scuba diving, the 1940s and early 1950s. In those far-off times depth was usually estimated, not measured, and many divers terminated their dives when breathing became difficult or even impossible, necessitating a 'free ascent'. As people became less reliant on home-made gear, contents gauges became popular. They are essential for safe diving using a single tank.

In the 1950s, when I joined the Royal Navy (RN) as a medical officer, the RN did not use contents gauges for scuba diving. Instead, they used twin tanks yoked together. The tanks were 'upside down', with the valves within easy reach just above the diver's bottom. The diver turned on one cylinder (A) and used it until it ran out; he then knew that he had used half his air. Turning on the second cylinder (B) equalised the pressures in both cylinders and then cylinder B was turned off. At this stage, the diver had used half his available air and was breathing from half the remaining half. When that air ran out, he still had a quarter of his original air supply in cylinder B. At this point, the diver turned off cylinder A and used cylinder B to return to the surface. This procedure was still in use in 1972.

Having a contents gauge, and looking at it, is much easier than remembering how many times you have decanted. The problem is that many divers do not look at their contents gauges often enough to avoid running out of air underwater. Even in the 1990s, running out of air underwater was the most common cause of death in Australian divers.[1]

Contents gauges

Until recently, all contents and depth gauges were Bourdon tube gauges, which are coiled tubes that uncoil or recoil as the pressure within them changes. This movement is transmitted to the needle gear system. If treated with loving care, as on anaesthetic machines and recompression chambers, they are reliable. However, when dropped or shaken the calibration may no longer be relied on. Nevertheless, divers do not have their contents or depth gauges checked every time they are bumped. The only way to conveniently check a contents gauge is to compare it with another. A contents gauge that does not return to empty when taken off the cylinder must be considered to be faulty.

The Diving Incident Monitoring Study DIMS has records of 37 contents gauge incidents, 10 (27%) of which were associated with morbidity. The divers involved suffered decompression illness (DCI), cerebral arterial gas embolism, salt water aspiration and pulmonary barotrauma. Inaccurate gauges were one of the frequently reported causes of running out of air underwater. Gauge problems from the Project Stickybeak database are also listed in Table 1.

Some divers did not understand the units used, mistaking imperial (pounds per square inch, psi) for metric (kg.cm^{-2} or kiloPascals, kPa) or bar. Other problems were rupture of the high-pressure hose or of an 'O' ring during the dive. Some divers were unable to read the gauges either because of poor visibility or because the numbers were difficult to decipher (Table 1).

The important thing about reading a contents gauge is the proportion of the contents remaining rather than the actual pressure (e.g., the rule of thirds). Many divers are also unaware that fluctuation of the gauge needle when a breath is taken indicates that the cylinder is not fully turned on.

Turning on the cylinder when the regulator is first attached is a sensible way of checking that the cylinder is full. But forgetting to depressurise the system after that can lead to trouble, as although the cylinder appears to be turned on it is, in fact, turned off. One should always take a few breaths from the regulator while watching the contents gauge before entering the water. Some years ago a buddy of mine entered the water without a buddy check and only obtained one breath before running out of air for this reason.

Depth gauges

DIMS has nine depth gauge incidents recorded. Two were associated with morbidity (decompression illness in both cases). Problems recorded included inaccuracy, a stuck maximum depth indicator and the maximum depth indicator not being zeroed before the dive. If the maximum depth indicator is stuck, it may prevent the depth gauge needle from moving properly. Such problems can be avoided by regular testing and servicing of depth gauges, and attention to maximum depth indicator usage.

In the mid 1980s a British magazine reported a study of over 100 Bourdon tube depth gauges. Approximately one third were accurate, one third overstated the depth (safe), and one third read shallow (dangerous). At the 1986 SPUMS Annual Scientific Meeting, I tested about 20 gauges in a small water-filled compression chamber consisting of a small perspex pot with a screw-on lid and a calibrated pressure gauge. Pressure was applied by screwing a 10 mm diameter perspex screw into the case. As there was no air in the 'pot', any reduction in volume increased the pressure. The results were similar, and the errors, whether too deep or too shallow, tended to be proportionately the same over any particular gauge's tested range.

