Saturation Diving

Dr John Knight

Saturation Diving is mainly used in deep diving work where the bounce dive would involve many hours of decompression which is economically and physiologically wasteful. This deep diving is mainly done on the off-shore oilfields, but deep dives in chambers ashore are used for research and equipment testing. Habitats are mostly used for research in physiology and in marine science.

The main advantages of saturation diving are that there is only one decompression for many hours work and that teams of divers can work round the clock.

Saturation is applied in research where chamber dives go to ever greater depths to test human physiology under pressure and to test equipment. Habitats are mostly restricted to marine science now as they are not as cost effective as chambers for physiological studies. In salvage and construction work the divers live in deck decompression chambers and "taxi" to work in a personnel transfer capsule (known as a "bell" to divers), never coming out of pressure until the job is done.

There are drawbacks to saturation diving of course. It is an expensive pastime running a saturation system, the basic engineering costs are high, the helium costs are high, and the labour costs are high. Besides a pressure proof system there is need to control and monitor the pressure and the atmosphere. The gas mix must be right with the level of oxygen critical to prevent pulmonary damage. It is now accepted that some nitrogen should be in the mixture, partly for haematological reasons and partly to help control HPNS, of which more later. Carbon dioxide must be kept at a tolerable level, about 0.5% surface equivalent is attainable. Other gaseous contaminants have to be removed, as does moisture. The circulation of gas is important to keep the atmosphere constant and the temperature within tolerable limits. Toilet facilities have to be provided, and interlocks on the plumbing so that the distressing case of the diver who lost some feet of his intestine down the pan when the wrong valve was opened cannot be repeated.

Human physiology is rudely jostled by deep diving and saturation diving is not problem free. Many divers suffer from compression arthralgia during the descent. On dives deeper than 200 metres the high pressure nervous syndrome (HPNS) is normal. It can be modified by slow compression and pauses on the way down for the symptoms to settle and by the addition of nitrogen to the breathing mixture. Luckily most of the saturation diving takes place in waters where the depth is shallower than 200 metres. All divers suffer weight loss during a long saturation dive in helium. Divers feel cold in a helium environment. The temperature range that is comfortable is much reduced and the temperature required for comfort during sleep is higher than that during activity. Even when working the diver is not prevented from heat loss without precautions. Helium is a good conductor of heat so the diver in a dry suit is inefficiently insulated and loses heat to the water and also through the respiratory tract as he warms the cold helium which needs more heat to warm it than nitrogen. The diver and his breathing gas must be heated at depths below 600 feet and it is highly desirable at much shallower depths. Ear infections are common (otitis externa) in the damp warm atmosphere of a chamber. Prophylactic ear drops are a good investment. Finally getting back to the surface. Decompression sickness is common on experimental dives and often takes the form of a vestibular "hit" at depth.

The talk was illustrated with slides of various chamber installations. These included shots of the Commercial Diving Centre at Wilmington California; the deep rescue chamber owned by International Diving Contractors which is now the hub of the British North Sea hyperbaric rescue system; and J Ray McDermott's Drilling Barge 21 in Bass Strait.

Diver protection From Cold

Dr John Knight

The commonest form of protection is the wet-suit, which being made of foam squashes with increasing pressure and so becomes less effective as an insulator.

The dry-suit used for 150 years depends on trapping gas in the diver's underwear for its insulating properties. Modern dry-suits, with the waterproof garment made of foam neoprene are effective insulators at the surface. However just getting into the water compresses the underwear, most commercial materials tested are compressed to 30% or so of their original thickness when under a pressure of two feet of sea water. So if the underwear is reasonably expanded round your chest it will be pretty skinny round your legs. Water getting into the suit ruins its insulation which depends on the layer of trapped gas. Your immersion diuresis will also deprive you of insulation if your bladder isn't big enough. Various gases transmit heat at different rates and while carbon dioxide is a good insulator it is not safe to have in the suit unless the helmet is completely separate from the suit. There is a concept for suitable underwear which will be comfortable, moisture absorbing, insulated, water impermeable but gas permeable. Unfortunately this paragon of clothing is still in gestation. At great depths even the dry suit will not keep the diver warm and he must be heated.

The common form of heating used in commercial diving is the hotwater suit. The open type is a wet suit with a number of outlets for hot water which flows over the diver and to waste. The closed form has the hotwater flowing in pipes in the suit but not coming into contact with his skin. This system can be used with a dry suit. In either case there is need for a hotwater supply, usually from the surface through the diver's umbilical.

In the cold water the diver needs heat added to his inspired gas to conserve his body heat. The simplest is a hotwater jacket round the supply hose to the diver's regulator. This has been reported on in Skindiver Magazine. The USN has settled for putting hot water round the inlet and exhaust hoses of its new Mark 12 recirculating diving gear, while in other equipment there is a heat exchanger through which the breathing gas passes and is warmed. The heat is provided either from the surface or from the PTC or a local heater carried on the diver. The USN is experimenting with a propane fired, air supplied diver carried unit. This functions effectively to 60 metres but thereafter the propane liquid vapour pressure is inadequate. Another heater under development is one powered by magnesium wool burning in oxygen. This gives off no bubbles so is suitable for warming those engaged in clandestine operations.

One more bright idea is under study. This is to provide the large amounts of heat for PTCs. It has been suggested that seawater pumped at a high pressure down to the PTC can be run through an inefficient turbine, which would produce heat for the PTC. It is even envisaged that a similar device might be made for the diver working out of the PTC. Maybe I misunderstood the mechanism but it doesn't appeal to me!