One recommended solution is a back-up depth gauge. I usually wear a capillary gauge, which is accurate in shallow water, but difficult to read accurately at depth. As long as it

TABLE 1
TYPES OF CONTENTS GAUGE PROBLEMS REPORTED IN THE DIVING INCIDENT MONITORING STUDY AND PROJECT STICKYBEAK

DIMS

1 Inaccurate gauge
2 Hose leak
3 Unable to read the gauge – poor visibility or legibility of numbers
4 Maximum depth indicator stuck
5 Maximum depth indicator not zeroed at start of dive

Project Stickybeak

1 Dangling and became snagged
2 Needle was loose

is looked after properly, and rinsed through with fresh water after use, a capillary gauge rarely malfunctions. When using a dive computer, a Bourdon tube depth gauge in the regulator console can be used as the back up.

Human factors that contributed to contents and depth gauge problems were lack of calibration and servicing, combined with the diver's failure to check the gauge before and during the dive. Design factors that contributed included gauges having red lettering, sometimes against another colour background, providing poor colour contrast.

Air integrated gauges are advocated by some divers. In the mid 1980s, I bought an early model air integrated gauge, which showed the remaining air pressure numerically and as a steadily emptying cylinder icon. It also showed how long the air would last at the current breathing rate, the depth in metres and temperature (°C). It took about 10 years for the battery to die, by which time the manufacturer had gone out of business and the battery was not replaceable!

Most dive computers possess reliable depth gauges (this being essential for accurate function of the decompression model on the chip), but errors have been reported.[2]

The DIMS results show that depth and contents gauges are essential for safe diving. They must be easy to read. Accuracy determines their safety, but are they accurate when they leave the dive shop? There are no legal requirements for recalibration or servicing of depth or contents gauges. Although there is an Australian/New Zealand Standard for gauges, it does not cover gauges of the accuracy of those used for recompression chambers, nor submersible gauges used by recreational or professional divers. The current Standards for diving and working under pressure usually refer to pressure measuring devices rather than gauges, as there are many substitutes for the Bourdon tube gauge.

Miscellaneous equipment problems

The DIMS reports include some unusual incidents leading to harm (Table 2). These include damage to the diver from exit ladders, surface signalling devices, light sources, shot and other lines, and the backwash from a dive scooter. Five divers had problems with the exit ladder, resulting in injury to four, including lacerated or crushed fingers and a lacerated scalp. Contributing factors were unfamiliar diving conditions, poor dive planning and rough seas. The lesson is that entry and exit from the water needs to be carefully planned. The range of equipment problems contributing to fatalities in Project Stickybeak is also shown in Table 2.

Eight incidents with surface signalling devices were reported to DIMS. Whistles, often supplied with buoyancy compensators, were not heard over the noise of the boat's engine. Whistles driven by cylinder contents are useless if the diver is out of air. Some divers were unable to inflate their 'Safety Sausage' because they were out of air.[3] Some inflatable devices were not seen because of rough water, or flopped over in windy conditions. The original Safety Sausage, being a deep red colour, was poorly visible in some water/light conditions, even from a relatively short distance.

TABLE 2
MISCELLANEOUS DIVING EQUIPMENT PROBLEMS CAUSING MORBIDITY IN THE DIVING INCIDENT MONITORING STUDY OR FATALITY IN PROJECT STICKYBEAK

DIMS	
1 Air cylinder:	Slipping out of BCD
2 Snorkel:	Non-functioning flap valve
3 Diving computer:	Not activated before the dive
	Battery became flat during dive
4 Depth gauge:	Inaccurate
5 Dive tables:	Misreading
6 Exit ladder:	Sea conditions made it difficult to use
Project Stickybeak	
1 Air cylinder:	Rusted inside
2 Fins:	Dislodged during the dive
	Too loose
	Diver forgot to put fins on
3 J-valve:	Incorrect position before the dive
	Diver did not know how to activate
4 Trophy bag:	Weight belt became snagged on it during release
5 Multiple gas:	Confusion, causing the incorrect gas mixture to be used

Here, I must declare my interest in the Safety Sausage. I became the Australian distributor for the original, invented in the 1980s by Bob Begg, a dive retailer in Dunedin, New Zealand.[3] The Safety Sausage suffered from two major disadvantages, it was cheap and it implied that diving could be dangerous. The first meant that dive shops had little incentive to sell it, and few dive shops were willing to be honest with budding divers and admit that divers could become separated from the boat that they were diving from.