A Visit to the US Navy Experimental Diving Unit, Panama City, Florida, June 1979

Speaker: Dr John Knight

Panama City is on the Gulf Coast of Florida in the northern part of the state. The day of our visit it was sunny and hot. We were shown over the facility, by the senior doctor, Captain WH Spaur, MC, USN. The party consisted of members of the Undersea Medical Society who had just attended the meeting in Miami.

The experimental Diving Unit exists to test and develop new equipment. To assist in this they have the new Ocean Simulation Facility which contains a large chamber complex capable of going to 2250 fsw (68 ATS) and also to a vacuum of 1 Torr (151,000 feet of altitude). The temperature in the chambers can be held anywhere between 29°F and 90°F in the wet chamber and between 50°F and 110°F in the dry chambers. Humidity can be controlled between 50 and 95% relative humidity. The wet chamber is 47'3" by 15'10". One end is a huge door through which submersibles can be placed in the chamber for testing. To reduce corrosion freshwater is used in the wet chamber. The turbidity and light levels are variable from dark to light. Any mixture of gases can be supplied and there are computers to maintain and check on the atmosphere and pressures. Besides this magnificent complex with its five interconnected dry chambers there is a double lock chamber 26'6" by 8'6" for treatment of diving emergencies and also an unmanned chamber for equipment testing.

The standard dress for divers has been unchanged for over 100 years. The USN divers' outfit of 1878 was almost indistinguishable from that of 1978. Modern commercial divers wear quite different gear, much lighter and less bulky, with better vision, but it doesn't anchor the man to the bottom so well for bottom jobs and men get accustomed to the gear that they have been trained to use. Learning to work in a hard hat is a special skill, and some divers are unwilling to adapt to the newer equipment.

The USN some years ago started the process of designing a new rig to replace the old hard hat. This is now operational and is known as the Mark 12 surface supported diving system. The new helmet has much improved vision and is neutrally buoyant with zero moment, making an ideal freeswimming helmet when used with a neck dam. With air the system is open circuit. When using helium there is recirculation and carbon dioxide scrubbing. The helmet had to be modified with recirculation ducting. Recirculated gas is directed across the faceplate and face to flush away carbon dioxide and gas is exhausted from the sides of the helmet producing an efficient carbon dioxide flushing system. A carbon dioxide absorber and recirculator pack had to be designed. Gas enters from the umbilical and passes through a venturi into the helmet. The venturi causes a secondary recirculating flow through the canister and back into the helmet. At peak efficiency the ratio of recirculated gas to fresh is 14:1. There is an emergency gas supply in the back pack which can be used either in the semi-closed or open mode.

Endurance was a problem at first. Everything except carbon dioxide absorption was OK. As with all absorbers failure follows a predictable pattern, good absorption slowly fails and then at the break through point carbon dioxide build up occurs.

The first manned trails to 450 fsw using 12 lb. Baralyme had an endurance of about 1 hour although unmanned trials had obtained 9 hours in 40°F water.

Testing showed that the problem was centred on the temperature humidity conditions in the system. The moisture content of the absorbent was considered important. Changes included using "High Performance Sodasorb", two varied condensers to retain moisture and insulation added to the canister. This again gave an unmanned endurance of over 9 hours. Used by men in a test pool the breakthrough was not for 10 hours. But manned at 600' it still failed to make the required 9 hours. It only lasted about 5 and a half hours before carbon dioxide build up occurred. Trial and error showed that running hot water over the top cap of the canister and using shrouds around the helmet hoses to allow the hot water to circulate round them gave acceptable performance.

Slides were shown of the EDU, OSF and the various items of equipment.

Thermal protection for the Mark 12 diver is with a dry suit provided with hotwater tubes on the inside of the outer nylon garment. The water is never in contact with the diver but he is kept warm.

Another interesting development which has been evaluated at the EDU is the push-pull system, the Mark 14 closed circuit saturation diving system. This is designed to be used from a PTC and circulates the PTC atmosphere to the diver using the PTC atmosphere control system to scrub the diver's carbon dioxide, The great advantage is the saving in helium compared with the more usual open circuit equipment. There are four parts to the system. The pump package, the PTC control console, the umbilical and the diver-worn equipment. Gas is taken from the PTC, compressed and pumped through a filter and through a hotwater heater to the diver's helmet. From the helmet it is sucked (the pull) through a water trap and a pump and released into the PTC.

The warmed gas enters the helmet through a diffuser (which reduces the noise level) and leaves through a safety exhaust valve and an exhaust regulator which maintains a relatively fixed positive pressure in the helmet while the suction on the downstream side is between 15 and psig. The safety exhaust valve is there to protect the diver in the event of the exhaust regulator failing. When there is a 50 cm of water underpressure in the helmet the SEV closes and blocks the exhaust path.

The USN requirements were not produced by three commercially available systems so the USN had to design its own system. There were problems with the pump design, limited life, high power demands and large size. The present pumps have proved reliable and the whole unit is the size of one of the gas cylinders on the PTC. Another problem during testing was the collapse of the return hose with its internal pressure up to 6 Ats less than ambient. Internal wire braid reinforcement was needed. For monitoring the equipment performance both manned and unmanned, a computerised system monitoring temperature and pressure a 6 locations as well as pump motor characteristics and helmet flow was designed. This allowed recording and retrieval of such things as helmet gas flow, minimum and maximum pressures over 3 second intervals and respiratory patterns.

Like all diving equipment respiratory resistances rise with heavy work. At 100 watts the helmet maximum pressure rose to 30 cm water during the 5 minute work spell and dropped again when the diver rested. At higher work levels the helmet pressure dropped (the diver was beating the pump) to levels which allowed some water to leak in round the neck seal.