Air from the cylinder via a regulator held inside the Safety Sausage with the open end underwater is an easy way to inflate one, or it can be inflated by blowing into it at the surface. The tension in the tube is increased, and the tube stiffened, by the lower end of the inflated tube being held deeper underwater. Later inflatable tubes, from different makers, were made of thicker, more durable materials, but, when inflated, usually less than a metre of the tube showed above the surface, compared with the two metres of an inflated Safety Sausage, so were less easy to see.

Four divers reported problems with their light source, including flooding, flat batteries, and the lamp snagging on other equipment or rocks during the dive. Contributing factors were poor design (unable to test the light before entering the water), lack of a battery charge indicator, lack of pre-sales testing and inattention on the diver's part. Shot lines and surface safety lines caused two incidents. In both cases the diver became entangled due to inattention, but no morbidity resulted.

Personal experiences

At an earlier SPUMS meeting, I observed a SPUMS member prepared to commit suicide if he fell off the edge of the boat. Dressed in a wet suit without its jacket, he was wearing his normal heavy weight belt whilst sitting on the gunwale of the dive boat without his scuba gear or fins on. Had he fallen backwards, his only hope of survival would have been immediate release of his weight belt. Unfortunately, few divers drop their weight belts before they die underwater.[1,4]

During the 1987 SPUMS ASM at Mana Island, Fiji, I maintained contact with the dive boat with a Safety Sausage for about 45 minutes after one dive when my buddy and I missed a short stern safety line in a strong current. As a safety measure, the captain had hung a spare cylinder and regulator below the boat. Unfortunately, the dive boat was short of a line, so one end of the 'Jesus' line was used to hang the cylinder under the boat, which shortened the surface safety line by some three metres. We were swept towards the open ocean, while the dive boat, which did not have a tender that day, had to wait for all other divers before coming to collect us. Although the dive boat had two decks and a sun deck above the wheelhouse, we could see the top of it only when we were on the crest of a wave. Without the Safety Sausage we would have been invisible. The boat could follow our progress toward the breaking surf on the reef because I had inflated my Safety Sausage.

Another personal experience, long before the establishment of the DIMS database, was starting a dive and getting a mixture of air and salt water on my second breath. For some reason, the diaphragm of the expiratory valve had flipped out of place and was sucked inwards with each inspiration, letting water into the regulator.

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Exposure suits: a review of thermal protection for the recreational diver

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Keywords
Thermal protection, hypothermia, wetsuit, drysuit, diver training

Abstract
Some basic diving science on diver thermal protection is reviewed. The common methods of thermal protection used by recreational divers and the potential advantages and disadvantages of various forms of exposure protection are discussed. Diving suit related incidents in the Diving Incident Monitoring Study and fatalities in Project Stickybeak are reported.

Introduction

Exposure suits/thermal protection, as used by recreational divers can be categorised into the following groups: skin; Lycra™ suits; 'steamers' (2–4 mm thick neoprene wetsuits with or without legs); wetsuits (5–9 mm or more, usually with arms and legs covered and often with a neoprene hood); semi-drysuits and drysuits. Some revision of basic diving science and diver cooling is required to review the need for exposure protection.

The thermal conductivity of water is 20 times that of air; that is, it absorbs heat more efficiently. In addition, water movement around the diver causes rapid convection of heat away from the body. As a result, thermal neutrality requires a water temperature of 34°C or more for diver comfort, in less than 34°C all divers will eventually cool to some degree. However, prolonged exposures in wetsuits in water less than 20°C without significant falls in body core temperature have been reported.